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# THIRD EUROPEAN MARINE SCIENCE AND TECHNOLOGY CONFERENCE

Lisbon, 23 to 27 May 1998

## Conference proceedings



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European Commission

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## Conference proceedings

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# CONSERVING THE OCEANS: PRODUCTIVITY, POLLUTION AND CLIMATE CHANGE

# Conserving the Oceans: Productivity, Pollution and Climate Change

*J G Shepherd, Southampton Oceanography Centre, University of Southampton, Waterfront Campus, European Way, Southampton, SO14 3ZH*

## 1. Introduction

In this lecture I hope to explain why I believe that marine science and technology is especially interesting, and especially important. This is an auspicious occasion: the opening of the Third European Conference on Marine Science and Technology, held in Lisbon to coincide with the opening of Expo 98, with its focus on the Oceans, and in 1998, the International Year of the Oceans. In the conference which follows there will be many specialist talks dealing with matters of detail. For this morning, therefore, I will try only to provide an overview, a reaffirmation of our purpose in investing so much time and effort on our studies of the oceans.

In summary, I shall deal with the role of the oceans in creating a habitable planet, and with the intimate link between water and life. I shall discuss the effect of the oceans on our environment, from the composition of our extraordinary atmosphere, through their role in the cycles of ice ages and warm interglacial periods such as our own, and on climate and weather on all timescales from centuries to days. I shall deal with the oceans as a resource, of food and of fuel, and as a provider of 'ecosystem' services. Finally, I shall deal with the three major threats to our oceans, from over-exploitation, from pollution, and from climate change.

The oceans of the world are vast. They cover 70% of its surface, and they are mostly several kilometres deep. They are nevertheless not infinite, and they are vulnerable to damage by man. They are a vital part of the biosphere, the life support system of our planet, and they are still relatively little explored and not well understood. They are also more than just a lot of salty water, because they are an active biogeochemical reactor, whose state is maintained by a dynamic balance of physical, chemical, biological and geological processes. As an active system they are capable of withstanding change, but only to a certain extent. It is our task to understand this system, and to deduce the limits to change, in order to conserve it.

## 2. The Oceans and Life on Earth

The Earth, seen from space, is an extraordinary planet. Its characteristic colours are all due to the presence of liquid water on its surface — blue for the oceans, white for the clouds, and green for plants. By contrast, Venus is hot, and dry, and Mars is cold and dry. The atmospheres of these three planets are believed to have once been similar, but are now quite different. Venus has a very dense atmosphere, mostly carbon dioxide. That of Mars is very thin, less than 1% of that of Earth, also mostly carbon dioxide. In neither case is there any sign of water, of oxygen, or of life.

Earth, however, is just right: just right for the presence of liquid water, with an extraordinary atmosphere of Nitrogen and Oxygen. This change is an astonishing feat of planetary engineering, which has removed carbon dioxide from the atmosphere and replaced it by oxygen, and this has been achieved by living things. They form part of today's Earth System, which links the oceans, the atmosphere, the cryosphere and the biosphere, exchanging water, carbon dioxide, and oxygen, all mediated by those living things.

There is evidence of water on Earth from the very earliest times, 3800 million years ago, just after it formed by accretion of cosmic debris, and while it was still subject to fierce bombardment by meteorites and comets. This evidence comes from rocks known as banded iron deposits, which are sedimentary rocks which could only have formed in surface water. There is evidence of life, too, from very soon thereafter, from fossil remains of bacteria in rocks such as the gun-flint chert. It seems that life, in the form of bacteria, began very early, possibly under conditions like those we now find at deep-sea hydrothermal vents, where extraordinary rich and diverse communities of animals live through symbiosis with bacteria, which themselves exploit chemical energy from the hot, toxic fluids. In the Atlantic we see strange shrimps, clams and crabs, whilst in the Pacific there are enormous tube worms, all flourishing quite independently of the energy from the sun which sustains all life near the surface.

Whenever life began, it flourished for perhaps 1000 million years before the next, crucial development — the evolution of organisms capable of using the energy of the sun by photosynthesis. These were not plants, but cyanobacteria (so-called blue-green algae), and with photosynthesis the transformation of the Earth began in earnest. Photosynthesis uses solar energy, carbon dioxide and water, and produces organic matter (carbohydrates) and oxygen, as a waste product. In the oceans it is still mostly carried out by tiny planktonic plants, and roughly as much occurs in the oceans as on the land. Photosynthesis in the oceans is the key process, however, because it is not all reversed by respiration. Some of its products, organic matter containing carbon, is buried. This, of course, forms fossil fuels, coal and oil, but it also permanently replaces carbon dioxide in the atmosphere by oxygen, thus achieving the feat of planetary engineering we have observed. At some point, too, the symbiosis of several kinds of bacteria led, in a way we still do not fully understand, to the development of more complex eukaryotic cells, the basic building blocks of the multi-cellular plants and animals we know today — though life on Earth is still really 'mostly bacteria'.

These more complex plants and animals also then began to remove carbon dioxide in another way, for some of them, notably coccolithophores and foraminifera, form tests or shells of calcium carbonate, which fall to the seafloor when they die, and are buried to form — eventually — limestone rocks. This process needs calcium too, and this comes from the erosion of crustal rocks, which is also of course mainly due to water, in the form of ice and rain. These rocks are all around us, from the White Cliffs of Dover, through the Dolomites to the summit of Mount Everest — all are marine limestones. In fact, 99.7% of all the carbon in the world is now locked up in sedimentary rocks and 97% of the rest is dissolved in the oceans. This means that only 0.001% is left as carbon dioxide in the atmosphere. Man is however, reversing this process by burning fossil fuels, and is well on the way to doubling that small

residual concentration, causing the Greenhouse Effect and global warming; the greatest uncontrolled experiment with our environment since the last ice age.

To summarise, the earth's atmosphere is in a sense artificial, since it has been manufactured and is now maintained by marine planktonic plants. Without the oceans, and the living things in them, the Earth would be totally different, and we would not be here to marvel at it.

# 3. The Oceans and Climate Change

The first, and greatest, threat to the oceans and thus to our environment, is that of climate change. The oceans are part of a complex system which controls our climate, and with which we are interfering. The oceans are very deep, once we get away from the flooded land we call the continental shelves, and they are cold, close to 0°C, totally dark, and subject to several hundred times atmospheric pressure. They are nevertheless not lifeless. Even though the abundance (biomass) of life in the deep-sea is relatively low, and its metabolic rates are slow, it is far from a desert. Its biodiversity may match that of the rain forests on land, and at the level of the major groups of living things (phyla) it is greater. The sediments which accumulate on the deep-sea floor also have become an archive of past climate and environmental conditions which we can now, with skill and care, read. The shells of foraminifera which the sediments contain, in particular, contain isotopes of oxygen and carbon which can be analysed to tell us about past temperature, ice volume and biological production. The records obtained from cores punched or drilled from these sediments show that our climate has varied, sometimes with astonishing rapidity, for thousands and millions of years.

In particular, for the last few million years the Earth has suffered periodic glaciations, with brief warm periods (interglacials) lasting for about 10,000 years, roughly once every 100,000 years. We are now living in an interglacial, which has already lasted for about 10,000 years. The reasons for these massive fluctuations of Earth's climate are not at all well understood. They seem to involve a coupled oscillation of the ocean/atmosphere/cryosphere system, and to be 'paced' by small variations of solar radiation due to periodic changes in the Earth's orbit, leading to characteristic Milankovitch cycles. These variations are, however, too small to cause the large changes of temperature experienced (about 5°C between glacial and interglacial conditions), and it seems that there is some positive feedback mechanism at work. This very likely involves the oceans, which drive the atmosphere on these timescales, and possibly also involves the concentration of greenhouse gases such as $CO_2$ and methane in the atmosphere. Analysis of the air preserved in bubbles in the ice of the Greenland and Antarctic ice-caps shows that atmospheric $CO_2$ concentrations have varied as the ice ages come and go, and are very highly correlated with the temperature records. We do not yet know if this is a cause or an effect of the temperature changes, or what the mechanism is. Other factors, including biological production on land and in the sea, and the availability of nutrients (including iron from atmospheric dust) may also be involved.

There is however good reason to suppose that transport of heat, $CO_2$ and nutrients by the oceans is part of the process. The oceans and the atmosphere together transport heat from the equator to the poles, in roughly equal amounts, and so prevent polar temperatures falling even further. The transport in the oceans is carried

out by the so-called Ocean Conveyor Circulation, the deep, slow density-driven (thermohaline) circulation that over-turns and ventilates the deep water below about 1000m. There is now evidence from both experimental observations and modelling studies that this circulation can be modulated, and even suppressed, by high run-off of fresh water into the North Atlantic (where the source of the circulation is located). It seems that this could be caused by unusually rapid warming, but if the circulation shuts off it leads to rapid cooling at high latitudes, and eventually to glaciation. We need to understand these mechanisms, especially the processes of deep water formation, and mixing in the deep oceans, whose balance determines the conveyor circulation, much better before we can make realistic predictions for more than a few decades of the probable effects of greenhouse warming. At the moment we are applying a large, unintended and uncontrolled forcing to a system whose dynamics we do not understand. Since the geological and ice records show that major climate changes have occurred in very short times — just a few decades — this is not a remote problem, but one which may well affect our children and our grandchildren.

Other better-known features of the ocean circulation, such as the Gulf Stream, are also liable to vary, and affect our climate on shorter (inter-annual) timescales. Whilst it is the heat transported by the Conveyor circulation (equivalent to the output of a million large power stations) which actually keeps northern Europe warm, changes in the Gulf Stream and the North Atlantic Current may affect storm tracks, and thus our weather, and they seem to be associated with a large-scale change of atmospheric pressure patterns known as the North Atlantic Oscillation. This, like the better known El Ni–o/Southern Oscillation in the equatorial Pacific, is a coupled oscillation of the atmosphere/ocean system, whose mechanism is, again, not well understood.

Since the ocean circulation can affect the climate on all timescales from seasonal to geological, it is important that we understand it better. It is for this reason that the World Ocean Circulation Experiment, of which the seven-year observational phase has just ended, was undertaken. Some indication of the scale and difficulty of observing the oceans can be gained from this, as with the combined efforts of all the countries with the necessary ships and skills, it has taken seven years to collect the sort of observations which meteorologists get routinely every day! Similarly, whilst we now have global ocean models which do simulate the ocean circulation reasonably realistically, these have to be run at much higher resolution than atmospheric models, and are something like 1000 times more difficult and expensive to run than atmospheric models. The task of testing these against WOCE data is just beginning, but we also need to develop usable reduced models for climate simulations, which are capable of being run for thousands of years many times over, as this will not be possible with the high-resolution global models for several decades yet. This means that we need to understand the processes which drive the oceans better, and find ingenious ways to represent them in models. There is much to do. The Earth/Ocean system is complex, subtle, and not yet well understood. It is interactive, dynamic, and liable to change. We need realistic models which couple the oceans, the atmosphere, the cryosphere and the biosphere (and even, on very long timescales, the lithosphere). This requires developments in the interdisciplinary science which deals with the interaction of physical, chemical, biological and geological processes concerned, since the creation of the simplified models we need will only be possible if they are based on a good understanding of the system.

# 4. Other Threats to the Ocean

The threat of climate change to the oceans, and especially to their circulation and biological production, is not only serious, but also involves very long timescales, and massive potential effects. There are however, other threats to the oceans, which are more immediate and perhaps more obvious. There is, for example, the over-exploitation of the world's fisheries. Here the scientific understanding of the problem is, whilst still imperfect, probably sufficient for us to identify the necessary action — to reduce fishing effort substantially. Achieving this is however difficult, since it also has serious social, economic and political effects. Indeed, these have so far proved to be so powerful that after decades of effort there are still only a few places in the world where fisheries can be regarded as well managed.

Similarly, the effects of pollution in estuaries and coastal waters are reasonably well understood, but reducing run-off of nutrients and pollutants from the land into rivers is not proving to be easy, even for the richest and most technologically capable nations. The exploitation of the non-living resources of the ocean is also an important part of our present world economy, and likely to become more so. Exploitation of off-shore oil is now a world-wide phenomenon, and inevitably leads to spills from accidents, including wrecks of tankers. Large oil spills have devastating effects locally, but luckily the oceans are able to repair the damage in due course. Several million tonnes of oil seep into the ocean naturally every year, and there are bacteria which have evolved to utilise it, and so biodegrade it. Thus the oceans can cope with oil — to a certain extent.

In future other minerals may be harvested from the sea, including perhaps those in the manganese nodules which carpet some areas of the deep-sea floor. Dredging for these is likely to disturb massive quantities of fine sediments, and we have as yet little idea what effects this would have on the deep-sea ecosystem, or how extensive those effects would be. Other possible uses of the ocean in future may include waste disposal. At present the political climate is firmly opposed to this, but this may change. Nuclear wastes have already been disposed of in the deep-sea, and it is not impossible that this could become a more favoured option in the future. There are many naturally occurring radionuclides in the sea. We should need to understand how these are affected by the oceanic circulation and biogeochemical cycles, in order to understand and control the effects and fate of man-made radioactive materials.

Finally, there is a further aspect of the climate problem. It is going to be enormously difficult, practically, politically, socially and economically, to reduce $CO_2$ emissions world-wide to levels which may be sustainable. We shall probably need to use all available means to do so, and that is likely to involve removing $CO_2$ from the fluegases of power stations and other industrial plants, and sequestering it somewhere out of contact with the atmosphere. Since carbon dioxide is quite soluble in water under high pressure, especially if it is alkaline, two possible locations are in deep geological formations, and in the abyssal waters of the ocean. As we have seen, in equilibrium most (97%) of any $CO_2$ resides in the ocean rather than the atmosphere — it is primarily because we release it into the atmosphere, and it can only slowly get into the sea, that the greenhouse effect is so serious. If one could short-circuit the rate-limiting step of ocean uptake by direct injection, the problem could be much reduced. Such an activity would however also have

environmental effects, including dissolution of deep-sea calcareous sediments, which would have to be properly estimated before it could be allowed.

# 5. Discussion

As we have seen, the oceans are an active physical and biogeochemical system, whose state is maintained by a dynamic balance between competing processes. As such, they are capable of adjusting to and coping with perturbations caused by human activities, but only to a limited extent.

Except in some coastal and estuarine areas the oceans are thankfully still relatively unspoiled, and it is possible for us to keep them so. However, to do this we must control possible damaging activities at tolerable levels, and this means that we must understand the system. A sensible balance between exploitation and protection can probably be found, but only on the basis of a sound scientific understanding of all relevant aspects of this complex and fascinating system. We must recall that at present this vital component of the life support system of our planet has not been thoroughly explored, and is not well understood. We should be prepared for further surprises, such as the deep-sea hydrothermal vents and their communities of animals, in the future, as in the recent past.

It seems probable that further use of the oceans will have to play some part in the struggle to reduce $CO_2$ emissions and overcome the greenhouse effect. Removal of $CO_2$ from fluegases for sequestration is not the only card which may need to be played. Emissions from vehicles are increasingly important, and could be sharply reduced by using hydrogen as a fuel for vehicles and homes. Hydrogen can be produced in various ways. Solar dissociation of water would be preferred, but may need to be augmented by electrolysis, using electricity generated by nuclear plants, perhaps. Alternatively, gasification of coal is feasible (it is the old Water Gas process). This, like combustion, produces $CO_2$ as a waste product, but in large plants this could be removed for sequestration. We have a few decades, probably, in which to implement such schemes, and need the scientific understanding to control them.

In order to control disposal of $CO_2$ and other wastes, we need to understand their effects on living things, their toxicity, their sources and sinks, their natural analogues, their dispersion, their residence times and their fate. Similarly, to control exploitation of renewable resources at sustainable levels, we need to understand growth, reproduction, migration and maturation, not only of the biota being exploited, but of the other components of the oceanic food webs on which they depend, or which they sustain.

Oceanography is an inter-disciplinary and an international science par excellence. The past decades have seen major international programmes on ocean circulation (WOCE) biogeochemistry (JGOFS) and now on ecosystem dynamics (GLOBEC). A major programme on the climate system and its variations (CLIVAR) is getting under way. In future we may need major surveys of ocean biota (still not well-known, except for fish in heavily exploited areas), and experimental studies (e.g. of ocean fertilisation), to augment our understanding of the system. It is therefore a great relief that the European Framework 5 programme to be defined in 1998, the International

Year of the Oceans, will after all contain a significant element of marine science and technology.

Oceanography has always been constrained by available technology — it is after all almost all remote sensing, even if the remote instrument is dangling on the end of a wire rather than flying on a satellite in space. We need new technology now as in the past, and cannot predict what surprises deploying new instruments will bring. We need continuing investment in infrastructure, such as new vehicles and instruments - especially for studying animals without catching them in nets! We also need to invest in the scientists of the future, by ensuring that we attract students to the field, and educate them well. This, the ultimate form of capacity building, is especially needed in the less developed world, whose oceans have been studied so much less than the northern Atlantic and Pacific. They will be needed, not only for research, but also to run the observing systems which will be developed as we make the transition to operational oceanography. Expedition-style programmes such as WOCE, repeated every few decades, are not enough to monitor the changes they have revealed to us — we need to deploy instruments, vehicles and people much more widely and more often, to detect and understand these changes and the system that produces them.

We should not, however, allow the need for scientific research, technical development, and reasoned and rational balancing of costs and benefits, to dominate our thinking. Certainly the oceans can and do contribute to the creation of wealth. This is however pointless unless it in turn contributes to improving the quality of our lives. Of course it can and should do so, but the very existence of the oceans also contributes directly to that end. There are ethical and aesthetic reasons for caring for the oceans, because they are a beautiful part of a beautiful world, and it is both a duty and a privilege to study them, understand them, and preserve them for the future.

# SCIENTIFIC-TECHNICAL ISSUES

# EXTREME MARINE ENVIRONMENTS IN EUROPE: SCIENTIFIC AND TECHNOLOGICAL RESULTS AND CHALLENGES

# The deep ocean: A model for processes functioning under extreme environmental conditions

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## 1. Introduction

The limits for life on our planet are defined by extreme conditions found today in the deep ocean and at the poles. The seafloor below ca.3000 m and at high latitudes generates physico-chemical conditions, ecosystems and geologic settings, that could be models of past and to some degree future environmental conditions on Earth. The functioning of life and the material turnover under these conditions require biological adaptations, reaction pathways and phase stabilities not usually found under Earth's surface conditions; hence research in these areas has the potential for generating true scientific progress. Besides the need for an interdisciplinary approach in understanding the basic processes under these conditions, a highly-sophisticated and specialized deep-sea technology is required for the access to samples and *in situ* monitoring needed to assure true progress. Therefore, we will examine processes operating in 3 types of settings of extreme environments: (1) Material turnover rates, reaction pathways, and temporal and spatial variabilities which operate over the vast expanse of the deep-sea floor, including the penetration of the microbial processes into the geosphere; (2) Hydrothermal systems of oceanic spreading centers and cold seeps of subduction zones; and (3) Mud volcanoes of accretionary complexes, gas hydrate-dominated systems of continental margins, and deep brine lakes of fore-arc basins.

## 2. Deep-sea and sub-sea material fluxes and turnover

Dissolved substances leave the sediment at the water/sediment interface and return to the bottom water. This flux is largely responsible for determining the concentration and distribution of nutrients and carbon species in the deep waters of the world oceans. The flux of anthropogenically introduced materials across this boundary from the sediment into the seawater needs to be examined.

Furthermore pelagic-benthic coupling needs to be examined in more detail. Specific questions are: How long does it take for the deep sea biota to respond to settling pulses of material? What is the frequency and magnitude of material pulses settling to the deep-sea floor? What are the rates and dominant mechanisms by which these pulses are consumed? What "residual signal" remains after consumption at the sea floor?

First, sensitivity tests of models simulating benthic material trunover show that reaction rates, kinetics and regionally variable fluxes which govern these exchange process at the deep-sea floor, have profound implications on for example oxygen distribution in the oceanic water column and atmospheric $pCO^2$. These parameters are poorly understood for the extreme conditions encountered at the deep-sea floor, trenches, and polar basins.

Secondly, the biological and geochemical fluxes should be *measured in situ* on the sea floor, and the measurement compared with quantitative, mechanistic transport-reaction-models, provided these parameters can realistically be established.

Recognition of the penetration of the biosphere into the Earth's crust is both exciting and profound. Micro-organisms may be ubiquitous in subsurface environments, with a biomass that represents a significant portion of the surface biosphere and may even exceed it. We are only at the beginning of exploring this new microbial ecosystem. The subsurface marine biosphere, as approximately 70% of the Earth's surface with sediments up to 15 km deep in places, constitutes a carbon reservoir and turnover "factory" of major importance.

# 3. Hydrothermalism at oceanic spreading centers, and cold seeps at subduction zones

The benthic organisms that settle in hydrothermal vents and cold-seeps of subduction zones, where methane-rich and sulfide-rich fluids escape from the sea floor, alter and control the entry of material from the vents into the bottom water of the ocean. This process involves the hydrothermal systems as well as cold seep systems. The microbial oxidation of reduced inorganic compounds by endosymbiontic bacteria produces a large benthic oxygen demand that affects the local bottom waters. The biological fixation in vent communities also results in formation of carbonates, sulfides, sulfates and other precipitates, concentrating exotic metals and fractionating extreme isotopes. Hydrothermal vents have a short lifetime, and the means by which they are colonized by these specialized communities is an open problem.

Matrix-fluid interaction under extreme temperatures and pressures is a wide-open field of research, even though discovery of hydrothemal systems is more than 20 years old. Growing research beyond mid-ocean ridge systems is now being directed towards more diverse, and economically more attractive, deposits in hydrothermal systems of other types of plate tectonic settings. For example the phase separation during boiling of hydrothermal fluids and associated transport and fractionation of elements is another major field of research dealing with matrix-fluid-interaction.

# 4. Mud-volcanoes, deep brine lakes, and gas hydrates

Convergent continental margins, with deep-sea trenches, fore-arc basins, and accretionary ridges are world-wide systems hosting a variety of extreme environmental conditions. Brines of extraordinary composition, gas hydrate exposures, and

mud volcanoes consisting of pure serpentinite slurries are recent significant finds in the deep-sea environment.

Another fascinating system to be explored are the numerous deep brine lakes in the eastern Mediterranean have been discovered. These anoxic hypersaline deep basins are among the most saline environments ever found on Earth. They contain the highest dissolved sulfide, magnesium, potassium, and helium concentrations ever reported for the 'open marine' environment, and show large compositional differences. Some also exhibit temperature anomalies. Their origin is unclear, as is their role in salt and solute transport, in this particular case to the eastern Mediterranean Sea.

The serpentinite mud volcanoes of the Marina's fore-arc are enormous outpourings of pure Mg-rich mineral slurries which are generated at the contact between the downgoing Pacific plate and the overriding Philippine Sea plate. Their role in the Mg-budget must clearly be profound and is not yet well-known.

Shallow and deep water gas hydrates, consisting of methane and hydrogen sulfide, have been found on active and passive continental margins. Gas hydrates are a mixture of water, methane and hydrocarbons, carbon dioxide, and hydrogen sulfide that form an ice-like solid in the pore space of the sediment. They exist at physical conditions that are not normally accessible to sampling and measurements. Their mechanism of formation and their stability are major unknowns. They present a special environment for marine life. They could potentially serve as a future energy source, and may play a role in climate change through their rapid decomposition in shallow waters. The decomposition of gas hydrates may cause submarine slope failures which generate tsunamis with possible consequences for coastal populations.

# Azores Mid-Oceanic Ridge Ecosystem Studies (AMORES): an integrated research programme on deep-sea hydrothermal transfer and fluxes

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The AMORES programme is aiming to study the physical chemical and biological fluxes from four contrasted hydrothermal fields situated area on the South Western limb of the Azores Triple Junction on the mid-Atlantic Ridge. During the past year (1997) three main cruises were carried out:

(1) In May-June 1997 an extensive plume process survey was carried out at the Rainbow hydrothermal field, during the "FLAME" cruise aboard RRS " Discovery ". Its principle objective being to study the physical, geochemical and biological dispersion of the neutrally-buoyant hydrothermal plume overlying the Rainbow hydrothermal field on the Mid-Atlantic Ridge, near 36°15'N

(2) Between July 6 and August 10, 1997, 29 dives were conducted with the deep-sea submersible " Nautile ", operated from n/o " L'Atalante "on four different volcanic segments during the FLORES cruise to investigate geological and geochemical processes at the vent scale. Scientific objectives include: high resolution multibeam mapping, geological mapping of the active sites, hot water and gas sampling, mineralogical and geochemical analyses of sulphides, volcanic and ultramafic rocks, and plume studies.

(3) From August 13$^{th}$ to September 13$^{th}$, 19 dives of the deep-sea research manned submersible "Nautile" were also performed during the cruise MARVEL between 36°13'N and 37°50'N. The objective of the cruise was to study the biodiversity and functioning of biological communities thriving at the vicinity of hydrothermal vents in four active segments along a depth gradient which decreases when approaching Azores hotspot.

During the FLAME cruise, a series of hydrographic CTD stations were occupied, complete with a lowered Acoustic Doppler Current Profiler (L-ADCP) to provide instantaneous measurements of prevailing current directions with depth in the water column. This was coupled with a suite of deep-tow CTD tow-yo sections using the hydrothermal plume instrument BRIDGET. This preliminary data set yielded an understanding of the nature of plume dispersion which was then utilised to target further water column sampling using a combination of further CTD hydrocasts for water column samples, in situ filtration of particles for mineralogical, geochemical and microbiological investigations and RMT 1+8 Net trawls for biology. The neutrally buoyant plume, which was revealed to be dispersing under topographic control, was traced to a distance of greater than 50km down-stream. As the programme

progressed a grid of closely spaced (0.5 nautical miles) orthogonal survey lines were occupied across the suspected site of venting, yielding a resolution of closest approach to the source of better than 200m. Finally at Rainbow, a suite of 8 current-meter moorings were deployed around the vent-site to monitor long-term (>12 month) fluxes of physical parameters including suspended particulate material away from the site of venting. In addition to sampling at Rainbow, 6 CTD stations were occupied in the southern portion of the FAMOUS segment and RMT 1+8 Net Trawls were completed in the Southern AMAR, AMAR, FAMOUS, North FAMOUS and Lucky Strike segments as well as in the non-transform discontinuity (NTD) offset immediately to the south of the Lucky Strike segment.

During the FLORES, diving targets were selected to study the influence of depth (pressure), composition of source rocks, and tectonic versus volcanic activity on hydrothermal processes (including biology). The Menez Gwen (MG) (37°50'N) and Lucky Strike (LS) (37°20'N) fields are located respectively at 820 and 1700 m below the sea level. The newly discovered Rainbow field (36°14'N) is located at 2300m. Lucky Strike and Menez Gwen are clearly controlled by the volcanic topographic high at the centre of the segment. On the opposite the Rainbow field is controlled by non-transform offset faults away from areas of recent volcanic activity. Source rocks are also variable, MG and LS are related to interaction and exchanges between E-Morb and Seawater while Rainbow is influenced by interaction between seawater and ultramafic rocks from the Mantle. Due to phase separation processes at shallow depth, hydrothermal fluids both at LS and MG have low salinities and are enriched in gas. At Rainbow fluid and gas compositions are strongly influenced by the ultramafic rocks. Hydrothermal precipitates are also influenced by the source rocks. Unlike other sulphide deposits on the MAR controlled by N-Morb, LS and MG are highly enriched in Ba and other elements typical of the E-Morb. At Rainbow the influence of mantle rocks is seen as Co and Ni enrichments in sulphides. The deposits are also highly enriched in Cu and Zn compared to other deposits.

During MARVEL, we studied the micro-habitat of the vent organisms, which varies at a centimetric scale due to the turbulent mixing between seawater and hydrothermal fluid, a large number of discrete water samples and temperature time records were made among the populations of the dominant species. A new water sampling device was used, able to collect 4 water samples with temperature recording. The environment surrounding the organisms is a dilute hydrothermal medium (88 to 100%) of seawater. The size-frequency structure of mussel populations, which are the dominant organisms on Lucky Strike and Menez Gwen, was studied and demonstrate the existence of discontinuities of recruitment and a synchronisation of reproduction at a vent field scale. The trophic food web was studied by natural isotop ratios and organic tracers. The MARVEL cruise showed that it was possible to keep the major vent species from the Lucky Strike and Menez Gwen sites alive in cooled aquaria under atmospheric pressure. Several experiments were performed aboard to study adaptations to the toxicity of the environment. Vent mussels, *Bathymodiolus sp.*, from these sites need both methane and hydrogen sulphide for their symbiotic bacteria and have now been kept alive for 9 weeks in aquaria supplied with these two gases. Measurements of the uptake rate of these gases was made during the cruise and the growth of mussels deprived of either one or both of these energy sources was measured. Mussels were used as small-scale water samplers, since they rapidly close during disturbance and the water inside the mantle cavity could be used from freshly collected animals to analyse the

composition of the surrounding diffuse vent water. Several long term experiments including colonisation arrays, temperature recorders, time lapse video camera, were disposed on the bottom and will be retrieved during the PICO diving cruise planed for the next summer.

# A Deep Bacterial Biosphere In Marine Sediments

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The presence of microbial populations in deep environments — marine, terrestrial and oil reservoirs — has recently been demonstrated. Depths extend to 2.8 km and even into basalt and granites. The deep bacterial biosphere in marine sediments alone is estimated as ca. 10% of the surface biosphere. Bacteria can grow at temperatures up to 113°C and possibly higher and pressures over 1,000 atm. Hence, with an average thermal gradient of ca. 30°C/km in marine sediments temperatures would not be limiting for several kilometres and the "classic" separation between biologically catalysed alteration of organic matter to ca. 60°C during diagenesis, followed by thermal alteration, catagenesis, may no longer be appropriate. Conditions within deep environments would still be considered to become more hostile with depth, however, as buried organic matter becomes increasingly recalcitrant. Hence, the presence of high bacterial populations in deep sediments are enigmatic, especially as in some marine sediments bacterial activity can actually increase in deeper layers.

The distribution of bacterial populations and activity in a range of deep marine sediments will be described. The geochemical impact of this activity demonstrates that bacterial processes are substantial in deep sediments. In gas hydrate sediments bacterial activity is stimulated within the deep gas hydrate zone to such an extent that maximum activities can be greater than those close to the sediment surface. Below about 100 m in these sediments low molecular weight volatile fatty acids begin to increase and continue increasing with increasing depth (acetate > 15mM at 691 m, 3 orders of magnitude increase. This seems to be due to an increase in the bioavailability of organic matter during deep burial and heating, and results in a large stimulation in bacterial activity. If this processes is widespread it would provide a fuel for a deep bacterial biosphere which could extend to greater depths than has previously been considered.

# Diversity of thermophilic micro-organisms at deep-sea hydrothermal vents

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At deep-sea hydrothermal vents, hot fluids are emitted at temperatures up to 350°C through mineral structures called smokers or chimneys, or deep layers of sediments. Such biotopes have been investigated by our group in the Eastern and south-western Pacific, the mid Atlantic, from where samples of fluids, chimneys and sediments have been collected using the manned-submersibles Nautile and Alvin.

The hot fluids create an anaerobic environment, separated from cold seawater by a steep gradient, which generally does not allow for a hot and oxygenated niche. For these reasons, many microbiologists focused on anaerobic hyperthermophiles. However, certain specific environments at the Guyana's Basin and the mid-Atlantic Ridge allowed us to isolate for the first time aerobic thermophiles, some of them identified to the genus *Thermus*, and several new spore-forming bacilli as well. About the anaerobic hyperthermophiles, we mostly investigated chimney samples collected in the North Fiji Basin (SW Pacific). From a single site, 21 isolated of heterotrophic anaerobic Archaea were obtained and assigned to the Thermo-coccales. The diversity among these isolates appeared higher than previously expected since 6 new genomic species of *Thermococcus* and *Pyrococcus* have been detected, based on DNA/DNA hybridisation. One of these new species, *Pyrococcus abyssi* is currently used as a model strain for physiology, biochemistry and genetics studies. By screening this collection of isolates, the first plasmids for these groups of hyperthermophiles were found, one of them, pGT5 has been fully described and appeared to replicate by a rolling circle mechanism. The different sizes and homologies found between the plasmids detected could suggest that exchanges of genetic elements might occur within these hyperthermophilic communities. Deep-sea hyperthermophiles also are exposed to high hydrostatic pressures. Recent experiments allowed isolating a novel *Thermococcus* species whose growth rate is clearly enhanced by high pressure. Moreover, this *Thermococcus barophilus* expressed a stress protein when cultured at atmospheric pressure. Exploration of deep-sea vents for hyperthermophiles started less than 20 years ago. Although numerous data had been obtained, exploration of these extreme biotopes must be continued to provide the best knowledge of our planet and take advantage for biotechnology purposes of the fascinating diversity of extreme microorganisms.

# The seafloor sediment cover in the deep Arctic: The archive of an extreme ocean environment

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The deep eastern Arctic Ocean has remained virtually unexplored until European nations began to deploy research ice-breakers, the Swedish YMER–80 expedition being the first serious attempt to penetrate the margins of the sea-ice cover in the northern Barents Sea and Fram Strait area. The region provided a sediment cover with much higher stratigraphic resolution than the western Arctic Ocean. Penetrations of the Arctic Ocean to the North Pole have been successfully achieved several times since then by Swedish, German, American and Canadian research ice breakers; during the various expeditions a substantial amount of geophysical profiles and sediment cores have been acquired which allow for the first time to draw a quantitative and detailed picture of the Late Cenozoic paleoceanographic history of the central Arctic Ocean. These data are supplemented by drill sites of the first ODP Leg reaching the Arctic Ocean proper in the area of the Yermak Plateau immediately to the North of Svalbard. It is now clear that the Arctic Ocean has been sea-ice-covered since Miocene times and that it was never ice-free during the Quaternary. The glacial-interglacial changes of the climate over the northern hemisphere led to important increases in iceberg-fluxes to the central Arctic Ocean from the surrounding terrestrial ice sheets during times ice-sheets growth and decay. Interglacials resulted at times in relatively high abundances of biogenic sediment components (mainly coccoliths and planktonic foraminifers) suggesting that the sea-ice-cover was less dense during certain interglacials than during others. The longest sediment records from the central Arctic ocean have reached Pliocene deposits, representing a time when the Arctic Ocean had acquired an ice-cover. The onset of northern hemisphere sea-ice-covers in the Arctic Ocean and elsewhere remain an enigma.

# Characterisation of the local state of ice cover

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Sea ice covering the northern and southern seas creates many scientific questions and technical challenges. At present, a key problem in ice cover mechanics is characterisation of the local state of an ice cover. This characterisation includes both description of the ice cover morphology and understanding of the local deformation processes causing changes in the morphology. Such information is needed in studies on ice cover dynamics in the mesoscale where it is important to know the ice cover thickness distribution and how it changes due to mechanical deformation. Knowledge of the local ice cover morphology and deformation is important also in analyses of trafficability of ships in ice covered seas and in analyses of ice forces on offshore structures. The pressure ridge formation due to winds and currents is a similar process than the pile-up process of an ice cover against a structure. Once an ice pile-up or a pressure ridge has been initiated, subsequent growth and loading depends on breakage of the ice cover and ice floe accumulation apart from the driving forces. These problems have been addressed in the ICE STATE project supported by the European Commission through the Marine Science and Technology programme (MAST III).

Three deformation types: (i) rafting of ice floes, (ii) rafting of ice sheets, and (iii) formation of ridges, have been studied experimentally in the test basin at the Helsinki University of Technology and computationally by using a discrete element method. The objectives of these physical and numerical experiments were to describe and model the processes involved in local ice cover deformation. For the first time, pressure ridges were produced in laboratory conditions and thus relations between morphological features and forcing can be formed. One of the main results is that ice sheets of uniform thickness do not form ridges, they only raft. The studies suggest that the important parameters in ridging/rafting processes are ice cover thickness, its non-homogeneity, and Young's modulus. In the laboratory tests, all ridging processes started as finger rafting, which is the reason for the observed curvilinear ridge shape. Comparisons with field measurements support the laboratory scale results, similar curvilinear ridges were found and measured during a field campaign.

Further, interconnection between the local scale and mesoscale in describing the ice cover morphology and deformation has been addressed. One approach is the strategy of downscaling, which involves derivation of the forcing of local mechanical processes from the mesoscale velocity fields. This is not trivial, as the mesoscale stresses in an ice field are about two orders of magnitude less than the local stresses. To solve this problem, a scale structure describing how new ridges are distributed in an ice cover under deformation, has been formulated. In this approach, the magnitude of local stresses can be estimated from the morphology by

using results from the local scale deformation studies. The proposed scale structure produces similar ridge spacing distribution than that observed in the field.

# Thermohaline circulation in the Greenland Sea studied by novel techniques

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During the past two years a unique experiment aimed at studying processes of deep convection has been carried out in the Greenland Sea under the ESOP–2 project funded by the MAST-III programme of the European Union. Deep convection is a key process for renewal of the water masses of the world's ocean interior, and is very important for the climate system. The process has strong impacts on the transfer of $CO_2$ from atmosphere to ocean, and on the flux of oceanic heat in the North Atlantic. It is therefore partly responsible for the benign climates of Northern Europe. With the realisation that key questions of the physics of the process, and the rates of mixing and advection involved are poorly understood, ESOP–2 was organised to tackle these problems by a new type of methodology. This involved the deliberate release of a tracer (SF6) to the central parts of the gyre, a lagrangian experiment with isobaric floats to track movements of water masses, a full scale carbon cycle experiment with ship-borne and autonomous measurement techniques, a study of sea ice-ocean interaction and a range of modelling activities on large to small scales. Since the successful release of the tracer in August 1996 and subsequent mapping of the movement of the tracer field during four campaigns we know can state that the execution of all these technologies in a combined experiment has gone extremely well. The results are surprising and highly interesting. The presentation will review the current status of how convection processes have evolved and have been modelled during the last two years, how the oceanic carbon uptake varies on a seasonal basis and how the different technologies have performed during the adverse conditions of the Greenland Sea.

# Spatio-temporal variability of benthic assemblages as a response to sea-floor conditions at selected abyssal North East Atlantic stations

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In the past decade, a new perception of the deep sea floor as a changing environment has developed in response to: - evidence of environmental spatial heterogeneity, — the coupling of the deep-sea benthic ecosystem to surface production, -seasonal patterns of sedimentation and -the dynamic response of the benthic community to food input. Four selected stations in the North East Atlantic investigated for benthic ecology studies, in the frame work of the EUMELI programme and the on going MAST3 BENGAL project, provide examples of how deep-sea benthic assemblages are structured and affected by different local environmental conditions. Both programmes employ the same strategy of biological sampling and environmental monitoring at the three tropical EUMELI sites, at 2000 m, 3100 m and 4600 m depth and at the 4800 m deep BENGAL site at temperate latitude. Density and biomass of meiofaunal, macrofaunal and megafaunal invertebrates were determined at three periods of the year and although the data are preliminary for the BENGAL project, it allows first time comparison of the biomass and the structure of the assemblages, at different period of the year in relation with trophic conditions and hydrodynamic regime at different latitudes. Our results show that:

1) For the three distinct EUMELI sites, not only do density and biomass of each size group decrease with increasing depth and decreasing food supply, supporting the general notion of benthic standing stocks limited by trophic conditions, but each size group shows a specific response to the different environmental settings. The largest faunal size category (megafauna) is dominant, in terms of biomass, when the food input is high, whereas the macrofauna is the most important component of the benthic metazoan community at intermediate trophic conditions, and the meiofauna predominates where food input is the lowest and the is the greatest. Globally the degree of variation in biomass of the three major size categories is different, with the greatest variation being shown by the megafauna and the least variation by the meiofauna.

2) Although located at great depth, the Porcupine Abyssal Plain (BENGAL site) receives a relatively high organic input (equivalent to that of the tropical "mesotrophic" site at 3000m depth) which, together with the hydrodynamic regime, may explain our preliminary results which show that the total invertebrate biomass

is similar at both stations. However, whereas the macrofaunal biomass is the most important category at the EUMELI tropical mesotrophic site, the megafauna is dominant at the temperate BENGAL site and its biomass is twice that of the macrofauna. Although the taxonomic composition varies between sites, echinoderms dominate with a predominance of holothurians. In contrast to trawl samples taken previously at the BENGAL site between 1989 and 1994, the samples taken since 1996 show a highly significant change in the composition of the megafauna. Two holothurian species that were minor constituents of the benthic community before 1996 have undergone population explosions and are now the dominant animals numerically.

3) Whereas at the tropical sites, no seasonal variation was observed in terms of community structure, which corroborates the absence of seasonal input of organic matter, preliminary results in terms of density from the BENGAL site show that the increase of flux of particles ( phytodetritus from the overlying euphotic zone) observed in June 1997, even though weaker than expected , induces some variation in the total abundance of macrofauna between the three seasons with a minimum in autumn and a maximum in summer.The change occured mostly as a result of changes in polychaete abundance (56 to 72% of total abundance) for which a high number of juvenile forms were found in samples collected during March and July 1997, while none were observed in September 96 samples. A more accurate examination of polychaetes must be done to confirm our results and to verify the importance of juveniles during the winter and summer seasons.

Pluridisciplinary investigations, replicate sampling and time-series observations which are seldomly undertaken at great depth, already demonstrate spatial and temporal variability of benthic assemblages within and between deep sea sites. However, this level of sampling effort needs to be enhanced in order to analyse changes at the level of population and to achieve a much better temporal and spatial resolution across the North East Atlantic. Understanding general principles about deep-sea life and why natural changes occur is essential in forecasting, or even recognising, changes resulting from man's direct impact on the deep-sea environment.

# Composition and origin of hypersaline Eastern Mediteranean brines

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An increasing number of deep brine lakes in the eastern Mediterranean has been discovered and characterized during the last few years in successful Mast programmes such as MEDRIFF and PALAEOFLUX. These anoxic hypersaline deep basins are amongst the most extreme environments found in the Mediterranean, with one of the highest dissolved suphide concentrations ever reported for the 'open marine' environment (upto more than 12 mM), and demonstrating large compositional differences between different brine pools: going from a nearly 5 M MgCl2 solution and below seawater Na content (Discovery Basin) to a nearly saturated 5.3 M NaCl solution(Tyro Basin). One of the most extreme environments thusfar discovered is Urania Basin which contains the highest radiogenic supersaturations ever observed for the marine environment (3He / 4He of 1.10-7 and 40Ar / 36Ar of 470), the most extreme d11B (28‰), the highest methane content (> 260 ul/ml), and the highest bottomwater temperature (> 48°C). Irregular methane-driven (?) mud-eruptions appear to occur from the latter bottom at least upto 600 m above the basin-floor, i.e. to a waterdepth of 2900 m. The composition of most of the brines seems to relate to a 'relict brine' or the dissolution of evaporites both originating from the Messinian period during which the Mediterranean is thought to have been dessicated (Bannock, Atalante and Tyro Basins). On the basis of various isotopes for most of these basins the 'relic brine' option seems the most plausible. In addition, the compositions of relevant major and minor elements appear to be in near coincidence with the theoretical seawater evaporation path. Urania brine is the most extreme exception to this picture, its major and minor element composition, but in particular its isotopic signature clearly relates to a source area that must be much deeper than that of the Messinian evaporites, and which is clearly influenced by high-temperature interactions with old sediment and volcanic (ash layers?) units.

In addition to their individual compositional characteristics, each brine demonstrates a typical and for most of them rather stable internal brine structure of various different brine levels. Subtle as well as outspoken temperature and compositional differences occur between the different brine levels in individual basins. The transition between different brine levels, and between brine and seawater may be relatively gradual but usually is extremely abrupt. In particular the seawater/brine itransition is dramatic changing from seawater to 10× seawater concetration within a depth interval of 100 cm. The interface is further characterized by a strong dip in Transmission (= high suspended matter content).

# Material turnover at cold vents

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The chemical composition of vent fluids from different subduction zones is presented and related to the sediment-water interactions occuring within accretionary prisms. It is demonstrated how chemical and isotopic data may be used to deciper the origin and source depth of vent fluids. The biogeochemical processes at vent sites are presented focusing on the biogenic mixing of vent fluids and bottom water, the oxidation of reduced inorganic compounds, and the precipitation of carbonates and barite. A model is presented that may be used to determine the biologically- and tectonically-driven fluid flows. Different procedures for the measurement of fluid flow rates at cold vent sites are presented and critically discussed. The fluid flow rates and dissolved carbon concentrations in vent fluids are used to construct a carbon budget for subduction zones.

# SEAFLOOR CHARACTERISATION / MAPPING INCLUDING SWATH BATHYMETRY, SIDESCAN SONAR AND GEOPHYSICAL SURVEYS

# Seafloor mapping and imaging: Characterisation of seafloor spatiotemporal variability

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## Abstract

The capabilities for exploration of the sea have undergone a revolution during the last 30 years and the knowledge of the seafloor have subsequently higly increased. After a period of important development of research in plate tectonics and global climate change, new challenges will probably be increasingly focused on environmental studies and assessment of resources of the sea and their interaction. The future will allow to adress questions about the seafloor dynamics at different scale which means that the seafloor will be studied at different scale in terms of spatial variability but also in terms of temporal variabilty to observe active processes.

Since the mid-19th, navies and oceanographers have constantly attempted to improve their knowledge of the morphology and the nature of the seafloor. From wide beam to narrow beam aperture echo sounders and more recently to multiple beam arrays, the techniques of seafloor mapping and characterisation have grown impressively. New acoustic mapping systems have undergone a revolution thanks to the development of modern multibeam echo sounders. Figure 1 shows the difference of time necessary to produce a bathymetric map for a given area: 1.5 months in 1974, involving numerous scientists working by hand, using data acquired with a monobeam system to be compared with 12 hours in 1990, using the multibean echo sounder of the R/V L'Atalante. Figure 2 shows the bathymetric map of the Nice- Baie des Anges completed after the 1979 collapse of the Nice airport, this map can be considered as the best bathymetric map possibly produced at that time using the SEABEAM system hull-mounted on the R/V Jean Charcot. Twenty years later, the SIMRAD EM 1000 system allows producing a fully detailed bathymetric map which give us a totally different view of the seafloor.

Today, the spectacular dévelopment of sonar imagery and improvements in digital signal processing almost enable the seafloor to be "seen". Modern techniques have been further developed in the framework of, and for the purposes of, international scientific programmes aiming at a better understanding of global seafloor processes as well as for industrial needs related to increasing use of the sea and the exploitation of its resources. Due to the nature of submarine processes and to the distribution of all wavelengths of seafloor morphology, the range of tools needed is very wide. In terms of frequency, they vary from some Hz to some hundreds kHz covering all the data required for ocean floor mapping and characterisation, from multichannel seismics to high resolution side-scan sonar. It may be also useful to remember that we are dealing with a range of scale which governs the required

resolution of data going to global scale (altimetry) to working site scale (station) (see the following table).

| | | *Range* | Spatial resolution |
|---|---|---|---|
| Scale 1 | Satellites, altimetry | *Global* | 2500 m |
| Scale 2 | Research vessel, Multibeam echo sounder, multichannel seismics | *regional survey ($10^3$ km)* | 100 m |
| Scale 3 | High resolution seismics, Deep-tow | *local survey ($10^1$–$10^2$ km)* | 10 m |
| Scale 4 | Very high resolution seismics, Deep-tow, Submersible | *site survey (1-10 km)* | 1 m |
| Scale 5 | R.O.V. / in situ experiment, sampling, monitoring | *working site (station)* | $10^{-1}$ m |

The collections of papers assembled in this special issue on "Seafloor characterisation/mapping including swath bathymetry, side-scan sonar survey and geophysical survey" exemplifies the research being conducted on european seas and the methodological and technical developments undertaken and in progress. It is clear that european research institutes play an important role in such a topic if we take into account several international programmes such as MAST and the range of exiting tools such as GLORIA, TOBI, SAR, different commercial multibeam systems hull-mounted on many european reasearch vessels and all tools allowing in situ experiments.

# Scientific objectives

The seafloor can be considered as an active domain where many processes are still barely discovered. The processes can be grouped into three main fields according to both their scientific and technological specificities: coastal areas, margins and the oceanic crust.

## Coastal areas

The coastal areas are, for example, typically affected by the action of currents and the erosion, transport and deposition of sediments in interaction with man's activity (pollution, installations). Specific problems arise for mapping the coastal area. If we consider the shallowest part of the sea (<20 m water depth), the part which is directly related to man's activity, it appears that mapping this zone is curiously not easy and therefore not well developed because of severals reasons including saturation (boats, tourism, fishing...), tidal movements and mainly narrow multibeam coverage in such a shallow water. For these reasons the use of satellite data can be considered as a serious alternative (see paper from Wensink et al., in the present issue) when it is possible in very shallow water even if marine survey are still essential.

Many studies which demand an accurate knowledge of the seafloor morphology are now conducted to propose models of currents and subsequent sediment transfer in coastal water. An important effort should therefore be made to map coastal areas. Many local studies have been indeed conducted for different thematic purposes in several european countries. These studies may be based on the use of specific acoustic responses of the seaflloor which give us spectacular example of seafloor characterisation such as mapping of the benthic communities (see paper from Conradsen et al., in the present issue). These different approaches probably need a better intercalibration of the data and to fix common nomenclatures.

## Margin

European margins, as any margins, have given rise to numerous investigations using all sort of tools to map and characterise the seafloor. Margins is considered as the place where many fundamental sedimentary processes, such as active sediment transfer to the deep ocean take place and provide a record of climatic changes. Margins are also a major province of record of sea level change, earthquakes, gas hydrates, slope instability, cold seeps... (Fig. 3) This is also the area where human activity is increasing and where it will go deeper and deeper (ex: deep offshore oil industry).

Among the different and numerous phenomena which can be mapped and characterised on the oceanic margin, the slope failures and associated mass-movement are very often reported. Large sediment failures along the world's oceanic margins has recently been recognized. Striking examples of major slides are given by two case studies presented in this issue. One of these examples concerns recent slope failures and associated mass-movements in the NW Mediterranean Sea which represent huge sedimentary events characteristic of the post-glacial history in this area (see paper from S. Berné et al., in the present issue). The other example correspond to well known Storegga slide which is presented as a natural laboratory for the interaction between gas hydrates and slope instabilities (see paper from J. Mienert et al., in the present issue). Megaturbidite occuring during the last glacial Maximum are often reported and are tentatively associated to the existence, at the time of the failure, to gas hydrates such as for example the Baleraic Basin of the western Mediterranean (Rothwell et al 1998). These examples highlights the importance of gas hydrates, or assumed this importance. They show that there is a huge interest of the scientific community for this topic including fluid migration processes, gas escape at the seafloor, colds seeps, associated specific biosphere (macro and micro-) and geochemical reactions and even interaction with climate change related to the hypothetical release of substantial amounts of the greenhouse gas methane. Many processes have still actually to be understood which may explain how fluid migration interacts on the dynamics of the seafloor such as for example slope failures.

Several european research programmes such as MAST ENAM and STEAM and numerous industrial ventures and academic regional investigations have also demonstated evidence of giant slope failure on the european continental margins. These events can obviously form major hazards to human settlements along european coasts such as tsunamis (ex: the well known event which occured in Lisbon in 1755). These geohazards are also directly concerning human activity on margin which is now undergoing a very important development in deeper water: the

deep offshore oil industry. These major processes are also mainly reponsible of sediment transport from the slope to the deep sea and their study can contribute to the understanding, thanks to spectacular case studies such as the recent discovery and mapping of an active deep sea fan in the Celtic Sea (fig 4; Auffret, pers. comm.), which give a very representative example of sedimentary bedforms considered as "analogues" of oil and gas reservoirs. Taking into account the recent wide development of offshore exploration, the understanding of sequence architecture and depositional facies in turbiditic environment is becoming one of the main challenge for sedimentology studies to be conducted on modern depositionnal systems. These purposes imply integrated studies (from the alluvial plain to the dep sea) of sedimentation on European margins including Quaternary sea-level changes, sequence stratigraphy and gravity-laden processes.

The offshore oil and gas industry is undergoing a huge development in deep water. The activities concentrate in N.W Europe, Brazil, Golfe of Mexico and West Africa where a great deal is expected. European oil companies are involved in all these area. This industrial development call for new research in Earth Sciences and technology for deep water investigation. Development of new methodologies implying efficient tools and softwares for mapping and characterising the seafloor at different scales are also required. All the scientific objectives which concern study of geodynamics, thermicity, sedimentary basins, sequence stratigraphy, gas hydrates, gravity processes and deposits, slope instabilities, are in fact the base of a new start for margin and sedimentary process studies for geoscientists who are facing an important challenge to answer many questions really requiring scientific approaches to be solved. Several initiatives have therefore been proposed in different countries (european and north american) to launch MARGIN programmes.

## Oceanic crust (Needham, pers. comm.).

It is useful to remember that about less than 10 % of the deep ocean floor has been covered using modern surface ship mapping and imaging. Concerning crustal studies, the crest of the mid-oceanic ridge has attracted particular attention. The mapping had led to huge advances in knowledge of the details of segmentation and surface structure, in guiding the collection and interpretation of all sorts of geophysical and petrological data and in exploring for understanding active hydrothermal systems. Crustal studies require a global approach and it is important therefore that Europe has a global and not a provincial approach. There also clearly a particular opportunity to develop research in the region of the Açores and surrounding area. Many problems not only of local but of general interest are posed there.

The Açores represente a major mantle-melting anomaly (hot spot). The North American/African/ Europe plate boundary triple junction is located there. Both normal and unusual deep and shallow crustal processes are expressed in the region. It is an area of important hydrothermal activity and associated biological communities and metallic sulphide deposits. It is a zone of volcanic and seismic activity which presents natural risks to the population. And it provides an exceptional opportunity (thematical and logistical) for developing submersible projects, for exploring the possibility of new R.O.V.s and for planning long-term seafloor observations. Future aims as different as assessing hydrothermal chemical and thermal budget and their impact on the oceans or understanding the distribution

and modes of tectonic and submarine volcanic activity, can be adressed only in harmony with an intimate knowledge of bathymetry, morphology, slopes, sediment and bare-rock distribution and other properties of the sea-floor. This implies mapping and imaging at all scales, including the use of deep-towed devices. A start has been made, the axial area cutting through the Açores plateau and to the South and part of the plateau itself, for example have been mapped and imaged with hull mounted EM 12 systems. But there are years of work, particularly fine-scale work still to be done in order to have a full picture of the area and to begin recording temporal variations in this active part of the ocean

Characterisation of the mid-ocean is crucial for understanding accretionary processes and, for example, their consequences on biological populations associated with the creation of new crust. The study of the ridge gives us a good example of the necessary tools needed to map it by successively using a range from satellite altimetry, multibeam bathymetry, acoustic imagery and finally to optical imagery (Desbruyeres D. Michel J.L 1997).

# Tools, data processing and methods

## Mapping

More efficient and therefore cost-effective tools such as hull-mounted systems, which permit more efficient and extensive surveys, should be one of the major trends in future technology where it is possible and when appropriate resolution can be attained. The major development of these systems concern the improvements of their performance, especially in terms of imagery and therefore data processing (see papers from Canepa et al. and Lurton et al. in the present issue).

Moreover, the need for more accurate geophysical measurements, in response to the requirements for high or very high resolution deep water studies, will trigger the development of new deep-towed multipurpose tools. One good example is given by Savoye et al (in the present issue) with the recent development of the PASISAR system which is a first step to solve the problem of the near bottom seismic profiling in deep water. The future tools which will follow the generation of SAR and TOBI sonars will obviously integrate several sensors such as mid-range side-scan sonar, multibeam system, deep-towed seismics and other geophysical and geochemical sensors. A particular progress will be made in developing deep-towed seismic source. The problem of positioning, even if it is more or less solved by using ultra short base line positioning system, still remains to be solved in order for such instruments to be routinely used by scientific teams.

## Seafloor characterisation

New acoustic mapping systems have recently undergone a revolution; standart image processing algorithms such as contrast enhancement are an example, but data processing is definitively more than just image processing. If acoustic backscatter generally relate to sediment characteristics, some simple assumptions such as the hypothesis that coarser sediment always produces greater acoustic backscatter are wrong. An example is given by figure 4 exhibiting sandy lobe deposited in Celtic fan (N-E Atlantic) which indeed produces a spectacular low

reflectivity patch. We therefore need both ground truth and appropriate data processing system for characterising the seafloor. The aim of seafloor characterisation is to subdivide an entire image into classes that possess unique sets of image attributes (Pratson and Edwards, 1996). One of the most active areas of research is the development of automated techniques for classifying different terrains in remotely sensed data. The new generation of swath system allows the simultaneous record of the bathymetry and the seafloor reflectivity. The calibration of the reflectivity by samples generates an acoustic characterisation. A new image is calculated and forms the base of the classification; the geologist teaches the software the different facies by locating them on the mosaic. The acoustic signatures of these facies are determined and stored if they are discriminating enough; the label of the most similar facies is assigned for each of the pixels. The result is the so-called "segmented image" (see Lurton et al., in the present issue).

## Use of existing data

3-D seismic data, usually acquired for oil and gas exploration purposes, is now being used to supplement or in some cases, even replace conventionnal high resolution geohazard surveys (Gafford, 1996). Migrated 3-D exploration data represents a powerful addition to the detection, interpretation, mapping of deep water hazards to drilling operation and the floor engineering. Thanks to the regular density of coverage and the ease of manipultion of data in a computer workstation environment, the ability to extract reflectors attribute and to produce comprehensive 3-D maps of subsurface stratigraphy and seafloor images is a valuable addition to offshore geohazard investigation.

## In situ experiments

In situ measurements of physical and geotechnical properties of marine sediments are necessary to calibrate marine acoustic data and because of different quantitative studies requiring reliable measurements of the seaflor properties. These properties cannot be accuratly obtained with laboratory analyses because of the remolding effect of core sampling. For example, in case of study devoted to slope stability assessment, some specific physical and geotechnical parametres are required to characterise the sedimentary layers involved -or potentially involved- in slope failures. Some static parameters such as density, shear strength etc... are first measured. For that purpose boreholes can be considered as the best, but more expensive, way to access to in situ measurements. For cheaper, and probably more efficient measurements, some equipements have been recently developed in some european research institute for superficial in situ experiments such as SAPPA (see paper from Best et al. in the present issue) though a few tool have been developed for deeper penetration. But it is clear that these first experiences will allow developing tools for a deeper penetration below the seafloor in order to study the mechanical behaviour of the seafloor that should be mainly addressed with in situ measurements.

On the other hand, dynamic parameters are also ideally needed, for example seismic acceleration in case of earthquake, or excess pore pressure as a response to earthquake or in case of fluid migration processes. For that purpose, long term site monitoring would be necessary to study either sediment behaviour or any seafloor processes. Many tools exist in fact -or can be improved- to investigate the

seafloor, but important questions arise now about the temporal variablity of seafloor processes at different scale (roughly 1 sec. to 10 years) (Desbruyeres and Michel, 1997). Important developments will be carried out, implying great technological progress for developing new sensors and to solve problems of energy, high capacity data storage, specific communications systems between seafloor and laboratory on shore such as the research conducted in the MAST-GEOSTAR programme.

# Conclusion

Fantastic progress have been made mainly in the framework of plate tectonics and climate change research programmes; they have now created the scientific context for developing new challenges that will probably be increasingly focused on environmental studies and assessment of resources of the sea and their interaction. Therefore, exceptional opportunity exists now to develop research on margins where there are clear present common interests of science and industry, especially for the deep offshore oil industry.

Hull-mounted systems such as multibeam echo sounders should still undergo an important development in terms of higher resolution for mapping and especially for imaging the seafloor. On the other hand, new deep-towed tools integrating several sensors are required for very high resolution deeep water multipurpose studies. In any case, experience shows that a better use of highly sophisticated tools and methods needs, and will need, the support of ground-truth. Ground-truth supposes man's competence but also specific technology such as sampling, in-situ measurements involving specific developments of instrumented platforms, the use of R.O.Vs and obviously the tremendous need for boreholes. Many local studies have been conducted and have produced good geophysical data, but we tremendously lack of calibration, drilling should be now considered as the ultimate test of all geological model, especially on continental margins where both scientific and industrial objectives are concentrated.

These objectives will demand the development of new technologies, and their intensive use. Discussions have been recently undertaken between several european marine research agencies to take further steps towards the creation of a unified European fleet of research vessels with a common scientific programme (see Nature, 392, 637;1998). If taking into account the numerous existing data and national programmes in progress, we can at least hope that at the european level (1) a better coordination of research will be organized, especially for an efficient use of ship-time, which remains the most important means -and therefore difficult to obtain- for marine scientists and (2) an effort of standardization will be made to reach one of the ultimate objective: to map all the european margins and ridges, because mapping is the first step of all oceanographic research programme and many areas are still to be systematically investigate to produce a map of the european seas, even if many initiatives had already been taken, especially in deep sea where some regions are almost totally mapped.

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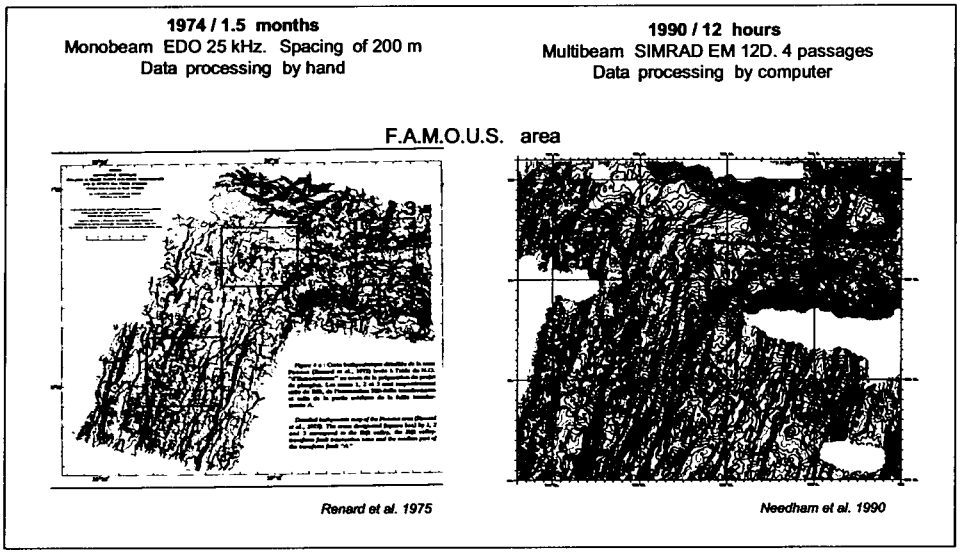



Fig. 1: Bathymetric map of the FAMOUS area. Comparaison of efficiency of different means between 1974 and 1990 for mapping the same area.

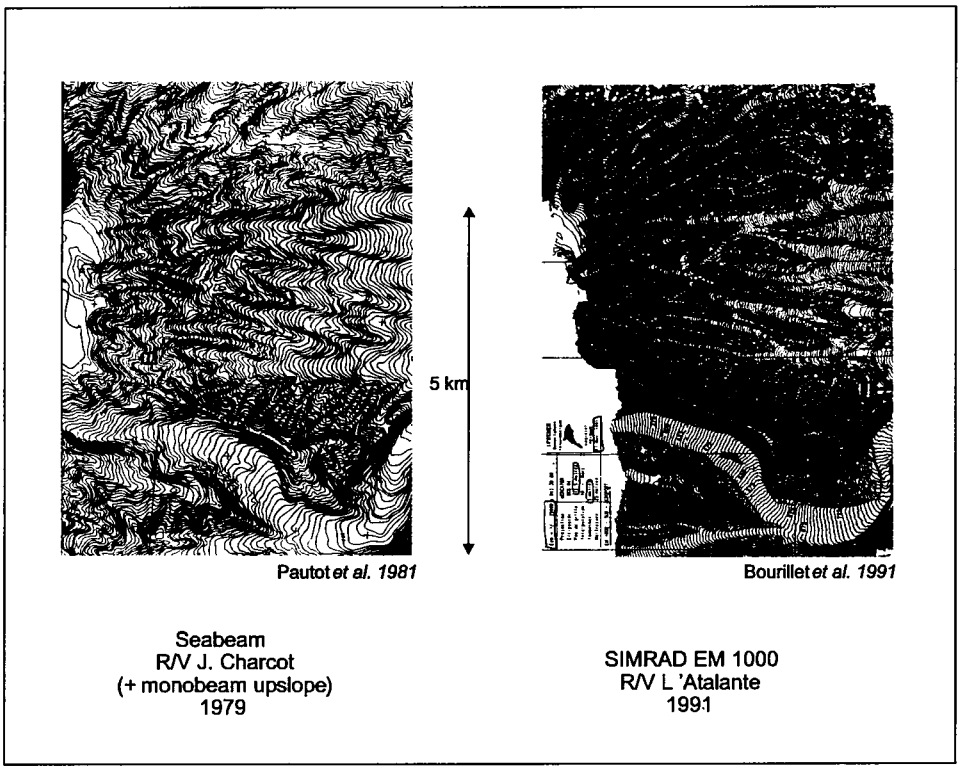



Fig. 2: Bathymetric map of the Nice-Baie des Anges. Different quality of maps acquired in the same area using different generations of multibeam echo sounders.

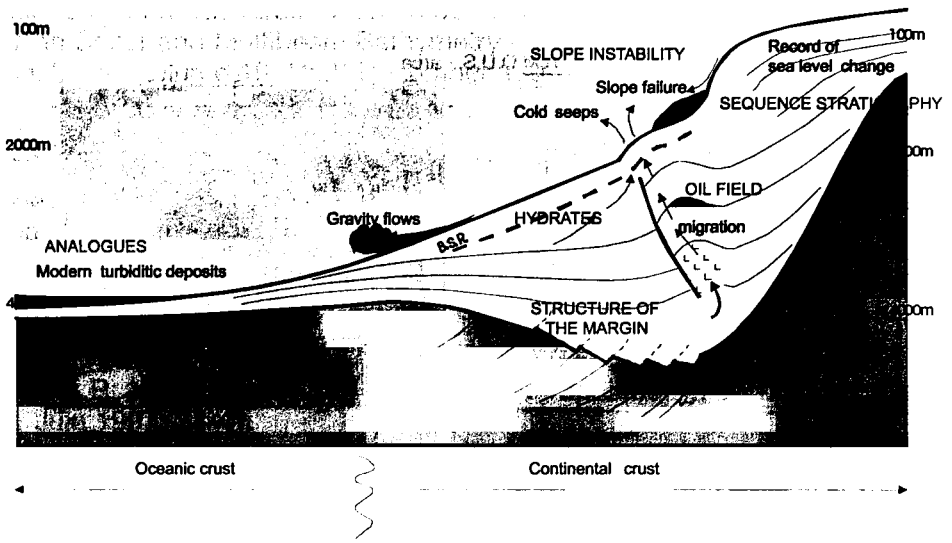



Fig. 3: Main scientific questions which can be adressed on margins in terms of sedimentary processes.

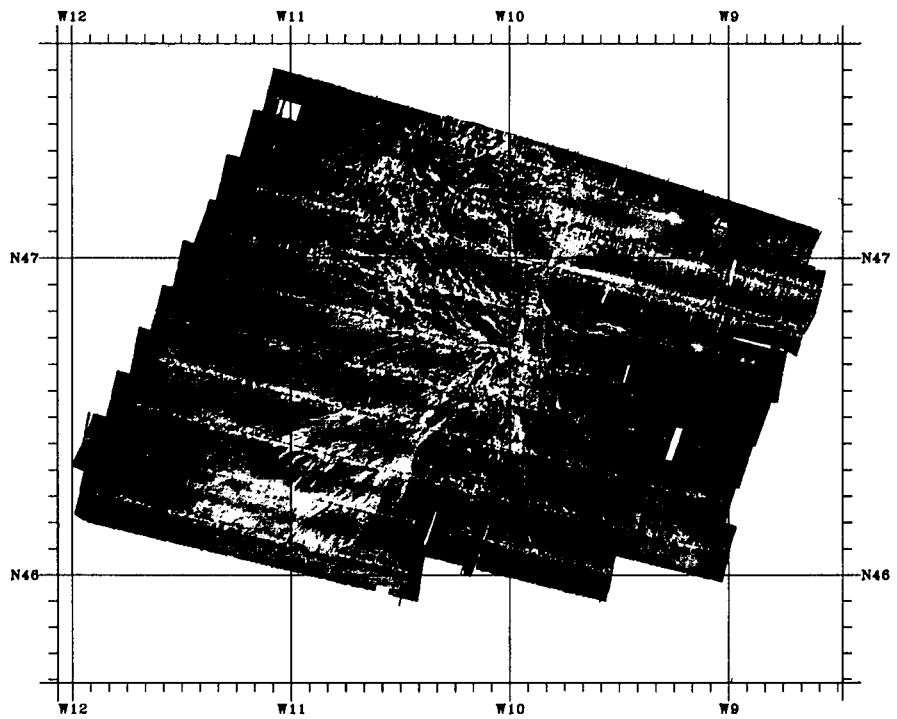



Fig. 4: Sonar imagery of the Celtic Fan exhibiting low reflectivity patches related to recent sandy lobe deposits (example showing that coarser sediments do not always produce greater acoustic backscatter). (by courtesy of G.A. Auffret, MAST Project/ ENAM)

# PASISAR: Several aspects of near bottom seismic profiling in deep water

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After a few decades of large-scale marine exploration, it is now time for more detailed studies even in very deep areas. Very high resolution seismic systems lack for such a type of work, because conventional seismic technology is not appropriate to obtain clear images of the seabed features in deep waters, for the following reasons: (1) increasing travel time implies a significant decrease of the shot rate, and (2) even with pre-stack migration, the blurring effect due to the width of the Fresnel zone could not be overcome, as the time arrivals are almost coincident on a very large area of the seabed.

During the last 10 years, IFREMER operated a deep-tow side-scan sonar system for high-resolution studies in water depths up to 6000 m: the SAR. Because hybrid seismic systems (with a sea-surface source and near-seabed streamer) seemed promising and seismic data could usefully complement SAR data, IFREMER developped the PASISAR project (Selsmic PAssenger for the SAR). It combines a surface conventional source with a single channel seismic streamer, towed at about 100 m above the seafloor behind the SAR vehicle. The geometry of this hybrid system is such that the seismic resolution is largely better than the one obtained using conventional surfaceship systems, but this geometry creates time arrival distortions.

The project started in late 1992, and the first trials at sea were carried out in February 1993. Since that time, 7 cruises were conducted with PASISAR up to 5200 m water depth. The seismic source is towed near the sea surface and can be an air-gun, water-gun or sparker. As with conventional surface seismic, the nature of the source is chosen in function of the desired penetration, resolution and water depth. The streamer was specifically designed for this project.

The main difficulty in interpreting PASISAR data resides in the effects of streamer motion, notably in changes of streamer height above seabed and streamer immersion, but also in changes of in-line offset between source and receiver. Several post-processes are necessary, in order to take full advantage of the increased resolution of the PASISAR system. The processing is now done on board during the cruises. The quality of the processing is highly reliable to those of the navigation data.

The PASISAR system is able to acquire high-resolution seismic data with significantly greater details than conventional surface seismic. They usefully complement other data from the SAR (very high-resolution side-scan sonar imagery, near-bottom bathymetry, near-bottom 3.5 kHz profiling and 3-component magnet-ometer data).

The SAR added with PASISAR can be considered as the forerunner of systems capable of integrated seabed studies in water depths up to 6000 m useful for research studies as well as for industrials needs. The European scientific community must take into account the capabilities of this new generation of deep-towed geophysical systems in defining new integrated research works.

# The SAPPA — a new instrument for-insitu seismo-acoustic measurements on seafloor sediments

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Remote seismo-acoustic observations of seafloor and sub-bottom sediments have the potential to give sediment properties information that is vital for quantifying the threat of slope failure. Our comprehension of wave propagation mechanisms in marine sediments is fundamental to our ability to extract useful parameters, such as sediment shear strength, from seismo-acoustic data. To conduct a systematic study of the relationships among seismo-acoustic and geotechnical properties requires an instrument that will provide reliable in-situ measurements in all water depths, and one that can easily be deployed from a range of research/survey vessels. Hence, the concept of the SAPPA (Sediment Acoustic & Physical Properties Apparatus) was born.

The SAPPA is a seafloor lander that can visit multiple sites per launch and is designed to operate in up to 2,000 m of water. It allows a flexible approach to sensor configuration according to sediment type and water depth. Measuring both acoustic and geotechnical properties on the same volume of sediment at the same time, it should provide the necessary data for unravelling the complex interaction of seismic waves with marine sediments.

In its present configuration the SAPPA comprises a circular-based, steel frame on which to test the newly developed seismo-acoustic systems. The latter consist of:

1. P-wave system. Two probes designed for penetrating up to 1 m of sand or gravel. One probe has mounted in its tip a mechanical, broadband, P-wave source giving frequencies in the range 1 — 10 kHz, the other has a hydrophone receiver also mounted in its tip.

2. SH-wave system. A novel, mechanical, shear wave generator is coupled to the seafloor and propagates horizontally polarised (SH) shear waves over a distance of 1 m to a three component geophone, also coupled to the seafloor.

3. SV-wave system. Vertically polarised shear waves are produced by the hammering action of the probes, thus giving a "reversed vertical seismic profile" geometry.

The S-wave systems have been tested on a sandy beach, and in shallow water on carbonate sands and gravels. The results from the beach trials clearly show polarised S-wave arrivals, from which it is possible to extract sediment velocity. The shallow water results are more difficult to interpret because of spurious arrivals (whether due to environmental noise, ships noise, the steel frame itself, etc.), but

nevertheless, it is possible to measure S-wave velocity on a number of records. Water tank tests of the P-wave source show that it produces a good broadband signal which can be used to measure both velocity and attenuation. Future sensor developments will enable S-wave attenuation to be measured, as well as velocity, and will include the addition of geotechnical sensors (e.g. cone penetrometer).

# Bathymetry Assessment System (BAS)

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Accurate depth information in coastal areas is essential for monitoring of morphological changes and to ensure the safety of shipping traffic. Currently water depths are measured using ship-borne echo sounders, which record the water depth along the ship tracks. From these measurements, 2-dimensional bathymetric maps are constructed through interpolation. The ship-borne surveys are expensive and time-consuming. A remote sensing technique has been developed to map the bathymetry by using Synthetic Aperture radar observations.

## Theory

Under normal meteorological and hydrodynamic conditions (moderate winds of 3 to 5 m/s and significant tidal currents of about 0.5 m/s), air- or space borne Synthetic Aperture Radar (SAR) imagery shows features of the bottom topography of shallow seas.

The imaging mechanism of mapping sea bottom topography by imaging radar consists of three stages.

(1) Interaction between (tidal) flow and bottom topography results in modulations in the (surface) flow velocity. This relation can be described by several models with an increasing level of complexity: continuity equation, shallow water equations, and the Navier Stokes equations.

(2) Modulations in surface flow velocity cause variations in the surface wave spectrum. This is modelled with the help of the action balance equation, using a relaxation source term to simulate the restoring forces of wind input and wave breaking.

(3) Variations in the surface wave spectrum cause modulations in the level of radar backscatter. To compute the backscatter variations a simple Bragg model can be used, but also available are two-scale and first iteration Kirchoff (Holliday) models.

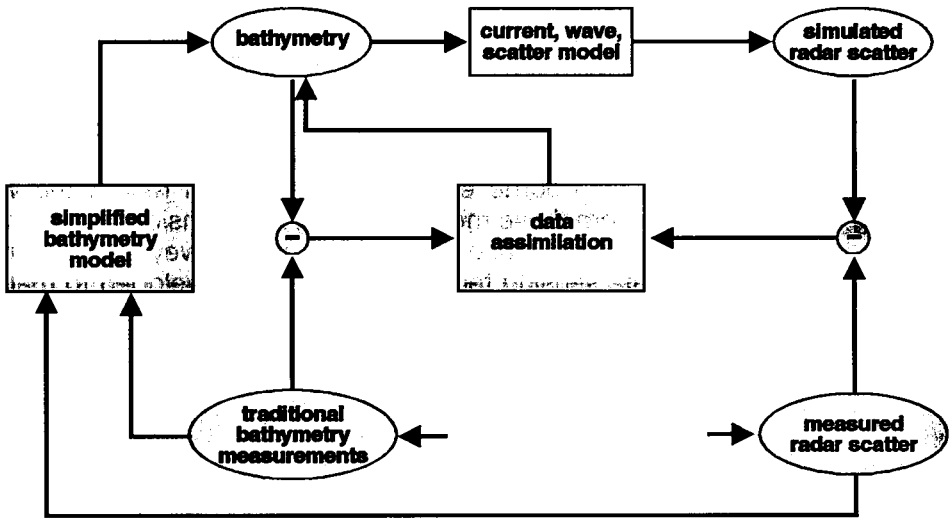
Based on the above three stage mechanisms, a suite of computer models has been developed and operationalized at ARGOSS. Models with different levels of complexity and physical detail are available for each step. These models describe the flows, waves and electromagnetic scatter and can be used for a quantitative analysis of radar imagery.

This suite of computer models generate the radar backscatter given the bathymetry and the wind. In order to invert this depth-radar backscatter relation, a data assimilation scheme has been developed, minimizing the difference between the calculated and the measured radar backscatter by adjusting the bottom topography.

A first pre-operational system has been implemented at the Ministry of Transport and Public Works in the Netherlands.

The structure of this modular system is shown in the figure below.

Figure Bathymetry Assessment System




At the conference technical information on the Bathymetry Assessment System, examples of bathymetric maps produced by the system and further developments will be presented.

# Underwater rail facility for highly controlled experiments at sea (*)

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This presentation will focus on the description of experiments designed and carried out in order to measure bottom reverberation and scattering from buried objects insonified by low-frequency broadband acoustic pulses at various aspects and grazing angles.

Detection and classification of buried objects is a difficult task due to the high levels of acoustic attenuation characteristic of some ocean sediments using conventional detection sonar system frequencies. In order to address this problem, recent research has focused on experimental broadband sonar concepts, utilizing frequency bands which extend down to the order of 1 kHz. As acoustic attenuation is generally less at lower frequencies, it is felt that acoustic detection of buried objects may be feasible using this approach. Also, the broadband nature of the sonar gives a large relative bandwidth over which target classification information may be extracted. In this context the bandwidth of the acoustic pulses used is in the ka range [1-15].

Attention is focused on:

- the detailed resonance response, as well as the effect of full burial on the magnitude of the target backscattered returns and, hence, on the target detectability as the grazing angle and the target aspect angle vary,
- collecting backscattering data under known and controlled geometry in order to allow reproducibility.

The parametric array TOPAS is used as transmitter. For acquisition under variable conditions of trial geometry, the transmitter is mounted on a variable-height chassis which in turn is mounted on a 24 m linear rail deployed on the bottom, along which it can be moved in a precise and controlled manner. The rail is equipped with a motor which allows accurate and reproducible displacement of the chassis along the rail. The TOPAS transmitter is mounted in a pan-and-tilt assembly with a MRU (Motion Reference Unit) so that arbitrary transmission directions can be accurately measured. As a receiver, a 1.4 m 16-element array can be deployed either vertically or horizontally close to the transducer.

Multiple targets can be deployed in front of the TOPAS. The TOPAS can move along the central range of 20 m of the rail.

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(*) This work was partially funded by EU in the context of MAST-III DEO (Detection of Embedded Objects) Project.

Trials with buried targets and bottom reverberation require environmental data in order to be able to interpret acoustic measurements. Cores must be taken in order to evaluate the geophysical structure of the area (e.g., depth of sand layer) and the geophysical properties of the sediment. The equipment described was used during a sea trial around Elba Island (Golfo della Biodola) in April and June 1997. A video recorded by an underwater camera will be presented showing in detail the various pieces of equipment and describing the different experimental phases (e.g., equipment deployment, target burial, etc.). The data collected during these trials will be shown.

# Seafloor characterization using multibeam echo sounders: Methodology and first results

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Modern multibeam echosounders (MBES) provide high precision bathymetric data, together with sonar images representative of the seafloor fine structure. Due to their capability of quick surveying and mapping of large zones, they provide a unique tool for characterization of the surficial seafloor, since various acoustical features may then be associated with extended areas. We propose here a methodology derived from the recent IFREMER works in the field of multibeam data processing for seafloor characterization.

Three major steps are to be considered. A preliminary data checking and preprocessing is intended to eliminate as far as possible all the MBES artefacts. Then the studied zone can be segmented into homogeneous regions according to acoustical criteria. Finally the characteristic features of the seafloor are to be used for a characterization, or at least a classification of the seafloor geological features.

Due to the fact that acoustical analysis of the seafloor essentially relies upon amplitude exploitation (average level, and fluctuation statistics), one has in any case to make sure of the validity of the levels provided by the echosounder and to eliminate artefacts, in order to go securely upstream back to the original physical data. While artefacts of bathymetric measurements are usually correctly addressed, we found that today's MBES do not provide sufficient guaranties about the actual acoustical level measurements. Confident that next generations of multibeam systems should remedy this, we had, in the meanwhile, to develop our own post-processing chains in order to compensate directivity effects and receiver processing gains. An example is presented of beam directivity pattern effects upon acoustical images, its estimation and post-correction.

The segmentation step is intended to partition the sonar image into homogeneous zones according to acoustical (and hopefully geological) descriptors. The first descriptor was taken to be the backscattering strength as a function of incident angle, since such a law (dependent on sediment roughness, impedance and inhomogeneity) is known to be characteristic of the seafloor type. It allows to associate each pixel of the sonar image with a most probable backscattering law, accounting for the measured level statistics and the local incident angle; this means that seafloor topography, and refraction by water sound-speed profiles, are correctly known and compensated for, meaning that the bathymetry processing has been previously performed. We propose to homogeneize the various segmented zones

using a classical image processing approach (Markov's fields). Results of this segmentation method are presented for some shallow- and deep-water cases.

The third step (characterization) is intended to assign to every segmented zone, either the objective characteristics obtained from acoustical measurements, or the result of a (more or less "blind") classification operation. The first approach aims at extracting physical features (acoustical impedance, microroughness) from the available acoustical data (average levels, amplitude statistics, time signal spectra, image texture). While "direct" modelling of sediment backscattering phenomena may be quite successful, inverse problem is made difficult by the non-unicity of relations between geological and acoustical features, leading to determination ambiguities. On the other hand, more commonly employed classification processes may use raw data without clear physical interpretation; they rely upon preliminary training phases that have to be supported by careful groundtruthing operations on test zones, and offer no guarantee that ambiguity problems should be solved. Finally, a geologist's best choice may be to directly calibrate the acoustically segmented areas using local groundtruthing. Hopefully the three approches may prove to be complementary.

MBES then prove to provide a very significant progress in the field of seafloor characterization, especially if used in conjunction with other seafloor survey systems such as sidescan sonars, sediment profilers and high resolution seismics. One cannot over-emphasize the importance of completing the geologist's expertize with (1) a good mastering of the MBES characteristics (and, as a corollary, the possible development of specific postprocessing) and (2) a thorough understanding of the involved physics.

# Automatic Outliers Elimination and Optimal Mapping: A Solution

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During the last twenty years, many multibeam bathymetric sonars have been produced. The instrumentation is usually accompanied by a system able to produce a seafloor map using the sonar data. There are also several public domain systems, which can be used to obtain a map from the data. All these systems produce a gridded map that must be filtered in order to reproduce the original seafloor surface because of the effect of the noise in the bathymetric data. Both the gridding and the filtering algorithm introduce a source of error that is not easily controlled. Moreover, gridded maps may use significant storage space for a small amount of information. Until now, a systematic solution with realistic run-time requirements to the problem of identification and elimination of wrong data (outliers) has not been available.

We present here an algorithm to fit bathymetric data and to deal automatically with outliers. The main characteristics of the algorithm are:

- Production of a triangulated map of uniform accuracy irrespective of seafloor features
- A map resolution which depends on the local data noise amplitude
- Automatic elimination of outliers
- Small computing cost even on large data files (more than 1 million points)

The algorithm was applied to synthetic data to understand its behavior when parameters are changed. In particular, data mapping with and without outliers has been tested for both continuous and discontinuous synthetic seafloors. The algorithm has also been tested on real data. Some tests were also performed on the triangulation engine behavior, algorithm implementation speed, and fitting errors.

The algorithm can be used to reduce the operator intervention during bathymetric data mapping. Raw bathymetric data are directly analyzed by the algorithm which automatically and robustly eliminates outliers and produces a map the parameters of which can be finely tuned by the user (number of nodes, smoothing, level of data cleaning, etc.). The algorithm has been implemented, exhaustively tested on synthetic and real data, and fully documented.

This work has been partially supported by EU, under the MAST-III initiative, project "ISACS", contract no. MAS3- -CT95- -0046.

# Mapping of the Benthic Communities Common Mussel and Neptune Grass by use of Hydroacoustic Measurements

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## Abstract

The optimal monitoring of benthic communities ranging over several square kilometres or more requires careful design of the transect grid to be used. Among other factors, prior knowledge about the local structure of the spatial variation of, e.g. Common mussels, can enhance the results drastically, when the end-goal is to produce interpolated distribution maps. In this presentation we present results based on two field campaigns in the Meditteranean and the sound called Oeresund between Denmark and Sweden. Methods applied include 2D semivariograms, top hat transformations of kriged maps and discriminant analyses including non-parametric classification.

We conclude that a two-step approach is recommended for mapping of most larger-scale areas, and that the use of proper groundtruthing is crucial for the quality of the resulting maps.

Scientific objectives of the research

In short, BioSonar is a project concerning how to produce reliable and precise distribution maps for benthic communities at optimised costs, that is applying as many automated processes as possible.

Described in another fashion the overall goals of the BioSonar project are

* Quantitative detection (ability to detect benthic communities, and the ability to characterise their density with satisfactory precision)
* Reliability (reproducible or traceable, objective methods)
* Automation (computerisation of all possible work processes)
* Change detection (methods for monitoring changes in benthic communities).

Scientific context of the research

Statistical image analysis, Geostatistics, Statistical sampling design, Marine biology

# Recent slope failures and mass-movements in the NW Mediterranean Sea

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In the Western Mediterranean Sea, catastropic events that cut telephone cables have been reported in modern times, e.g. the failure event off Nice in 1979 (Gennessaux et al., 1980; Malinverno et al., 1988) or the large turbidity currents induced by the 1954 and 1980 earthquakes offshore El-Asnam (previously named Orleansville, Algeria) (El-Robrini et al., 1985). A few millennia old, major landslide-derived deposit, tens to hundred km3 in volume, has been also reported on the western flank of the Rhone Deep-Sea Fan (Mear, 1984; Droz, 1983; Torres, 1995). Recent investigations (respectively in 1995 and 1997) in the Valencia Gulf (Canals and Alonso, 1996) and on the lower slope and rise of the Gulf of Lions-Rhone neofan transition zone (CALMAR Cruise Team, 1997) have mapped similar deposits, with evidences for recent origin.

The BIG'95 cruise of R/V Hesperides in 1995 allowed the mapping of a large slide scar and deposit, off the Ebro shelf. It extends from the prograding Ebro shelf break down to 1800 m water depth. A rough, distinct topography, very apparent on swath maps, characterises both the scar and the surface of the deposit, which forms a seismically transparent layer that buries the former sea-floor topography and partly fills the uppermost course of the Valencia mid-ocean type channel, opening between the Iberian and Balearic margins, in the Valencia Gulf. A horse tail structure appears on backscattering images, that corresponds to shallow, converging channels separated by segments with a blocky texture. Individual blocks have been measured to be as high as 35 m over the surrounding sea-floor. The mean thickness of the deposit is around 15 ms, with local maximum of 40 ms. The overall area affected by the slide covers about 1.300 km2, with a maximum width of 30 km between 1400 and 1600 m water depth. Its volume has been estimated to be around 26 km3.

In November 1997, a complete swath mapping (Simrad EM 12 and EM 950) of the Western Gulf of Lions slope and rise (water depths comprised between 150 and 2200 m) was carried out with R/V "L'Atalante" together with sub-bottom and seismic profiling, and piston coring. The research work carried out during this cruise constitutes the seaward continuation of detailed mapping of shelf morphology and Quaternary depositional sequences. The 3D mapping of canyons demonstrates that they are Plio-Quaternary (not Messinian) features, some of them having recently migrated in a SW direction. A striking feature is the presence of minor channels within the main course of several canyons, these channels being generally

connected to upper-slope scars. Some scars truncate lowstand shorelines deposited during Last Glacial Maximum, indicating that these events are younger than about 20,000 y. BP. Downslope, a large variety of gravity deposits has been mapped. The Pyrenean-Languedocian "deep-sea fan", with characteristic levees and sediment waves, occupies the western portion of the continental rise. To the east, the western levee of the Rhone deep-sea fan is flanked with the Rhone neofan. In between, the sea-floor is covered by a possibly multi-episodic, with various upslope source areas, large debris flow which is at the origin of distinct seismic and backscattered facies.

There is no doubt that both debris flows from the Valencia Gulf and Gulf of Lions represent the most recent sedimentary events in these two areas. An important aspect in future studies will be to establish the exact timing (possible synchronism) and origin of these sedimentary events, in relation with tectonic activity (seismicity and/or salt tectonism), changes in sea-level, hydrodynamical regime, physical properties of sediments and position of depo-centers. Beside the classical ways for dating marine sediment, the analysis of very well preserved shelf depositional sequences could be a way for determining the post-glacial history of slope mass-wasting in these two areas of the Northwestern Mediterranean Sea.

# Gas hydrates and slope instabilities on the European North Atlantic Margin (ENAM) as indicated by sea floor mapping and drilling

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The European North Atlantic Margin (ENAM II) studies are to provide geophysical and geological observations on sedimént instability, gas hydrates and major mass wasting events occurring on the continental slope from the Celtic Margin to the Norwegian Margin. Over 10,000 km2 sidecan sonar coverage and high frequency seismic profiles were obtained in selected areas. The determination of the timing, causes and flow processes of mass wasting events associated with gas hydrates and margin instability will provide detailed knowledge about the spatial and temporal variability of marine systems from the shelf edge to the slope, which clearly also has relevance for the offshore industry in designing platforms and infra-structures. The target areas presented are at the Traenadjupet and Storegga slides on the passive mid Norwegian margin. This appears to be a natural laboratory for the interaction between gas hydrates and slope instabilities, where the slides or potential hazards have been investigated using single and multi-channel seismics, Ocean Bottom Hydrophone seismics, TOBI high-resolution sidescan sonar, and finally drilling. It turns out that the hydrate zone is a complex, multiphase system with fluid transport, where one often observes up to 100 m high and several up to 1000 m wide mud volcanoes and pockmarks at the sea floor. The developments of such zones with time still needs clarification. We know that the stability of gas hydrates is mainly controlled by the temperature regime of the oceans and by pressure conditions on the seabed. They are directly linked to global change climate processes and thus to temperature and sea level changes. Seismic data show that large slides on the Norwegian continental margin seem to be associated with gashydrate reflectors. We cannot exclude that any major modification of the ocean's dynamic thermal structure in a warming world might cause outbursts of vast amounts of methane from the seabed reservoir and cause an increase in mass wasting activity. The morpholgical character of the Storegga slide for example and the preservation of structures may lead to the conclusion that the present slide scarp and the features down slope cannot be 25,000 yrs old as previuosly thought. The present slide zones and the associated seismically bedded areas indicate instead a much younger instability than previously thought. Modeling of hydrate formation and dissociation processes during climate changes (warming and cooling) and combining laboratory and field results may shed light on the still not well

# PROSPECTS FOR A EUROPEAN CONTRIBUTION TO INTERNATIONAL SCIENTIFIC OCEAN DRILLINGS

# Ocean Drilling: a Logic for Europe

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## Abstract

When 22nd century historians will reflect on the advances of Earth Sciences in the last centuries of the second millenium, two milestones will no doubt come to the foreground: the cruise of *HMS Challenger* in the late nineteenth century, which unveiled the deep oceanic environment of our planet, and the DSDP-ODP venture with the *Glomar Challenger* and the *Joides Resolution*, who brought to mankind not only the confirmation of plate tectonics but also the record of its past climate and of the subtle mechanisms of interaction between the various spheres of the outer Earth system. Ocean Drilling has become, like space exploration, a key vector for Man's quest in understanding his planet.

ODP has been driven throughout the years by mid- to long-term commitments of Science Foundations and Institutional Agencies, in harmony with their long-term strategies. Any realistic prospective for ODP should convince its major sponsors to continue their support for a global programme.

Two new elements have however moved onto the ocean exploration stage since the late eighties, especially in the European realm. The first one is a remarkable European effort for gaining a better insight in the seas and continental margins around Europe, through a programme called MAST. A programme which identified scientific topics with a European flavour but a global relevance, and which fostered European marine technology with a genuine generic development potential.

Throughout the programme phases MAST 1, MAST 2 and MAST 3, a tight scientific community has been forged which has identified major scientific challenges around the margins of Europe, some of them really at the leading edge of science. Many of these teams however still wait for the groundtruthing of their results by drilling, simply because the scale of an oceanic drilling exercise, even in shallower waters like the outer shelf or upper slope, generally exceeds the resources of any single project. A special support scheme has to be designed for allowing the full valorization of the resources already invested. In a way — a kind of "finishing touch" for Europe's past homework.

On the other hand, deep waters on continental slopes gain a widening interest as the next frontier in offshore hydrocarbon exploration and development, not the least on Europe's Atlantic margins. It is however a domain where slope instabilities and potential hazards related to e.g. gas hydrates are looming large. And recent discoveries suggest deep-water coral ecosystems display an avowed predilection for deep hydrocarbon provinces, for reasons still poorly understood. Beyond the fundamental questions evoqued, such areas call for a thorough assessment of the environmental impact of any future exploitation.

These are challenges which shape an optimal arena in which science and industry can and should meet, under the auspices of the European Union, in true harmony with the latter's nature and vocation. It is indeed a typical domain where a strong scientific rationale can be driven by the logics of EU economy and policy. Not only policy in sustainable marine resources management, but also policy in human resources — in a domain which by its scale will continue to strengthen the cohesion of a large European scientific community — and policy in the rational management of large infrastructures on Europe's scenery.

Large industrial equipment like geotechnical vessels are available for drilling specific shelf and slope targets and for testing innovating technology on Europe's margins, while a dedicated deepsea drilling vessel of the class of the *Joides Resolution* could and should be reserved for true deepsea targets. Project-oriented oceanic margin drilling, in complement to ODP, can as such take its place as a logic component of the oceanic drilling market, for the benefit of both science and industry. And at a sustainable pace, in harmony with the EU's Framework Programmes. The 5th one shoud herald such logic.

# A strategy for Challengers

When Charles Wyville Thomson sailed out of Southampton on board of the *Challenger* in 1872, few people realized he was about to write one of the most glorious pages in the exploration of our planet. The Challenger indeed, which would circle the globe with a voyage of more than 77000 miles, would unveil the nature of the seabed and life in the deep ocean as no vessel had ever done before.

About one hundred years later, in 1968, it was the *Glomar Challenger* which would open a new era in the exploration of the deepsea: the first scientific drillhole on Challenger Knoll, the onset of the Deep Sea Drilling Programme. Jointly with its successor the Ocean Drilling Programme, this venture will enter history as one of the major exploratory efforts of Mankind, at the same level as the exploration of space.

Which ***strategy*** did these two initiatives have in common, for both of them to have reached such a level of success and recognition — from a wide scientific community as well as from receptive sponsors?

The main spark was in both cases a provocative idea, a highly debated hypothesis which could only be verified or invalidated by sampling the deepsea, or by drilling.

In the early part of the nineteenth century, the voyage of the *Beagle* had given rise to Darwin's concepts on the origin and evolution of species. Edward Forbes, an influential English naturalist, maintained that the ocean depths below 500 m could not host life. To use his expression which got immediate fame: life's "zero level" had been discovered.

But this zero level wouldn't survive very long. Early submarine telegraph cables, pulled back to the surface for repair, turned out to be colonised by a wealth of animals, among which crinoids which were not significantly different form their well documented Palaeozoic ancestors. In 1869, on the maiden trip of the first really well equipped vessel chartered by the Royal Society for dredging the abyss in the quest of life — the *Porcupine* — Wyville Thomson dredged from depths of about 900 m,

just southwest of Ireland, fascinating deepsea corals, *Lophelia's*, apparently thriving in the cold and dark North-Atlantic waters.

So, clearly, there was life in the deepsea, a surprising life, which seemed to surface from the darkest geological Middle Ages. Was it truly possible that the deep ocean had become a sanctuary for living fossils, should we find there the missing links in Darwin's evolutionary model? Even stronger, the affinity observed by Huxley and Sorby in 1861 between samples of carbonate oozes recovered from the depths of the Atlantic and the chalks of the Dover cliffs gave rise to Lyell's bold statement that in the deep sea, we are still today living in the Cretaceous! A Cretaceous park...?

Those were the tantalizing hypotheses, which succeeded in rallying the support from a vast scientific community — across many disciplines — and which were able to mobilize the Royal Society for funding the worldwide, four years' expedition of the Challenger.

And when in 1876 the Challenger had carried home a real treasure of samples and data, it was thanks to the energy and visionary strength of a John Murray that the exploitation of the data of the Challenger took the shape of a true European programme *avant la lettre*: experts from all over Europe were invited to cooperate in the processing and publication of the results of the expedition. The more than 50 volumes of the Reports of the Challenger would not only become the bible of deep sea science, but maybe also one of the first examples of a truly European exploitation of a major scientific project.

So the strategy which brought the cruise of the Challenger into history was: one bright, provocative idea, rallying a wide support, mobilizing a ship for a significant time span; there was a wide international exploitation scheme, and a conclusion, a major publication. A grand, exemplary project.

To say like the French — *l'histoire est un éternel recommencement.* When Vine & Matthews, Harry Hess, Jason Morgan and others unveiled the principles of sea floor spreading and plate tectonics, this hypothesis sounded so challenging and potentially revolutionary, even shocking for Earth Sciences, that it urged to verification. The seafloor and its sedimentary record had to be drilled. Where the Mohole of the late fifties had failed, the plate tectonic model of the late sixties would succeed, born by the vision and the energy of a Cesare Emiliani, a Maurice Ewing and quite a few others.

With the support of the US National Science Foundation — and in a very pragmatic way — they started a first few legs, with modest resources, in a close to amateuristic way. Still they won, and put a project onto the tracks, which again would enter history: the Deep Sea Drilling Project — DSDP.

A strategy so far — so clear. Again: one challenging idea to be verified, rallying a wide support, leading to a breakthrough in science, and concluded, like the Challenger cruise, by a rich series of volumes.

Although... *concluded* — has DSDP ever been... *concluded*?

# Of projects and programmes

It was clear that the move for such venture towards a more professional approach requested a new, dedicated vessel, and for this a true — sustainable international support scheme. It is here that we observe a first major *change in strategy.*

The concept of a *project* in deepsea drilling — confined in scientific objective and time — has in the middle of the seventies given way to the concept of a long term *programme*.

DSDP was reorganized in 1975 as the International Program of Ocean Drilling (IPOD). And a few years later a dedicated vessel, the JOIDES Resolution — became available for the international scientific community within the framework of the Ocean Drilling Program — ODP.

This change in strategy has reflected upon the scientific contents of the programme. As a true *bottom-up* structure, ODP has offered advanced drilling facilities for serving virtually any highly rated proposal, whatever its discipline. In a way, with ODP we can take the *pulse* of marine geosciences over the past 20 years. From plate tectonic and basic stratigraphic themes, the accent within the cruises gradually shifted towards palaeoceanography, palaeoclimatology and Global Change. Studies of fluid flow in the oceanic lithosphere, both on ridges and along margins, have gradually taken a strong profile. And the JOIDES proved its value for instrumenting wells with prototypes for long-term seismological or hydrogeological observations.

In what I would call an "ODP Classic", each leg is a small project on its own, which has been ignited by its own little spark. Without any pejorative connotation, we can state that ODP has been operating as a grand management unit of an advanced drilling vessel, which encourages the emergence of new ideas, new sparks, new scientific perspectives. It is a system which has proven its value, and which — for this reason — has enjoyed a sustained support from Science Foundations from many countries.

Maybe here we should stress how on top of the distinction between projects and programmes, it thus might be useful to make the distinction between *support programmes* and *science programmes*.

A Science Programme will only make sense if it allows to mobilize on top of tools also substantial human **resources,** if they focus on a certain **objective,** which can be realized within a certain time frame. A major Science Programme needs an objective which appeals to **Society**. And it will only strenghten its muscles if it also meets **economical** perspectives.

Do we have true economical challenges in the deepsea? The exploration and development of deep hydrocarbon resources, beyond the shelf edge, below the slope, in water depths already exceeding 2000 m, is a reality today. Also for Europe, which has the ambition to unlock its potential resources on the North-East Atlantic slope, its Western Frontier.

Where Science, societal interests and economical interests are converging, we move beyond the domain of policy, into the domain of **politics**. It is here that the European Union moves onto the scenery, in its full societal, economical and political dimension.

# Europe

Since quite a few years, the European Community first, the European Union next has structured its scientific actions into Framework Programmes. Within these programmes, ocean research has got a profile in the Marine Science and Technology Programme — MAST. Scattered European teams, often historically geared towards a one-way cooperation with large American institutes, have learned to join forces within Europe. Small new teams have got a chance, in any country. Even if many of us have not really been conscious of it, European politics have been at work, steadily fostering cohesion and cooperation. Mixed European teams on cruises have become the rule instead of the exception.

Scientific results are not minor either. Tremendous good science has been generated. The exploration of Europe's margins and offshore basins, and even of the Mid-Atlantic ridge within the European realm, has expanded our knowledge, but it is leaving many more questions unanswered, simply by the lack of ground-truthing. High-quality seismic profiles around Europe's margins shed some light on fascinating dynamics, which can only be fully elucidated, quantified and dated by drilling.

This need for groundtruthing, for boreholes of a few hundreds of metres penetration on Europe's outer shelves and slopes, beyond what any global deepsea drilling programme like ODP can and should reasonably offer, has been formally expressed at many European conferences, from the Grand Challenge conference in Bremen 1994 to workshops in Brussels 1995, Kiel 1996, and more recently, in the 1997 Position Paper of the European Marine and Polar Science Boards: "European intiatives in science and technology for deep-sea coring and drilling"

A MAST III concerted action CORSAIRES has been started in 1996, with objectives:

- to contribute to the design of a coordinated access scheme to appropriate drilling vessels, in particular low-cost geotechnical vessels, which could tackle a number of sites especially on the outer shelf and upper slope, and this a sustainable way both in terms of resources and scientific exploitation,
- to strenghten the cohesion of pan-European research projects and programmes targeted on the study of seabed processes, through networking, conferences and educational initiatives,
- to stimulate European technological proposals for deepsea drilling and borehole measurements.

# Scientific challenges on Europe's margins

A first action of CORSAIRES was to verify the concrete needs of the European scientific community, and to try to design a structure for a coordinated support action. In just two weeks time early 1995, 98 proposals were submitted, most of them displaying quite a reasonable level of maturity and preparation through high-resolution seismic work.

These proposals could be grouped into 5 core areas, documenting a wide spectrum of scientific themes:

- the Norway — Faeroer — Rockall core group

— the Porcupine — Celtic Sea — English Channel core group
— the southern Portuguese margin
— the French — Italian Mediterranean core group
— the Greek Mediterranean core group

And within these core areas, we can identify two kinds of objectives:

— really groundtruthing boreholes, which should allow the full exploitation of investments made in MAST II and MAST III projects or even other European projects — in a way, to finish our homework properly, and
— truly prospective objectives, opening new and challenging horizons.

Along the polar North Atlantic margins, *gas hydrates* turn out as a major potential hazard for slope destabilization. Ongoing studies point out the role they may have played in the genesis of the largest submarine slide documented so far along Europe's margins: the Storegga slide. A brainstorming about gas hydrates and their relevance for margin stability and climatic change has been organized under the CORSAIRES Concerted action in Gent in 1996. The proceedings are coming out in a few days.

In Porcupine Basin, southwest of Ireland, recent high-resolution seismic surveys over a prospective CORSAIRES drilling site — a cluster of deepsea carbonate mounds discovered by commercial seismic investigations — have unveiled a giant province with more than a thousand of buried deepsea mounds, many of them featuring intriguing ring shapes, never observed before. The ring shapes suggest an association with seeps on the seabed, but the main feeding mechanism of deepsea corals — the very same ones as those discovered by Wyville Thomson in 1869 — are no doubt the current-controlled fluxes of zooplancton.

Further south on the Porcupine margin, impressive barrier-like reefs, up to 200 m high, are fringing what looks as a buried palaeo-shelf edge, at depths between 600 and 1000 m.

Not the Bahama's, but Irish waters...

So we are just starting to lift the veil over maybe one of the world's most fascinating deep water coral reef province, right on top of a hydrocarbon basin, where intensive exploration is preparing the 1998 South Porcupine Offshore Licensing Round. The site surveys for CORSAIRES have identified various phases and events of possibly seep-stimulated mound growth, gas hydrate-induced slope destabilization, interlaced with contour current — controlled, and hence climatically controlled episodes of drift deposition. A story which seems to have developed throughout Plio-Pleistocene times, but obviously we lack any elementary chronological control.

Just like the oceanic methane hydrates, these deep water carbonates cannot be dissociated from the ocean and atmospheric biogeochemical dynamics, from the global carbon cycle. On a recentmost CORSAIRES-sponsored Workshop on Carbonate Mud Mounds and Cold Water reefs, Dr. André Freiwald from Bremen, who has studied these cold water corals for years, formulated a stimulating thought: if we consider the vast distribution of cold water corals along the North-East Atlantic margins, as illustrated by the maps he courteously provided, and if we add the now discovered giant carbonate mud mound provinces, aren't we possibly on the track of the climate modeller's "missing $CO_2$ sink"? A challenging question.

If we want to quantify the carbonate, the $CO_2$ trapped in these coral and mound provinces, if we want to identify the diversity of species which have contributed to the growth of such giant mounds — some of them reaching heights up to 300 m, an Eiffel tower — if we want to identify the deep bacterial biosphere and its role, if we want to decrypt the messages carried from the depths through seeping fluids, and the climatic messages locked into these sequences, we have to drill.

We are touching here a topic where the Geosphere and the deep Biosphere are truly meeting. As illustrated again by Dr. Freiwald, deep reefs are in the focal point of a wide number of converging disciplines and topics. In addition, their occurrence right in a hot spot in hydrocarbon exploration, and within an area of active fishing and deepsea trawling, raises a number of questions regarding the possible environmental impact of human activities on such reefs. The extensive record of reef growth and decay preserved in the sediments of Porcupine Basin can make us understand how they are born, how they grow, how they die, and under which conditions and how fast they can recover from external stresses.

This example of convergence between scientific, industrial and societal, environmental interests illustrates how a *project dimension* can make science and industry advance in pace. The need to identify ocean drilling objectives, where science and industry can progress in harmony is also a central statement of the EMaPS Position Paper on Ocean drilling. Hence there are clear opportunities in Europe, but opportunities to seize now, in the forthcoming years, in full coherence and logic with the industrial momentum which develops. Many of these sites are located in water depths which could be drilled by alternative drilling vessels, like geotechnical vessels. Such could also serve as additional platforms for testing European technological developments in coring, in measurement while coring and in downhole measurements.

In addition, as has been demonstrated by initiatives within the CORSAIRES Concerted Action, the surveying of sites and other upstream or downstream activities related to a scientific drilling exercise should offer unique opportunities for transnational training and education at sea. Let us not forget our youth is our best investment in any European strategy.

# Towards a European strategy

So how could we blend, integrate these various elements into a European strategy for ocean drilling? And allow me to express here a fully personal view. With a few provocating statements, if only for provoking my provocateur.

Let me start with a straightforward iconoclast statement. We all know ODP's Long Range budget plan. A scheme which suggests a steady state, two-vessel strategy from 2003 onwards. It has been virtually endorsed under the recent terms of reference of CONCORD and the two-ship Integrated Ocean Drilling Program (IODP).

There are a few items which make me feel uncomfortable in this scheme.

First the fact that only the drilling effort and operations are budgeted. The science behind it is not dimensioned. We have got used in European programmes to quantify the full cost of an effort, including staff, laboratory costs, etc. How could we rate these costs? Just allow me to make a gross, wet finger approximation, stating that

for each dollar or Euro spent in drilling, we need another dollar or Euro for funding the science behind it.

Doubling the vessel capacity in 2003 means we need to double our teams, double our resources of all our labs and research centers, in a sustainable, steady state way. If not, the increased data flow will never be properly exploited.

Is that feasible, is that realistic? I am fond of ambitions, I love challenges, as far as they resort under common sense. My fear is that in such a scheme, we are reaching the limits of common sense, or even that we slightly transgress them, at the risk of seriously compromising the future of ocean drilling. What means a budget of over two hundred million dollars — or Euros — a year? It means, just for each year, the total budget of an average of two hundred typical 3-years MAST projects. Just for ocean drilling. And our community is not alone on Earth. At such levels of funding or even below, we are getting into competition in Science Foundations or Science Policy Offices with GOOS-type operational oceanography, with space station commitments, or even with the fight against cancer, or Aids.

Can we win?

Should we win?

The second point which I feel as a gap is the lack of a plausible analysis of the market structure, the resources and their origin. Even if it is right now a difficult exercise, we need to do it, or at least we have to draft a project *structure* which looks *attractive* to potential sponsors.

Is the LRP budget scheme in this respect a structure which openly invites for input from the European Union, which — as we know — has for instance a financial planning structured in 5-years Framework programmes? Does such an open-ended structure invite for funding from industry? I am not fully convinced. I expect industrial support — if we succeed in raising it — to be confined to projects, with well defined expectations after a few years. Any strategic plan for ocean drilling will hence to my opinion — to be credible — at least need a *structure* which makes the possible input from partners like the EU and from industry credible.

In addition, what should we remember from history? We have to preserve in a long-term strategy both the opportunities of a long-term support programme for bottom-up science proposals, like ODP has achieved, and the force of impact of large projects, building upon innovative ideas which can generate true quantum leaps in our knowledge and technology. The art is to find the right balance between both, for achieving sustainability.

Why not try out a scheme along these thoughts? My conviction is that we need and should be able to convince our Science Foundations to support a reasonable steady-state ODP-type programme, a **baseline programme**, which I would propose to dimension on a realistic, single platform scheme. Whether this vessel should be an upgraded JOIDES Resolution, or a new JOIDES "light", or a riser vessel like the Japanese vessel proposed within CONCORD, I do not wish to discuss here. It is up to the competent scientific and technical committees to make a choice — but, a sustainable choice.

On top of that baseline, we could graft ambitious "**Core Projects**", the verification of new ideas, in the spirit of the *Challenger* expedition and the DSDP venture, and

which could mobilize where needed additional *ad hoc* platforms from the industrial realm, the right vessels for the right purpose, without over-dimensioning, with the state of the art in technology, for confined periods and objectives.

Regarding this state of the art in technology, let us not forget that deep oil exploration is booming, and that high-tech drilling vessels and platforms are and will be available from the industrial realm, platforms which will have to follow or even anticipate the terms of reference of industry — as no scientific vessel could ever follow. Presently, demand is high and there is a shortage of high-tech platforms for deep drilling, so prices are high, but markets fluctuate and attractive opportunities for science might open in a few years. With state-of-the-art vessels. If only we have the resources in standby to strike quickly.

Such a plan — to be fully credible and complete — again needs not only to budget the vessel and drilling, but also to quantify and include the required additional human and operational resources of the participating teams, for ascertaining the full exploitation of the results.

Could such a geometry be truly attractive for a wider partnership for ocean drilling?

I believe it has this potential. The long-term baseline programme is a natural environment for support from Science Foundations, as they have demonstrated in the past. If some of them have shown some signs of panic at the perspective of a programme doubling its costs, the more realistic figures of a single-platform baseline scheme should be able to restore serenity and confidence. As in the past, this backbone programme should be very open to bottom-up initiatives, which might yield the embryo's for future Core Projects.

The 4 to 5 years Core Project modules, focusing on themes with a large scientific, Societal and economic relevance, should be the natural environment where an additional EU and industrial component can dramatically enhance opportunities and strengthen Global ocean drilling.

Can we suggest scientific themes for such Core Projects? If we take the two scientific themes which are appearing on top of the list of the CONCORD Statement:

- "Understanding Earthquake Cycle by Direct Long-term Observation of active Processes in the Seismogenic Zone"
- "The Deep Biosphere: Exploring the Lost World"

... I believe we have two outstanding themes for the next ten years.

If we want to boost the first theme beyond what has already been realized by ODP e.g. in the Barbados, we need the riser technology, such as that proposed on the Japanese vessel. As suggested in the CONCORD meeting, this topic stands out as a priority for starting about 2003. But if I fully sympathize about the relevance of research on seismogenic trenches off Japan, I wish to remind that Europe has dramatic settings of a similar societal relevance in the Eastern Mediterranean.

The second topic however is in my opinion fully mature for direct action, with support from the 5th Framework programme, which has identified "sustainable marine ecosystems, and Global Change, climate and biodiversity" as Key Actions. The recent discovery of unique settings along Europe's margins, which do raise intense interest from the industrial realm, makes such an action even more timely.

Again — *l'histoire est un éternel recommencement...*

The cruise of the Challenger built upon a provocative idea: is there life below 500m in the oceans, Forbes "zero level"?

The question we raise today is: how far *in* the seabed can we further move Life's "zero level? We have already a few clues that a fascinating and largely unknown bacterial world, a Lost World, is waiting for discovery deep under the seabed, and inside these giant carbonate mounds. The first bacterial analyses of samples taken just a few metres inside the mounds of Porcupine display a fascinating diversity.

On base of the analyses of bacterial colonies from gas hydrate horizons drilled by ODP, Dr. Parkes stated in the Saturday session on extreme environments that the deep seabed might host a biomass, about 10 % of all known biomass on Earth.

It is not quite a familiar terrain for me, but if we observe the booming interest of the biotechnological industry for enzymes from bacteria discovered in extreme environments, we may carefully suggest that we might be on the track of a fundamental topic with vast perspectives, also beyond academic relevance.

To use a term which seems to get into oblivion: maybe we are facing right here a true *Grand Challenge*.

# Global scientific drilling in the 21st century

*John Ludden, CRPG-CNRS, Nancy, France & Gerold Wefer, Universität Bremen, Germany*

## Introduction

For close to 30 years scientists have undertaken a programme of scientific ocean drilling in order to understand the dynamics of the Earth. In the early days of the Deep Sea Drilling Project (DSDP), in which many of the scientific endeavours were exploratory and the models of plate-tectonics were in their infancy, most of the drilling targets were aimed at simply 'seeing what's there'. As our knowledge evolved, the Ocean Drilling Project (ODP) has undertaken a more focused study of the oceanic basins involving testing of models of global tectonics, climate change, sea-level variation etc.. The ODP project has also seen the implementation of a series of bore-hole laboratories in which fluid fluxes, crustal stress and global seismicity can be monitored. The final phase of the ODP 1998-2003 has set out important goals in terms of understanding climate change and the tectonic processes that fashion the oceanic and continental crust, including important problems related to erosion of the continents and the understanding of natural hazards.

Scientific drilling is a key component in any global geoscience programme and must be continued after the end of the phase III of the ODP. A significant part of the ODP activities in the next five years should be dedicated to preparing for post 2003 drilling projects. Drilling post 2003, and if possible prior to this date should involve a multi-platform approach in the oceans and an integrated approach in ocean and continental drilling. European countries, as a consortium, should aim to represent about one third of the future IODP. In the short term the European countries should create a European committee for scientific drilling, which, with industry involvement will foster collaboration and aid in planning for proposal driven projects involving European parties interested in using drilling to solve first-order geological problems on a global scale.

## Scientific objectives

About 1100 sites have been drilled over the last 30 years. This represents a sampling density equivalent to 1,5 holes for the surface area of France. Neither the DSDP and ODP have been unable to drill in very deep areas, hydrocarbon provinces; methane source areas, shallow water and ridges, for technical and/or safety reasons. We also note that the full drill-string of the JR (9000m) has never been deployed.

Highly significant accomplishments can be listed for the DSDP and ODP projects, for example on the following scientific issues:

*tectonics* — understanding of the nature of the lower oceanic crust, and uppermost mantle; extension processes and the nature of continental margins;

*geochemistry*: methane production in the oceans; cold seeps; formation of mineral deposits at ridges;

*climate*: cooling steps in Tertiary, rapid climate change.

Nonetheless, a considerable number of key scientific issues remain which require oceanic drilling using a variety of platforms. Among these we cite here:

— understanding earth's changing climate

— ocean feedback to global change

— causes and effects of sea-level change

— gas hydrates (role of slope stability and as green house gas)

— continental slope instabilities

— deep sub-sea-floor biosphere

— processes of transfer of heat and materials to and from Earth's interior

— evolution of atmosphere (interaction with oceanic and continental crust)

— deformation of the lithosphere and earthquake processes

— the evolution of deep continental margins

# The need for a multi-platform approach

Despite the success of the DSDP and ODP, oceanic drilling in the 21st century must involve a new vision involving a multi-platform approach to drilling the oceans and the continents (see summary of projects above). These platforms must include:

- deep-penetration in deep-water environments involving a riser capability for bore-hole stability;
- coring in shallow water (including lakes, estuaries, lagoons, and fjords) and involving high resolution recovery in diverse lithologies;
- coring in ice covered areas (Arctic and Antarctic) involving frozen-in platforms.
- conventional coring for site-characterisation and reconnaissance studies.
- deep penetration at sea and on land in tectonically unstable and hot-rock environments

Future drilling projects must include an integrated strategy involving, where necessary, 3-D seismic characterisation, tomographic surveys, ROV mapping of prospective drilling sites, preparatory drill holes. Plus a comprehensive assessment of post-drilling objectives for observation, monitoring, and testing of active processes, including laboratory requirements for shore-based studies, synthesis and formulation of new hypotheses.

# Potential platforms

Given the rapid evolution of oil industry technology in (i) deep-water continental shelf environments and (ii) horizontal drilling, it is difficult to assess the availability of different platforms and technologies in 2003. We stress that it is important for the scientific community to monitor closely the development of drilling technology by industry, and indeed work in collaboration with them on joint projects of interest. Despite these reservations, we have listed below several possibilities that are the subject of current debate:

***The Japanese riser drill ship*** — this vessel planned by the Japanese to be in operation by 2003, will be dedicated to deep penetration by riser drilling and is planned to start a test phase of operation in 2003 in Japanese waters. Although several projects were identified at the CONCORD meeting in Tokyo in 1997, we suggest that three projects of high scientific priority will be retained in the first phase of operation (2003 — 2006) for which water depth limitations of 2500m are imposed:

- Seismogenic zone, Japan (High-priority for Japan, societal importance)
- Deep Penetration of oceanic crust (problems with appropriate water-depths in the best sites for normal fast-spreading Pacific crust 15Ma >3500m and controversy concerning the possibility of a 4000m riser system).
- Deep penetration of continental margins (possibility of incorporating industry interests in deep offshore geology)

We note here that the British ODP group present at the Lisbon meeting (May 1998) championed a deep drilling project involving a series of sites on the western European continental margin, aimed at understanding the early rifting and extension of a continental margin. This project would be of great interest to the petroleum industry, and such a project could become a European initiative involving the Japanese riser vessel.

***A Joides Resolution drill ship*** — It is widely recognised in the ODP community that the JR will have reached the end of her useful life by the end of ODP phase III. An international meeting planned for spring 1999 will discuss the scientific objectives to be attained using a new scientific drilling vessel (or an extension and refit of the JR). We consider that such a vessel should have a riser capability (slim-line, or sea-floor) in order to allow operation in over-pressured environments in gas-rich regions, or regions involving deep penetration of hot-rocks. The vessel should also be able to operate in shallow-water and recover continuous undisturbed sections. For this excellent heave-compensation is required.

We note that such a vessel, and other platforms of interest, need not be equipped with an expensive lab-stack and many sampling and core-description operations could be shore-based.

***Piggy-back operations with industry*** — an interesting possibility which would be much less expensive than leasing a specific riser platform, is to develop key projects with industry on the continental margins. Industry has the drilling capabilities at < 500m water-depths and is rapidly evolving towards operations at a maximum of 2000 m water-depths. This collaboration could involve complete coring of sections of drill-holes that industry would have otherwise only spot-cored, or extending

coring of industry holes to greater depths that might be of scientific interest, where, for financial reasons, industry may not have extended drilling.

We note that for these ' piggy-back ' operations it may be of interest for the scientific community to develop specific coring and logging tools with the help of both industry and the EC funding.

***Rental of shallow-water platforms*** — at present geo-technical vessels and jack-up platforms are unavailable to the scientific community due to the high demand from industry in the current explortaion boom. This situation may change in the next 4 years and, if possible, the rental of platforms for specific problems should become a normal means of operation for scientific drilling.

***Probes and portable drilling systems*** — a series of portable and robotic systems are in the process of being developed and pogy-type drilling will become routine in site characterisation, drilling of short holes in reef systems, sea-floor ore deposits and other environments in the future.

# Co-ordination at the European level

Europe should be represented as a single member of an International Ocean Drilling Programme organisation post 2003. Individual country memberships (preferably of equal value for the UK, France and Germany), would be pooled and representation on IODP planning committees and research cruises would be proportional to the countries contribution. The objective should be to participate at a 1/3 level with the USA, Japan.

It is important that a European co-ordination group for scientific drilling be established well before the 2003 date. This group should include ODP representatives, participants in EC programmes involving drilling, participants from the petroleum industry involved both in exploration and technology, in addition to participants from the minerals and geo-technical industry. We note that an informal EMaPS group exists and this group could be enlarged to create a ' European Scientific-drilling Planning Committee '. We further suggest that this group should include the continental drilling community as many of the scientific objectives are common to these two groups.

# EC framework programmes and scientific drilling

Given the probable increase in costs of a multi-platform programme it is suggested that Europe should contribute to a base-budget from the pooled country contributions, which maintains the programmes running costs (including sample archiving). Additional financial commitments from the EC and industry, should provide support for specific projects; such support could be either as a direct contribution to a research vessel, or an in-kind contribution involving drilling materials or platforms. The development of drilling technology, specifically slim-line deep-water riser systems, sampling in over pressured environments, specific projects related to the biosphere should be seriously pursued by the EC.

We note that research in climate change, natural hazards, and marine resources and (petroleum, gas, metals) are included in the 5$^{th}$ framework programme. Anyone of

these projects could be supported as part of a preparatory project for post 2003 drilling.

As stated above on particular area where European scientists could make a major contribution to ocean-drilling post 2003 is in the realms of continental margin evolution. Such a project involving pre-site characterisation, preparatory drilling, deep-drilling and post-drilling observatories could provide a natural laboratory for which specific add-on funding would be requested from industry and the EC.

Other areas where the EC could play a role are in educational outreach concerning the oceans and the study of natural hazards, and in providing a forum for interaction between industry, government and academia. We note the excellent training potential of participating in IODP, both in terms of young scientists participating in the programme, and in terms of communicating the results to schools and museums

# Industry involvement

In addition to the ' piggy-back ' drilling projects cited above, we stress the importance of data exchange between industry, government and academia. In particular site-survey data including 3D seismic record and interpretations will be required in future drilling projects. Logging data and testing of particular logging tools also require closer collaboration with industry.

It is clear that ODP collects a lot of data that is only of marginal interest to industry. Nonetheless, when new areas of exploration are opened up (such as the deep-offshore) the ODP cores are often the only data available, and provide important basic information on reservoir characteristics, transport mechanisms, and physical properties of deep sedimentary systems). It is thus important that the oil, gas and minerals industry in Europe endorses scientific drilling. This can be done by actively participating in the planning structure of a future IODP.

# Summary

The oceans must be considered as a dynamic system linked to the atmosphere, any single part of the ocean basin system is relevant to European scientific drilling in the 21st century. The involvement of the European Community in ocean drilling in the 21st century must look past its own margins and become global. The new Integrated ODP now being planned will present a new vision for scientific drilling for which the EC should be intimately involved in both the planning and the execution. The new programme must involve a multi-platform approach to drilling and the costs involved are large if not prohibitive. Europe will only be able to participate in these exciting global initiatives through a co-ordinated approach involving industry, government and academia of its member states. In order to accomplish the planning required it is important to establish a European structure for co-ordinating scientific drilling, involving both the continents and the oceans.

# Point by point replies to specific questions

## How can Europe participate in IODP?

All of these points have been covered in the document above.

## European (ESF) Consortium or National membership?

Essential, to the success of European participation;

Provides the ' base membership ' of an International programme;

Aim for at least a 1/3 participation;

European scientific planning committee;

Participation in programmes based on proportion of base membership

## European ' in-kind ' contributions to IODP?

Provides a means of adding to the base membership

Either as extra funds for specific EC or industry projects, additional platforms, technology development

## Role of the EC Framework?

Development of new drilling technologies

Add-on support for specific projects (e.g. Deep continental margin initiative)

Training programmes; Industry and Public awareness

## Scientific value of riser drilling?

Deep penetration in over-pressured horizons — essential in deep fault zones, gas bearing sequences, penetration below blind reflectors (salt), hot-fractured rock systems etc..

## National and European Scientific priorities?

To be defined by member states and at the Edinburg Ocean drilling meeting (Sept 1998). Margin initiative.

## Alternatives to the Japanese/US vessel?

See text for platform possibilities including ' Piggy-back projects with industry, portable riser systems.

## Would riser drilling involve a new community?

Tectonics physical properties community — seismogenic objectives

Biological community — deep biosphere

Industry — deep structure of margins

## When realistically will the Japanese riser ship be available outside of Japan?

The Japanese will make a final decision late this summer for the construction of the vessel. In 1998-99 they will be constructing a riser system that will probably be tested on the JR. If constructed the vessel could be available before 2005 for operations outside Japanese waters.

# Report of the session

*Petter Bryn, Norsk Hydro ASA, Stabekk*

## 1. General introduction

The report summarises the results from the open discussion on the topic "Prospects for a European Contribution to International Scientific Ocean Drilling." arranged during the Third European Marine Science and Technology Conference in Lisbon on the 25th of May 1998. The content represents the opinion of the attendants, and the limitations and the possibilities regarding the contribution to scientific Ocean Drilling from the commission are outlined.

The open discussion on the European Contribution to International Scientific Drilling was attended by leading scientists from Europe, representatives from the National Science Foundation in the USA, representing ODP, representatives from the OD 21 project in Japan, representatives from the industry and representatives from the European Commission.

The Chairman proposed the following key questions as a guide for the open discussion:

*How should the European Commission be involved in funding and co-ordination of Ocean Drilling?*

*How should Europe be involved in scientific Ocean Drilling outside Europe (ODP)?*

*Should there be a new drilling vessel or is the question of the multiplatform concept more valid?*

*What about the contribution of Ocean Drilling to science as such?*

*What should be the post 2003 activity? Should there be a single European project or a set of projects? Should there be a project on deep penetration of the European continental margin?*

*How should the Ocean Drilling be integrated with terrestrial or continental drilling?*

*What should be the involvement of industry in the Ocean Drilling activity?*

## 2. Open discussion contributions

### What should be the role of the European Commission in funding and in co-ordination of Ocean Drilling activities including ODP in future and post 2003?

During the discussion several speakers addressed the **need for stronger co-ordination of Europe's contribution to international scientific Ocean Drilling.**

This also includes co-ordination of the initiatives taken to drill on the continental margins of Europe, which can also be defined as a contribution to international scientific Ocean Drilling. There is also a need for Europe to define which European proposals should be included in distinct European initiative and which proposals should qualify for an ODP type of programme, as well as defining the priorities of the proposals. Both scientific and technical aspects can influence the classification of a drilling proposal.

The European scientists participating in the meeting clearly expressed the urgent **need for a common European strategy for Ocean Drilling** and an organisation responsible for co-ordinating this activity. This is required to ensure European consensus on the scientific objectives and priorities, and consensus regarding the platform and tool strategy and common agreement on requirements for technical developments. It is proposed that **Europe could act as one consortium member** the same way as the ODP European consortium under the umbrella of the European Science Foundation functions today.

It is expected that the European Commission will help to fulfil Europe's needs to improve the European contribution to international scientific drilling. It is also a clear wish and proposal from the scientific community that **funding of Ocean Drilling should be included in the forthcoming framework programmes.** This will stimulate further Ocean Drilling initiatives from the European scientists. The importance of the European Commissions role in this respect was also clearly expressed during the discussion.

The outcome of the European Research projects, including those from community programmes (MAST, ENVIRONMENT, etc...), the different drilling initiatives taken in Europe, and the capacity of the European Industry, clearly shows that both the science and the technology for Ocean Drilling, exist in Europe. There is no doubt also, that the European margins provide a number of excellent Ocean Drilling locations of global importance.

The potential of the Commission in co-ordination and funding of Ocean Drilling is limited by the framework programme of Community Research. The funding and the content of the framework programme are agreed by the European Council and the European Parliament. Institutional support to ODP from Europe through the European Commission, to complement the national funding from the member states is not regarded as a possibility, at least not during the 5th Framework Programme (1999-2002). Funding through the 5th Framework Programme should normally be achieved on a project by project basis. Project proposals will be evaluated in a competitive way.

The 5th Framework Programme will possibly **open up for funding of research infrastructures**, as part of the support to marine research facilities. This will include the **possibility to provide support to research vessels,** which in principle has been restricted in the fourth framework programme. Technology research and specific topical research relating to scientific drilling will also be supported through some of the programme key-actions.

It was also pointed out that the Commission is prepared to help to find ways to achieve the scientific goals and to find new ways of organising and funding Ocean Drilling activity. However the member states and the scientific community should take the initiatives.

## Ocean Drilling in Europe and out of Europe

The European Commission funded MAST programmes have been very successful. There is no doubt that these programmes have contributed in the maturing of a number of scientific sites in Europe to the stage where groundtruthing, in terms of Ocean Drilling, is required to provide real add-on value for the European Community. Drilling results are the only logical and practical way to verify or modify the scientific theories and models and to improve them.

A number of proposed drill sites along the European Margin are of local European interest and some are of global interest. The sites of unique global interest should be included in ODP-type of projects. Some sites in Europe may have a combined scientific and industrial interest, which may require drilling in a shorter time frame than possible through the ODP programme to provide the best added value to the European Community.

The proposed scientific drill sites of global interest located on the European Margin should be based on a fully integrated scientific approach. The best global scientific sites shall have priority and the European scientists shall perform their work in a global context to ensure the best add-on value for Europe. When Ocean Drilling sites of interest to Europe are chosen outside the European waters, European scientists should be included in the project teams and European scientific knowledge and technology should be utilised. This is also the condition for EU contribution in such projects.

Participation in drilling programmes of global interest is important for Europe; in general as a contribution to the global scientific development, and especially to improve our knowledge regarding similar scientific problems on the European Margin. Both the deep structures of the European Margin requiring riser drilling vessel and the shallower part of the margin including deep biosphere, slope stability, gas hydrates and climate change sites should qualify as primary global objectives in an ODP type of programme.

The educational effect of the participation in international Ocean Drilling programmes is also an important factor for development of the European scientific knowledge of topics such as the deep biosphere/geosphere, deep structure of passive margins, the seismogenic zone, deep oceanic crust, paleo climate and slope stability. Participation will stimulate good scientific work in Europe.

Based on the Lisbon discussion **Europe should contribute both in the ODP type of Ocean Drilling programme and in complementary drilling initiatives on the European Margin.** It is also clear that **Europe should find a way to participate as "one unit" in the ODP system,** this should ensure a good global scientific balance and an optimal add-on value for Europe in return for funding and scientific work.

## Should there be a new drilling vessel or is the multiple platform concept more valid? What should be the role of the European Commission?

The status for new purpose built drilling vessels or platforms is not very clear (ODP and OD21)

Regarding the possibilities for a new ODP vessel the following was reported:

The US NSF is fully committed to continue to play an important role in advancing the global scientific ocean and continental drilling for the future in co-operation with the global scientific community. The budgets and resources for further vessel commitments after 2003 are not decided and the economical situation includes uncertainties. The intention is to attempt to have the resources to maintain a programme that will involve multiple platforms including a riser type platform. The ODP management is based on long term lease of a drilling ship, making difficult any project by project approach. Beyond 2003, there are open management models for the future Integrated Ocean Drilling Program.

Regarding OD21, the planned new Japanese platform for Ocean Drilling, the progress of the project is likely to be influenced by the current economical situation in Japan, and a positive outcome will depend on a strong support from the international scientific community. The Japanese government has committed US 23 million dollars for this year to develop equipment, including a diamond drilling system and downhole measurement systems, for the new drilling vessel. This equipment can also be utilised by the Joides Resolution. Earthquake prediction research would be one of the primary objectives for this riser-drilling vessel, in the frame of a global scientific programme. If the project is to be realised, the new vessel should not be operated by Japan only, but made available for the entire community.

Presently there is no common European funding system for Ocean Drilling on the European margins and neither for ODP drilling. Likewise, there is no equipment or vessel available to contribute to an ODP type of programme on a common European basis. However, **European funding of a new built drill ship or platform for scientific drilling seems unrealistic.** Europe should continue to contribute to ODP/ OD21 programmes in the future, in making its participation more efficient and more co-ordinated. ODP is open to other ways of contribution and funding from Europe after 2003.

For specific drilling initiatives in Europe, hiring of commercially available vessels is proposed and could be an alternative. Several scientific institutions and the oil industry have performed scientific and geotechnical borings utilising available drill ships in Europe and in other parts of the world. If a drill ship is hired when it is needed for a European drilling programme, the economical exposure is limited. This also ensures the possibility to specify the most updated technology at the time of the commencement of the drilling programme. By committing to some months per year and agreeing on the requirement for equipment, water depth and type of drilling the Contractors running this type of vessels will commit themselves to upgrade the systems and equipment to meet the requirement for the scientific drilling also in deeper water. Presently the capacity of such vessels is in the range of 2000m to 3000m water depth. One of the limitations for using these vessels for scientific drilling in Europe, up to now, is the lack of budget for large infrastructure running within scientific programmes. It has been suggested to the Commission to permit such funding in the fifth framework so that it opens up for co-operation with the drilling contractor industry in Europe, a co-operation which was argued by one of the leading geotechnical contractors in the world.

## Priority of European science beyond 2003: A single European project or several projects? Shall deep penetration of the European margin be included?

A working group consisting of participants from both academia and industry in UK on post 2003 UK commitment to scientific drilling, proposes two prime targets for European drilling. One of the targets is a **passive margin deep hole** and the other is an **environmental processes deep hole.**

The **passive margin deep hole** in the Rockall Trough is proposed to understand what controls the 4D evolution of the basin geometry of rifted margins. A high proportion of the prime global sites for this drilling are situated within the European Margin which means such a drill site is both global and European. As a result of industrial activity in this area, site survey and exploration 3D seismic is available for pre-drilling studies.

The proposed **environmental processes deep hole** is named "Deep Ocean Drilling for integrated paleo climate deep biosphere and diagenetic studies". It is necessary to drill deep to find the limits of the biosphere and to understand the biochemical cycle in full, especially in areas of rapid deposition.

These two proposals will be discussed in a European context to define them on a European priority list at a later stage. This will occur at the Edinburgh conference in September 1998, entitled: "Planning for European contribution to international scientific Ocean Drilling"

The paleo climate research scientists are presently working towards resolving climatic cycles on a decadal scale in the oceans. **ODP or deep drilling should include paleo climatic high- resolution cores on a longer perspective and during different forcing regimes than we observe today.** Many high-resolution cores around the globe are required to achieve progress in paleo climate research.

The Arctic Oceans of Europe have not been explored in terms of Ocean Drilling. Seismic studies have been performed and it is becoming technically feasible to drill in these areas. It is proposed to have **Ocean Drilling in the Arctic Oceans** on a high priority list for the next phase of ODP.

Deep drilling in the seismogenic zone outside Europe is clearly of interest to Europe, and Europe should take part in such drilling programmes. Europe, however, has also its own strategic sites for earthquake research prediction.

It is proposed to establish larger, common European, thematic projects rather than having individual proposals. Such thematic projects could also be partly funded by the commission, provided they meet the objectives of the research framework programme.

## Involvement of industry, new forms of public and private partnership

There is a new trend in the industry with respect to co-operation between the oil companies. Groups of oil companies work together to reduce cost and avoid doing the same work several times. It is nowadays more common to share data and

information with the exception of data on hydrocarbon potential, than only a few years ago.

In the approach towards deeper water the industry needed new knowledge on the processes and the possible geo hazards on the continental margins. The well-organised scientific research work performed by a number of scientific institutes and universities under the MAST programme became attractive for the industry. Groups of oil companies have established co-operation with scientific institutions. Examples of such co-operation are the Western Frontier Association, including most of the operators and partners working on the deep-water margin west off Shetland, and the Seabed Group, consisting of the operators and partners performing exploration in the deep water areas outside Mid Norway. The Western Frontier association has concluded a co-operation agreement with BGS (ENAM partner) as co-ordinator and contractor to exchange relevant scientific knowledge.

The Seabed Group has established a co-operation agreement with the MAST project ENAM (European North Atlantic Margin), which includes full exchange of all seismic data including 3D exploration seismic data and bore hole data from deep geological/geotechnical borings as well as research results. The co-operation also includes common survey cruises and some economical support from the industry. The co-operation is also ensuring important exchange of technology and has an educational benefit for both parties.

There is no tradition in the oil industry for such co-operation and the expectation to achieve something from co-operation with scientific institutions and universities was initially low in the industry group. However, the attitude towards such co-operation has gradually evolved among the partners in the Seabed Project as the results of the co-operation have proved to be very useful both scientifically and economically for both parties. There is no doubt that this co-operation is successful and as such it is a good example of involvement of industry. One of the keys to this success was that the timing of the ENAM project matched the first step of exploration into the deep-water margin off Mid-Norway.

One of the problems in involvement from the industry or co-operation with the industry is the **timing of the industrial project versus the scientific projects**. The time from award of a licence to the first drilling is about one year. During this year a 3D seismic data set is gathered and processed. After a discovery, the time for field development may be as short as 3 years in cases of an oil discovery. In general the scientists perform their work in longer time frame which does not match project specific needs of the industry. This implies that all relevant investigations, surveys, mapping, drilling, ROV surveys and studies of seafloor conditions required for the design and development of an oil field have to be performed within this short time frame. In most cases it is thus not possible to rely on planned activities by the scientific community and only the existing and available information from the scientific community can be utilised. However, it is of great value for industry that the scientific community works systematically on improving the geological knowledge of the oceans in general, and nowadays on the deep water margins in particular. This is the new challenging area for exploration and field development (Brazil, Angola, Gulf of Mexico, Mid-Norway....). **Improved knowledge of geo hazards like submarine slides, gas hydrates, mud volcanoes, cold water corals and ooze sediments is important to the industry independently of the location for the scientific studies.**

When the oil companies perform exploration near ODP, DSDP sites or other stratigraphic borings, the information from these borings forms a very important database for the exploitation of the area and for planning exploration drilling.

In areas where the oil companies are doing exploration or have finished their exploration, a high quality 3D data set and high-resolution site survey data and well logs usually exists. Such data set will in most cases be available to the scientific community and may form a cheap and excellent data set for further mapping and planning of Ocean Drilling. The possibility to piggyback on to unsuccessful industry wells and deepening them for scientific purposes can also be an efficient way to get deep boreholes at a low cost for the scientists.

The oil industry is investing large amounts of money in developing cost effective and high quality technology. Most of this technology is available commercially from the contractor and service industry serving the oil business. **The most important industrial technological developments for the scientific Ocean Drilling activity is the advanced tools and methods for downhole measurement, logging while drilling, VSPs and seismic while drilling.** Co-operation with the industry will ensure necessary updates about available technology and important experience feedback regarding utilisation and interpretation of the results from the measurements.

**Riser technology for deep and ultra deep drilling is presently being developed by the oil industry**. The largest oil and gas fields discovered the last years are located in deep water and exploration will continue into even deeper water when the technology is available. The oil industry has presently several research and development projects ongoing to develop riser technology for deeper water and ultra deep water, as this is one of the few technological limitations for exploration and production in such areas today. **The scientific Ocean Drilling programmes should take all possible advantage from such development rather than investing money in parallel riser technology development themselves.** Before supporting and investing in development of new technology the state of the art of available technology from the industry should be in hand.

The oil industry has worked hard to increase efficiency and reduce cost for drilling exploration wells and production wells the last years and also to improve the quality of the geological results from the drilling. Experience and technology from the industry can possibly increase the efficiency of Ocean Drilling activities and increase the available capacity for scientific drilling. This becomes even more important when deeper boreholes in deeper water are planned.

Geotechnical vessels presently performing geotechnical and stratigraphical drilling for the oil industry and for scientific institutions like BGS will be available for Ocean Drilling on a commercial basis as described under the drilling vessel discussion.

In general the co-operation between the scientists and the industry seems to have improved in the last years. It is suggested that the European Commission should take further initiatives and improve the strategy for such co-operation, this to ensure that the scientific community gets involved through sound collaboration with industry.

### Integration of terrestrial and continental drilling (mega science)

This subject was mostly introduced by the Commission. Such integration probably could be beneficial both in terms of scientific co-operation and of technology development, because an extensive experience already exists from deep-drilling continental programmes. The topic was not really investigated during the session. It has, however, been suggested that in the frame of a global approach after 2003, a better integration of continental drilling with Ocean Drilling was likely to occur.

# 3. Conclusions

### *Role of the Commission in funding and co-ordination of Ocean Drilling after 2003, in particular with respect to ODP*

There is a strong wish by the European scientific and technological community that the European Commission should play a stronger role in co-ordination and funding of the Ocean Drilling both regarding European programmes and contributions to ODP. A common strategy for Europe for Ocean Drilling seems to be required.

The 5th Framework Programme has clear limitations as to how the Commission can contribute, but within these limits the Commission can play a more active role in co-ordination and funding of Ocean Drilling based on submitted proposals from the scientific community. The 5th Framework Programme may open up for supporting research vessels. Such support has been limited up to now.

New ideas on the Commissions role can be discussed for the sixth framework programme, for the period beyond 2003.

### Ocean Drilling in Europe and out of Europe

The investments and the scientific results from the MAST programme require scientific drilling operations to provide the required add-on value to Europe.

Europe shall contribute both in the ODP type of Ocean Drilling programme and through separate drilling initiatives on the European Margin. Several scientific problems and sites on the European Margin qualify as primary global objectives for Ocean Drilling.

Europe should find a way to strengthen its position as "one unit" towards the ODP system to ensure optimal add on value for Europe and the member states in return for the funding of international scientific Ocean Drilling.

There is a clear demand from the European Scientific Community in Europe for adaptation within the ODP programme and mostly through its successor so that a better integration of scientific topics specific to the European margins is achieved.

### New drilling vessel or multiple platform concept

The OD21 project is planning to make available a riser-type drilling vessel for the international community. The Japanese authorities have already committed some resources to scientific equipment, in the frame of the project. A positive outcome for

OD21 depends significantly on the support of the scientific community to the project.

The status for an ODP-type vessel successor of the Joides-Resolution post 2003 is under discussion, within the International Working Group for an Integrated Ocean Drilling Programme (IODP). The intention is to maintain a drilling programme that will involve multiple platforms including a riser type platform.

European funding of a new built European drill ship or platform for scientific drilling is unrealistic. The European members of ODP should continue to participate to ODP/ OD21 in the future, through various financial support schemes, including the standard project by project approach used at Community level.

A multiple platform concept seems to be required to fulfil the needs related to both the future European targets and the global targets for Ocean Drilling.

## Priority of European science beyond 2003 and organisation of the drilling activity

The main targets for Ocean Drilling after 2003 identified during the discussion were the following:

- Passive-margin deep hole (Europe)
- Environmental process deep hole (Europe)
- Paleo climate high resolution holes (Global and Europe)
- Arctic Ocean Drilling (Europe and Global)
- Seismogenic zone deep hole (Global and Europe)
- Sediment related problems (seafloor stability, gas hydrates, geosphere/biosphere coupling (shallow holes, Europe))

It is proposed to establish larger common European thematic drilling projects based on long term baseline programmes. These programmes should be both sedimentary orientated and seismic oriented and include both European targets and global targets. A multiple platform approach is proposed to ensure the drilling platform utilised is according to the different needs.

## Involvement of Industry

The oil industry is conducting intensive and extensive research to enable exploration and production drilling in deep and ultra deep water. This includes development of deep-water riser technology and other related technology required for deep sea drilling. The rapid development of downhole measurement and logging tools is also important for scientific drilling. The scientific community should take all possible advantage from the industrial technological development and limit their funding of new technology.

Further stimulation of the co-operation between science and industry may be required to ensure information and availability of the state of the art technology to the scientific community.

Site survey data, 2D and 3D exploration seismic data and coring and drilling data can in many cases be available for scientific work. Relevant scientific projects useful for the industry will stimulate co-operation and ensure that such data can be exchanged.

Geotechnical vessels commercially available in Europe can drill in 2000m of water and can be technically upgraded to drill at least to 3000m water depth. The drilling contractors for these vessels are interested in co-operation. Technical needs for scientific drilling can mostly be accommodated if these vessels are hired for scientific Ocean Drilling for some months per year over a certain period of time.

Short term needs and the "best return of investment philosophy" of the oil industry is a practical problem for the co-operation between the scientific community and the industry.

# NEW TECHNOLOGIES FOR THE WORLD MARKET: INSTRUMENTS AND RESEARCH PLATFORMS

# New technologies for the world market

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Last year the word El Niño was used more than ever before. In newspapers, magazines and on satellite TV El Niño was news.

A complex ocean phenomena became a news item. Journalists and reporters tried to explain the mechanisms and the effect of El Niño. The large forest fires in the Far East were on the front page. The tornadoes in the USA are claimed to be the children of our Christmas child El Niño. Oceanography on a world scale was translated into a human scale and human interest was obvious.

Last year was also the year of the Titanic. The most successful motion picture ever about the luxury cruise vessel that sunk on his maiden trip after it ran into an iceberg.

More than 10 years ago the wreck was found with sophisticated oceanographic technology. A remotely operated vehicle, operated from a manned submersible Alvin, flew into the wreck and showed us the chandeliers still intact hanging in the Ballroom were the music stopped.

This year, more than 10 years after the dramatic pictures of Alvin, millions of people saw the movie and the documentary of the ROV survey was broadcasted on all TV channels.

Again the human factor in oceanology and the importance of oceanographic technology became tangible.

Today we can not imagine that a floating castle like the Titanic would sink because of an undetected iceberg. Technology developed in a unprecedented way during this age. Nevertheless accidents happen because of undetected phenomena.

An illustrative incident is the damage of the high speed ferry Discovery sailing between Hook of Holland in the Netherlands and Harwich in the UK. The largest and fastest catamaran in the world was commissioned in June last year. With a speed of 80 km/h (two times the speed of the Titanic) and 1500 passengers and 375 cars it crosses the North Sea. On January the third the fibre nose of one of the floaters ran in to a wave of 5 metres and was blown away. The predicted significant wave height was 4 m, so within the operational limit. One single wave of 5 meters did the job. The ship was out of operation for more than 2 months. The loss for the company was over 10 million ECU.

After the incident a wave radar and a real-time link with the North Sea Monitoring Network were installed on board the ship to get information on the actual waves on the route.

The title of my paper is New Technologies for the World Market. You may wonder why I tell you these stories.

I told you about El Niño, the Titanic and the Discovery to illustrate three things:

First they show the relation between offer and demand of oceanographic information and the technologies to acquire this information.

Secondly they illustrate the different scales of oceanography from global, regional to local.

And thirdly they show when and how the public gets really aware that adequate oceanography and oceanographic instrumentation is needed for sustainable and safe use of the oceans and regional seas.

This aspect is of the outmost importance because it forms the basis for the activities of the oceanographic community on a scientific, technical and political level. I will come back on this later.

# Basic Technologies

It is not my intention to show you a parade of innovative and promising new technologies. A variety of technologies will be presented during this conference.

I like to focus on the basic technologies for oceanography and the trends we may expect in the future. The basic technologies in oceanography are acoustics, optics, radar, electronics and mechanics.

*Underwateracoustics* is or can be used to measure all physical parameters like sea-level, waterdepth, morphology, current, suspended matter, stratification, silt and sand. It is used for communications and positioning. The application of under-wateracoustics in bathymetry, underwater positioning and measurements of current velocity and direction are success stories.

Multibeam and singlebeam echosounders and Acoustic Doppler Current Profilers are widely used workhorses of oceanographers. New developments in under-wateracoustics are expected to continue in the upcoming years. In particular accurate spot measurements and profiling of sediment load and particle size distribution are or will soon become operational technologies.

*Optics* are used for measurements of both physical and biological parameters. Light attenuation, light excitation and backscatter techniques are used to measure suspended sediment and material of organic origin. Lasertechnology opens a complete new field of applications. Lasertechnology for depth measurements is operational for more than 10 years now. Lasertechnology to measure particle size distribution or the number and species of micro-organism has recently been introduced or is on the brink of operational application.

*Radartechnology* is extensively used at sea for safe navigation. For oceanography it was not so commonly used but the situation is changing rapidly.

Radar measurements from satellites, platforms and from shore can or will in the near future reveal information on sealevel, depth, waves and current. Side Looking

Airborne Radar, High Frequency Surface Wave Radar, X-Band Radar; each frequency and technology has its own specific field of application.

A strong aspect of radar technology is the large range and coverage and the fact that it is a remote sensing technology practically not sensitive for the hostile marine environment.

*Electronics and Mechanics* are traditional basic technologies in oceanography.

Applications vary from CTD-strings to Remote Operated Vehicles, from water samplers to benthic chambers, from piston corrers to the accelerometer in a wavebuoy.

# Technology Trends

From this short introduction on the basic technologies and their application to monitor physical, chemical and biological oceanographic parameters one thing becomes clear.

The set of instruments and technologies to measure *physical* parameters is very dominant. The traditional hydrographic parameters needed for safe navigation and defence determined the set of core oceanographic technologies.

Oceanographic technologies to measure *chemical* and *biological* parameters in-situ automatically are still limited. In most cases samples are collected and measurements are done in the laboratory with standard equipment. In the last decades demand and offer of in-situ measurement of chemical and biological parameters slowly emerge.

In the upcoming decade these technologies will become of the same importance as those for the physical parameters. This is illustrated by the fact that six out of nine papers presented in this session will deal with this category of technologies.

Based on this short introduction of the types of oceanographic technologies and their applications I like to discuss with you some general trends in the development of new technologies.

I already mentioned the extension of in-situ real time monitoring and the shift from physical towards chemical and biological parameters.

Generally speaking the range of application of the basic technologies for different parameters will be extended.

The effectiveness too will increase strongly because:

- Real-time processing, presentation and analysis will become more common practice.
- Autonomous operation of instruments and instrument carriers will increase and
- The integration of the technology clusters, in-situ measurements, remote sensing and modelling into effective monitoring and forecasting systems will take place.

With respect to the integration of in-situ measurements, remote sensing and modelling it is interesting to see the result of one of the questions ask to some 60

key persons in 8 countries during the SeaNet Survey (figure 3). The respondents were asked to indicate the importance of each of the three technology clusters in 1995 and in 2005 by dividing 10 points over these clusters. The outcome shows the balance in contribution by the three technology clusters that is expected in 2005.

The cause of the indicated trends is the boom in *telematics* and *informatics*. The increase in processing power and communication facilities strongly upgrades the possibilities of the basic technologies used in oceanography.

Real time processing of huge datasets, use of complex algorithms, user-friendly and versatile presentation facilities. It all became possible due to the enormous increase of affordable computer power. Telematics offers complete new opportunities in remote operation of autonomous systems, data collection and data exchange. The effect of telematics and informatics on the development of new oceanographic technologies has not yet come to an end. It will determine to a great extent the technological developments in the upcoming years.

# Market

Compared to other industrial sectors the oceanographic technology sector is a small one, but one with a clear growing potential. It comprises a large number of small companies, that contribute the major part of the innovative technologies and a limited number of larger companies that deliver services and tools. The number of products that became a success on a world scale, like wavebuoys, ADCPs, echosounders and sonars is still limited. The market is still strongly national oriented due to the fact that national agencies and institutions play an important role as users. The sector is not well structured.

But things are changing. In the past decade MAST and Euromar stimulated the development of new oceanographic technology in an unprecedented way. Some five years ago EuroGOOS and SeaNet started to develop a structure and strategy for the oceanographic community. Recently the ECOA, the European Commercial Oceanographic Association was born.

The objective of the ECOA is to represent and promote the interest of European companies active in oceanographic manufacturing and oceanographic services. ECOA can express their collective view and act as a liaison with the public sector on a European level.

The structure of the oceanographic technology sector is not yet well prepared to an adequate response to the process started by EuroGOOS. Although products and services are on a high level, the sector still is one of the technological and industrial niches with a fragmented character and a low organisational grade. The establishment of a European Commercial Oceanographic Association is a first step to improve this situation and to be recognised on a European level as a part of the structure for the realisation of European Ocean Observing System. It means however that the sector has to work out and materialise its position on a very short term; with full appreciation of the fact that public bodies will indicate the goals and draw the lines towards a monitoring and forecasting system for the European seas.

In this perspective the activities within the Euromar framework in the past ten years can be considered to be the testing ground for the upcoming phase. The next step

will be the implementation and exploitation of European marine technology on a European and global scale in close co-operation with Europe's institutional marine bodies. The globalisation of marine environmental awareness means that Europe has to respond quickly. The high quality of marine environmental products and services is no guarantee for success. The physical and mental realisation of a European marine network that demonstrates European skills and cohesion is of great importance too. It means that the national oriented approach of most European countries has to be extended via an European approach towards a global one; a large shift in a relatively short time, but a feasible one now a Global Ocean Observing System is being discussed.

# Users and Suppliers

In frames like EuroGOOS, SeaNet, Euromar and the ECOA public and private parties can meet. In none of these European frames however all relevant public and private parties can participate on an equal basis. This is a logical consequence of the typical origin and objectives of these frames. It blocks however the open and constructive discussion between users and supplier with the explicit goal to start operational oceanographic demonstration projects on a European level.

To fill in this gap it is proposed to establish a European Oceanographic Technology Platform where public and private parties can discuss and take initiatives towards joint European demonstration projects. Such a platform or network has to take full advantage of all elements and opportunities brought up by EuroGOOS, SeaNet, MAST, EUREKA and the Fifth RTD Framework programme of the EC.

Such a thematic network will create a liaison between the EuroGOOS, SeaNet, Euromar and ECOA. Representatives of these frames can investigate the feasibility and initiate joint European public private partnerships for demonstration projects in the EU.

Euromar and MAST have lead to impressive scientific and technological results over the past decade.

EuroGOOS and SeaNet have awakened the awareness that the needs and opportunities in the field of operational oceanography on a European and global scale ask for action.

The dialogue between public and private parties involved in operational oceanography is moving from a national level towards a European level. Conferences like the first EuroGOOS conference (The Hague 1997) and the European Marine Science and Technology Conference (Sorrento 1995, Lisbon 1998) contribute significantly to this process. The European discussion on operational oceanography is in progress. The implementation of the outcome into demonstration projects on European level has to follow.

# European Approach

SeaNet is an example of such a demonstration project focussing on existing fixed monitoring networks in the North Sea region. The long-term objective of SeaNet is to realise a North Sea monitoring system based on fixed monitoring networks as a

contribution to an integrated European marine monitoring and forecasting system. On the short term it resulted in the SeaNet Data Interface project to interlink national fixed marine monitoring networks and make a (selected) set of data from each country available for all.

Specific and generic technologies are no longer the major limiting factor to work on operational oceanographic systems on a European scale. It is no longer primarily a technical issue to bring marine environmental observing and forecasting systems on a European level.

It is a matter of willingness of all parties to work on integrated European solutions based on a public private co-operation and to make the means available to do so. The Fifth Framework Programme of the EC, EUREKA and national programmes offer adequate opportunities in case the European oceanographic community accepts the challenge and transforms it into European demonstration projects. To make this step forward four things are essential:

1 Governmental agencies and scientific institutions, the major users of oceanographic technologies must continue and if necessary intensify their strategic, scientific and technological efforts and act as leading parties in frames like EuroGOOS and SeaNet. They are the binding factor leading to the necessary growth of cohesion in the oceanographic sector.

2 Through a European Commercial Oceanographic Association private parties must organise themselves on a European level, act as counterpart for the public entities and operate as a European industrial oceanographic technology cluster.

3 Public and private parties must seek co-operation in European demonstration projects in the field of operational oceanography focussing on the integration and implementation of proven and innovative technologies (MAST, Euromar and others) and existing facilities and structures (ships, platforms, satellites, databases, models, networks).

4 Public and private partners must maximise the use and the support of frames like the Fifth RTD Framework Programme, EUREKA and national programmes.

# Public Awareness

The title of my paper is new technologies for the World Market. I am aware of the fact that I put the emphasis of the last part of the title: the World Market. That was on purpose because I believe that the implementation and demonstration of new technologies on a European and Global scale will lead to a substantial market volume and to mature technological tools as building blocks for EUROGOOS and GOOS. It will also be a strong stimulant for further development.

I promised you to come back on the importance of human interest for oceanographic technology and the information it provides.

The interest of the people in Europe for the state and the future of our regional seas and ocean is of great importance because it will have great influence on politics and finally on the health of the ocean. In this respect it is not a coincidence that this third European Marine Science and Technology Conference is held next to the World

Exhibition of the Oceans. I hope it will have the impact one may expect on the public and on us, members of the oceanographic community.

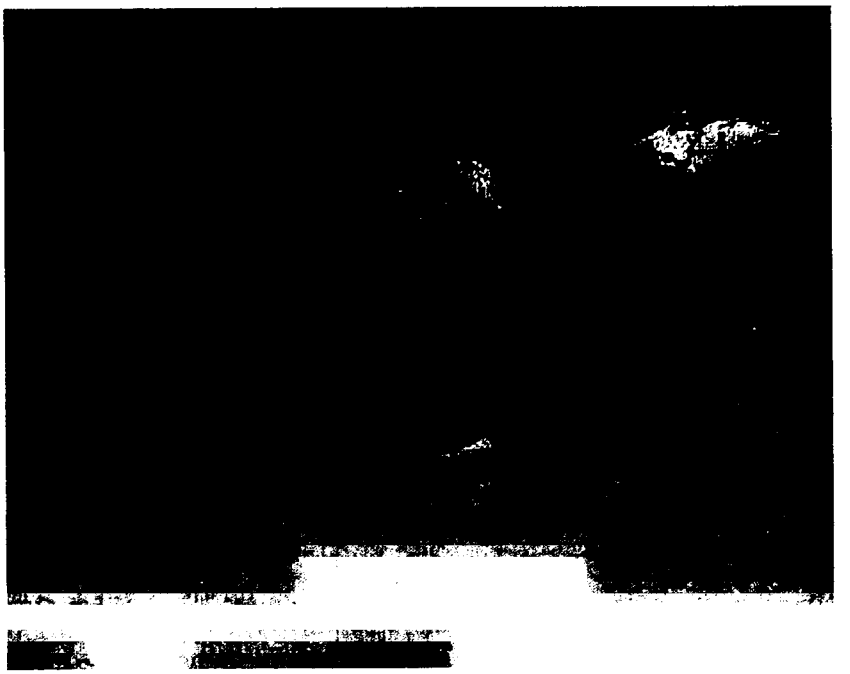


Figure 1. The manned submersible Alvin approaches the Titanic.

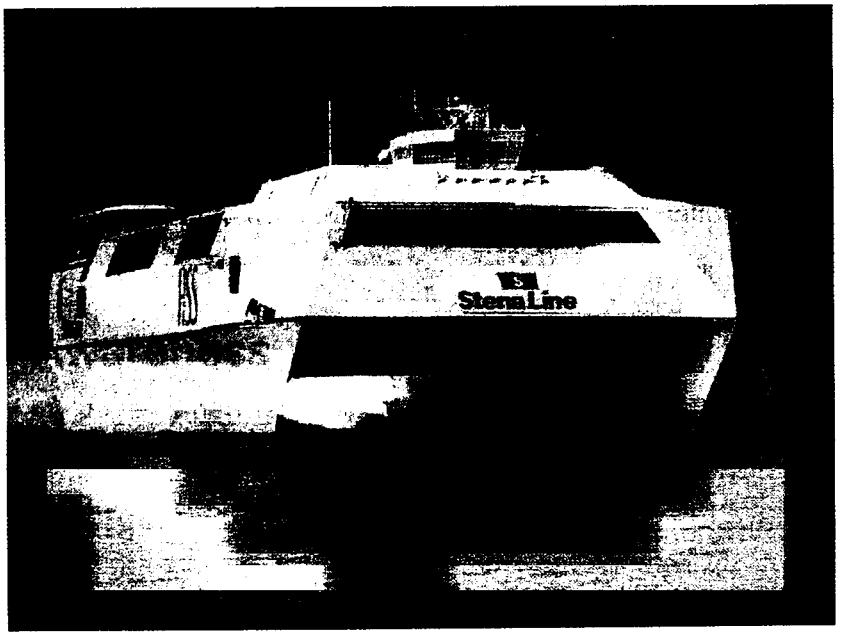
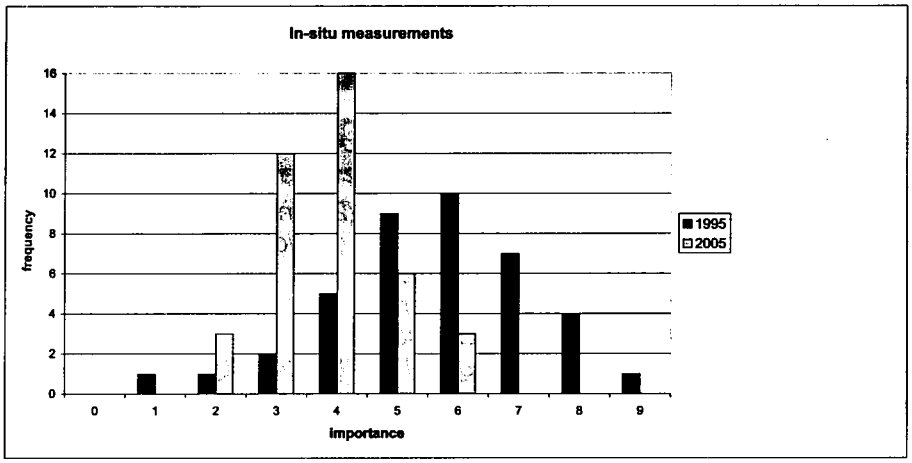
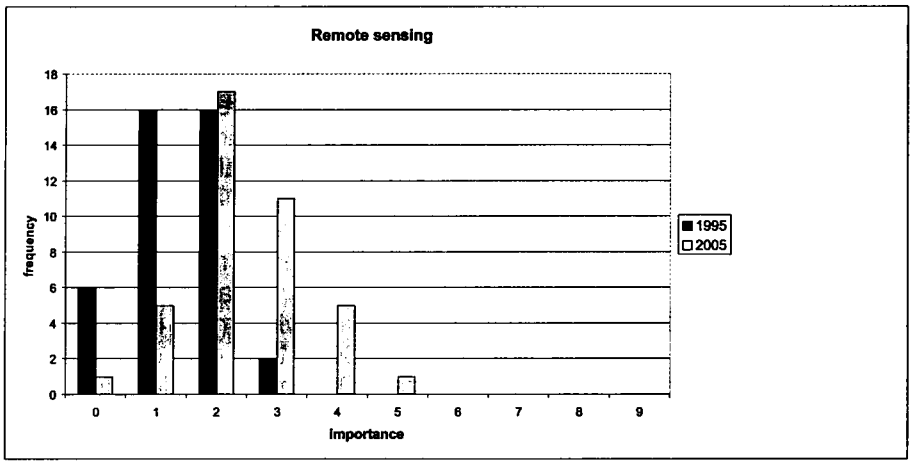
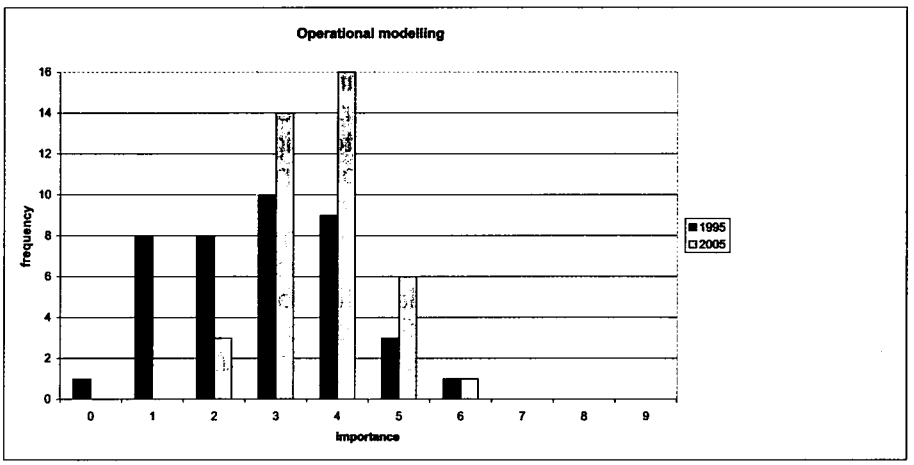



Figure 2. The high speed ferry Discovery.

Figure 3. frequency distribution of the relative importance of in-situ measurements, remote sensing and operational modelling now and in the future for all respondents




Source: SeaNet Survey, July 1996

# Development of new pH and $pCO_2$ micro-optodes for fine-scale measurements in aquatic sediments and biofilms

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Measurements of pH and $CO_2$ are of paramount importance for most biogeochemical studies in the marine environment. The sulphide and carbonate systems are pH dependent and most other chemical or biologically catalysed redox processes affect the pH. Carbon dioxide is a key parameter for primary productivity studies ($CO_2$ fixation) and for studies of mineralization processes, that form $CO_2$. In order to understand the carbon flow and biogeochemical cycles in marine systems pH and $CO_2$ measurements are thus essential. A complicating factor in sediments and biofilms is the fact that the physico-chemical microenvironment is characterised by steep gradients of key variables like pH and $CO_2$, that can only be measured precisely by microsensors with a tip size <0.1 mm. While electrochemical microsensors exist for both pH and $pCO_2$, they are time consuming and difficult to construct. Therefore, we have initiated the development of fiber-optic microsensors (micro-optodes) for pH and $CO_2$. We developed a pH micro-optode for measuring pH in seawater in the range of pH 7-9. The measuring principle is based on the pH dependent absorption change of an acid-base indicator immobilised at the end of a tapered optical fiber. The absorption changes at the fiber tip are monitored via the same fiber coupled to a light emitting diode (LED) as a light source and photodiode as the detector. Fiber-optic $CO_2$ microsensors were developed around the Severinghaus principle, where $CO_2$ diffuses through a gas permeablemembrane and induces a change in pH of an internal buffer. In our sensor, the internal buffer contains a pH indicator solution, which is monitored via a tapered optical fiber. Both microsensors have tip diameters of <50 micrometer. Here we present the measuring principles of the new fiber-optic microsensors and show first results from sensor tests in the laboratory as well as in situ.

# Direct measurements of nitrate and methane by micro-biosensors

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Recently micro-scale biosensors for direct measurement of nitrate and methane have been introduced in marine science. The tip of the bio-sensors contains bacteria in a minute reaction chamber in front of a traditional electrochemical micro-sensor. A diffusive supply of nutrients from a built-in medium chamber allows the reaction chamber to function as a microscale chemostat, in which the respiration is limited by solutes entering through the sensor tip. The typical micro-biosensor has an outside tip diameter of 20-30 µm and a response time of 15-60 seconds. Due to the minute size of the region with bacterial activity (chemostat) the medium chamber of app. 0.1 ml can sustain growth of the bacteria for many months. Thus solely minimising the sensors solves the general biosensor problem of having a constant source supply of reactants. Data from marine applications and in situ measurements will be presented and discussed.

We thank the Commission of the European Community for support under the MAST III Programme MICROMARE (950029)

# Thin-film microelectrode array detectors for in-situ stripping analysis of trace metals

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In order to meet the stringent demands of environmental monitoring for artifact-free data, a substantial effort is put into developing in-situ measuring schemes. In this context, the development of microfabricated electrochemical detectors for stripping analysis of trace metals has attracted particular attention in recent years. Using thick- or thin-film technology, mainly carbon and Ir microelectrode and microelectrode arrays detectors are being investigated. Following their modification with a thin-film of Hg, these devices are presenting promising characteristics for potentiometric or anodic stripping analyses of trace metals in both fresh and sea waters.

In this presentation we report on the fabrication and characterization of thin-film Ir microelectrode arrays for Square Wave Anodic Stripping Voltammetry (SWASV) analyses of trace metals. For the in-situ use, the arrays should be protected by a layer of an antifouling gel. In order to facilitate the control of the deposition of this gel (e.g. agarose) and to improve its mechanical stability, a thick polymeric containment ring has been formed around the array.

## Technology

The choice of iridium as a substrate for a mercury film or semisphere deposition is based on previous investigations using a single Ir microelectrode showing that a) the solubility of Ir in Hg is very low ($< 10^{-6}$ wt.%) and b) the wettability is favorable for the formation of stable Hg deposits. Realized on a $Si/Si_3N_4$ substrate, the arrays consist of 100 interconnected Ir microdisks of 5 µm diameter inlaid in a 2000 Å $Si_3N_4$ layer. The microelectrodes are arranged in 5x20 array with the interelectrode spacing of 150 µm. Using a recently developed Epon SU 8 UV-sensitive epoxy which allows to pattern thick layers with an excellent geometrical definition and mechanical stability, a containment ring of a 300 µm thickness was deposited and photolithographically patterned around the 5×20 microelectrode array. The final devices are bonded to a custom-made printed circuit board and encapsulated using an epoxy resin.

# Characterization

The microelectrode array characterization performed before the deposition of a thin-film Hg layer consisted in SEM and AFM observations and electrochemical experiments in ferrocyanide solutions. These tests have been carried out systematically in order to qualify the developed technology with respect to the reproducibility and reliability. A ± 5% reproducibility within different fabrication batches has been achieved.

Following the deposition of thin-film Hg, an extensive laboratory and field testing of the devices in a flow-through set-up has been successfully performed at the CABE, University of Geneva.

# High-resolution *in situ* holographic recording and analysis of marine organisms and particles (*)

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It is well known that a detailed knowledge of the distribution and dynamics of marine organisms and particles in the marine water column is crucial to our understanding of chemical cycles in aquatic systems. Because of its particular properties, holographic recording and imaging of marine systems offers a unique tool to scientists for the analysis of such systems. The overriding benefit of holographic imaging is that it allows non-intrusive and non-destructive recording, *in-situ*, of living, motile, organisms and inanimate particles in their natural environment. The inherently high resolution of holography, its three-dimensional imaging properties and the ability to perform "optical sectioning" on the replayed image, allows enumeration and identification of specific organisms together with their size, and three-dimensional spatial distribution. Simultaneous combination of a large depth-of-field and high-resolution of a hologram enables the recording of large volumes of small particles in a single exposure; compared to that of a photograph, vastly more data can be recorded in a hologram. In addition, the wide dynamic range enables holographic images to yield information where photographs would possess exceedingly high levels of background noise. Low-noise is particularly valuable in recording semi-transparent particles of micron dimensions at low concentrations.

In our collaboration, we are developing a fully functioning, prototype, underwater holographic camera (holo-camera) to record large-volumes (up to $10^5$ $cm^3$) of marine organisms (marine plankton and seston) within the upper water column. The holo-camera will be capable of either ship deployment or attachment to a fixed buoy, will be remotely controlled and operate to about 100 m depth. Two basic recording

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geometries, in-line and off-axis, are employed depending on the local particle concentrations and the specific requirements of the user. Although the recorded objects are located in water, replay of the image is carried out in air, in the laboratory, using the real-image mode of reconstruction. The image is located in the real space between the observer and the holographic film and is life size, fully three-dimensional and retains all the parallax and perspective information of the original. A dedicated and automated reconstruction facility allows optimisation of the holographic image and computer-controlled precision-translation of a TV camera or measuring microscope through the image. Using image processing techniques, individual species can be identified together with the ability to extract information regarding orientation, dimensions, relative position and measurement of local concentration and distribution of a variety of marine organisms.

Experimental validation has been carried out in the laboratory on a series of calibrated targets and living marine organisms. Using in-line holography, cultured samples of biotic particles (*Asterionella formosa* and *Tetrahymena pyriformis*) were clearly resolved to better than 10 μm. Three-dimensional co-ordinates of 601 individual diatoms, in a sub-volume of 98 $cm^3$ of the total imaged volume of 2400 $cm^3$ were measured. A field sample of marine plankton yielded a "textbook" image of the dinoflagellate *Ceratium tripos*. Off-axis holography provides lower resolution than in-line (around 100 μm), but affords images of the larger macro-zooplankton (e.g. Calenoid copepods) of dimensions of around 0.5 mm to 2 mm. The off-axis method allows recording of particles in higher population concentrations than in-line (up to 200 $cm^{-3}$ in water volumes of 2400 $cm^3$). Experiments on cultures of living *Phaedodactylum tricornatum* showed that illumination with high power laser light did not affect growth.

# CytoBuoy: In situ analysis of phytoplankton and other microorganisms with a buoy mounted flow cytometer

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There is a clear need for technologies that allow rapid and adequate monitoring of phytoplankton and other microorganisms. The particulate matter found in natural surface waters consists of a variety of microorganism types with large differences in size, shape and physiological properties. This enormous diversity impairs the application of most particle analysis techniques, either owing to ambiguity in the relation between the measured entity and particle size, or by physical limitations to sensitivity, analysis resolution or particle size range. In addition, most techniques apply a single detection principle only, allowing hardly any discrimination between particle types beyond the elementary small-large assessment. In flow cytometry (FCM), several correlated measurements are made simultaneously from each individual particle. These may include light scatter at various angles, fluorescence form chlorophyll-a and other pigments and particle length. However, the diversely sized and shaped phytoplankton found in coastal zones and fresh waters cannot be analyzed properly with standard flow cytometers. Therefore, experimental flow cytometric equipment was developed for (ship board) lab use. The EC MAST III Cytobuoy project aims at transferring this flow cytometry technology to in-situ platforms. The advantages are the availability of continuous quantitative water column observations in time or space (tracks), yielding more insight in system dynamics and patchiness and more reliable overall results, which is important for intercalibration with other platforms and for input in ecological and biophysical models.

A small (Eur)OPA type flow cytometer was designed for mounting in a 90 cm buoy to allow for moored operation. One of the new aspects as compared with existing technology, is that the optics and fluidics, as well as data acquisition electronics are designed and built to allow optical scanning of the particles, with transmission of the raw scan data to shore for off-line analysis. Pulse shape analysis can be applied which allows more features to be extracted from the both quantitative and morphological (one-dimensional) data. This is a great advantage over existing and more complex flow cytometers. The measuring principle as well as the main design criteria and bottlenecks will be explained. First experimental data and examples of particle scans will be shown with emphasis on the morphological features that can be extracted from the data.

Flow cytometry has the potential to play a key role by providing data on particles for species composition on the one hand and the correlated particulate distributions of optical properties for ocean optics analysis and sea truth on the other hand. Further developments will help to integrate flow cytometry in operational monitoring systems. The Cytobuoy is a significant step in this process.

# Variability of nutrient concentrations in the Elbe estuary and in the German Bight: Detection of wind-induced events and chemical-biological processes by quasi-continuous measurements

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Nutrients play an important role for the water quality of coastal areas. In the past, monitoring of nutrients was carried out by sampling from ships and analyses in the laboratory. Recent developments in automatic nutrients analyzers provide the possibility of automatic measurements from unattended systems, e.g. buoys. Within the Eureka/Euromar-project "MERMAID" such analyzers had been developed by the company ME, tested and qualified by the GKSS Reserach Centre together with the German monitoring authority "Federal Maritime and Hydrographic Agency, BSH". These tests demonstrated that the instruments are suitable for operational monitoring purposes with the same accuracy as conventional laboratory methods.

The instruments were used on a small prototype network consisting of three stations in the Elbe estuary and the German Bight in order to study the behaviour of nutrients during the transport from the river to the North Sea. Due to the new instrumentation, for the first time quasi-continuous measurements of nutrients could be carried out over many weeks. The examples show that the transfer of nutrients and of contaminants in the estuary and in the coastal zone is strongly influenced by different short- and long-term events, i.e. freshwater discharge rates and wind actions. Additionally, in summer chemical and biological processes influence to a high degree the fate of these substances on their way from the river to the coastal zone.

In this contribution results of nutrient-concentration time-series measured in 1995 and 1996 on the three MERMAID stations are presented and discussed on the basis of corresponding meteorological and oceanographic records.

# Application of the Microstructure and Turbulence (MST) Profiler in the MAST-III project PHASE, and its impact on the related turbulence modelling

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## Abstract

The central objective of the MAST-III project PHASE (Physical forcing and biogeochemical fluxes in shallow coastal ecosystems) is to determine the interrelations between the nature and strength of physical forcing functions, including the connected mixing processes and the biogeochemical fluxes and trophic structure in the coastal ecosystem.

During two field campaigns undertaken in 1996 and 1997 within the PHASE project, two profilers were used simultaneously by the Space Applications Institute and ME Meerestechnik-Elektronik GmbH to investigate mixing processes and related fluxes.

The whole water column from the surface down to the bottom was covered, by applying a unique technique, one profiler was used in the ascending mode from about 6 m above bottom up to the surface and the other in descending mode from about 3 m depth down to the bottom.

The measurements during the 1996 campaign were performed in the Easter Scheldt, Netherlands, a quasi homogeneous macro-tidal estuary, for about 8 days. One microstructure profile was taken every 15 minutes. Measurements in 1997 were located in the strongly stratified micro-tidal Knebel Vig, Denmark. The burst sample mode was employed, recording about 10 profiles per hour.

The modelling was initiated trough the application of a 1D K-ε turbulence model for the measured situation in the macro-tidal area. These preliminary model runs showed no agreement between measured and modelled turbulent kinetic energy dissipation rates. Only after considering further important effects such as stratification due to suspended sediments, was reasonable agreement between model data and measurements achieved.

This clearly demonstrates the necessity for modellers and experimental scientists to collaborate closely, and the need for new instrumentation in order to improve the understanding of turbulence and mixing processes in water.

# Utilisation of multi-frequency acoustics for studying suspended sediment processes: Assessment and results under currents, waves, and combined currents and waves

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## Scientific objectives

To simultaneously and non-intrusively measure high temporal and spatial resolution profiles of suspended sediment concentration, particle size, and flow within the wave and current boundary layers. These measurements will be used to assess theoretical descriptions of fundamental sediment processes and mechanisms on the turbulent and intra-wave scales in currents, waves, and combined wave-current conditions.

## Context of research

The in-situ measurement of suspended sediment concentration and particle size is an evolving technological area. However, those who work in the marine environment clearly recognise that the presently available instrumentation does not satisfy all requirements. Few instruments will measure particle size, even fewer will measure particle size and concentration, and none will provide profiles of concentration, particle size and velocity. The objective of the present MAST III programme of study, TRIDISMA, (Three dimensional sediment transport measurements by acoustics) is to provide the technology and methodology using high frequency acoustics to obtain non-intrusive detailed observations of nearbed suspended sediment and flow profiles. Such instrumentation will provide the marine scientific community with the capability to examine the fundamentals of sediment processes.

## Summary of the results

The application of sound scattering, coupled with inversion methodologies, for remotely investigating forms and structures, is central to a great deal of acoustics.

Two problems require a solution, (i) an understanding of the interaction of sound with the processes of interest, and (ii) the application of this knowledge in an inverse mode to investigate the processes using the interaction of sound with it. The present study has tackled both of these problems. The interaction of sound with suspensions of marine sediments has been studied, the scattering characteristics have been identified, and theoretical descriptions formulated. These results have been used to devise a framework for inverting backscattered acoustic data from suspended sediments to obtain sediment and flow parameters. Using these inversion methodologies combined with recent technological developments an instrument has been developed which provides profiles of concentration, particle size, and flow velocity. To assess this acoustic approach a series of measurements have been conducted under controlled current, wave, and combine wave-current conditions in a flume. High resolution measurements of the flow and suspension field have been obtained and these are being compared with data from reference instruments, and utilised to examine the complex interactions between the flow, the suspended sediments and the bed. These observations are beginning to providing new insights into the fundamental mechanisms of sediment transport, and providing data which can be used to assess present theoretical descriptions of nearbed sediment processes.

# Conclusions

Methods for applying acoustics to the study of the fundamental mechanism of sediment entrainment and transport have been developed. Hardware has been constructed and assessed under controlled conditions. Measurements have been obtained under current and wave conditions, and these data are being used to assess descriptions of sediment resuspension processes.

# Data fusion of sensors data, images and networking for structural response and actions exerted by storm waves over a vertical breakwater wall ( Las Palmas, Reina Sofia Breakwater.Spain.Canary Islands)

*Keywords: control of instrumentation,networking, integration of diverse controller platforms, on site data adquisition, merging technologies.*
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The present proposal deals with the innovative advanced instrumentation developed jointly for the Puertos del Estado organization and the Centro de Estudios de Puertos y Costas CEPYC/CEDEX, targetted to achieve prototype measurements on dike structures constituted by caissons, obtaining valuable results concerning the impact forces, and accelerations due to wave attack over the structure.

The instrumented sections (two caissons) are located at Las Palmas harbour in the Canary Islands, that was considered the best site for these studies. The paper considers different aspects of the instrumentation as well as the appropriate selection of sensors, the installation works, the analysis network developed and the first results received,jointly with the data fusion and remote control procedures.

The actually working sections (two of them) are supporting 11 pressure sensors at the vertical face of the wall, all of them in titanium body and diaphragm, 4 pressure sensors to study the effects of subpressures and 3 accelerometers. Sea parameters such as wave heights and the directionality of the sea states will be provided via the scalar buoy data (placed nearly the instrumented sections) and radar image evaluation. Also is considered the appropiate selection of sensors, materials, and assembly procedures, as well as the distributed data scheme for data adquisition/ transmision based on multiple computers and device controllers linked by a network.

# The prototype dike instrumentation

On site instrumentation, data merging and control must be a high interest concern for engineers increasing its importance due to tests performed succesfully at prototype, even when many other similar field instrumentations have failed at the stages of the useful exploitation of the results. The possible explanation for the failures of these experiences may be considered as follows:

- No pressure sensors were developed until recent years capable to resist the marine environment conditions (specially in highly corroding warm waters), physically and chemical or biological, or when considering interface problems due to electrolisis effects.
- Few sites around the world count with operative networks for logging and exploiting maritime climate data, of basic importance for analysis and correlations with instrumentation data.
- The software capable to exploit jointly the pressure data in synchronization with climatological data (winds, waves and tides) with data merging and remote control of the instrumentation is until now poorly developed.

# Objectives

- Installation of a set of instruments allowing the monitoring and data logging for a vertical dike during three years at least, with correlation of data for pressures and accelerations with registered simultaneus data for wind, waves and sea level, data fusion and remote control of the different computing platforms and device controllers, and image support and interpretation for the wave sea state directionality.
- Simultaneous pressure register over the vertical wall with nonbreaking wave conditions in two sections with the diverse wave conditions and sea states, including the measurement of subpressures and accelerations under the same wave conditions.
- Exploitation and analysis of the recorded data and quality control for the merged data allowing comparisons with the physical model tests and mathematical theories and empiric formulations in use.
- Considering the results produce an evaluation of the safety conditions and mechanical behaviour for the instrumented dike from the point of vue of the several failure mechanisms involved in a maritime engineering design stage, deriving considerations for the influence on the surroundings.

Is considered to instrument a vertical structure with non breaking wave conditions, with nearly positioned level and wave high meters allowing for correlation and simultaneous analysis. The Reina Sofia dike of Las Palmas harbour matches all of these conditions. The transversal section of this dike, from 40 to 50 meters deep, is a caisson of reinforced concrete of 22 x 29 m., founded at –20 respect MSL, featuring a vertical wall among +12.20 m. to –18.40 m.

Considering these aspects, the dike becomes one of the most important vertical caissons dikes in the world, capable to resist nonbreaking wave efforts with return

periods of more than 300 years. The choosed alignment to instrument is of 370 m. length, orientated NW-SE, receiving with few obliquity the higher and frequent storms NNE-NE. At the vicinity are located two scalar buoys from REMRO and a mareographic device from REDMAR.

All the assembly schemes are based on the use of a previous built elevator that allows the diver to place, check and operate the sensors. All the assembly has been conceived as mobile one, in such way that sensors may be changed or taked away for inspection, recalibration, cleaning or substitution.

Other measurement equipment will be consistant of devices to provide maritime climate data. Among them is very important the radar system designed to measure some degree of the directionality of waves, fitted at the top of a metallic tower, located at the head of the dike. Also is present a weather station and the control unit for the data sended by the buoys, all of them located in the same control cabin. Four of these cabins have been arranged, one for each section to be instrumented, one for radar and maritime climate devices and the last one devoted to contain an electric generator to avoid unregistered data due to power supply fails during storms.

# The designed network

Generically speaking, we have developed a distributed data adquisition scheme over an heterogeneous network. The used algorithm has been based on client-server architecture, with the idea of not to block anyone of the data receiving stations, being fully independent of the servers to maintain external communications. The complete system is composed actually of nine platforms, six of them configured as data receivers and the three remaining stations as communications ports servers. Data coming from pressure and accelerometric sensors are processed from platforms that link with the platform serving the modem line by the parallel port at typical speeds of 140 Kbytes/sec (1.120.000 baud).

Data are raw stored over a DAT tape with SCSI interface, without interruption of the data adquisition procedures. Due to DAT capacity is possible to maintain about six days of continous readings with the stablished sampling rate. Any change of the state for this platform is sended to the monitoring station via the parallel port and from the communications server by telephone lines.

For the data adquisition has been used a National Semiconductor board with configurable software speeds, actually implemented ranging from 25 to 250 s/s. The implemented software has been centered around double buffer techniques and data compression prior storage schemes, because of the near 45 Mbytes/hour data we plan to take.The two data adquisition platforms are connected to the modem server by RS–422 at 56 Kbaud.

Also are involved the weather station, near the experience site, connected via RS 422 and tidal meter station that sends information directly to the display unit via a single port RS 232. Finally, the more advanced the experience, is planned to include fiber optics transmission devices to substitute telephone lines via FDDI.

# The Development of Thick Sectioned Composite Pressure Vessels for use in Oceanography

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The objective in the MAST II Contract MAS2-CT92-0028 was to develop the analysis tools and manufacturing techniques for producing thick sectioned fibre reinforced plastics (FRP) pressure vessels ultimately capable of 6000m depth operation with a lower buoyancy to weight ratio than is possible with metals. The demand for data collection from the oceans is growing as a result from growing interest in, for example, climate change, pollution monitoring and ocean floor exploration. This has stimulated an interest in lightweight structures and specifically pressure vessels for autonomous underwater vehicles (AUV's).

Previous work had highlighted the problems in predicting material properties and performance for thick section fabrications. Work was carried out on tokens and pressure testing small scale cylinders to correlate theoretical and actual results. The materials used were Grafil XAS (later to become unavailable) and Tenax J UTS 531 12000 carbon fibre with Ceiba Geigy MY750/HY917 epoxy resin. A summary of the test results for the key specimens are shown in Table 1.

In addition to pressure test work, the effects of defects and means of detection were investigated. Defect tolerance tests showed the effect of delamination to reduce the failure pressure by 8% on 125mm inside diameter tubes, regardless of the defect size produced. Non destructive examination (NDE) ultrasonic methods, C scan and ZIPSCAN, successfully detected intentional delamination defects, resolving defects separated by only two plies.

Analysis and testing was carried out on CFRP end domes (see Table 1) but is seen that the actual ultimate strength falls a long way short of that predicted, due in part to the difficulties in manufacturing a dome with homogeneous properties and geometry throughout. As a result, subsequent work used titanium end domes, paying careful attention to the boundary conditions created at the dome/cylinder interface.

Following the knowledge gained from all this work, a larger scale vessel was produced and tested to destruction in the pressure test facilities at IFREMER (see Table 1).

| Description | Material | Thickness (mm) | Mean radius (mm) | Theoretical collapse pressure (Mpa) | Actual collapse pressure (MPa) |
|---|---|---|---|---|---|
| Cylinder | XAS | 6.0 | 65.7 | 29 | 30.8 |
| Cylinder | XAS | 7.5 | 66.5 | 54 | 56.3 |
| Cylinder | XAS | 14.0 | 69.7 | 200 | 83.0 |
| Cylinder | XAS | 19.7 | 72.5 | — | 108.7 |
| Cylinder | Tenax | 19.8 | 72.6 | — | 98.9 |
| Dome | CFS001 pre preg | 11.0 | 130.5 | 181 | 39.8 |
| Cylinder | Tenax | 38.8 | 244.3 | 70-93 | 61.0 |

TABLE 1 Summary of Pressure Test Results

The work has significantly advanced the understanding of thick section composites and confirmed their potential for deep ocean applications. A vessel of significant size has been produced and tested showing theoretical modelling is in reasonable agreement with practice. More work remains to be done in the field of predictive modelling, the determination of accurate material properties and the consistent production of FRP domes. This theme is continuing under a MAST III programme with a major objective to produce two all FRP pressure vessels 450mm inside diameter, 1250mm cylindrical length with a working depth of 2000m. Both will be instrumented, one will be tested to destruction and the other deployed in the ocean at 2000m for a 12 month period to observe the effects such as creep strength, water absorption and fouling.

In parallel with these two programmes the Natural Environmental Research Council (NERC) Autosub project, hosted at the SOC, has successfully developed the AUV Autosub–1, utilising this technology for the main pressure vessel. The Autosub programme has now entered a new phase to develop the endurance and depth capability to 1000km and 2500m depth respectively. The continuing MAST programme will be of direct relevance to the further development of AUVs and other oceanographic equipment.

# Advanced Concepts for AUV Docking Downloading and Recharging

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## Abstract

Autonomous Underwater Vehicles are on the verge to become a universal tool for scientific ocean exploration and industrial underwater applications although the operative range of AUVs is at the current state restricted to their directly adjoined area.

A submerged docking station is a suitable means to overcome some of the problems associated with today's use of AUVs: Their limited capacity to store energy and data on board and the necessity to periodically launch and recover the vehicles from the support ship.

A universal Docking-Downloading-Recharging system will be developed and demonstrated within the EURODOCKER project, a joint RTD venture by five partners of Denmark, France, Italy and Germany supported by the EC MAST III programme. The main functions of the EURODOCKER system will be to re-energize the AUV, to download data gathered during the previous surveys and to upload operation management data for the subsequent mission while the vehicle is docked.

The docking system also has to manage low-bit-rate communication during the mission and mid-bit-rate communication during close navigation, the position and navigation during the release and approach phases and finally the alignment and docking of the AUV while on reentry.

It will consist of a ship or platform supported Mechatronic Docking Device and its mechanical counterpart on board the AUV.

EURODOCKER's objective is to provide the basic technologies and means to enter the worldwide market for commercial submodules for unmanned underwater vehicles with an advanced European product.

An extensive system engineering task prior to the design of EURODOCKER's main components and the constant monitoring of AUV's now on the market or under successful development are clearly devoted to this aim.

# Autosub–1: Mission Programming and Control of an Autonomous Underwater Vehicle

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Some autonomous underwater vehicles (AUVs) have reached a sufficiently advanced stage of development as research platforms that we can forecast confidently that they will take a key place in world markets for oceanographic instrumentation over the next decade. The Autosub–1 AUV falls into this category. Funded by the UK Natural Environment Research Council with support from the Ministry of Defence and by the EC for some of the generic systems research the vehicle was developed by the Ocean Technology Division of the Southampton Oceanography Centre and the design has recently been licensed to industry.

This presentation will focus on a particular aspect of Autosub–1: mission script programming and autonomous mission control. Other aspects of the vehicle design and performance have been described in journals and at conferences over the last two years, but this will be the first detailed presentation on the mission control of Autosub–1. With a length of 7 m, a displacement of 3.6 tonnes, a depth rating of 500 m (to be increased to 2500 m by the year 2000) and an autonomous range of 200 km Autosub–1 is not just a research platform for robotics, it is a vehicle capable of being used for purposeful science missions and already has over 110 missions to its credit. The types and requirements of missions will be discussed along with relevant aspects of the vehicles control architecture. The simplicity of the vehicle's control systems and mission programming will be emphasised as a significant factor in the vehicles rapid development and operational reliability. This will lead into the main substance of the presentation which focuses on the operational path from the scientific requirements of a mission through mission specification, vehicle programming and control configuration to mission execution.

The mission script specifies the navigational and control requirements for Autosub. It consists of a list of mission lines containing two fields: the event field and the command field. Commands are executed conditionally depending on the occurrence of the specified event in the event field. Examples of events are: "way point reached" or "on surface". Commands include the control demands such as, "depth demand" or "altitude demand", as well as the required mode of operation such as "depth follow" or "altitude follow". Off-line tools have been developed for compiling and checking the mission script.

Autosub–1 uses a completely distributed control system — individual networked nodes carry out the sensing and control functions. The position control node carries

out all the control functions in the horizontal plane, while the depth control node controls the vertical plane behaviour of the vehicle. Other distributed networked nodes measure the vehicles depth, altitude, velocity, position, and attitude. The mission control node is a relatively simple event driven command interpreter for the mission script, issuing demands at appropriate times to the control nodes. Once the mission program has been written and checked it is downloaded over a radio link along with any relevant control configuration to Autosub–1's respective control nodes.

To illustrate our approach to mission programming we will show examples from recent trials off the coasts of the UK and US. Finally, some practical limitations of this simple approach to mission programming and mission control will be described, leading onto a discussion of how best to proceed with the next versions of the mission control system and mission script compilation software.

# Technological solutions in the "GEOSTAR" benthic observatory

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GEOSTAR (GEophysical and Oceanographic STation for Abyssal Research) is a technological and scientific project (MAST-III) aimed at the design, manufacturing and testing of an autonomous benthic observatory able to perform long-term (up to 1 year), continuous geophysical and oceanographic measurements in deep seafloors (up to 4,000 m).

GEOSTAR is conceived as the prototype of a new generation of multidisciplinary ocean bottom stations, capable to operate as node of future deep-sea observatory networks. For this reason a maximum effort has been paid since the early phases of the project, started in 1995, to find solutions capable to overcome limitations of the present methods and instruments used for deep-sea research. The developed concept is therefore based on three main elements, each featuring innovative technological solutions:

— extension of the operating capabilities of the instrumented bottom station;

— surface assisted deployment and recovery;

— maximum interaction with operator during the mission.

The Bottom Station supports all the scientific packages, and is designed for maximum autonomy and reliability during the mission. Scientific payload includes geophysical (seismometer, scalar and vectorial magnetometers), geochemical (CTD, transmissometer, pH, Eh, $H_2$, $H_2S$ electrodes) and oceanographic (Acoustic Doppler Current Meter) sensors. Among the enabling technologies characterising the Bottom Station: low power data acquisition and control system, high capacity mass memory system (2 Gbytes), automatic management of a long-term mission. The developed system is characterised by a high degree of modularity and expandability. Specific solutions have been also developed for the deployment of packages (seismometer and magnetometers) that must be released from the Station once arrived at seabed.

Deployment and recovery operations are carried out by means of a special thrustered Vehicle, connected by umbilical cable to the support vessel. The Vehicle is designed for heavy loads, allowing a controlled and accurate deployment of the station at seabed, and subsequent re-entry on the station for recovery after the scientific mission. The Vehicle is equipped with two thrusters to ensuring mobility on the horizontal plane [x,y], while a winch of the support vessel regulates the descent/ ascent [z]. Visual and instrumental systems are used to locate the pre-determined installation area or find the Bottom Station for retrieval. A mechanical connector ensure coupling between the Vehicle and the Bottom Station, while an electrical

connection enables the surface operator to maintain the complete control of the Bottom Station during deployment and once at seabed.

Interaction with operator is ensured by an original communication system, based on expendable data capsules, periodically released by the station and transmitting by ARGOS satellite link once arrived at sea surface. These capsules will be used both for data retrieval and station status checks. An Acoustic Transmission System is also available to enable bi-directional transfer of data and commands using ships of opportunity. Interfaces for real-time transmission systems (e.g. cables) are also provided in the Bottom Station.

GEOSTAR will carry out the first demonstration mission in Adriatic Sea during Summer 1998; the execution of the first scientific mission is scheduled in Mediterranean Sea, offshore Ustica Island (3400 meters w.d.) in the second phase of the project (1998-2000).

In the present paper the main objectives of the project, system description and results of the laboratory test phase are reported and discussed.

# *In Situ* Monitoring of Processes in the Deep-Sea Benthic Boundary Layer using Autonomous Lander Instrument Platforms

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Traditionally research in the deep-sea has been carried out by lowering instruments or sampling gears to the sea floor by cable from ships. This has two main disadvantages; physical changes (pressure and temperature) can affect any measurements made in the laboratory on retrieved samples and it is also very time consuming. Particularly chemical and biological processes are best measured *in situ* and much progress has been made through the use of manned submersibles. However submersibles can only remain on the sea floor for <10h per dive and have difficulties in operating in bad weather conditions prevailing for much of the year in temperate regions.

Autonomous platforms have the capability to remain on the sea floor for a year or more and can be left in place during bad weather conditions when ships cannot operate. By analogy with space-craft, such platforms are know generically as "landers". Comparing landers with gear on cables shows that for any task lasting more than 4 hours on the sea floor the lander is the preferred option in terms of efficient utilisation of ship time.

Landers comprise the following basic modules. Retrieval systems (radios, lights visual signals), buoyancy, main chassis, scientific payload, ballast release and ballast. For work in the NE Atlantic ocean, twin parallel acoustic releases are preferred, time releases (even as a back-up) create dangers of recovery in bad weather and have been rejected for use in this area. For reliability, release electronics should be entirely separate from the scientific payload. Buoyancy can be glass spheres or syntactic foam either mounted directly on the chassis or above the lander on a mooring line. The lander can stand directly on the sediment or be suspended above the sea floor depending on the task to be performed.

Experience on a cruise of the *RRS Discovery* in 1996 showed that it is possible to operate

11 landers in relays from a single ship achieving 5 hours of sea bed experimental time for every hour of ship's working time. For a small ship, unable to carry a full ocean-depth cable a compact lander can provide a means of taking measurements in the deep sea. Landers can vary in size from 200kg weight for a compact lander to approximately 2 tonnes weight for the heaviest scientific landers.

Scientific payloads include, micro-electrodes probing the sediment, chambers enclosing areas of sediment, physical monitoring of flow and chemistry of water above the sediment and tracking of free-swimming animals at distances up to 500m away from the lander. Operation of fleets of landers can achieve coverage of the sea floor on temporal and spatial scales not possible through any other means.

This work was supported by EU-MAST-III contract CT950010 ALIPOR. Autonomous Lander Instrument Platforms for Oceanographic Research.

# DESIBEL, 'New methods for Deep Sea Intervention on future Benthic Laboratories': Analytical comparisons and at sea feedback

*Vincent Rigaud, Dominique Semac, Marc Nokin (Ifremer), G Tietze (Geomar), H Haman (Thetis), V. Goetz (VWS)*

Amongst the tools at the disposal of the scientific community, benthic laboratories and benthic stations are going to experience an increasing interest on account of the missions they will permit: observation, measurement and long term experimentation completed on the sea floor. Several dedicated benthic labs have already been successfully implemented; we can conceive for the future the development of more sophisticated systems allowing to complete more complex works and at a larger scale.

The general objective of the MAST II DESIBEL project was to investigate new methods for deep sea intervention that could be used in the future to deploy, supply, operate and recover benthic laboratories.

This project co-ordinated by IFREMER was conducted with a winning partnership including THETIS Technologies GmBh (D), GEOMAR Technologies GmbH (D) VWS (D) and Instituto Superior Technico (P)

Four different concepts were studied in the project:

1. an active docking system with a mobile hook (LOMOS),
2. an active docking system with a special Remotely Operated Vehicle (REMORA),
3. a deep sea 6000M depth scientific Remotely Operated Vehicle (ROV 6000),
4. a free swimming vehicle teleoperated through acoustics (FREE MODULE named SIRENE).

The optimum scope of application of each system was determined according to:

- the benthic lab characteristics (size, weight, life duration),
- the vessel characteristics (positioning, weight, handling capability, heave compensation),
- the applications (lab handling, labs interconnection, energy source recharging, data recovery).

For each concept engineering studies were conducted as well as cross comparisons mainly based on simulations. About this last point Comparative

studies of dynamic behaviour and acoustic performances were carried out by THETIS and GEOMAR Companies. In some cases equipments or mock-ups were realised and tested at sea by IFREMER with other partners. Operational results for the operations with the ROV6000 VICTOR, the GEOMAR MOBILE WINCH, (part of ROVs and active dockers concepts) and free swimming shuttle SIRENE developed by IFREMER with the collaboration of IST for the control of the vehicle, will be described and illustrated by video.

The paper will particularly emphasis description of hardware and software developments conducted during the project and will described more deeply at sea trials and lessons with the really tested systems. The electrical GEOMAR mobile winch applicable to LOMOS and REMORA concepts, the free swimming shuttle SIRENE, an the ROV 6000 VICTOR operating the SAMO IFREMER benthic station with hydraulic manipulation.

# Specialized vessel for deep sea intervention – "DSI-vessel" – A European project of the maritime industries forum, panel 2

*Uwe Jenisch, Kiel*

## 1. The Idea

The deep sea is one of the most important subsystems on earth. So far, we have understood little of the transport of energy and matter and their time scales in the deep ocean. Nor do we understand the biological, geological, climatic and other processes in the deep ocean spaces which represent some 50% of the world surface, i.e. water depths over 5000 m. Apart from various and urgent research needs, the entry into force of the UN Law of the Sea Convention on November 16, 1994 and the subsequent establishment of the International Seabed Authority add a fresh impetus to global ocean research and development.

The deep sea, its sediments, the subsoil and their role for the understanding of the global climate and energy balance is one of the remaining great challenges. While it is relatively easy to handle marine research in the water column the seabed and its subsoil is a much more difficult environment posing all kinds of problems for the physical presence of man and equipment.

The proposal for a DSI-Vessel comes by no means out of the blue. It has its own history:

1. Members of the European family of marine scientists will recall the French proposal "NEREIS" (navire européen de forage et d'intervention sous-marine) of 1989 as a multidisciplinary platform for environmental, biological and tectonic research and able to carry heavy drilling equipment.

2. A more sectoral approach has been persued by ECOPS/ESF (European Committee for Ocean and Polar Sciences) since 1992, — i.e. a proposal for deep-sea instrumentations capable of doing scientific research and coping with the technological challenges of deep sea working conditions. This proposal includes submersibles, benthic laboratories, other research tools and handling systems for the professional and safe launching and recovery of major instrumentation on the high seas.

   For further details see: ECOPS Report "The Deep-Sea Floor as a Changing Environment", 1994.

3. Moreover, the EC Commission – D.G.XII – initiated in 1991 (within the MAST II programme) two studies on the feasibility of abyssal benthic laboratories, which can be operated reliably for short term and long term missions.
4. The current MAST-III programme (1994 – 1998) sets its own priorities for the deep sea floor in the "Research Areas A" (Marine Science) and "C" (Marine Technology).
5. Finally, the DSI-vessel is one of the project ideas of the European Maritime Industries Forum (MIF) – panel2 – "Marine Resources" as contained in the Proceedings of the Fifth Plenary Session, Rotterdam 1994, p. 74.

# 2. The Vessel

The initiatives and reasons mentioned above suggest the need for a joint European specialised vessel capable to operate in deep water. The vessel must be able to achieve oceanic research. Her missions could include (subject to further investigation by experts)

- the handling of abyssal labs, long-time monitoring stations, ROV's and other types of submersibles and payloads of 400 kg and over,
- drilling equipment for coring (50 meters and more with a reasonable diameter),
- climatic research including the behaviour of $CO_2$ in the deep sea,
- volcanic and earthquake research,
- testing of new equipment for industry and science,
- studying the effects of disposal and mining,
- other deep sea missions

The vessel could also be mobilised in case of marine casualities, natural hazards or other spontaneous events such as submarine landslides or tsunamis. Wreck search and recovery of archaeological and other lost objects are another option. Of course, the vessel will be a tool and a platform for carefully monitoring all deep-sea activities from an environmental/precautionary point of view.

# 3. The Design

For this variety of purposes the vessel has to be flexible in its design and equipment. Flexibility can be achieved by **containerisation** or module-like equipment of labs, testing facilities, winches, workunits etc. In other words: the vessel is not only a multipurpose research vessel but also a **show-case** for modern marine research technology and services, thus becoming a nucleus for the closest possible co-operation between **industry and science.**

Needless to say that the DSI-vessel will quality the European marine science community (and shipbuilding and equipment industry) to remain a valuable partner in the co-operation with the US and Japan.

# 4. Legal and Financial Format

The legal/organisational and financial format of the DSI-vessel requires a courageous and innovative solution as well.

The vessel could be defined and acquired on an à la carte approach by interested EU members states (not necessarily all) or sponsor states. She should be financed and operated jointly by member states and by the Commission similar to the existing NATO research vessel "Alliance".

The NATO vessel "Alliance" provides an interesting model of ownership, maintenance, operation and funding under the guidance of a "Joint Board". The ship was financed jointly by NATO partners, built in La Spezia, Italy in 1983/4, equipped with various research hardware from member states, managed by a British shipping line, registered in Germany, based in La Spezia and operated by the Scientific Branch of a NATO Command.

Paramount attention should be given to the circumstances that allow for low running costs of the vessel, such as flexile modular containerised equipment as a "pacemaker" for modern marine research technology of the next generation, small crew and innovative shipbuilding materials and design.

The vessel could fly the European flag and thus become both a **political symbol** for European co-operation in a key sector of science and **a vehicle to win public support for marine science and the MAST programme.**

Politicians and the man in the street will understand the need for a workhorse at sea and its contribution to the progress of Europe.

At the same time the vessel will be an example of progressive scientific technological co-operation under the **subsidiarity clause** in a field which otherwise is too expensive or too complex to be covered by national R & D.

# 5. Steps Towards Implementation

## 1. Initial Project Team

The scientific and the shipbuilding definition of the DSI-vessel is a task to be entrusted to a project team of 7 – 12 experts from

- science (deep sea orientated scientific institutes)
- shipbuilding (yards with RV experience)
- equipment industries (marine research technology).

The Kick-off Mandate of the project team would include:

- review the present (and future) needs for deep-sea research and intervention in a dialogue with scientists and users,
- define the main requirements of vessel and equipment,
- give a conceptual idea of vessel and equipment,

- study the option of transformation of an existing vessel against the option of a newly built vessel,
- estimate the capital and operating costs,
- offer a model to cover the construction costs.
- in a second phase the enlarged/specialised project team will elaborate:
- the system of "user rights" for all interested EU member states (research institutes, industry), possibly under the guidance of a Joint Planning Board manned by representatives from science (and industry) and linked to existing European marine scientific fora and the MIF,
- a financial scheme to cover the running costs, draft annual budgets, leasing tariffs for users, logistics,
- legal instruments for the property rights of the vessel, for the registry, for the management of ship and crew by a private shipping company,
- organisational framework for the scientific operation of the vessel,
- possible steps of realisation of the project.

## 2. Ship Project Department (SPD)

During the initial phase, or at the end of it, the necessity for a Ship Project Department (SPD) may arise that adds some kind of institutional structure to a complex project of this size. The Ship Project Department carries the responsibility and authority for the management of acquiring the vessel and bringing it into full operational service.

At some critical point in time during these phases the DSI-vessel project will be incorporated into the then existing specific programmes of the 5$^{th}$ Framework Programme or be made the subject of a separate new programme, as the case may be.

## 3. Decision Phase

Finally, a Council decision on the acquisition of the DSI-vessel will be required.

Let me end with a very pertinent citation from Professor Hjalmar Thiel (Environmental Protection of the Deep Sea: "A Challenge for Engineers, Scientists and Politicians", Proceedings of the 7$^{th}$ International Offshore and Polar Engineering Conference, Honolulu 1997 p. 1):

> "Controversy ranging between the extremes of total disapproval and enthusiastic consent typically governs most discussions on uses of the deep sea. This "inner space" represents the largest niche on Earth, yet it is the least understood, the hardest to imagine, and the most difficult to investigate".

The optimum I can hope for on the subject of this presentation is to get a fair discussion somewhere between disapproval and consent.

# Establishment of an Airborne Geoid Mapping System for Coastal Oceanography (AGMASCO)

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Within the EU MAST-III project AGMASCO, an airborne gravimetry/altimetry system has been established to determine geoid and sea surface topography in coastal and shelf areas.

To study the dynamic sea surface topography large progress has been achieved with the performance of satellite missions like ERS–1 and ERS–2. But there are still deficiencies: in coastal areas (islands, shoals, local tides etc.), and in the polar regions (covered by sea ice and only partly covered by satellite observations). To overcome this drawback an additional flexible, fast and cost saving system has become necessary. The AGMASCO system is based on most advanced sensor technology (accelerometer, laser and radar altimeter, GPS, INS) for gravity and sea surface height data acquisition and new data processing methods to deliver most accurate products. Because of the homogeneity of these data, they are well suited for assimilation with satellite data to develop more detailed geoid and sea surface models in regions of interest.

First demonstration projects (Skagerrak/1996, Fram Strait/1997) and a full application project (Azores/1997) has been performed. The already obtained results from the still ongoing data processing reveal accuracies at the 10 cm level regarding geoid and sea surface heights. This is derived from a comparison with available data, and simultaneous shipborne "ground truth" measurements (gravity, ADCP, CTD, by R/V Hakon Mosby). The airborne and shipborne measurements along the ERS–2 and Topex/Poseidon tracks allow a direct comparison of the different techniques and will show the advantages of each system.

After the development and establishment of the AGMASCO system, an integration in larger application projects has to be striven for. This is a requirement to improve continually the system efficiency (smaller hardware components, more automatic data acquisition and processing) and to adapt it to future demands and available

sensor technology. To increase the number of potential users, the AGMASCO group can as a technology spin-off offer the employment of their airplane based system for geophysical objectives in the field of geodynamics research or resource exploration. The hardware can be operated over sea as well as over land, therefore bridging important data gaps.

# Lidar profiling and mapping of phytoplankton and organic compounds in sea water

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The methods of remote sensing play an essential role in investigations and monitoring of marine environment. The application of laser remote sensing (lidar) technique for the analysis of organic materials in natural waters has been developed essentially during the last decades. One of the principal merits of laser remote sensing is the possibility to obtain extensive information with high spatial resolution from large water surfaces. In comparison with other remote methods (satellite multispectral imaging, passive remote sensing) the lidar techniques is more selective, not sensitive to the atmosphere and illumination conditions, and provides both qualitative and quantitative remote analysis.

The lidar system installed on board of aircraft or helicopter can work in an economical and low cost effective manner providing fast screening of large water bodies. Because of complex and multiple interacting of physical, chemical, and biotic factors in water ecosystem the ON-LINE monitoring of water quality is a most effective tool to detect unwanted deviation in the characteristics of the water environment.

The paper presents the results obtained by tuneable lidar in different applications of remote sensing of marine environment. The Fluorescent Lidar System (FLS, Laser Diagnostic Instruments Ltd, Estonia) based on excimer and dye- lasers and multichannel optical detector is described. The optimisation of operational parameters of the FLS made it possible to use module construction of lidar on board of ship or aircraft.

The approach of selective excitation of phytoplankton pigments is applied to investigate the small — scale spatial inhomogeneties of phytoplankton distribution over the water basins, including stratification, and to produce the maps of various taxonomic groups of phytoplankton. The UV excitation channel of FLS serves to map Dissolved Organic Matter and organic pollution in sea water. By using difference in spectral shapes of returned fluorescent signals recorded by gated multichannel detector even the trace amounts of oil pollution can be detected.

The FLS has been used to investigate the spatial distribution, temporal and seasonal dynamics of phytoplankton in Atlantic ocean and coastal zones of Baltic and Norwegian seas. The efficiency of lidar application has been proved in airborne

experiments aimed to detect organic pollution in sea water at the ppm level of concentration. The field data of shipboard and airborne remote sensing of organic pollution, DOM and phytoplankton are presented. The future developing of the module lidar technique for application on board of small helicopter is discussed.

# Monitoring the Nearshore Zone with the ARGUS Video System A tool for Coastal Zone Management

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Since 1992 hydrodynamics and beach morphodynamics are studied from argus video observations, a technique developed at the Coastal Imaging Lab, Oregon State University. Presently, argus video cameras are present at ten beach locations world wide, four of which are situated in Europe. Every daylight hour a snapshot, a 12 minute time-exposure and a variance image are collected automatically and fed into a central database covering many years of observations. In this way nearshore coastal processes are studied over a wide range of space and time scales, varying from a storm-event (hours-days) to longer term beach development (years-decades), especially under rough conditions. We expect that this will contribute importantly to help resolving the morphology predictability issue, to help identify coastal erosion problems and to assess local nearshore wave and climate statistics.

## The use of video techniques to classify beach systems and understand bar dynamics

Time-averaged video images show bright, longshore bands, clearly indicating the locations where waves preferably break. In the nearshore zone the breaking of waves is generally caused by depth-limitation, so bright image intensity patterns can be assumed to reflect the underlying bar bathymetry.

With the help of so-called Ground Control Points, an oblique image can be mapped on a horizontal plane and the apparent beach state can be determined from the observed wave breaking patterns. Investigation of these plan view images over a time span of years yields an indication of the variability of the wave breaking patterns — hence the bar system — both in time and in space. Doing so for different argus sites, varying from very dissipative (Noordwijk) to very reflective (Hawaii), beach systems world wide can be classified, In addition, the variability of a bar system as observed from argus images can be studied in relation to the forcing conditions (waves, tide) measured off-shore. In this way video imaging helps us to improve our understanding of beach morphodynamics.

Apart from these efforts on the (more or less qualitative) study of intensity patterns, we see a tendency in research towards a more sophisticated, quantitative

interpretation of image intensities. For instance by relating them to the process of wave dissipation. With the help of numerical wave decay models, the surfzone hydrodynamics can be modelled inversely which enables the mapping of nearshore bathymetry, based on hourly taken video images. These type of tools are under continuous development. In view of the exploitation of the video technique, we feel that an ARGUS camera allows enhanced opportunities for the monitoring of coastal systems to both scientists, consultants and coastal zone managers, at relatively low costs and over a wide range of time scales.

# Acknowledgements

The ARGUS video technique has been developed with funds generated by the Coastal Imaging Lab, Oregon State University. Furthermore, work is undertaken in the pace and safe projects, in the framework of the eu-sponsored Marine Science and Technology Programme (mast-iii), under contractno. MAS3-CT95-0002 and MAS3-CT95-0004 respectively. It is cosponsored by the Dutch Ministry of Transport and Public Works (Rijkswaterstaat) and delft hydraulics.

# BIO-ECONOMIC RESEARCH IN SUPPORT OF THE COMMON FISHERIES POLICY

# Bioeconomic modelling in support of the common fisheries policy

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## 1. The Recent History of Bioeconomic Modelling in Europe

A bioeconomic model has as its objective maximisation of an economic utility such as economic (social) rent or fleet, company or vessel economic profitability subject to demand and supply constraints. The supply constraints may include those describing the ability of the resource to replenish itself, the technical effectiveness of fishing, and useage of other production inputs determined by their costs, and the profit incentive to fish. Other commercial, social, and political constraints may also be specified.

Most work has been done at the fleet level, and I intend to leave aside the question of modelling for the benefit of individual enterprises in this paper.

Most bioeconomic models of fisheries have limited themselves to an examination of some aspect within the context of a single species fishery (eg Kennedy 1992, Glen 1995), though recently there has been a greater emphasis on a multi-species approach to economic models (eg Frost *et al* 1993, Hillis *et al* 1994, Flaaten 1996, Lopez *et al* 1997). The single species (or single biomass) approach has had the virtue of simplifying the complex bioeconomic system on which the economic activity takes place. While there are many such single species fisheries to be found, these models can make no attempt to describe the complex interrelationships which exist where, because of the behaviour of the fish, only multi-species catches are possible, or where there are alternative fishing opportunities.

Among the earliest attempts to build a more thoroughgoing bioeconomic model to advise fishery managers was undertaken in the late 1980s by the North Sea Working Group of the then STCF (1989).

Since then some of those who participated have gone on with others to push forward the development of bioeconomic models and modelling, usually with the support of DGXIV. Indeed, I think it fair to say that without the funding from DGXIV directly and through the AIR, FAR, and FAIR Programmes bioeconomic modelling would have been limited mainly to a relatively few academic exercises. Unfortunately this is not to claim that a suit of models now exists for fishery managers to use but it does mean that we are a lot closer to having useable models than we would otherwise have been.

The North Sea Working Group developed a sophisticated model which forecasts *ex ante* the size of fish stocks from a given starting level according to a range of differing scenarios. Each age cohort of each stock has applied to it a level of natural mortality and a level of fishing mortality.

Some participants went on to produce the study of the North Sea Multispecies Multiple Gears Fishery (Frost *et al* 1993) partly funded under the EU AIR programme which has been seminal in creating a number of strands of thought and approaches to modelling. These have represented a significant step forward.

The study identified and developed two forms of model, simulation models and optimisation models, which can serve different objectives of the ultimate users, fisheries managers and fishing enterprises.

The ultimate objective was to construct a model capable of evaluating the effectiveness of past and current regulations, such as the EC structural policy, and the possible effects of alternative management schemes.

The study has proved to be the precursor for a series of simulation and optimisation models conceptually derived from it for other fisheries.

Hillis *et al* (1994) applied a general model which is capable of simulating the principle aspects of the behaviour of a fishery to the Irish Sea. The model disaggregates the fishery by country, fishing gear (or method), and species by size and age.

Vestergaard and Frost (1995) developed their illustrative linear programming model for the North Sea Study to estimate the optimal exploitation of fish stocks. They assumed three different fishing vessel types (each having two fishing gears), three areas, and three species, each of which can be exploited independently but with a by-catch. Further they assumed two different qualities of landed fish and two harbours into which they could be landed.

Thus from a conceptually sophisticated economic model they estimated how much time should be allocated to fishing each species and area in order to maximise total revenue. The species are subject to a quota and not available in every area. Fishing takes place only if total costs, including both fixed and variable costs, are covered. Besides calculating the level of inputs, days fishing, which maximises profit, they also showed how much could be paid, at the margin, for increased quota or days at sea.

There is much here that is of potential use to fisheries managers. Not only can the effect of changing quotas be shown, but the impact of more economically efficient management regimes, such as individual transferable quotas or purchased fishing licences, can be estimated.

A detailed simulation model of the Dutch North Sea flatfish fishery has now been developed (Jansson *et al* 1994).

Contemporaneously, IREPA developed a multispecies, multi-gear, model to relate landings to fishing effort and the model is being used to assess the potential impact of the Italian management regime.

One of the weaknesses of the early models was that they treated fishing activity as an entity without reference to its spatial allocation. This limits their effectiveness in replicating accurately the costs of fishing and prevents them entirely from

considering the implications of sea area closures as a means of stock conservation. This gap was filled by a study of Spatial Effort Allocation which developed two approaches, a mathematical approach and a statistical behavioural approach (Jorgensen *et al* 1993).

Kennedy (1992) built a dynamic programming model to calculate the optimal sequence of Total Allowable Catches of western mackerel which would maximise the present value of the stream of annual social rents. To an economist this is a tidy and efficient objective.

He concluded that to achieve the maximum, a moratorium on fishing was necessary for two years. I will return to this in a moment.

Glen (1995) constructed a multiperiod Mixed Integer Programming model which was also applied for illustrative purposes to the western mackerel fishery. He overcame the problem of the model suggesting a moratorium on fishing in the early years by imposing bounds below which the catch could not be allowed to fall. He also highlighted the problem of having to specify a terminal value for the spawning stock.

Kennedy and Glen show two difficulties of using optimal control models. If unrestrained they are prone to suggest an economically disastrous moratorium in the initial periods and then leave the terminal stock completely fished out in the last. Models which suggest moratoria as a solution to biological overfishing ignore the costs of ending production and of then restarting (Smit 1988). This is a fundamental omission.

Glen in particular has recognised these difficulties. It is not a problem with the methodology. It is a problem with the specification of the model, though it is fair to say that the problems presented by the mathematical specification remain to be solved.

As things stand, however, optimal control models can have a wide range of solutions which depend on the minimum catch and terminal stock values imposed by the modeller. As such therefore they cannot yet be truly described as providing economically efficient solutions.

Currently major models are being developed by teams for the English Channel trawl fishery (Pascoe 1995), the Irish Sea whitefish and nephrops fisheries, the North Sea pelagic fisheries, and work is continuing on the ECOPES model — all partly funded by the European Commission.

# 2. A Critique of the Approach Taken in Modelling

I have been very discriminating in my selection of bioeconomic models above. Unfortunately, there have been considerable numbers of models produced which their authors have described as bioeconomic which I do not feel deserve to be.

Fishing is an economic activity where the objective can be described as maximisation of a social welfare function broadly defined to include all utility derived from the activity or from foregoing the activity. Acting on the social welfare function is the whole panoply of economic constraints associated with supply and

demand for a product plus an additional one — that created because the raw material is a self-renewing natural resource.

Unfortunately, a pre-occupation with the biological aspects which has obscured the importance of the economic factors has also led to the development of a series of models whose objective function was not originally economic or financial but natural.

These models have usually been derived from strictly biological models designed to simulate stock sizes under different levels of fishing mortality and under the assumption of mean recruitment. They frequently include only a price module on the economic side and leave a wholly unbalanced structure without the crucial human behavioural feedback mechanisms.

An example of this arose when the Scientific and Technical Committee for Fisheries of the European Commission set up a working group on improving the exploitation pattern of fish stocks in the North Sea (STCF 1989).

The model is typical in structure and concept to many and reflects serious weaknesses in its economic section. It amounts to a biological model with a price module added to determine revenue changes. The model stops at the revenue calculations, however. There are thus no feedback effects from profitability, costs, wages, investment or capacity into the control variable, fishing effort. It is vitally important in bioeconomic modelling to understand that when the size of the stock changes so does its economic value, and with it the incentive to fish. A larger stock produces a greater incentive to invest in fishing.

I have been a little unfair to those of us who built it, in that most of us had had little opportunity to work with people from other disciplines in bioeconomics and there was a lot to learn.

A remaining criticism that must be levelled from a strictly economic view is that almost all the models have been partial in their approach. Only recently has Bernard (1998) demonstrated a general equilibrium approach, and that in a elatively single species context. This area must be extended further so that, for example, the demand effects of changes in the cost of labour are accommodated.

# 3. The Reasons for Disappointment So Far

Some years ago a Commission Official was reported as expressing disappointment at the results achieved from bioeconomic modelling to the meeting in Crete of Directors of fisheries research institutes. I doubt if they would say anything different today.

However, given the minimal resources deployed we should not be too disappointed. Considerable progress has been made in a number of directions but it is true that bioeconomic modelling has not yet to proved useful to the Commission. In Denmark and Italy, among others bioeconomic models have been used in the decision-making process. In Denmark a model was used to estimate the impact on the fleet of the days-at-sea management regime. In Italy the IREPA catch-effort model is used to estimate the impact of the structural policy on fleet activity and output. It will be immediately noticeable, however, that both these models are short-run. The real

absence is in long-run models, some of which have been developed but not improved and put to use.

There are several reasons for this.

First, fishery managers have been reluctant to demand models which make estimates in response to a given question. I suspect they do not know what bioeconomic models can do, and that puts an onus on modellers to explain. The effect has been that the modellers themselves have chosen the objective for each model. This means that they must try to second guess what is in the manager's mind. Indeed, given that good models capable of assessing the impact of management measures take a long time to build they have to anticipate what a manager may wish to know.

Secondly, my own experience has been that the disciplines involved in modelling do not easily work together as a result of differing objectives and a lack of understanding of each others subject. Economists are used to using biomass-based models (Gordon 1954, Schaefer 1954) while scientists prefer cohort models using stock numbers. The economists use of opportunity costs rather than financial costs, and of economic rent rather than financial profits is not widely understood.

In addition, different methods of working among the disciplines involved have proved a difficulty. Most bio-economic models lack what an economist would consider to be a thoroughgoing approach. A clear knowledge of what should be the structure of a fully developed bioeconomic model is seldom demonstrated. It is not known what data are necessary in order to estimate the parameters for such a model. Worst, the models include no feedback mechanism driving human economic behaviour.

The economist working alongside fisheries scientists on bioeconomic modelling projects will be struck by a marked difference in their way of approaching a problem. The scientists first agree what they want to examine and then assemble the data. Next they put the data into standard, generally accepted models, and run them.

Economists invariably begin by having to develop the conceptual framework of the model. Admittedly, the scientific models of stock behaviour are simpler than economic models of fisheries but the delay involved in developing models means that economists are seldom ready to answer questions from managers on policy options. It also means that there is no precise information on the data that is needed. A given variable in the real world may be represented in a model by one of a number of available proxies.

Thirdly, there is a failure to understand that the objective of any bioeconomic model must be economic (since it attempts to model human behaviour and its consequences) and that stock levels and gear selectivity are constraints in the system.

The recent EU-funded concerted action to produce a proposal for a study of the North Sea pelagic fisheries, which was coordinated by the distinguished Dutch scientist Ad Corten, has been a notable and encouraging exception to this and it shows that in the future these difficulties will be overcome.

Financial models, claiming to be bioeconomic have not added to credibility. Such models are usually produced to show much improved financial profits from

restrained activity as if this will act as an incentive to the fleet to somehow do as the modeller wishes. Fishing enterprise know, and economics has explained why, such increased profits cannot be achieved without an effective management system.

The reader should beware models which proffer increases in profits from improved stock exploitation patterns yet which include no opportunity for changes in costs and activity as a result of those profits and the stock incentive.

Perhaps too the breadth of progress has been a problem. I have outlined the variety of types of model and their functions. A concerted attempt to solve a single type of question, say what will be the impact of a change in mesh sizes, might have concentrated effort and produced something credible to encourage work elsewhere in the field.

# 4. The Important Factors in Modelling

There are several factors of fundamental importance to be considered in modelling. I will mention just three and deal here only with the second. First, fishing is an economic activity. Secondly, fishing enterprises react to changes in costs (including the economic cost of the stock harvested), and thirdly that recruitment appears to be all but stochastic in most species.

## Fisheries Production Functions

The production function is the crucial link between the economic side of any bioeconomic model and the biological. It also is of primary importance to gear technolists.

The essence of a production function is that it relates the physical (as opposed to financial) quantity of output obtained by the use of specific combinations of physical quantities of inputs. These inputs have traditionally been grouped under the headings, land (resource), labour, and capital (see eg Samuelson 1965).

The related isoquants and budget constraints explain the cost-minimising input structure for a given level of output. In fisheries where there is no property right one input, the stock, is costless to the fishing enterprise but not to society.

Measured in physical units of each employed rather than by their opportunity cost, these may be

$$Q = Q(S, L, K) \qquad (1)$$

translated in fisheries into resource $^{S}$, labour $^{L}$, and capital $^{K}$ such that

Fisheries production functions using an effort index, $^{E}$, (about which there are serious doubts (Rodgers 1995) collapse the inputs into a single index and assume that effort alone, given the stock abundance, suffices to explain output. (The criticism essentially is that substitutability between the non-stock factors of production is assumed to be impossible when an effort index is used. However, Campbell (1991) and Dupont (1991) have estimated non-zero elasticities of input substitution.)

$$Q = H(S, E) \qquad (2)$$

Such functions are usually of some form (eg Cunningham, Dunn, and Whitmarsh 1985) such that

$$E \equiv \Phi(L, K) \qquad (3)$$

Given Equation 1, however, it may be seen that $^{K}$ here represents an index of capital.

Leaving aside the question of whether an effort index can adequately be defined the production function is usually mis-specified as

$$Q = qSE \qquad (4)$$

A correct specification would include coefficient index numbers such as that used by (Frost and Vestergaard 1995) which is soundly based in economic theory and recognises the inseparability

$$Q = \gamma \beta^{a0} V^{a1} D^{a2} \qquad (5)$$

of the production function. Their production function was of the form where $^{V}$ is the number of vessels in the fishery, $^{B}$ is the stock biomass, and $^{D}$ is the number of fishing days.

The index numbers are vital because in the case of the non-stock inputs they represent returns to scale and in the case of the stock they represent spatial distribution throughout the sea. It is hard to imagine any model being reliable if it does not recognise the behavioural difference in shoaling between, say, herring and cod.

The point of this type of specification is that it permits indifference curve analysis to be used to track the adjustment of non-stock inputs. Without it one cannot determine, for example, the optimal mix between numbers of vessels and days at sea. In socio-economic terms this would be all the more important if labour were included as an input, as in Equation 1, since changes in the optimum level of employment would emerge.

# 5. The Dearth of Data

There is another marked difference between fisheries scientists and economists. Scientists are almost always employed by their governments, though recently there have been changes in this. Either way they have direct access to log-book information. The position of economists varies enormously from country to country. Some are civil servants, other are in public sector bodies, some are in academia, and in some countries the economic input to the decision-making process is wholly private. Mostly, they do not have access to log-book data.

The effect has been that economic data is either inaccessible or not collected. Yet ultimately it will not be possible to produce and run credible bioeconomic models unless information on levels and values of outputs and inputs is not available.

The problem is that without data a sound model cannot be built but without a model the need for the data cannot be adequately demonstrated. The only solution to this

impasse is to build the model and determine intuitively those coefficients that cannot be estimated for lack of data. It is then possible to test the sensitivity of the objective function to them. Then it is possible to demonstrate the potential of a model and to ask for real data. There is a danger in this approach in that the model will be mistaken for the real thing leading to a belief that there is no need to collect the data. It is essential to be clear what is only for demonstration and what is a robust model.

# 6. The Future

In order to strengthen bioeconomic modelling and to enable models to be used in support of the Common Fisheries Policy, it is tempting to suggest that the first need is to determine what questions are to be answered. However, I think that fishery managers, especially in the member states, are not yet entirely aware of how bioeconomic models can be useful. Thus we need first to develop general models replicating behaviour that can be readily adapted to demonstrate what they could offer and what data they might need. It is not possible to anticipate every question that fishery managers might ask. There remains a need for simulation models to track the impact of measures and optimisation models to calculate the economic potential of fisheries.

I have already said that there is reason for optimism that the different disciplines involved in bioeconomic modelling can work effectively together, but it does need an open-minded approach.

The continued exploration of single species models and of models attempting to replicate complete multi-species fisheries is also needed. The difficulty for the latter is that they require huge amounts of computer memory if they are to encompass all the nations, fishing methods, species caught, and age-cohorts present in some of the more important fisheries.

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# Co-Governance of Catch and Market: An Institutional Approach towards Integrated Management in Fisheries

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Within fisheries there is a need to restrict access to fish harvesting from the perspective of sustainability and a need to increase the value added to fish products in the market place. In this study we examine fisheries in terms of catch and market acting as mutually influencing variables to open up opportunities for guaranteeing fishermen a reasonable share of the income from the additonal value derived from satisfying consumer demand for higher quality products.

At present the fish production chain is in direct competition with other food production chains which are increasingly well-organised and able to meet super-market requirements for quality assurance and consistency of supply. However, experience to date has shown that any increased concentration of fish processing entails the disappearance of locally owned processing firms and the domination of internationally operated companies, leaving fishing dependent communities out of the direct control of the value-added aspects of the chain. But whilst the sharing of management responsibility between state and fishermen is now seen as an important element of the Common Fisheries Policy, it has not yet been matched by a development in which the responsibility for quality assurance is shared between the state and fish traders and fish processors.

In this study we looked at alternatives to concentration, through re-organising the fish chain and further chain-integration, to strengthen the position of fishermen and provide new options for employment and investment.

Different theoretical perspectives were used to analyse chain phenomena in terms of interaxtions taking place between the catch and market, their institutionalisation and the management and governance of these interactions in the Netherlands, UK and Spain. Three levels of governance were considered: at the most basic level, problems and opportunities were indentified in terms of flows of information, interactions and trust and co-managament of quality. At the second level, the different roles of institutions in influencing pelagic and demersal fisheries and the institutional effects of different forms of co-operation in fisheries were examined. At the third or meta-governance level the relations between state, market and participatory modes of governance were analysed as the broad societal frames of reference. In addition, market information and catch planning systems were considered; both create opportunities for increasing stability in supply and demand, but as this study showed, the institutional aspects of these systems require far more attention to make them function effectively.

Organisations in which the regulatory role in controlling fishing effort and economic role of processing and marketing are mixed were seen as potentially fruitful institutional forms for European fisheries; these were considered sustainable in the economic as well as ecological sense. In this sense, Fishermen's Organisations, such as in Shetland, were seen as the only type of organisation in fisheries management which could potenitally provide the nuclei needed to link co-management schemes, and hence enlightening for the whole of Europe. In addition to the existing tasks of the FO's, it was concluded that national governments should delegate more commercial functions to them, such as the Producer Organisations, to give them a more explicit role in quality control. Initiatives aimed at restructuring the fishing industry should also be supported by the development of structural and strategic capabilities, including training in the governance of organisations and their links to public authorities and a concerted effort in the CFP by public and private parties to develop a view of the chain as a whole rather than as separate components.

# Property rights in fishing: Effects on the industry and effectiveness for fishery management policy

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The paper identifies measures that have created property rights in the Danish, Dutch and UK fishery sector. Property in this respect is not considered as an asset in the stock of fish but as a stream of benefits, resulting from the right to fish.

The limited access to the fishery by the vessel licence and by the recognition as a commercial fisherman have created two forms of property rights in the Danish fishery.

In the Netherlands, the national TACs for the individual species have been transformed into transferable individual quota (ITQs). Furthermore, horsepower licences have become valuable private property rights.

In the UK, gradually more and more fleet segments and species were brought under restrictive licencing schemes. The approach varies by species and sector with the licences giving access to the fisheries reflecting this. All licences are subject to Ministerial discretion which means that uncertainty remains about the quality and duration of this property right.

The paper assesses the consequences of property rights on individual enterprises and on the fishing industry as a whole. These consequences have been most important for the Dutch and UK fishing enterprises. Transfers of rights have led to high prices of ITQs, Track Records and licences. Valuable rights may hamper the transfer of the enterprise to the next generation or to other family-members in these two countries.

Implementation of more private rights in the Danish fishery, by means of an ITQ-system, could increase the gross margin of the fleet substantially, as a model exploration has indicated.

Some concentration of rights i.e. ITQs has occurred in the Netherlands, though not as intensively as in the New Zealand and Iceland ITQ regimes.

Finally, the paper evaluates the effectiveness of property rights for fisheries management policy, within the framework of the Common Fisheries Policy (CFP). In this respect, the property rights systems in the Danish, Dutch and UK fishery sector are compared on a scale, running from 'state property' towards 'private property' of the resource flow. Although there are big differences, all three systems have moved or seem to move into the direction of private rights.

# Bio-economic models for fishery management: The italian and icelandic cases

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## Abstract

The bio-economic models for the management of multi-species, multi-fleet, multi-gear fisheries that have been developed in Iceland and Italy are described, and comparatively analyzed.

The Italian model, developed at IREPA, is designed as an advisory tool for managers of particular fisheries under a given fisheries management regime.

In this institutional context, the IREPA model can supply the fisheries managers with estimates of optimal fishing effort (subdivided on area, fisheries, fleet and gear) and calculate the outcome in terms of biomass, harvest and economic rents. Alternatively, given the pattern o fishing effort, the IREPA model can calculate the same outcomes.

The Icelandic model, developed at the University of Iceland, can calculate, given fishing effort, the outcome in terms of biomass, harvest and economic variables, providing assistance to the practical fisheries manager. The main strength of this model lies in its ability to investigate the impact and economic efficiency of fisheries management regimes.

The most relevant results achieved by the authors within a FAIR project on

"INNOVATIVE INTEGRATED BIO-ECONOMIC MODELS FOR THE MANAGEMENT OF MULTI-SPECIES AND MULTI-GEAR FISHERIES" are presented. The results obtained by application of Bayesian techniques to the estimation of catch-effort models are also discussed.

# Explaining the European foreign trade of seafood products with a panel data model

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## Abstract

Previous attempts to model the foreign trade of seafood products usually refer to demand or supply functions between two countries for specific products categories (Tsoa & al. 1982, Mazany & al. 1994, Hannesson 1995, Schrank & Roy 1991). In these papers, the estimation suits to standard econometric techniques. In the present article, the same import functions are tested through an extension of the models towards a multi-country and multi-product context based on a panel data approach. Such an approach requires specific econometric methods because of heterogeneity biases. The results are fairly consistent with theoretical expectations but show significant differences between the European countries regarding some of the variables, in particular the nominal exchange rate. In overall, the European foreign trade of seafood products appears to be very sensitive to changes in price competitiveness.

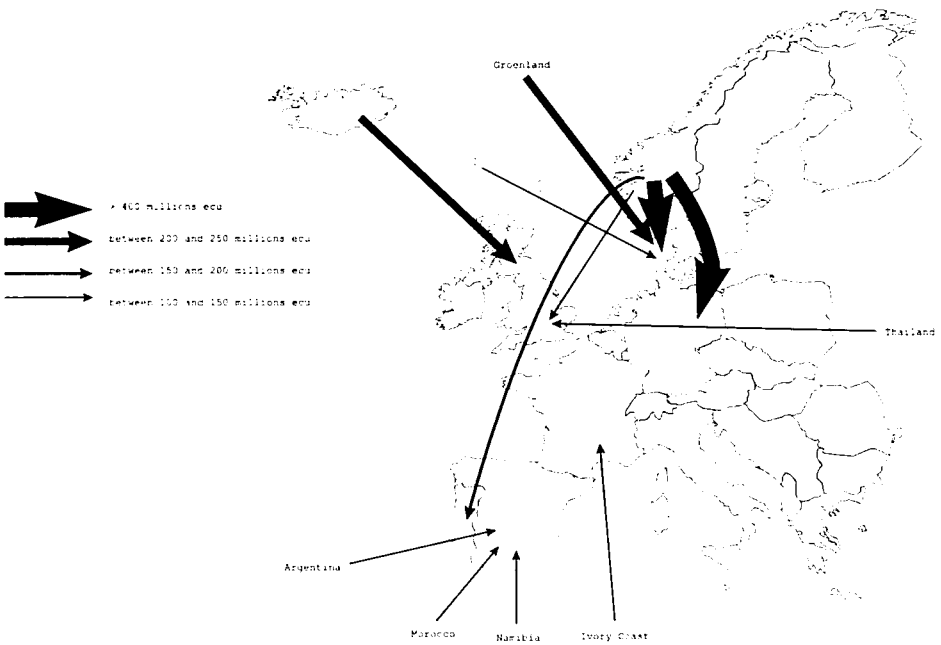
## 1. Introduction

This paper is part of a global research on the foreign trade of seafood products in relation to price levels in Europe. The overall research started with a question

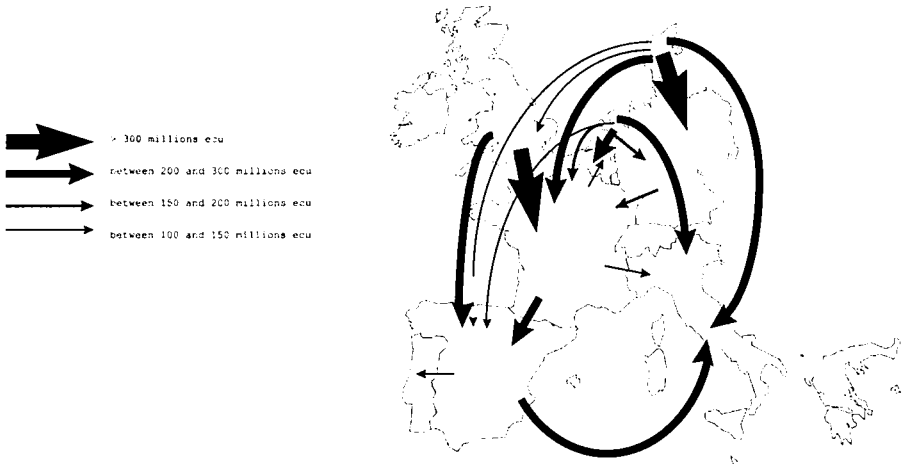
addressed by the French fishermen during the market crisis of 1993 and 1994: are the imports of fish products responsible for the decrease in prices under the domestic fish auction markets? Behind this simple issue lies a request for better understanding of the level of integration between domestic and foreign fish markets due to international trade of seafood products. In particular, the reciprocal influence of foreign trade on price levels is of great interest to analyse the complex interactions between demand and supply of goods based on natural resources..

Various aspects of the problem have been envisaged in order to highlight the main features of trade patterns within the European communities. Since the issue has been poorly addressed at the level of the European fishing industry except a few attempts (Arnason & Felixson 1994, Hannesson 1995), we had to start almost from scratch in order to first characterize the empirical determinants of seafood trade and secondly to estimate the relationship between prices and foreign trade. However, substantial progress has been done in the field of testing import functions both from a theoretical and empirical point of view (Bergstrand 1989, Dagenais & Muet 1992, Goldberg & Knetter 1997).

Therefore, the first part of the work gives some insight to the main feature of regional trade patterns in Europe. Not surprisingly, the European communities with 12 countries (i.e. before the last widening of the EU in 1995) show a huge deficit of the trade balance in seafood products vis-a-vis third countries, estimated to more than 6 billion ECU in 1994. All the European members face a deficit with third countries, except Ireland. Looking at the regional trade patterns indicates that the commodities are rather coming into the European markets from the northern countries




**Map of major intra-European trade flows of seafood products in 1994**




downwards to the big consumption markets in the south of Europe. This situation is somewhat changing because of increasing relationship between Asian or south-American countries.

A panel data model of bilateral trade flows is tested in several European countries in the second part of the paper, showing great relevance of price competitiveness effects on seafood trade, although the nominal exchange rate has different impact on import levels from a country to another.This gravity model (Bikker 1987, Anderson 1979, Evenett & Keller 1997) suits to the case of seafood trade because the distance between countries appears to be particularly significant to explain the high travelling cost of perishable goods.

# 2. The regional trade pattern of the European seafood industry

The demand for fishery products in the European market exceeds by far the domestic production capacity, thus explaining the tremendous deficit of the trade balance in seafood products (6 billion ECU in 1994). In quantity, imports have augmented from 820,000 tonnes of products in 1976 to nearly 3 million tonnes in 1994. All the member states now participate to the whole European deficit vis-a-vis third countries, except Ireland.

However, the European fishing industry also represents some 12 million tonnes of nominal catches, i.e. 14% of total worldwide catches (FAO 1995). Some of the member states with long tradition in the fishing industry, hence producing and consuming, are involved both in imports and exports. The current features of the regional trade patterns indicate quite clearly that the biggest producers are located in the north of Europe, closer to the fishing zones, whereas the consumers of large quantities and varieties of fresh fish can be found rather in the south, as shown by the following maps.

The EFTA countries represent major suppliers of the European market, through the United Kingdom, Denmark and Germany downwards to the south of Europe. However, more and more products are imported from Asia, south America and Eastern Europe. These three zones of origin represented 42% of total European imports of seafood products in 1994, against less than 35% in 1988. Parallel to this evolution, a decline of domestic prices for fresh fish has been observed in some European countries, particularly in France.

The question becomes naturally: is there any relationship between the imports of seafood commodities and prices? One way of dealing with such an issue is to look at import functions so as to scrutinize the response of import levels to changes in price internal competitiveness, i.e. the ratio between import and domestic prices, or even both prices separately. A high value of price elasticities within an import function would tend to highlight a relation between imports and import prices in the first place, which is expected despite the dependence of the European markets towards external sources of supply, but also a relation between imports and domestic prices, as if domestic and imported products were highly substitutable. This question is analysed through a panel data model presented in next section.

# 3. Presentation of the panel data model

In most studies focusing on the econometric estimation of trade terminants (Tsoa & al. 1982, Mazany & al. 1994, Hannesson 1995, Schrank & Roy 1991), the import funtion takes the following form:

$$\ln Q_{i,t} = a_i + b_i \ln Q_{i,t-1} + \Sigma c_{ij} \ln P_{j,t} + d_i \ln P_{i,t} + e_i \ln I_{t-1} + \varepsilon_i$$

Where:

$Q_{i,t}$ is the quantity demanded of the ith product in time t
$Q_{i,t-1}$ is the production of the ith product lagged one period
$P_{j,t}$ is the price of the jth product ($j \neq i$)

$P_{i,t}$ is the price of the ith product
$I_{t-1}$ is the disposable income lagged one period
$c_{ij}$ is the cross-price elasticity between the ith product and the jth products
$d_i$ is the own price elasticity of the ith product
$e_i$ is the income elasticity of import demand lagged one period

The model is log-log specified so as to produce elasticities of the independent variables through the parameter estimates. Some extra-information through dummy variables (seasonal patterns, structural changes in demand, etc.) can be found in some of the models (Arnason & Felixson 1994, Jian 1995, Bjørndal & al. 1992). However, the model is often seen as bilateral between two trade partners (like the US and Canada, or the US and the UK), and for specific products (such as frozen blocks of cod fillets).

One can argue that foreign trade must be considered on a more aggregated basis, i.e. in a multi-product and multi-country context (Anderson 1979, Bergstrand 1989) allowing some insight to actual bilateral relationship. For instance, some variables related to the distance between countries, hence the gravity equation (Bikker 1987, Evenett & Keller 1997), as well as the tariff and non-tariff barriers affecting the level of trade, are likely to be taken into greater consideration. In that respect and by extending the import function model to panel data, the model tested took the following form:

$$\ln Q_{i,j,t} = a + b.\ln Q_{i,j,t-1} + c.\ln PIMP_{i,j,t} + d.\ln CONS_{i,t} + e.\ln PROD_{i,t} + f.\ln PPROD_{i,t} + g.\ln EQUI_{i,j,t} + h.\ln DIST_j + k.\ln CHG_{j,t} + \varepsilon_{i,j,t}$$

Where:

$Q_{i,j,t}$ is the quantity imported of the ith product from the jth country in year t (1000 tons)
$Q_{i,j,t-1}$ (or QMP in the results) is the quantity imported of the ith product from the jth country lagged one period (1000 tons)
$PIMP_{i,j,t}$ is the import price from the jth country in year t (unit values, in ECU, 1993=100)
$CONS_{i,t}$ is the domestic consumption of the ith product in year t (1000 tons)
$PROD_{i,t}$ is the domestic production of the ith product in year t (1000 tons)
$PPROD_{i,t}$ is the domestic production price of the ith product in year t (in national currency, 1993=100)
$EQUI_{i,j,t}$measures trade barriers (tariff + NTBs in tariff equivalent) of the ith product imported from the jth country in year t.
$DIST_j$ is the distance between the jth supplying country and the country of reference (distance is expressed in kilometers between the two economic centers of the considered countries)
$CHG_{j,t}$ is the nominal currency exchange rate between the country of reference and the jth country in year t (value of one unit of the foreign currency in terms of the national currency; 1993=100)

The originality of this model lies in the panel data set that has been used for the estimation, including three dimensions:

— a sectoral dimension (various species crossed by several types of processing)

— a spatial dimension (the major partner countries) (*)

— a temporal dimension (seven years between 1988 and 1994)

Such a data set provides a wide quantity of information (125,000 observations in overall). The advantage is that the great number of observations improves the efficiency of the parameters. Moreover, multicollinearity problems are less important since, by offering many more degrees of freedom, the gap between the information requirement of the model and the information provided by the data is reduced (Hsiao, 1985). However, this multidimensional data set potentially introduces heterogeneity biases. Consequently, special econometric methods are required to separate these various dimensions.

Basically, given the particular nature of the data set (three index panel), OLS can be used only if parameters are homogeneous among countries, time and products (Greene, 1993). In this case only, the specification of the model may be:

$y_{ijt} = \alpha + \Phi' \chi_{ijt} + \varepsilon_{ijt}$ *(classical model) (1)*

where α is the constant, homogeneous term across time, countries and products,

$\chi_{ijt}$ is the vector of dependent variables

$\Phi'$ is the vector of parameters

$\varepsilon_{ijt}$ is the error term

Except this particular case, the general form of the model should be:

$y_{ijt} = \alpha_i + \beta_j + \gamma_t + \Phi' x_{ijt} + E_{ijt}$ *(fixed effects model) (2)*

or:

$y_{ijt} = \alpha + \Phi' x_{ijt} + u_i + v_j + w_t + E_{ijt}$ *(random effect model) (3)*

where:

$\alpha_i$, $\beta_j$, $\gamma_t$ are the separate constant terms for each product, country and time unit

$u_i$, $v_j$, $w_t$ are the specific error term for each product, country and time unit.

The choice between models (2) and (3) is motivated by two factors: on the one hand, the Hausman test tends to favor model (2) against model (3); but on the other hand, model (2) cannot be estimated for time and industry invariant variables, such as the geographical distance. To overcome this problem, we estimated both model (2) without the geographical distance, and model (3). The comparison of the results indicates that both models provide very similar results as far as the value of the parameter estimates is concerned. Since the distance variable is a key variable in our model, we decided to keep model (3) for the final model and for the estimation.

(*) The choice of the partner countries included in the model has been made as follows: partner countries which account for at least 1% of total seafood imports of the reference country, have been included. All the other countries are excluded from the model, unless they account for at least 20% of imports of the reference country for a particular seafood product.

# 4. Results and discussion: the impact of prices on trade

Using FGLS (Feasible Generalised Least Squares) to cope with the problem of heterogeneity, we found out the following results at the EU–12 level:

*Table 1: Parameter estimates of the trade model for all fish products 1988-1994 through FGLS regression procedure: The EU–12 import function*

| variable | PARAMETER | T-ratio | Prob | LR elasticities* |
|---|---|---|---|---|
| import prices | –0.287 | –13.131 | 0.000 | –1.354 |
| domestic prices | 0.048 | 4.924 | 0.000 | 0.224 |
| domestic pdtion | 0.070 | 1.053 | 0.292 | n.s. |
| trade barriers | –0.005 | 1.890 | 0.061 | –0.025 |
| distance | –0.095 | –10.823 | 0.000 | –0.450 |
| lagged imports | 0.788 | 381.755 | 0.000 | |
| exchange rate | –0.349 | –2.561 | 0.010 | –1.646 |
| intercept | 0.350 | 0.625 | 0.532 | |
| Nb of observ. | 124992 | | | |
| F-value | 21411.10 | Prob>F: | 0.00 | |
| r2 adj | 0.55 | | | |
| White X2 | 4334.60 | Prob>X2: | 0.00 | |
| cond.number | 249.20 | | | |
| LM test | 54255.60 | Prob value: | 0.00 | |
| Hausman test | 0.00 | Prob value: | 1.00 | |
| F-test for L.O.P. | 97.7 | | | |

(*) The long run (LR) elasticities have been estimated from the short-run elasticities (parameter estimates) through the equation

$$\alpha = \frac{\beta}{1 - b}$$

where $\alpha$ *is the long run elasticity,* $\beta$ *is the short-run elasticity and b is the parameter of the lagged imported quantity.*

All variables are significant at the 1% level, except trade barriers (10%) and domestic production (non significant). The latter would mean that imports do not react to the production level in Europe, the gap between domestic demand and supply is so high as the European markets do need to import whatever the production level. Indeed, a huge quantity of imports are made up by intermediate goods for further processing in Europe.

Undoubtedly, the most striking results concern the response of European imports of seafood products to the price levels: both domestic (positive sign) and import prices (negative sign) do affect the import flows coming into the European markets. If both

prices affect simultaneously the level of trade, they are likely to be inter-related at each other. However, imports are more sensitive to foreign prices than to domestic prices: a 10% decrease of international prices would produce a 14% increase in imports of seafood products in the long run. Such a result would mean that imports and domestic production are imperfect substitutes. The impact of import prices is all the more important as trade barriers show very little influence on the import level. The great proportion of trade flows coming into the European markets without any trade barriers must be reported: such imports are estimated to about 80% of total trade.

The nominal exchange rate can also be considered as strongly determining trade: a 10% depreciation of US dollar vis-a-vis the ECU imply a 17% augmentation of imported goods. Tested on a French import function, the nominal exchange rate effect has proved to be even more influential since the 6.5% appreciation of the French currency vis-a-vis ECU that occurred between 1988 and 1994 would be responsible for a 26% increase of imports in the long run. On the other hand, the same variable has not been significant in the estimation of the other trade function tested for Spain, the United Kingdom and Norway.

As a conclusion, the French fishermen complaining against the impact of trade on domestic prices were somewhat right because the nominal exchange rate effect has certainly revealed with greater strength the comparative disadvantage of the domestic fishing industry now competing on a worldwide market. Only one positive fact is mitigating against the weak competitiveness of the European industry: the geographical distance still plays a significant role in lowering imports. The further the partner country, the lesser the imports. The reasons might be found in the difficulty of travelling for these perishable goods or because of the too small value/volume ratio.

# 5. Conclusion

Beyond the classical tests of import functions using bilateral and single-product models, a panel data model has been prefered to tackle the issue of the relationship between foreign trade and prices. The model itself becomes much more demanding in information and data consuming because of many product flows (as many products coming from as many partner countries as possible). Furthermore, it requires special econometric techniques because of potential heterogeneity biases.

However, such a model is likely to emphasize actual bilateral relationship at the most aggregated level of the fishing industry: trade barriers, distance, nominal exchange rates, etc. Most of the European countries and the EU taken as a whole have shown great dependence of their import levels to changes in prices. The greater import price effect tends to demonstrate that imports and domestic products are not perfect substitutes, although inter-related. Finally, the shifts of nominal exchange rates have affected differently the countries' trade levels but has proved to be very influential on the trade level in overall. All the models need to be extended to a more disaggregated level (at a product group level for instance) in order first to scrutinize the same pattern of effects and secondly, to assess the reciprocal implications between seafood trade and the European policy. This has been done further in the most recent developments of the project.

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# The management of high seas fisheries

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## Abstract

The intergovernmental United Nations Conference on Highly Migratory and Straddling Stocks, initiated in 1993 and finished in 1995, addressed the conservation and management of fishery resources located both within the coastal state 200 mile Exclusive Economic Zone (EEZ) and the adjacent high seas. These types of marine resources continue to be a source for international conflicts and debates. The original United Nations Law of the Sea of 1982 failed to address transboundary fisheries in a proper way. In particular, the agreement did not recognize the emergence of the complicated "straddling stock" issue. In the new United Nations Lax of the Sea agreement of 1995, a consensus was reached that the management of the straddling and highly migratory fish stocks should be carried out through regional fisheries management organizations. We present a review of the straddling stock issues in the international agreement emerging from the negotiations within the United Nations. The review is contrasted with and clarified by game theoretic analyses. We also discuss one international fishery exemplifying the case, the Norwegian Spring Spawning Herring. The main conclusion is that the local problems, faced during the stage of setting up regional fisheries organizations for the management of straddling and highly migratory fish stocks, are expected to be much more complicated and difficult to solve as compared to the cases of "shared fish stocks". in the current paper, we present two reasons for this increased complexity. The first is the larger number of players as compared to the case of "shared fish stocks" and the second is the possibility of new members entering the regional fisheries organizations.

# Bio-Economic Modelling of Northern Bluefin Tuna

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## Abstract

This paper present a bio-economic model for Bluefin Tuna.

The Northern Atlantic Bluefin tuna is caught by many countries using a diversity of gears and the management of its stocks falls under the aegis of the International Commission for the Conservation of Atlantic Tunas (ICCAT).

The economic analysis starts by computing cost and revenue functions, by gear. The resulting aggregate profit function is then linked to the biological model through an estimated relation between fishing mortality and effort. Armed with this framework the Sustainability of the stock is analysed. The paper finishes with the analysis of the impact of different economic instruments and regulations for the profitability of the different gears.

The results obtained, so far, show that given the existing high demand from Japanese market and the difficulty in restricting total catch to the sustained level a situation of depletion is most likely.

Submitted to: SC — Bio-economic research in support of the Common Fisheries Policy (or other if considered more appropriate).

# Implications for fisheries management systems of interactions between farmed and wild caught species

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## Scientific objectives and context of the research

Implications of european market conditions for the trade policy of the EU and its sustainibility.

Definition of consumption behaviour in european seafood markets and possibilities of its adaptation to the marine resources situation in the actuality. Aquaculture development and diversification of farmed species.

Probability of success of these policies.

Context: European Union Members.

## Main results

Habits differences between Atlantic and Mediterranean european regions and seafood markets.

Aquaculture tradition in some countries in front of others as a primary condition of the sustainibility of the marine resources.

Fundamental role of Common Fisheries Policy in contributing for planning the sustainibility of seafood production structure in EU economies. Trade measures in reinforced the EU sector versus imports coming from third countries. Selective measures and wel.

Importance of advertising and valorisation of traditional seafood products in changing little by little EU seafood consumer behaviour.

Relevance of EU authorities in maintaining a strong defense of an Ethical World-wide Code for the substainibility of marine resources around the world seas and an active fight to non-sustainable fishing methods of developed and developing countries.

# Main conclusions

Necessarily of an active and selective EU trade policy as a complement of the CFP.

Incidence in consumers education trough advertisement and diffusion actions.

Potentiation and education of Aquaculture initiatives to the EU seafood market reality.

Actions of regeneration of the coastal zones and sustainable fishing methods.

Importance of trade in modulating EU seafood production structure and new productive initiatives.

Fundamental role of fishing agreements for the national seafood extractive firms

Necessity of cooperation among Mediterranean and Atlantic european farming installations in learning for the success of this sustainable seafood productions.

Important future possibilities from EU seafood markets integration.

Main features of succeed farmed initiatives.

# Bioeconomic modelling of the fisheries of the English Channel

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## Abstract

Commercial activity in the multispecies Channel fisheries is predominantly undertaken by fishermen from the UK and France (although a small quantity is also undertaken by Belgian fishermen). The fishery is currently experiencing difficulties common to many multispecies fisheries. These include overcapitalisation, overexploitation and incompatible quotas, resulting in discarding of valuable fish and low stock levels.

The overall objective of the project is to develop a bioeconomic model of the English Channel/La Manche fisheries (ICES divisions VIId and VIIe) that can be used as an input into management decision making. The model will focus on effort allocation between the various fishing activities within the Channel, so that the effects of management changes in one area of the fishery on other areas in the fisheries can be identified. The model will be able to provide managers with information on the optimal fleet configuration, potential profit levels and the relative effects of alternative management options against which the current situation can be compared. In particular, the model will provide information on how changes in management will affect the economic status of fishermen. The model will also be used to predict exploitation rates on resource populations, the effect on stock biomass and the resultant short and long term yield in the fishery.

In this presentation, the technical detail of the model being developed will be outlined. Expected modelling difficulties and their proposed solutions will also be discussed. Finally, a preliminary estimate of the current economic status of UK and French fishermen based on the results of the research to date will be presented.

# Assessment of Economic Impacts of Fishery Management Decisions within the Scope of the Common Fishery Policy Application of Computer-based Simulation Models

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Until now, recurring questions from European institutions, national governments and the industry concerning measurement of economic impacts of fishery management decisions are generally attacked by an ad hoc approach. There is a strong need for model-based instruments with regard to the assessment of such economic impacts.

Together with counterparts in the Netherlands and Spain and financially supported by the EU within the FAIR Programme an economic simulation model is developed which will enable political institutions and fishing industries to assess the economic effects of individual and political decisions concerning quotas, fishing grounds, catch rates and prices on the costs and the gross margin of particular fleet segments. Such a model could become an useful instrument for any manager in the field of fisheries to assess the consequences of all kinds of management decisions, not only at the macro-economic level, but at the micro-economic level (individual vessels) as well.

The paper presents the model structure and some examples demonstrating the impacts of different political and management decisions on the economic results in selected fleet sectors. The authors will demonstrate the usefulness and applicability of the model by calculating different scenarios and assessments of economic impacts of various management measures.

From a scientific point of view the model approach is just a step forward from existing studies. But the model presents a basis for an uniform approach to the assessment of the economic situation of a wide variety of segments of the European fishing fleets. As such it could make a significant contribution to arriving at s standardised "Economic Report on the State of the Fishing Industry of the European Union", the counterpart of the biological reports on the state of the fish stocks that is being developed by several groups of fisheries economists.

The structure of the model will be such, that it will require only a limited amount of effort (by an expert) to adapt it to other, similar segments and little more to adapt it to other, less similar fisheries.

The developed computer-based simulation model describes empirically the operational behaviour and the related structure of costs and earnings of a selection of "standard vessels" representing fleet segments fishing in the North Sea, Baltic and Mediterranean. It is maximising the gross margin of "standard vessels" of selected, largely homogeneous fleet segments by using logbook data with regard to fishing areas, effort time, fish species and by including book-keeping data containing fixed and variable costs and prices. Furthermore, marketing possibilities in different ports are taken into consideration. In principle, all combinations of the above-mentioned variables can be used for defining activities within the model configuration. Under free-choice constraints the GAMS solver is looking for the best combination of fishing activities by maximising the gross margin.

A strong feature is the empirical applicability of the model, that will guarantee practical and useful results, expressed in concrete, practical terms. Therefore, the demonstration of the applicability encloses feasibility tests of the developed model by making simulation of management scenarios with different variables in the field of fishing efforts, cost structures and marketing. A number of different hypotheses will be considered in the light of the empirical evidence. In particular, the effects of decreasing quotas, remote fishing grounds, varying catch rates, modification of days at sea, changing cost structures and sales prices on the gross margin will be calculated. This will be of great interest for political decisions within the CFP context.

# RESEARCH IN GENETICS AND PATHOLOGIES IN AQUACULTURE AND FISHERIES

# Gene transfer in fish: approaches, progress and perspectives

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## Abstract

To increase our knowledge on the molecular mechanisms that govern development, growth, sexual differentiation, immunity and many more key processes in fish, the use of transgenic technologies is a valuable and appropriate tool. They offer also the possibility for genetic improvement of cultivated fish in a controllable and efficient way. While the results from a steadily increasing number of successful experiments using gene transfer methods for the analysis of gene function are fulfilling the promisses of the new techniques, the application to fish of commercial interest is only barely elaborated. Problems connected to this are still unanswered questions about biosafety, acceptance by the consumer or the economical as well as the ecological impact of the genetically altered fish.

In principle two different approaches can be taken, namely the addition of new genetic material to the fish genome (conventional transgenesis) and targeted modification of existing sequences (gene replacement). For conventional transgenesis, which is already widely used, issues of importance are the availability of promoter and gene sequences of homologous (fish) origin, efficient methods for delivery of the additional sequences to the host genome, transgene integration and stable transmission to the offspring and — at present the most critical because not completely resolved point — fidelity of transgene expression. For cultivated fish several measures, like ploidy manipulation, are elaborated to guarantee that the transgenic genome cannot be introduced into the natural environment. Gene targeting methods are much less developed at present. They mainly depend on the availability of embryonic stem (ES) cell lines which retain the competence after retransplantation into host embryos to participate in normal development and to contribute to all cell lineages including, most importantly, the germline. Thus it should be possible to regenerate whole fish from the *in vitro* cultured cells. For gene targeting, which is performed on such ES cells because they offer the possibility for selecting *in vitro* for the desired, but usually very rare genetic event, homologous recombination has to be achieved.

# Introduction

The production of genetically modified commercial fish species like salmon or carp which, due to the overexpression of a growth hormone transgene, show an enhanced growth has raised on the one hand a lot of enthusiastic interest, but, of course, on the other hand also a lot of concerns about the impact of this new technology. Although transgenic technologies in fish, if compared to the situation in mammals, are still in their infancy, the methods are rapidly developing and will certainly within due time reach a perfection where they will become readily available tools for researchers. Quantitatively, most efforts are made in laboratories of the basic research area which use fish as model systems (e.g., zebrafish, medaka, goldfish, loach, etc.). Considerable efforts are going on worldwide to use the techniques of gene transfer in cultivated species, as they have been taken up by industrial and institutional research groups in Canada, the USA, Israel, South East and East Asia. With the obvious benefits in mind that the new techniques will offer above all conventional techniques to solve problems of aquaculture or reach breeding goals, but also being aware of some concerns by certain groups about a possible remaining minimum risk, it will be up to the single researcher, fish breeder, farmer and consumer, but also to environmental organisations and the human society to decide in the single case and in detail either to make use or not of the perspectives gene transfer in fish is offering.

The motivations for genetic modification of fish are manyfold and a lot of them do not differ substantially from what is aimed at in classical fish genetics. An important goal is to obtain resistance or tolerance against viral or bacterial pathogens and the numerous parasites of cultivated fish. One also hopes to solve the unevitable appearing problems connected to the cultivation conditions of modern aquaculture, for instance the consequences of the social stress evoked by the high stock densities. Another issue is resistance to environmental stress like low oxygen or low temperature. Other goals include either the elimination of undesirable traits or the expression of beneficial traits like enhanced growth and food conversion rate, higher meat quality and organoleptic criteria as well as the possibility to either positively or negatively interfere with sexual maturation. Last but not least, a major point of all genetic research is to understand how fish genes work in general and in particular. It is obvious that for this area the gene transfer technology as compared to many decades of classical genetic research has brought within short time an enormous progress. Developmental biology has made the best use of it so far, but other areas like fish immunology, fish pathology and the large research field of sex determination and differentiation are widely employing transgenic animals to study the function of fish genes. Also in the more applied research areas the technological advantage of utilizing recombinant DNA technology and gene transfer is evident. The manyfold increase in growth rate observed in the growth hormone transgenic salmons (Devlin et al. 1994) is by far more than what could be reached by conventional methods of classical genetic breeding and selection (at least within a few generations). Approaches for introducing freeze resistance or at least cold tolerance by transferring genes for anti-freeze proteins from freeze-resistant species (Fletcher et al. 1992, Wang et al. 1995) that are adapted to more moderate temperatures are only possible in the terms of transgenic fish. The same holds true for the so-called "new product" approach in transgenic animals where they are aimed to be used as bioreactors to produce commercially and medically valuable products. In the same

line are ideas to introduce genes that code for enzymes which would make more abundant and less expensive food resources exploitable by farmed fish.

The current strategies for genetic modification of fish are twofold. The first is the stable addition of a foreign gene to a genome which leads to transgenic lines of genetically modified organisms (see Iyengar et al. 1996, Devlin 1997). Genes can also be added transiently to a fish. This is the case in experiments where transient expression from DNA injected into embryos is investigated or after messenger RNA injection (see Winkler and Schartl 1997). Such techniques are very useful, because they offer quick methods for experimental basic research, while another transient genetic modification, the somatic gene transfer, has a lot of applications for cultivated fish.

The second group of strategies for genetic modification works by eliminating the function of an endogenous gene or at least by replacing it by another version. Transient modifications can be achieved as demonstrated in zebrafish (Xie et al. 1997) by injection of ribozymes, RNA-based enzymes that degrade specifically certain gene transcripts, or by antimessage which partially or totally can inactivate transcription of a gene by binding to the endogenous transcripts. Both techniques are currently used in a transient way, but introducing genes encoding the ribozymes or the antimessage could lead to stably modified fish if they are feasible and desirable to produce. The most sophisticated technology is stable gene replacement by an altered version of the original gene which also represents the minimal modification of the genome and which can be as small as only a few nucleotides.

# Transgenic fish

The most common and therefore by far best developed technique is the production of transgenic fish upon injection of a foreign DNA sequence. There are several crucial steps in this procedure, the first of this being the construction of a suitable DNA construct. While the first generation of transgenic vectors consisted of genes and promoter sequences of heterologous (mammalian) origin, it turned out that in most cases a reliable expression of the transgene can only be obtained if the gene to be transferred as well as the promoter region governing its expression are of fish origin (Friedenreich and Schartl 1990, Bearzotti et al. 1992, Bétancourt et al. 1993, Iyengar et al. 1996). This has also a practical consequence, because a genetically modified fish which contains "only" sequences from other fish might appear, with respect to certain concerns, less problematic than a fish containing, for instance, a mammalian growth hormone gene under the control of a retrovirus promoter. Although the number of fish genes and available regulatory elements of fish origin available to date (Tab. 1) is increasing, it should be noted that for a lot of studies in basic research the strong viral promoters with well characterized features are still widely used successful tools (see Winkler and Schartl 1997). While the promoters used today are generally the core regulatory elements, the benefits of higher order structures, like locus control regions (LCR), are under scrutiny. Studies have shown that the inclusion of introns (again best of fish origin) improves transgene expression (Bétancourt et al. 1993) and that the polyA signal supplied with the transgene is usually sufficient for correct transcriptional termination, thus making the use of viral polyA signal like the widely used SV40 termination cassette suspendable. As a general rule in the production of transgenic animals, vector sequences necessary for

the construction process and the production of the DNA in bacteria should be eliminated before the gene transfer procedure. A few studies have shown that, like in mammals, the injection of linear rather than circular DNA enhances the frequency of successful transgenesis (Chourrout et al. 1986, Penman et al. 1990, Iyengar and Maclean 1995, Toyohara et al. 1996). A transgene can be delivered to single individuals either by injection of a DNA solution into the cytoplasm of the early cleavage stage embryo (usually all the 2-4 cell stage) or into the yolk. To increase the efficiency of this procedure, recently a method was elaborated which works through the coinjection of peptides encoding a nuclear localization signal that obviously facilitates the transfer of the injected DNA from the cytoplasm or yolk into the nucleus of the cleavage-stage embryos (Collas and Alestrøm 1997). It would appear that the injection of the DNA directly into the nucleus is even more efficient. However, during the first stages of development where the DNA has to be delivered the nuclei of the embryonic cells are usually invisible. So far only in a small laboratory fish, the medaka, a protocol has been established which works through the injection of the DNA to the oocyte nucleus followed by *in vitro* maturation and fertilisation (Ozato et al. 1986). Contrary to treat single eggs or embryos, procedures have been developed for batchwise transfer of foreign DNA. Electroporation has shown some positive results (Sin et al. 1993, Symonds et al. 1994), but seems not to work in everybody's hands. Thus this application is still outnumbered by trials using conventional DNA injection. The bombardment of eggs and embryos with DNA-covered microprotectiles has been reported (Zelenin et al. 1991). However, this method of DNA transfer appears to find its wide application more in the field of somatic transgenesis (see below). Reports about sperm-mediated gene transfer by just mixing sperm with DNA or subjecting the mixture to electroporation and using this for fertilization could not be reproduced (see Chourrout and Perrot 1992). But the technology has received a recent revivement by reports in the frog Xenopus on using decondensed sperm chromatin after treatment with oocyte extract as an efficient vehicle in an injection protocol (Kroll and Amaya 1996). Pseudotyped retroviruses which had been engineered in a way that they infect the cells of a developing fish embryo may also carry transgenes into hosts (Lin et al. 1994). However, questions about confident expression of the transduced DNA, limitations in the size of the DNA that can be transferred and the high safety measurements that have to be taken in the initial steps of working with the pantropic viruses have restricted the use of this method to a few laboratories so far. Most recently, it has been reported that reactivated or active transposable elements of fish (Ivics et al. 1997) or even invertebrate origin (Raz et al. 1998) may be used to efficiently integrate foreign transgenic DNA into the genome of cultured cells and embryos. Thus comparative testing the efficiency of such elements in transgenic experiments is awaited with much interest.

Following transgene delivery, stable integration into the host genome has to occur. This process occurs at random and is still responsible for very insufficient results. One problem is that in a lot of cases the transgene obviously integrates into a region where it becomes transcriptionally silenced, for instance, through DNA methylation. Possibilities for improvement of this step are offered by reports from transgenic experiments with mammals where sequences that facilitate recombination with the genomic DNA enhance integration rates (Miller et al. 1992) and that inclusion of an avian matrix attachment regions (MAR, the sequences which link the chromatin to the nuclear envelope) may act as methylation insulators also in fish and thus prevent transgene silencing (Caldovic and Hackett 1995). Another complication is that

integration occurs not immediately after DNA injection but only later during embryogenesis. This leads to a high degree of mosaicism which consequently results in only a limited number of transgenic offspring from the founder animal that has received the transgene.

A phenomenon has been observed after DNA injection into fish eggs and early embryos that should be advantageous for the process of producing transgenic fish. While in other organisms, except for frogs where the same phenomenon, although to a much lesser extent, is also apparent, the foreign DNA is rapidly degraded after injection in fish it is replicated and acquires the host-specific methylation pattern (Stuart et al. 1988, Chong and Vielkind 1989, Winkler et al. 1991, Volckaert et al. 1994). Thus after a short time up to ten times more DNA than originally injected can appear in the developing host, thereby — at least theoretically — increasing the chance of integration of the transgene.

Once the transgene is stably integrated into the germline DNA, its transmission to the offspring occurs usually at Mendelian rates and stability of transgene inheritance has been observed up to several generations (see e.g., Tewari et al. 1992, Kinoshita et al. 1996). The last goal in the procedure for producing transgenic fish that has to be achieved is the fidelity of transgene expression. This is the most crucial step and nonexpression of transgenes is the most common reason for failure of transgenic experiments to date. The most advances have been made in laboratory fish (see e.g., Long et al. 1997). Use of optimal gene constructs, expecially of all fish origin, can obviously take care of part of the problems. However, the main issues of transgene silencing are still unresolved.

# Somatic gene transfer in fish

A new method of transient transgenesis in postnatal animals was developed some years ago by Wolff et al. (1990). The technique is based on the direct introduction of naked plasmid DNA into somatic tissue of an adult organism. The genes contained in the plasmids are efficiently expressed although not integrated into the genome and can be maintained for long periods of time as extrachromosomal DNA (Wolff et al. 1992, Tan and Chan 1997). The fact that the gene pool of the recipient organism is not invaded makes this technique attractive in the light of ethical and safety concerns as an alternative to stable transgenesis.

The introduction of genes into the soma was initially developed in the mouse by directly injecting plasmid DNA into skeletal muscle. Since these first experiments other target tissues (Malone et al. 1994, Tsan et al. 1995, Hengge et al. 1995) and different animals (Wolff et al. 1991, Hansen et al. 1991, de Luze et al. 1993, Malone et al. 1994) have been tested. In fish the technique has been assayed in several species, mostly using plasmids containing reporter genes and constitutive promoters (Table 2).The preferred target tissue has been muscle, using injection of dissolved DNA as the delivery system. Besides injection the bombardment with gold or tungsten particles covered with DNA (so-called "biolistics") is certainly a promising alternative for the introduction of the genes. Its advantages are a better delivery of the DNA into the cells and the possibility of reaching tissues that are difficult to inject (e.g., the integument). In fish until now only a few trials have been done by bombardment with DNA (Gómez-Chiarri et al. 1996) and injection is still the preferred method.

The somatic gene transfer offers in some cases a good alternative to stable transgenesis. It can be used when a gene product is only required during a certain period in the life of the fish. The technique itself is fast and simple and can be used as an already operative tool for those species of fish where a stable transgenic technique is not developed yet. Its potential applications are manifold: in mammals it is being improved as a non viral gene therapy technique (Ledley 1995, Choate and Khavari 1997), in fish the most important application so far is the immunization of fish against different pathogens and parasites (Anderson et al. 1996a, Leong et al. 1997). The DNA vaccines are indeed an easy and inexpensive way of producing immunoprotective antigens.

The somatic gene transfer is expected to become also an important tool in basic research, as it offers the possibility of rapidly studying promoters or different transcription elements (Gauvry et al. 1996, Schulte et al. 1997). For assaying *in vivo* the expression of the constructs previous to a stable transgenesis experiment a somatic gene transfer test can be the appropriate control.

This technique still needs a lot of improvement, especially more tissues have to be tested. The muscle injection should also be improved to render a better diffussion or to permit for example the delivery of peptide hormones into the blood circulation (Anwer et al. 1998).

# Procedures for gene replacement by the ES cell technology

The ES cell technology consists of four major steps: 1) Establisment of embryonic stem (ES) cell lines from the cells of early fish embryos at the blastula stage, the most important feature of such lines being that they have to retain their full developmental potential to give rise to all cell types including germ cells; 2) Introduction of transgenes into the genome of ES cells; 3) Screening and propagation of cell clones properly expressing the integrated transgene; and 4) Transplantation of transgenic ES cell clones into recipient embryos to generate germline chimeras which are then crossed to produce fish homozygous for the transgene. Because gene delivery and screening are performed in tissue culture, the transgene can be easily characterized for copy numbers of integration and more importantly, for levels of expression prior to germ line transmission. This ensures that transgenic fish derived from such defined cell clones will express desirable phenotypes.

Production of transgenic fish by direct gene delivery into eggs is a long-term project and its outcome is generally not predictable, because low frequencies of transgene integration and scarcety of proper expression usually require large numbers of individuals to be screened over generations. Prescreening for integration and expression *in vitro* utilizing the ES cell technology after co-transfection with antibiotic resistance genes should be a useful improvement. Thus extremely rare events can be enriched and characterized prior to germline transmission. A further possibility offered by the ES cell technology is that the function of a particular gene can be disrupted or modified through gene replacement by homologous recombination. This loss-of-function or modification-of-function approach may be utilized to remove harmful or undesirable functions of a particular gene. Its first

potential, however, will be in basic science where it can be used as the ultimate tool to understand how fish genes work and what their function is, similar to what we currently observe in mouse genetics where gene replacement is becoming a routine.

The precondition for ES cell-based transgenesis is the availability of ES cells. In fish most studies have been done in a small aquarium fish, the medaka (*Oryzias latipes*). Here feeder cell-free culture conditions for deriving pluripotent fish ES cell lines have been developed (Hong and Schartl 1996). A considerable strain difference for deriving undifferentiated cell cultures from medaka blastulae was noted (Hong et al. 1998b). Pluripotent ES-like cell cultures can be reliably obtained from certain permissive strains while others were not suited. Medaka ES-like cells after long term cultivation retain a normal karyotype and the competence to be induced to differentiate into various cells types *in vitro* (Hong et al. 1996). Most importantly, they retain the *in-vivo* pluripotency which becomes apparent by their capability to give rise to viable chimeras at high frequency (see below). Therefore, they are promising candidates for ES cell-mediated transgenesis. Besides medaka, reports on ES-like cells exist from zebrafish, but their competence for chimera formation could not be shown so far or was even lost (Sun et al. 1995).

The ability of cultured vertebrate ES cells to undergo homologous recombination opens the possibility to replace an endogenous gene by a new copy after designed modification *in vitro*. Because of the rareness of homologous recombination events, suitable selectable markers are required. A dual selection approach called "positive-negative selection" (PNS) procedure has widely been used for enriching precise gene replacement products in mice (Mansour et al. 1988).

Another key step in the ES cell technology is gene delivery into ES cells and the establishment of selection procedures. Transgenes can be easily transferred into medaka ES-like cells at a satisfactory efficiency. After testing various promoters and enhancers, plasmids expressing selectable genes have been constructed and the PNS procedure appears to work satisfactorily in cultured fish cells (Hong, Chen and Schartl, unpublished).

Chimeras have been generated in medaka at high efficacy using many independent ES-like cell cultures including one stable cell line, MES1 (Hong et al. 1998a, b). The chimera-competence of MES1 is not abolished by gene transfer. Thus it appears not impossible to establish the ES technology in fish, although the germline contribution of medaka ES-like cells remains to be achieved. At least by transplantation of non-cultivated blastomeres germline chimeric medaka have been obtained (Wakamatsu et al. 1993).

# Nuclear transfer in fish

Transgenic fish using ES cells as vehicles can be obtained in two ways. The first is direct cell transplantation which is the classical technique and was used for the formation of somatic chimeras (see above). The second approach is nuclear transplantation which consists of three major steps: 1) preparation of enucleated, recipient eggs (cytoplasts); 2) preparation of donor nuclei; and 3) introduction of a donor nucleus into the recipient cytoplasm. Nuclear transfer has recently proven to be successful in cloning sheep (Campbell et al. 1996, Wilmut et al. 1997). This approach has also some history in fish.

In fish, oocytes are mechanically enucleated and used as host cytoplasts. Donor nuclei are usually prepared from blastula-stage embryos and injected into single enucleated oocytes. Reconstituted eggs are reared in a balanced salt solution until hatching. In mammals, usually the oocyte nucleus is chemically inactivated and the donor nucleus is introduced by cell fusion through electric pulses. A similar procedure has preliminarily been attempted in fish (Li et al. 1990).

Fertile adults have successfully been obtained in several fish species and even between different genera using donor nuclei from non-cultivated blastomeres (Table 3). Although reconstituted eggs developed to fry, no adult fish have been obtained when nuclear transfer was made between different families. If nuclear donor and cytoplast host species are more distantly related, development cannot proceed beyond the blastula stage. Encouraging enough, nuclei of cultured embryonic cells or even kidney cells have proven capable of developing into adult goldfish (Chen et al. 1986). Although these cultured cell-derived fish had aneuploid karyotypes and were sterile, this experiment does point to the possibility to produce cell culture-derived fish by nuclear transfer.

Recently, the usefulness of nuclear transfer from cultured cells for cloning of sheep has been demonstrated (Campbell et al. 1996). One of the key factors is the synchronous cell cycle arrest of donor cells in culture and the use of nuclei from these quiescent cells as donors. This is thought to help the donor nucleus to cope with the developmental program of enucleated host oocytes. Future work will determine whether this approach can improve the efficiency of nuclear transfer in fish.

# Problems with transgenic fish

The benefits of transgenic technologies for basic research are obvious. Analyzing the expression and the function of fish genes in the intact whole animal is the highest level of analysis that one can reach and it is desired that these tools can be applied as widely as possible. Positive expectations are connected to transgenic fish also in the applied field of science and in many countries from a commercial point of view transgenic fish are generally regarded very optimistic. Regional differences exist and hesitations to invest considerably in the further development of transgenic technologies in some areas are obviously connected to the problems with the production and use of transgenic fish. This should be expected for any newly emerging technology and is legitimate. One problem, and maybe the easiest one to solve, is the question of patenting of transgenic fish strains. The issues that may arise here are not substantially different from what is going on currently with transgenic mice, sheep, cattle, etc. The efforts to come up with clear solutions for the transgenic higher vertebrates can be easily adopted to fish. We could hope that, when the field of transgenic fish has caught up with the advances made in higher vertebrates, a common solution for all the problems connected to patenting of genetically modified organisms will be available.

Another, but more severe problem which, although gradually different, is also already intensively discussed in connection to genetically modified higher vertebrates, is the general concerns by scientists and the public about ethic issues if the soma or the germline of an organism is genetically altered. With respect to genetically modified farmed fish that are cultivated for human consumption,

consumers' concerns about the safety of the so-called "gene food" have to be faced. Again, the problems might be similar to what we currently observe for cattle and transgenic plants, and it is clear that a lot of research has to be done to give definitive answers to the justified questions.

One problem with genetically modified organisms that seems to be relatively easily manageable in mammals appears to be much more severe in fish, namely the escape of a transgenic fish and the introduction of transgenes into natural populations. At present this problem has been managed satisfactorily for all laboratory studies, because a close containment that prevents escape of fish or fertilized eggs into the environment is giving the highest level of security. Similar precautions can be taken for fish that have to be kept in outdoor ponds. The problem becomes more severe as it comes to the questions of the possible culture of transgenic fish in fish farms. Unlike transgenic farm mammals, transgenic fish would not be easily identifiable once they had escaped, and in a lot of cases they differ only marginally from their non-cultivated conspecific relatives. Thus an escaped fish could easily mate with a wild fish and thereby release its genetic modification into the gene pool of a natural population. Therefore, besides physical constraints which already should give a very high level of security, biological constraints have to be employed to prevent the introgression of altered genes into natural gene pools. Most of such techniques are to date still barely developed and much efforts will have to go into further elaboration of the strategies for reproductive isolation either through ploidy-manipulation or inhibition of sexual maturation. Transgenic cultivated fish might be also rendered reproductively incompatible with wild fish through biochemical modifications of their eggs, sperms or accessory fluids. Metabolic deficiencies can be used to guarantee for a fish its survival only in captivity where it is regularily supplied with a essential factor. Conversely, suicide genes could be cointroduced into transgenic animals which will be inactive only as long as the fish is within the closed containment of the outdoor pond where an essential factor is supplied with the water that inactivates the suicide gene.

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**Table 1: Examples for available regulatory elements derived from fish**

| GENE | SPECIES | EXPRESSION | REFERENCE |
|---|---|---|---|
| metallothionein | rainbow trout | ubiquitous | Zafarullah et al. 1989<br>Hong et al. 1993 |
| histone H3 | sockeye salmon | ubiquitous | Devlin 1997 |
| β-actin | carp | ubiquitous | Liu et al. 1990 |
| prolactin | tilapia<br>chinook salmon | pituitary<br>pituitary | Poncelet et al. 1993<br>Xiong et al. 1992 |
| myosin heavy chain | carp | muscle | Iyengar et al. 1996 |
| anti-freeze protein | ocean pout | liver | Davies et al. 1989 |
| ependymin | goldfish | brain/meninx | Hoffmann 1992 |
| tyrosinase | medaka | pigment cells | Koga and Hori 1997 |

**Table 2: Somatic gene transfer in fish**

| FISH | PROMOTER | GENE | TRANSFER PROCEDURE | TARGET TISSUE | [DNA] OPT. | TIME SAMPLES | REFERENCE |
|---|---|---|---|---|---|---|---|
| Tilapia | carp β-actin | CAT | injection | muscle | 5-10 µg | 1d, 2d, 7d | Rahman and Maclean 1992 |
| Rainbow trout | CMV/ fish promoters | Luc | injection | muscle | 50 µg | 5-7d | Anderson et al. 1996b |
| Rainbow trout | CMV-tk | Luc/lacZ | injection/ bombardement | muscle, gills, eye | 25-50 µg | 2d | Gómez-Chiarri et al. 1996 |
| Carp | SV40 human MxA rabbit β-cardmyo | CAT lacZ | injection | muscle | 50 µg | 4d | Hansen et al. 1991 |
| Zebrafish | CMV-IE SV40-tk | CAT/Luc/ lacZ | injection | muscle | 5 µg | 7d (up 1 yr) | Tan and Chan 1997 |
| Salmonids | CMV | Glycprotein from infectious hematopoietic necrosis (IHN) virus | injection | muscle | 10 µg | 42d | Anderson et al. 1996a |
| Carp | carp myosin heavy chain gene promoter | CAT | injection | muscle | 50 µg | 14d | Gauvry et al. 1996 |
| Fundulus | Ldh-B | Luc LacZ | injection | muscle | 50 µg | 1d | Schulte et al. 1997 |
| Xiphophorus | CMV-tk SV40-tk | Luc lacZ | injection | muscle melanoma | 20 µg | 6d | Schulte et al. submitted |

**Table 3: Nuclear transplantation in fish**

| PHYLOGENETIC COMBINATION | DONOR NUCLEI | HOST OOCYTES | MOST ADVANCED STAGE OF DEVELOPMENT | REFERENCE |
|---|---|---|---|---|
| **Donor nuclei from noncultivated blastomeres** | | | | |
| Same species | goldfish (dom. var.) | goldfish | fertile adults | Yan et al. 1990 |
| | goldfish | goldfish (dom. var.) | fertile adults | Yan et al. 1990 |
| | loach | loach (diff. ploidy) | fertile adults | Yan et al. 1990 |
| | medaka (pigmented) | medaka (albino) | fry | |
| Different genera | common carp | goldfish (dom. var.) | fertile adults | Tung 1980 |
| | goldfish | common carp | fertile adults | Yan et al. 1984a |
| | grass carp | blunt-snout bream | fertile adults | Yan et al. 1984b |
| | goldfish | bitterling | fry | Tung et al. 1973 |
| | bitterling | goldfish | fry | Tung et al. 1973 |
| Different families | loach | goldfish | fry | Yan et al. 1990 |
| | goldfish | loach | fry | Yan et al. 1990 |
| | zebrafish | loach | fry | Yan et al., unpublished |
| Different orders | tilapia | common carp | fry | Yan 1989 |
| | tilapia | loach | fry | Yan et al. 1991 |
| | tilapia | goldfish | blastula | Yan et al. 1990 |
| Mammals/fish | mouse | loach | blastula | Li et al., unpublished |
| **Donor nuclei from *in vitro* cultivated blastomeres** | | | | |
| Same species | goldfish (blastula cells 53-59 passages) | goldfish | 1 adult, sterile | Chen et al. 1986 |

| PHYLOGENETIC COMBINATION | DONOR NUCLEI | HOST OOCYTES | MOST ADVANCED STAGE OF DEVELOPMENT | REFERENCE |
|---|---|---|---|---|
| **Donor nuclei from *in vitro* cultivated blastomeres** | | | | |
| Same species | goldfish (blastula cells 53-59 passages) | goldfish | 1 adult, sterile | Chen et al. 1986 |
| | goldfish (kidney 7 days) | goldfish | 1 adult, sterile | Chen et al. 1986 |
| Different genera | grass carp (somite-stage embryonic cells, 16 passages) | black carp | prehatched fry | Zhang et al. 1990 |
| Different subfamilies | grass carp (blastula cells, 15 passages) | blunt-snout bream | somitogenesis | Zhang et al. 1990 |

# Aquaflow
# European network for the dissemination of aquaculture RTD information

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The presentation will aim to provide information about the network. The main objectives, the methodology, the preliminary results and the countries and sectors involved in the project will be introduced with the view of helping the network extension.

## Summary of the objectives

1. to establish a wider and faster circulation of information on the results and progress of EU funded (and eventually relevant non EU funded) programs of research, technological development, and demonstration in the field of aquaculture to the potential end users across Europe.

2. to communicate comprehensible data of interest and use to the end users, leading to an increased interaction and communication between the small and medium enterprises (SMEs) and the research community involved.

3. to enhance communication among traditionally isolated SMEs.

4. to allow for two-way communication, to refine the services of the network, and to develop an efficient and long-term sustainable system.

5. to collect feedback from the SMEs in relation to problems and bottlenecks encountered, and to identify further requirements from both research and technology and associate information services.

6. to increase the awareness of the industry to the possibilities of using electronic communication media, and to improve the service of the Aquaculture Associations.

7. to enhance the application of research results, and hence the competitiveness of the sector, resulting in a growth of employment opportunities in aquaculture.

## Summary of the methodology

Research results from EU funded projects will be transferred to the end users (SMEs) as technical leaflets translated in each national language. In addition, the information will be disseminated through specific work shops and presentations in general meetings and trade shows. Internet and E-mail are also envisaged as

communication means. A feedback collection from the SMEs will be acquired. To perform this task, in each country, a National Aqua-flow Team (NAT) was established. They are composed of a National Network Leader, usually from a Research Institution, and members of National Producers Associations. By their improved cooperation, the NAT members maintain a close link between the end users, their networking partners and the Project Management Team (PMT). Three European associations are represented in the PMT, the Federation of European Aquaculture Producers (FEAP), AquaTT and the European Aquaculture Society (EAS) (who acts as coordinator).

COUNTRIES involved: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.

# Selective breeding for stress tolerance in aquacultured sea bream, *Sparus aurata*. Comparison with rainbow trout *Oncorhynchus mykiss*

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## Summary

Sea bream and trout were selected for high or low stress response, measured by plasma cortisol levels, and tested after repeated confinement stress. The consistency of the response and the correlation with other indicators was analysed. After this, crosses between either high cortisol (HR) male and female responders and low cortisol responders (LR) were made. Reproductive parameters were measured and correlated with cortisol. The results show that selected fish consistently show the corresponding high or low response and that growth rate is higher in HR. Reproductive parameters show slight differences in trout between HR and LR

in trout whereas in sea bream, HR show lower egg quantity but better quality. F1 generation show the same pattern of cortisol responsibility as the respective progenitors.

## Introduction

The overall aim of this study is to assess the feasibility of increasing the tolerance of finfish to stress selective breeding. Because ideal husbandry practices are of necessity compromised by the economic realities of large-scale fish production, stress is an unavoidable component of the finfish aquaculture environment. Although the physiological response of fish to isolated stressors is essentially adaptive, fish under intensive culture conditions are exposed to repeated acute stress and in some instances to chronic stress. In these cases the response becomes maladaptive resulting in adverse effects in growth, flesh quality,

reproductive function and immunocompetence (Pickering, 1993; Campbell et al., 1994; Pickering and Pottinger, 1989; Sunyer et al., 1995). Therefore, an enhanced tolerance of stressful procedures is likely to improve food conversion and growth, reduce disease incidences and improve broodstock performance. Thus, an investigation on selective breeding of fish for stress tolerance has been undertaken in the gilthead sea bream *Sparus aurata* and rainbow trout Oncorhynchus mykiss. The selection procedure is based on traits which are strongly linked with responsiveness to stress: Plasma cortisol and lysozyme, as previous work from the laboratories participating in this work estimated the potential heritability of these traits (Fevolden and Roed, 1993; Fevolden et al., 1991, 1994; Roed et al., 1993a,b; Pottinger and Pickering, 1997).

# Material and Methods

## *Sea bream*

Broodstock of sea bream of 900g (147 fish) from both Mediterranean and Atlantic populations were subjected to 3h confinement in their own tanks by restricting the living space with net walls. In this way, space restriction is reached, but avoiding loss of water quality, as water flow and renovation is always maintained After confinement, fish were individually netted, anaesthetised, weighed and blood was sampled through caudal puncture. This procedure was repeated every month during 5 consecutive months (June to October). Plasma and serum was obtained after centrifugation and concentrations of cortisol, glucose, lactate, osmolality, and agglutination activity were determined. Once the fish samples were analysed for cortisol response to the stress, two males and one female of fish of high cortisol response and the same for low cortisol response were placed in individual tanks. The fish were classified as high cortisol responders (HCR) or low cortisol responders (LCR) depending on the consistency of the response to the stress along the five months. The offspring of these families was analysed in terms of quantity and quality of the eggs. The variables measured were: Number of eggs per female, spawning viability, percentage of hatched eggs and larval size after hatching.

## *Trout*

Two year-old mixed sex rainbow trout were individually identified and subjected to 3 hours confinement (10 fish per 50 l tank) at monthly intervals. After confinement fish were transferred to anaesthesia and 1 ml of blood was removed. Plasma cortisol, glucose and lysozyme levels were determined. To perform the crosses, 15 females from the HR and LR groups were made with the corresponding 15 males. In addition, 15 males and females randomly chosen from the US group were mated. Total egg volume and egg size, egg mortality and sperm count were determined

# Results and discussion

The results of the selection procedure in terms of the cortisol response has resulted in a consistency, as the fish selected as either high or low response continued showing high and low levels respectively in sea bream and trout. Similarly, in both

species a positive correlation was found between growth and high cortisol response (see table 1). Regarding the differences between species, the results are the following:

Table 1: Cortisol and growth rate in high and low responders. Mean and SEM

| | Cortisol (ng/ml) | Growth rate (% day) |
|---|---|---|
| Sea Bream | | |
| High responders | 109.1 ± 21.1 | 3.13 ± 0.48 |
| Low responders | 60.6 ± 12.2 | 2.47 ± 0.34 |
| Trout | | |
| High responders | 110.8 ± 8.9 | 0.78 ± 0.04 |
| Low responders | 42.9 ± 3.4 | 0.76 ± 0.04 |

## *Sea Bream*

The results obtained up to this moment regarding reproductive parameters show the following trends: Only 65% of the pairs selected for HR or LR spawned whereas 100% of unselected pairs spawned. No correlation was found between the number of spawns and post-stress plasma cortisol in females. There were no significant differences in the number of eggs per kilogram of female between HR and LR. However, both groups had significantly more eggs per kilogram of female per day than the US group. Egg quality in terms of viability and hatching rates was significantly better for HR than the other groups, whereas lipid droplet diameter was lowest in US group. No significant differences were found for newly hatched larvae length between groups (Table 2).

## *Trout*

The evaluation of the impact of a stressor on the reproductive system of selected fish showed that confinement caused a clear decrease of 17B-estradiol but no differences between HR and LR. No significant differences were found in GSI, number of eggs per female, individual egg weight, sperm counts in males or egg mortality at hatching and eyeing. However, egg volume was lower in LR and sperm count was higher either HR or LR than in unselected fish (US). See table 3.

Table 2: Factors associated with gamete quality in sea bream. Mean and SD.

| PARAMETER | HR | LR | C |
|---|---|---|---|
| number of spawns | 41.37 ± 32.33 | 26.74 ± 28.52 | 41.80 ± 25.06 |
| eggs/kg female/day | 51807 ± 16492 | 54243 ± 26825 | 33172 ± 16491 |
| egg viability (%) | 61.24 ± 28.63 | 42.82 ± 27.37 | 54.74 ± 26.69 |
| hatching rate (%) | 84.83 ± 21.61 | 74.88 ± 33.96 | 77.43 ± 27.32 |
| egg diameter (mm) | 0.957 ± 0.016 | 0.966 ± 0.018 | 0.964 ± 0.015 |
| lipid droplet diameter (mm) | 109.1 ± 21.1 | 93.78 ± 14.50 | 109.1 ± 21.1 |
| new-hatched larvae length (mm) | 60.6 ± 12.2 | 74.13 ± 10.16 | 60.6 ± 12.2 |

HR=High responders, LR=Low responders, C=control (unselected group)

Table 3: Reproductive parameters in trout. Mean and SEM

| PARAMETER | HR | LR | US |
|---|---|---|---|
| 17-β Estradiol (ng/ml)* | 24 ± 2 | 19.9 ± 2 | — |
| Gonadosomatic index | 14.4 ± 0.6 | 15.5 ± 0.9 | 14.3 ± 0.4 |
| number of eggs/female | 2776 ± 179 | 2541 ± 165 | 2385 ± 89 |
| individual egg weight (mg) | 80.2 ± 8.5 | 75.3 ± 2.2 | 78.4 ± 1.5 |
| egg volume ($mm^3$) | 80.8 ± 1.8 | 74.3 ± 2 | 79.3 ± 3.1 |
| egg mortality at hatching (%) | 19 ± 2 | 15 ± 5 | 24 ± 6 |
| egg mortality at eyeing (%) | 8 ± 1 | 5.3 ± 2 | 9 ± 1 |
| sperm count ($x10^3$ per ul) | 13432 ± 1522 | 14786 ± 1302 | 9577 ± 1143 |

* The estradiol measurement is after 48h of confinement (maximal suppression)

The first examination of the stress-responsiveness of the F1 strongly indicates that the fish display the same traits for HR or LR as the parent generation. Up to three assessments on the progeny show high significant differences in post-stress cortisol levels in HR than in LR.

Table 4. Metabolic parameters in trout progeny subjected to chronic stress. Mean±SEM

| | SGR | F.E. | C.F | AAT | PK | PFK |
|---|---|---|---|---|---|---|
| Uncrowded | | | | | | |
| LR | 2.92 ± 0.02 | 1.24 ± 0.03 | 16.3 ± 0.18 | 183.8 ± 2.21 | 110.7 ± 4.8 | 36.9 ± 1.8 |
| HR | 2.26 ± 0.07 | 1.10 ± 0.01 | 15.0 ± 0.12 | 246.6 ± 22.1 | 139.8 ± 6.1 | 33.9 ± 0.3 |
| Crowded | | | | | | |
| LR | 1.96 ± 0.05 | 1.21 ± 0.02 | 14.83 ± 0.44 | 269.6 ± 16.2 | 11.9 ± 1.8 | 40.12 ± 2.1 |
| HR | 1.66 ± 0.03 | 1.13 ± 0.01 | 12.73 ± 0.60 | 260.4 ± 20.6 | 131.2 ± 0.9 | 40.62 ± 1.3 |

LR=Low responders, HR=High responders, SGR=Specific growth rate, FE=feed efficiency, CF=condition factor,
AAT=alanine aminotransferase, PK=Piruvate kinase, PFK=Phosphofructokinase

Different results have been found as regards the metabolic response of the progeny of HR or LR fish under *chronic* stress. Unstressed fish show better growth rate and feed efficiency in LR group, whereas in fish subjected to high density, growth rate and feed efficiency was significantly lower in HR and condition factor was lower for the HR crowded fish. Liver Alanine Aminotransferase showed lower activity in LR both in crowded and uncrowded fish and Piruvate kinase showed higher activity in HR also in both groups. Phosphofructokinase increased in the HR crowded group.

Regarding heretabilities of selected traits as cortisol and lysozyme, the results showed moderate to high heretability estimates, whereas the common full-sib effects due to other than additive effects was negligible.

In conclusion, these preliminary results show that in sea bream and trout, the selection for cortisol appears to be consistent and heritable. Nevertheless, it is not clear whether selection for low cortisol response is always recommendable. Further analysis will be carried out on the consistency of stress/cortisol response on this and next generation to see whether the selection for this characteristics may help to decrease husbandry problems and improve the profitability of aquacultured fish.

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# Population genetic survey of eigth species of Sparidae with an Atlantic-Mediterranean distribution by means mitochondrial and nuclear markers

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We have carried out a population genetic survey on 8 commercially valuable species of fish belonging to the family Sparidae, namely Sparus aurata, Dentex dentex, Pagrus pagrus, Pagellus bogaraveo, Lithognathus mormyrus, Diplodus sargus, Diplodus puntazzo, and Spondylosoma cantharus. The populations investigated cover a wide geographic range including the Atlantic coast of Portugal, Eastern Spain, the Adriatic coast of Italy and Greece. The genetic analysis included both mitochondrial and nuclear markers. In particular, we have investigated the hypervariable region (D-loop) of mitochondrial DNA (mtDNA) using a combined approach of SSPC (Single Strand Conformation Polymorphism) and sequencing. As to the nuclear markers, we have studied both allozymes and microsatellites. The results concerning the mtDNA revealed a remarkably high degree of variation in the Dloop region for all the species investigated (number of alleles ranging between 13 and 32) but one, namely S. aurata, which displayed a surprisingly low polymorphism (number of alleles = 4). The statistical analysis consistently showed significant genetic differentiation between the Atlantic populations as compared to the Mediterranean ones in the majority of the species investigated with a further population structuring within the Mediterranean area only in some cases. The most striking Atlantic-Mediterranean separation was shown by D. dentex and L. mormyrus where the Atlantic populations did not share any allele with the Mediterranean ones, indicating for both species a complete absence of gene flow between the two areas. In addition the large sequence divergence between the Atlantic and Mediterranean set of alleles observed in both species account for their ancient separation. The results obtained by the mtDNA analysis were partly supported by the nuclear markers analysis. In particular, allozymes tend to confirm the genetic divergence of the Portuguese population for L. mormyrus, however, the low level of protein polymorphism which usually characterises vertebrates, is less sensitive to detect population structuring. On the other hand, microsatellites turned out to be too polymorphic to find any geographic gradient since they showed

significant differences in almost all population comparisons. In conclusion, our data support the genetic approach as a powerful tool for identifying differences among geographic populations which in some case can be recognised as distinct stocks. Such information appear to be of major importance in stock assessment and fishery management.

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# Parathyroid hormone-related protein (PTHRP) and PTHRP gene expression in normal and dystrophic sea bream

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The marine teleost sea bream (*Sparus aurata*), is heavily exploited in aquaculture in southern Europe. One of the problems associated with the culture of this species is the relatively high incidence of spinal abnormalities. The cause of such deformities is unclear but may be associated with collagen or other connective tissue malfunctions and in sea bream frequently appear before ossification of the notochord. The biological systems involved in these deformities are as a yet unknown but xenobiotic pollutants may be causative agents. An endogenous factor involved in epiphyseal cartilage development in mammals is PTHrP (Amizuka et al., 1994, J.Cell Biol. 126, 1611) and partial deletion of gene expression reduces hypertrophy and proliferation of epiphyseal chondrocytes. The spinal columns of sea bream with axial malformations have regions of chondrocyte hyperplasia, particularly where ossification is most delayed. Immunoreactive PTHrP (irPTHrP) has been detected in plasma and tissues of post-larval stages of the sea bream (Danks et al., 1993, Gen. Comp. Endocrinol. 92, 201) and we have now examined the spinal columns of normal and dystrophic fish for PTHrP gene expression and irPTHrP, as a possible aetiological factor in axial dysplasia in this species.

Spinal columns were dissected from normal and dystrophic immature sea bream, fixed in sublimated Bouin-Hollande, de-calcified and wax embedded. Sections mounted on APES-coated slides, rehydrated and irPTHrP detected using antisera to the N-terminus 1-16 amino acids of human PTHrP (hPTHrP) and to the conserved pentapeptide 107-111. This pentapeptide was conjugated to bovine thyroglobulin for antibody induction and the antiserum exhaustively absorbed with the same thyroglobulin before use in immunohistochemistry. Two oligonucleotide probes were selected from the genomic DNA of chicken PTHrP (Schermer et al., 1991, J. Bone Min. Res. 6, 149) which included four conserved bases common to chicken and human PTHrP.

In normal tissue irPTHrP was found in the remnant notochord cells, in the two dorsal tracts of the spinal cord, axial muscle, particularly the red muscle, in the chondrocyte caps of the centra and their periosteal sheath. The structure of the dystrophic spine was grossly distorted and numerous hyperplastic chondrocytes containing irPTHrP and low levels of PTHrP mRNA were seen in this region but were absent from normal spines. Notochord cells, cells of the periosteal sheath, which was distended and discontinuous, and disorganised red axial muscle all contained

irPTHrP. High concentrations of irPTHrP were found in motor neurones and neurones of dorsal root ganglia, which also were abundant in PTHrP mRNA. Thus PTHrP protein appears to be present in several tissues associated with the spinal column but gene expression is restricted to neurones in normal fish. However, it is specifically detected with hyperplastic chondrocytes of dystrophic fish, suggesting that it is an aetiological factor for axial malformations.

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# Characterisation of the immune defences available in marine mussels for combatting pathogen exposure

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A principal constraint of the aquaculture industry for bivalve molluscs is the problem of disease outbreaks. It may be possible to reduce the susceptibility of bivalve molluscs to pathogens by enhancing their internal defence capability. In order to do this it is first necessary to have an understanding of the components and functioning of the immune system. The specific objectives of the research were to characterise the blood cells and antimicrobial activity of the marine mussel, Mytilus edulis (galloprovincialis). To do this mussel blood cells were separated, using density gradient centrifugation, and characterised with electron microscopy, lectin-binding, functional assays and with monoclonal antibodies raised against the blood cells. Actin and fibronectin were also isolated and characterised from the mussel blood cells and haemolymph. Specific enzymes associated with immunity in mussels were localised in the blood cells using cytochemical and immunocytochemical techniques. The humoral component of the immune response in mussels was also investigated and specific agglutinins, lysins and antimicrobial peptides identified. In particular a member of the arthropod defensin family, MGD–1 was identified and purified by reverse-phase HPLC. The results demonstrated the overall capability of mussels to mount an effective response to pathogen exposure and showed the importance of both cellular and humoral components of the immune response. The findings indicated the possibility for modulating aspects of immune function in bivalve molluscs and provided an insight into the potential for enhancing resistance to disease agents by manipulating specific components of the immune response.

# Cloning of a Mussel Gene Family and Expression of Vectors in Primary Cell Cultures

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This project was devoted to the development of new tools for exploring the biology and the pathology of bivalves of commercial interest. Cloning and characterization of gene expression was undertaken as an initial step for the in-depth understanding of the basic mechanisms underlying the biology of marine bivalves. This approach led to the construction of specific expression vectors in the aim of developping a mollusc cell line and, on the long term, as a tool for genetic transformation.

In order to obtain specific expression vectors, a mussel genomic library was constructed and used to isolate a family six distinct actin genes. A first group of genes was found carrying a promoter region immediately in front the first coding exon. Interestingly, we identified a second type of actin gene that contained an additional non-coding exon that is present as a multicopy gene. Interestingly, these different copies were found to be functional and to encode distinct peptidic sequences, although the significance of such a sequence variability remains to be determined. Based upon the experimental determination of transcription start sites, sequence analysis revealed consensus motifs for TATAA box and enhancer elements, thus defining the location of the promoter regions.

Tissue-specificity of expression of each promoter was then studied by assessing the steady state level of the RNA for each actin gene in different tissues using quantitative PCR and *in situ* hybridization. In addition, development-specific expression of the different genes is currently under investigation using similar techniques.

Once defined, the promoter regions of the first group of genes were inserted in front of a ß-Galactosidase reporter gene, leading to a series of mussel-specific expression vectors which have been tested in cell culture conditions. In addition, the SV40 large T antigen, an oncogene, was placed under the control of a mussel-specific promoter.

Oyster and mussel derived primary cell cultures were maintained in 20% hemolymph in sea water at 25°C and lipofected after different periods in culture. After 48 hours of treatment, cells were fixed and detection of the ß-Galactosidase activity was performed through histochemical, spectrophotometric or luminiscent quantification. Expression of the ß-Galactosidase was detected under light microscopy by the appearance of the characteristic blue coloured cells, after incubation in the presence of a specific substrate (X-gal) or by using a ß-Galactosidase enzymatic assay, showing that the transfection procedure worked, although it remained inefficient. To further increase detection sensitivity, the ß-

Galactosidase was replaced with the luciferase, a more sensitive reporter gene. In addition, transfection of primary cell cultures was carried out with the oncogene expressing vector, but until now it failed to induce mollusc cell immortalization.

In conclusion, the results we are presenting show that the molecular biology of mollusc appear to be similar to that of other biological systems. In addition, tissue- and development-specific patterns of expression were defined for this gene family. While, the actin-derived mollusc-specific expression vectors are active in primary cell cultures, more work remains to be done toward the obtention of mollusc cell lines.

# Acceleration of sporogenesis in some large-scale cultivated seaweeds

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In the scope of the AIR3-project (AIR3-CT94-2235) "Biological and genetical bases for the large-scale cultivation and genetic improvement of *Laminaria digitata* L." the German participant has conducted experiments on the induction of sporogenesis in *Laminaria digitata* and comparatively *Laminaria saccharina* to show the species specificity of induction mechanisms. The main objective of the BAH (Biologische Anstalt Helgoland) was to gain control over the induction of sporogenesis in *Laminaria digitata* and to reduce the time it takes individual algae to start reproduction. This contribution to the project facilitates faster investigation of genetic strains conducted by CNRS-CEOBM, Roscoff, as well as an extension of the annual period for mariculture.

Compared to the occurrence of "sorus"(sporogenous tissue) on *L. digitata* in the field, the experiments showed the acceleration of sporogenesis by 5 months under certain conditions in the laboratory. Pieces of young tissue developed sorus under various light regimes and a range of temperatures. In contrast to *L. digitata*, *L. saccharina* tissue required short-day conditions for sorus formation that was obtained at least two months ahead of natural occurrence.

The minimum plant age of *L. digitata* facilitating sporogenesis was found to be 7.5 months at the start of the experiment, with the first sorus showing after 5 weeks. This corresponds to our findings in mass cultures* of local *L. digitata* which have been undertaken close to the island of Helgoland. They rendered early formation of sorus on 8.6 months old sporophytes as calculated from the zoospore stage, contrasting to 18 months in natural populations and reconfirming findings in mass cultures at CEVA, Pleubian.

The youngest tissue forming sorus in the experiment was collected from a second year plant and was only 14 to 28 days old. Older pieces of the thallus preceeded younger pieces in sorus formation.

Nutrient enriched seawater accelerated sporogenesis compared to pure seawater, but had the disadvantage of facilitating luxurient growth of epiphytes.

The viability of the laboratory raised spores was tested and a completely normal development of young sporophytes obtained. 340 m of culture string were densely seeded with *L. digitata* spores from 12 disks with an original diameter of 23 mm.

"Phycotrons", designed by IFREMER, Nantes, and employed at Helgoland showed that in parallel experiments isolated disks of thallus preceded whole algae in the formation of spores by far. The same was found in a different experimental setup.

To investigate the reasons for the different behaviour of isolated pieces versus whole thallus in terms of sporogenesis, experiments were conducted at CNRS-CEOBM, Roscoff, and at the BAH on Helgoland. An oxidative stress following the punching out of thallus disks was tested, but could not be proven. Addition of various oligosaccharides to disks resulted in burst-like releases of $H_2O_2$ by disks.

* One of the ring shaped floats used for mariculture off Helgoland is displayed in the German pavilion at the EXPO98 in Lisbon.

# Genetic Immunisation of Fish

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Our five partner consortium (FAIR CT–95-353) is concerned with developing recombinant DNA vaccines for Infectious Pancreatic Necrosis (IPN). IPN is now recognised as the most serious problem in salmonid farming in Norway and affects both juvenile and post-smolt fish. Recent estimates of losses due to IPN disease are circa 54 Million ECU per annum. A major part of our research initiative is the development of nucleic acid vaccines against IPN. To date, this has focused on the use of naked DNA constructs and packaged RNA viral particles harbouring the IPN VP2 gene. The VP2 gene product is known to be a protective antigen and the world's first recombinant subunit fish vaccine based on this protein purified from Escherichia coli has recently entered the market place. However, there is considerable evidence that conformational epitopes are important in protection and thus, a bacterial product is unlikely to adopt the correctly folded structure. Nucleic acid vaccination circumvents this problem as the protein is made and folded in its natural host cellular environment. DNA vaccination is now emerging as an exciting technology in fish vaccine research. Several groups have shown that the Cytomegalovirus (CMV) immediate early promoter works very efficiently when injected into fish muscle. As in other biological systems, injected DNA persists in the muscle tissue for a considerable time where it can stimulate extended antigen synthesis. It appears to exist as an episomal plasmid and does not integrate in the host genome. We have made recombinant plasmids harbouring the VP2 gene under the control of the CMV promoter and have tested their ability to express VP2 in cell culture. These plasmids have also been injected into fish muscle and expression and immunological analyses are on-going. We are also investigating the ability of an Alphavirus system based on a Semliki Forest Virus vector to deliver recombinant RNA. This system allows one to package RNA encoding VP2 and infect fish cells with suicide virus particles. Recombinant VP2 particles have been produced and are currently being tested in fish. The merits of DNA vs RNA delivery will be presented. In addition, the prospects for the use of genetic immunisation to combat fish disease and the likely public perception are discussed.

# Population structure of anchovy *(Engraulis encrasicolus)* in the Mediterranean and adjacent seas using molecular genetic markers

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Supported by FAIR -CT-96-1899

Restriction Fragment Length Polymorphism (RFLP) analysis of the mitochondrial DNA (mtDNA) of European anchovy (*Engraulis encrasicolus)* in the Mediterranean and adjacent seas revealed a very interesting and uncommon geographical pattern for a marine species. In total 46 mtDNA haplotypes (mitotypes) were detected, which fell into two distinct groups (phylads A and B). The frequency of the phylads differed greatly in the studied area. Phylad A was practically the only phylad present in the Black Sea, with its frequency dropping to 85% in the northern Aegean, to 40% in the rest of Mediterranean and the Bay of Biscay, and to 15% in the Adriatic Sea. These findings suggested that there is a unidirectional gene flow from the Black Sea to the Aegean possibly through passive drift of larvae in Bosporus straits, and that restrictions to the gene flow exist between northern and southern Aegean and between northern and southern Adriatic.

Recently, in order to increase the resolution power of the study we performed sequencing analysis of a hypervariable segment of the control region (D-loop). A nucleotide divergence of app. 9% between the two phylads was detected. Moreover, a quick test for the characterization of the individual animals regarding their phylad was developed. This test includes PCR amplification and restriction digestion of the
product and may substantially facilitate future work for routine stock monitoring. Moreover, in order to substantiate the observed pattern of population differentiation, the analysis was extended to microsatellite DNA, which is a highly variable nuclear marker. Primer pairs for PCR amplification of two microsatellite loci in this species have been developed and the analysis is currently in progress.

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# RESEARCH ON TECHNOLOGIES FOR MONITORING AND ENFORCEMENT OF FISHERIES AND FISHERIES RELATED REGULATIONS



# Keynote speech

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## Introduction

For nearly twenty years, all around the world, from the coldest Arctic regions to the warmest tropical seas, an alarming trend has emerged in the world's fisheries: the catch is far exceeding the supply. Extinction of some fish species is certain – others are threatened. Many of these species have extreme economic importance to the world economy. The world's annual fish catch is declining instead of growing. This portends a woeful inadequacy in meeting the future food needs of a rapidly growing human population. Fish stock depletion in the world's oceans has the potential to become a major point of political instability and breed disorder.

Fishing enforcement agencies worldwide need to use every available technology to protect their living marine resources by detecting illegal fishing and increasing compliance with laws and regulations. Nations fortunate enough to have resources capable of patrolling vast Exclusive Economic Zones (EEZs) are searching for technologies to increase the effective deployment of those resources. Nations lacking this capability are looking for assistance to monitor the activities of their own fishing fleets and the activities of foreign fleets operating in their EEZs.

Major changes are occurring globally in fisheries monitoring, control and surveillance (MCS) policies. The focus is shifting from looking beyond national interests to international cooperation in MCS programs. Increased emphasis on MCS technology provides the key to unlocking the future of fisheries management and enforcement.

This paper acknowledges that there are too many fishers chasing too few fish. It recognizes that national budgets are inadequate for the "traditional", high-cost methods of patrolling vast ocean areas with ships and planes. It challenges scientists, researchers, enforcement officials and other marine science and technology experts to think "outside of the box" regarding new and innovative approaches to ensuring global sustainability and stewardship of our living marine resources. Our challenge, simply put, is, "How can we leverage existing technologies to maximize enforcement effectiveness while scanning the horizon for new and emerging technologies?". The practical application of these technologies, when integrated with traditional MCS approaches will yield new and exciting strategies for fisheries enforcement.

# Surveillance – Is the sky the limit?

Beginning with surveillance, the acts of determining where fishing vessels operate becomes a complex task when dealing with the vast oceans. Satellite-based technologies may offer new and exciting opportunities for enforcement officials to augment traditional aircraft and patrol vessel reconnaissance methods. We must begin conducting research on existing and emerging remote sensing capabilities. Technologies such as over-the-horizon radar, undersea acoustic surveillance, satellite-based synthetic aperture radar (SAR), advanced very high resolution radiometry (AVHRR), infrared radar (IR), high-resolution visible (HRV), and advanced space-borne thermal emission and reflection radiometer (ASTERR), provide several examples. Learning how to use these overhead technologies together with surface technologies may provide the key to the future of conserving and managing the world's living marine resources.

Present surveillance methods used to monitor fishing activities in national EEZs, on the high seas of various convention areas, and other ocean areas are generally limited by the availability, number, and endurance of the ships and planes of national governments. Many times, these assets are multi-tasked or multi-mission. They are too expensive to devote to only one task. National budgets never seem to stretch far enough to provide for the aircraft and ship time necessary to cover the EEZs and distant waters worked by the fishing fleets.

In many nations such as the small island countries of the world, resources do not exist to conduct fishing surveillance on fishing vessels of any type, foreign or domestic, operating in their extensive EEZs. Looking to satellite-based, wide-area surveillance technologies may enable these countries to provide a basic monitoring capability or enhance existing targeting methods.

For example, space-based synthetic aperture radar (SAR) can provide wide-area global observations to enhance present fisheries surveillance capabilities, and can provide developing countries and small island nations with their first effective means of monitoring their EEZ for illegal fishing activities.

The Norwegian Defence Research Establishment has pioneered the use of satellite-based SAR in fisheries enforcement applications. More recently, both Canada and the United States have funded research and demonstration projects to evaluate Radarsat data in fisheries enforcement and management applications. A project jointly funded in the U.S. will demonstrate the use of Radarsat observations in ship and shipwake detection as applied to fishing vessels.

A study is currently underway by Robert Gallagher of NAVIGS that will look at the possible evolution of satellite systems in European fisheries from two angles. The first will be to examine the potential for satellite monitoring systems to assist the task of policing and managing Europe's fishery resources, beyond their basic function of providing timely position information. To accomplish this, the data requirements of fisheries protection and management services will be collated with the data gathering and transmission capabilities of mobile satellite communications systems. This segment of the study will propose a system architecture that will give protection and management services a quasi real time indication of the provenance of fish caught in European waters and landed at European markets.

The second goal of the study will be to evaluate the existing and proposed mobile satellite communications systems to determine their validity, in terms of performance, cost and communications services proposed, for participation in a system based on the above architecture. Furthermore, the study will suggest generic guidelines for the suitability of services in general, thus providing criteria for the evaluation of services for which technical specifications are not yet available. (*)

The following three tables outline the existing and planned satellite systems along with useful details on their originators, instruments, applications, and other characteristics.

**Table 1 — Planned LEO satellite data systems**

| System Name | Originators | Details |
|---|---|---|
| ORBCOMM | OSC, Teleglobe | 26-36 satellites providing 2400 bps two way comms and location service |
| VITA/Final Analysis | Final Analysis Inc | 38 satellite constellation |
| GE StarSys | GE Americom, Starsys | 24 satellites with messaging and positioning capability |
| Safir | OHB, Germany | Store & forward satellites |
| Leo One | LEO One Corporation | Under negotiation with FCC |
| Courier/Gonets | Russia | Global electronic messaging for microcomputers using 36 satellites |
| ARGOS II | CLS, France | Two way, store & forward using 2 satellites |

**Table 2 — Planned satellite telephony systems**

| System Name | Originators | Details |
|---|---|---|
| Iridium | Motorola | 66 satellites in LEO providing global telephony using inter-satellite links |
| Globalstar | Loral/Qualcomm | 48 in LEO satellites providing global telephony via local Gateway Earth Station |
| ICO | ICO Ltd | 12 satellites in ICO providing global telephony vial local Satellite Access |
| Ellipso | MCI Holdings | 32 satellites in elliptical orbits providing focused coverage |
| Constellation | Constellation Comms. TELEBRAS | 46 satellites in LEO providing global telephony. 11 to be launched initially |

(*) Robert Gallagher, navigs, s.a.r.l., facsimile, 11 May 1998.

**Table 3 — Recent & planned Earth Observation Satellite Systems**

| System Name | Originators | Details | Fisheries Applications |
|---|---|---|---|
| ERS–2 | ESA (Europe) | SAR, ATSR–2 Wind Scatte-rometer | All weather vessel monitoring; Sea surface temperature moni-toring; Wind field monitoring |
| NOAA | NOAA (US) | AVHRR | Sea surface temperature monitoring |
| Radarsat | (Canada) | SAR | All weather vessel monitoring |
| Adeos | NASDA (Ja-pan) | OCTS | Chlorophyl concentration monitoring; Algal bloom monitoring; Sea surface temperature monitoring |
| Orb View 2 | Orbital (US) | Seaways | Chlorophyl concentration moni-toring; Algal bloom monitoring |
| Early Bird | Earthwatch Inc (US) | Panchromatic Camera Multispectral Camera | Vessel monitoring |
| Quick Bird | Earthwatch Inc (US) | Panchromatic Camera Multispectral Camera | Vessel monitoring |
| Ikonos | Space Imaging Inc (US) | Panchromatic Camera Multispectral Camera | Vessel monitoring |
| Orb View 3 | Orbital (US) | Panchromatic Camera Multispectral Camera Hyperspectral Imager | Vessel monitoring As yet unknown applications for hyperspectral data |
| Orb View 4 | Orbital (US) | As Orb View 3 plus SAR | Vessel monitoring |
| Envisat | ESA (Europe) | Advanced SAR Advanced ATSR MERIS | All weather vessel monitoring Sea surface temperature Ocean colour |

Tables provided by Mr. Robert Gallagher of navigs, s.a.r.l., May, 1997

Most fisheries enforcement monitoring applications will require the ability to conduct wide-area surveillance with sufficient spatial resolution to observe features at scales ranging from several meters (or less) for monitoring fish habitat, surface-detectable fishing gear such as driftnets and shipwake detection, to several tens of meters, to observe large factory trawlers. Moreover, this wide-area capability needs to be carried out under all-weather conditions. Satellite-based SAR may provide much of

the capability to meet these observational requirements. While the results of the ship and wake detection experiment are not yet available, sufficient investigations have preceded this work to suggest that satellite-based SAR can detect ships and their wakes under most conditions, except for conditions of high surface winds and waves. Where civilian SAR systems, such as RADARsat, lack sufficient spatial resolution to provide the needed detail for target classification, they may serve as a cueing tool for higher resolution remote sensing assets. In order to make aircraft reconnaissance flights more efficient, SAR observations of ocean regions could provide the basis for vectoring aircraft to suspect vessels for identification and photographic documentation.

For island nations with vast ocean EEZs, the wide-area surveillance capability of satellite-based radar for ship and wake detection has the potential to provide enormous economic benefits. Millions of dollars in licensing revenue may be lost each year to these island nations as a result of illegal fishing conducted unobserved or unchallenged, in their EEZs.

To serve as an operational fisheries surveillance tool, satellite-based remote sensing systems must have the capability to: 1) provide processed image data to users in near-real time (3-6 hours after observations), 2) provide georeferencing of images to less than 500 meters, 3) have an onboard storage/playback capability to permit observations in regions without ground stations, and 4) if the system is operated as a commercial enterprise, have a pricing policy that accommodates users with routine monitoring needs at affordable rates. (*)

To monitor compliance with fisheries regulations in near-shore areas defined as from the shore out to 200 nautical miles, patrol-based surveillance assets must use state-of-the-art detection technology. Several examples include, but are not limited to, advanced radar systems, digital video and still photography equipment, unmanned aerial vehicles, computers and Geographical Information System (GIS) computer-based mapping and tracking software.

# Vessel monitoring systems – How can the industry help?

Many nations are implementing vessel monitoring system (VMS) technology for vessel control and monitoring. The European Commission is leading the way with its program. Additionally, the United States, Australia, New Zealand, the Forum Fisheries Agency, Canada, Chile, Argentina, and several Asian countries are experimenting with or implementing major VMS programs. Generally, VMS involves integrating satellites, radios, cell phones and other communication systems with GPS or other accurate positioning systems to monitor the exact location of fishing vessels in real or near-real time. Established and emerging technologies using satellite-based fishing vessel tracking, catch reporting and communications provide a powerful tool for fisheries enforcers, managers, scientists, search and rescue officials, fleet managers and the fishers themselves.

(*) D.R. Montgomery, W. Pichel, and P. Clemente-Calon, "The Use of Satellite-Based SAR in Support of Fisheries Enforcement Applications."

While most VMS transceivers provide position reports only, these shipboard units, when connected to a personal computer or other programmable input device, can provide access to email, the internet, weather data, current fish prices, and countless other types of value-added information. They can send and receive messages, send catch reports in real time and can provide confidential communications between the vessel and a business, the regulating agency, a spouse or loved one and other vessels.

Sensors connected to VMS transceivers can send information on engine functions such as oil pressure and fuel consumption. Environmental sensors can send critical information on ocean and atmospheric conditions such as air and water temperature, barometric pressure and wind speed. Providing this information improves weather prediction and forecasting which, in turn, increases the safety for those entrusting their lives to the sea.

We desperately need applied research into the practical application of employing sensors that will send data through the VMS to distinguish between fishing and non-fishing activities. Sensors can measure loads on engines, increased exhaust temperature, winch and other gear deployment and retrieval equipment operation. Sensors attached to gear can signal when placing gear in the water may provide evidence of fishing activity that would help enforcement officials distinguish between lawful and unlawful activity. If the fisher knows that the technology is in place and functioning properly, voluntary compliance usually follows.

Achieving voluntary compliance takes acceptance and cooperation from the stakeholders. "Friendly," industry-supported VMS programs are more likely to succeed than "hostile," unsupported programs. The industry needs to join together in supporting, developing and helping to implement this technology. By recognizing its many benefits of increasing compliance, rebuilding depleted fish stocks, improving communications, sharing data, and saving lives, fishers can play a key role in ensuring their future and improving their safety.

# Marine forensics – Applying natural and physical science to the fisheries enforcement mission

Forensic science applies natural and physical science to the resolution of matters within a legal context. Therefore, forensic science involves the comparative and analytical analysis of the evidence, culminating in testimony regarding interpretation of analyses in the context of the crime.

Marine Forensic Programs have provided scientific assistance to fisheries law enforcement since the late 1970's. These programs are involved in Marine Biotechnology, Marine Biotoxins, Marine Ecotoxicology, Marine Lipids and Marine Mammal research within the laboratory. This work is only the beginning. The wide breadth of expertise in the world of ocean science lends itself well to the multi-disciplinary approach of marine forensic analyses.

In the early 1980's, marine forensics programs began using techniques such as isoelectric focusing (IEF) of soluble muscle proteins for species identification. This technique became further enhanced through the analyses of applying specific enzyme staining in a second gel, as a confirmation. Requests for the identification of

other species and marine resource parts and products led to the development of another method for species identification using fatty acid profiling.

Requests to identify species that IEF could not resolve and for evidence other than fresh meats such as blood and cooked meats led to directing research into the development of PCR-based DNA techniques. Combining these techniques with biochemical analyses, species identifications are possible in cases concerning endangered, protected, and regulated or otherwise managed marine species. We are only beginning to develop and use the forensic tools available to aid our investigations of illegal activities such as the unlawful importation and sale of protected species parts and products and to detect violations of fisheries laws. More recently, marine forensics has provided field investigative expertise in coordinating our responses to unusual mortalities of marine species.

In the future, forensic DNA or IEF test kits are needed to identify seafood products "on scene," when inspectors examine boxes of fish filets mislabeled to conceal to actual contents of valuable, but prohibited species. Detaining shipments of perishable, fresh fish while samples are sent to a lab, examined, and the results produced can have clearly disastrous consequences.

## Data management – Making the most of available information

Regulating fisheries is a pervasive business. Massive amounts of information are gathered daily and stored. In today's world, with rapidly expanding communication capabilities, sending and receiving data is no longer the problem. However, managing ever-increasing amounts of data from multiple sources is the key to success. The exercise of sorting data from a variety of sources, sharing data within agencies, among agencies and in certain cases, across international boundaries, is critical. Information management technologies are years ahead of their practical application within most fisheries law enforcement agencies.

In an ideal world, the movement and activities of fishing vessels should be known to officials at all times. Remote monitoring of compliance with EEZs, closed areas, and transshipping activities could occur today using existing VMS technology. Global implementation of VMS would drastically reduce the need to spend countless hours and millions of dollars searching for fishing vessels. Once targets are determined for random or compliance-related boarding, inspectors need information technology tools to simplify the inspection process and aid in detecting violations. Arming our fisheries enforcement officials with data identifying the vessel's characteristics, history, permit, fishing locations, quantity and composition of catch, and prior violations are basic requirements. These are not available to many inspectors as they struggle to complete their tasks.

## Compliance behavior – The human factor

Information management technology can play an important role in modeling and studying the underlying causes of non-compliance with fisheries regulations. Non-compliance plagues every nation. If we focus exclusively on applying resources to

researching, developing, and implementing technologies that increase our ability to catch the poachers and bring them to justice, we may forget that technologies exist enabling us to study the motivations underlying a fisher's compliance or non-compliance with the regulations.

What are the human factors underlying fisheries violation? The truth is, human factors surrounding fisheries compliance have not received much attention. Technologies, models and methodologies directed toward research on the role of non-monetary factors as well as the economic benefits and perceived costs of committing a violation in determining compliance behavior will pay high dividends in designing successful management programs.

The results of surveys, interviews, questionnaires and other data assimilation tools could provide valuable information to managers and enforcers alike. Armed with this knowledge, we can employ problem-solving techniques that identify new approaches to old problems of non-compliance. Worldwide, in areas outside the natural resource enforcement arena, programs involving community-oriented policing and problem solving, voluntary compliance and other concepts work extremely well. These programs generally involve determining the causes of non-compliance and developing solutions by working with the community or regulated industry.

Application of new technologies, implementation of improved regulatory programs and increased communication and cooperation with the regulated industry are all possible outcomes of gathering information on what motivates fishers to comply or not comply with management measures and regulations. Solving this question will result in increased voluntary compliance, reduced reliance on more costly enforcement schemes and enhanced effectiveness of existing resources.

# Conclusion

In summary, we must use existing and emerging technology to detect, apprehend and prosecute fisheries violators while using other available technologies to determine the "human factor" involved in committing living marine resource crimes. Decreased or non-existent fiscal resources for traditional patrol and surveillance platforms are a reality. Increased reliance on the practical application of applied technology research to seek out the underlying causes of non-compliant behavior and detect the violations that comprise the root cause of overfishing and global depletion of marine resources will help sustain a healthy ecosystem while reducing costs.

# Monitoring and enforcement of fisheries regulations

*Denis Bailly, OIKOS, Rennes*

Monitoring and enforcement in any activity is always a matter of allocating scarce public resources to the implementation of regulations justified by motives related to security, public health, social, economic, conservation or other objectives. The main incentive to comply with regulations is built-in with the definition of sanctions. In the regulation of commercial activities like the fisheries, sanctions are based first on economic incentives (fines), secondary on temporary prohibition of activity. The degree of compliance is a mix of effective dissuasion by these sanctions and moral incentives toward compliance. Explicitly or implicitly, the implementation of control considers that there is a limit in the capacity of the authority in charge to find infringents to the rules but also to impose sanctions directly or through prosecution. Looking at the implementation of regulations related to fisheries management, and excluding the cases of control related to safety or public order at sea, we may raise few questions.

First is the fact that in most cases the level of fines is far below the benefit of illegal fishing if we consider the probability of control. In many fisheries, vessels at sea are not controlled more than few times a year if any time. But the average benefit of one fishing trip is often above the maximum fine.

Second is that in the European countries, but not only, a fair proportion of illegal fishing cases prosecution is stopped before the sanction is imposed. There are many ways to do so, ranging from political pressure to local collusion and corruption. The local social peace is often quoted as the rational of that situation.

Third, fisheries regulations don't aim to control criminal or other socially unacceptable behaviour. Some intend to improve fishing efficiency in terms of physical or economic productivity other to limit the negative impact of fishing on marine ecosystems (environmental). For the first group the "benefit" of compliance do not go beyond the improvement of economic or living conditions of fishermen. As such there is little interest for the whole society to spend money on setting and implementing regulations. As the cost of it is not internalised by sanctions, as seen above, means to have the control paid by the beneficiary should be sought. The second group, environmental protection regulations, is based on a public concern. But the balance of foregone fisheries private benefit and conservation public benefit is more in political terms than any other. Therefore power relation play a major role in the effective level of implementation of these regulations.

Fourth, many of the illegal practices are incidental of "normal" practice. They are "joint products". Complying with such rule as no discard would mean no possibility of viable operation for many boats. This makes the implementation of control and sanction almost inapplicable. In other cases it is observed that, despite the high

potential benefit of non-compliance, a large part of fishermen behave according to rules. The social or moral incentives to comply seem to play a significant role.

All these consideration, lead the conclusion that the way to design regulations and to implement them should first reviewed to be adapted to the specificities of the case of fisheries.

# Session report

*Robert Crooks, MAFF, London*

**1.** In opening the Session **Snr Monteiro (Director General of Portuguese Fisheries)** sought to stimulate debate between managers, experts and technologists, against the background of the opportunities for Marine Research presented by the Fifth Framework Programme, opportunities which had only been included after some hard negotiations. He introduced the key-note speaker, **Mr Springer,** from the US National Marine Fisheries Service. Mr Springer had successfully led the US negotiations with Japan and other Pacific States on the introduction of Satellite Monitoring for the North Pacific Drift Net Fishery and now led the US Satellite Monitoring Programme for Fisheries.

## Keynote Speech

**2.** Mr Springer emphasised the criticality of the sea fisheries situation citing a CNN special that very morning on the devastating effect of fishing on the World's Oceans. There were many technologies and much science available to assist in managing and enforcing regulations on sea fisheries, but clearly there were still too many fishers chasing too few fish. He encouraged participants to think "outside the box" and to look at the issues in making better use of and getting better value from the science and technology available.

**3.** With vast oceans to be surveyed, comprehensive use of expensive patrol vessels and aircraft was not affordable. In any event for small remote island states there was often little resource or funding for any enforcement activity at sea. There needed to be a clear International strategy for deploying resources for global surveillance of fisheries to ensure the appropriate and cost-effective use of existing and new technologies.

**4.** He emphasised five areas where technologies and scientific research could be more focused on the needs of enforcers.

### 1. Remote sensing technologies

Satellite-based wide-area surveillance technologies clearly had the opportunity to meet the need for comprehensive surveillance but if they were to be of practical benefit to enforcers, Mr Springer believed that such technologies would need to be able to:

i) deliver a near real-time service (response within 3-5 hours of request)

ii) provide geo-referencing of images

iii) have on-board storage and playback mechanisms for areas out of range of ground stations

iv) accommodate customers with routine surveillance requirements at affordable rates

## 2. Vessel Monitoring Satellite systems

Automatic satellite position reporting systems provided the opportunity for benefits to both managers and fishermen. He believed the introduction of sensors (eg for engine exhaust temperature and gear deployment) and the provision of sensor data alongside position reporting could assist Enforcement Authorities in distinguishing between fishing and non-fishing activity. More applied research was needed in this area. With such systems adding to the evidential weight of position reports he thought that more voluntary compliance could be gained from fishermen.

He asserted that 'friendly' rather than 'hostile' programmes with shared use of terminals were more likely to succeed. Fishermen greatly value the weather, safety and market information services that are now becoming available over satellite links. He cited the example of personal communications, e.g. between husband and wife, as being of great benefit in the Hawaii fishery satellite programme creating a dependency on the terminal that could not then be so easily broken by the fishermen. With shared use and common aims satellite systems could play a key role in conserving stocks and improving the life of fishermen at sea.

## 3. Marine forensics

Mr Springer considered the aim here was to develop the practical means for delivering the analyses required to enable an Inspector to determine the species and if possible the provenance of fish caught whilst on board or at the place of landing. A portable DNA toolkit would be extremely useful if backed up by accepted science — recourse to laboratory assays whilst fish rotted was clearly unacceptable.

## 4. Data Management

A clear priority for an enforcer was to have key data about a vessel and its activities at the time of boarding or inspection at the quayside. Integration and presentation technologies needed to be focused on the decisions the Inspector had to take before and during an inspection

## 5. The Human Factor

It was too easy to get carried away with the technology and forget about the people involved. There was a dire need to understand more clearly the motivations of fishermen. Analyses and surveys were urgently required to understand the reasons for non-compliance. Experience in other fields suggested that determining causes and then working with communities to develop solutions could be very effective. Getting policemen 'out of their police cars' could be an alternative and more fruitful approach to the problem of sea fisheries than applying more enforcement technologies.

**5.** In concluding Mr Springer believed that in principle there was already sufficient technology available to tackle the problems of fisheries enforcement, the key issue was getting the technology applied, accepted and delivered to the front-line of enforcement activity.

**6. Snr Monteiro** next introduced **Mr Bailly** as the Provocateur. Mr Bailly was a Professor in Marine Economy and Law at the University of West Brittany, having obtained degrees at Tokyo and Grenoble Universities. He was a well-known expert in the monitoring of coastal resources and his article on the Fisheries Crisis had been included in the 1993 Larousse Livre de l'Annee.

# Provocateur speech

**7. Mr Bailly** considered that there was a need to return to an analysis of the basic economics in fishing. He set down three questions for debate

1. Is current enforcement and surveillance activity costing more than it delivers in benefits?

He asserted that technology should be used to drive down costs not to add further expense. We must be aware of the Orwellian fallacy of accumulating more facts and observations to no purpose

2. Why do we manage fisheries?

A recent analysis of European Regulations suggested a move from improving the productivity and marketplace for fishermen to one of conservation of fish stocks. Mr Bailly believed we had to be clear about the purpose of regulation. On matters of conservation, it might be justifiable to have enforcement costs borne by tax payers. However it was not so clear that the tax payers should bear the costs if enforcement regulations are concerned with improving the marketability and profitability of the Industry.

3. What are the key inputs, outputs and ownership issues?

Mr Bailly believed that monitoring had to be considered in a wider socio-economic context that included issues of ownership and access rights. Could we continue with the notion of fish as a Common Resource when the life and well-being of our Oceans and ultimately ourselves depended on healthy fish stocks? Rather than responding to the increase in non-compliance with more enforcement should we not step 'out of the box' and understand the wider socio-economic issues? Might not a policy of constructive engagement, education and collaboration bear more fruit (or fish!) in the longer term?

# General Discussion — 1

**8. Snr Monteiro** thanked both the speakers for setting a number of important issues for discussion and invited questions from attendees.

**9. Mr Levieil (DG XIV, European Commission)** was anxious to know about existing and forthcoming research that put Fisheries enforcement in a wider environmental context.

**10.** A speaker from **British Maritime Technology** addressed the Remote sensing criteria set down by Mr Springer. Certainly Earth Observation Satellites did not provide frequent coverage, some maybe taking up to 14 days to return to the same location. Remote identification of vessels was a key issue being faced by a number

of Agencies not just those involved in enforcement. But he believed that the required technologies were there to solve these issues, what was needed was collaboration between technologists, academic researchers and the various Agencies involved. This was the key horizontal issue to be addressed

**11.** An economist agreed with Mr Bailly that a wider socio-economic approach was necessary, employing more resources on enforcement was clearly not working. Perhaps incentive rather than coercive systems could gain greater compliance. Had the economic of employing inspectors on board fishing vessels been properly considered?

**12. Mr Legende (IFREMER)** considered that the Session was focusing on controlling the fisherman and neglecting the question of monitoring stocks. More work was needed to understand the science of fish reproduction cycles, and to develop technologies for locating and distinguishing stocks. There was already sufficient technologies available for enforcement, the question was now one of effective policy, regulation and application. However there was much still to be done on stock assessment.

**13. Snr Veiga (FRESTI, LDA, Lisbon)** wondered how far one could go in using a remotely sensed image in obtaining a prosecution? Were there any cases known by the audience?

**14.** A speaker from the **Institute of Marine Biology in Crete** emphasised the need for consensus between fishermen and scientists in assessing stocks and in agreeing which needed protection. This was now necessary on a global basis given the increasing exploitation of stocks on the high seas.

**15. Snr Machado Leite (Director, Portuguese Fisheries Inspectorate)** was concerned that there should be a focus on making enforcement cost-effective. There needed to be clear, and consistent rules across the Community for implementing enforcement measures. He believed this was not the case too much discretion had led to fuzziness in implementation that did not help enforcers. On the question of evidential quality, the Portuguese Inpsecotrate was now submitting dossiers for prosecution cases that included prints of fishing vessels positions from their Satellite Vessel Monitoring system alongside more traditional enforcement evidence such as photographs and written witness reports. He hoped this would build confidence in the VMS data and as yet this type of evidence had not been challenged by the Courts.

# Responses — 1

**16. Snr Monteiro** summarised the first group of questions as falling into two main areas:

1. Getting better use from new and existing technologies, where greater collaboration and clarity was called for and attention to the Human Factor and on bringing technology into application were key issues
2. The question of monitoring resources.

**17.** He invited responses from the speakers.

**18. Mr Springer** in responding to the use of technologies and the Human Factor, cited the experience of the US in running eight(8) different Management Councils which sought to bring together scientists and the Industry to establish agreed stock assessments. At these Councils fishermen and scientists continued to disagree on assessments and sadly some 70% of US stocks were now over-exploited. There was a key need for research into how we can establish effective enforcement regulations, collaboration with all the parties involved and achieve compliance.

**19. Mr Bailly** considered that fish stocks and fishing both needed to be monitored but in different ways. He believed that fishing was primarily an economic activity. The driving imperative for fishing vessels was to be profitable. One extreme view held was that if the market was allowed to regulate itself then there would be no need for Administrations to know the state of the stocks. The last fish could never be caught and stocks would always be able to cover whereas Industry could not. Whilst not subscribing to this view he believed the wider economic view had to be taken. The Canadian Newfoundland and US collapses were due to over-investment by Government in fishing vessel capacity.

**20.** If the satellite 'blue boxes' were to be accepted by Industry then they would have to be seen in the context of assisting a vessel's profitability e.g. they would enable the Authorities to weed out fraudsters, they could provide information to direct fishing activity to good legal fishing grounds. If 'blue boxes' were to be used for conservation purposes then fishermen's freedom of activity will be curtailed and they will lose money. Fishermen were confused as to the purpose of the 'blue boxes'.On analysing recent EU fisheries legislation it was clear that the majority were not aimed at improving the profitability of the Industry but at conservation.

**21. Mr Levieil** noted that no Session had been included at the Conference on Fish Stock assessment research as this was a large subject in its own right. He wished to hear more discussion on the practical issues of applying research and technologies to enforcement activity and where further research could be directed. There was already some work being done on enforcement technologies and he reminded attendees of the Poster exhibition for the EU's 4th Framework programme research projects, but clearly more was required in the area of applying technologies. On the evidential standing of remotely sensed images he thought there were a whole raft of issues not least those relating to scale, distance and authentication.

# General discussion — 2

**22. Snr Monteiro** invited further questions from the floor.

**23. Snr Leite** returned to the issue of appropriate regulation and wished to understand more about the preparation of regulations and the involvement of Industry in this. On the evidential quality of photographs, his Inspectorate often presented photos taken at 45-50 metres altitude sufficient to see ropes for nets and activities on-deck. A comprehensive date/time/location stamp was automatically inserted on each negative at the time of the photo being taken.

**24. Mr Jorgensen (Statistics Dept, Denmark)** wished to have the opinion of the speakers on the idea of all the global fish stocks being sold to private industry with the proviso that after ten(10) years the biomass of the stock should either be the same or higher

# Responses — 2

**25. Snr Monteiro** invited final comments from the top table

**26. Snr Cavaco (Commission)** clarified the wide participative process involved in preparing Community legislation. Fishermen and their Industry representatives are involved regularly in wide-ranging discussions and consultations. Even now there was a proposal under the UK Presidency to increase the openness and transparency of enforcement controls across the European Community as well as improving controls for post-landing activities and over 3rd country vessels fishing in EU waters. He emphasised that under the Council's direction for subsidarity enforcement was a matter for individual states to implement. However there would always be room to do more.

**27.** Noting the discussion, the areas of research he would particularly wish to see taken up included:

1. Aerial observation
2. Evidential issues
3. Traceability of the origins of fish
4. Information management
5. Socio-economic aspects
6. Cost-benefit work

**28. Mr Levieil** re-emphasised the panorama of projects currently funded under the 4th Framework programme but was keen that more should be done using a multi-disciplinary approach to explore the problems of fisheries enforcement activity.

**29. Mr Bailly** noted that Agriculture had tackled the ownership problem of the 'Commons' a long time ago and it was legitimate to question why fisheries have not similarly been handed over to private ownership. Whilst he did not believe this sole measure could solve the problem it would be worth considering further to highlight and clarify issues relating to exploitation, straddling and mixed stocks, consumer and environmental protections and what guarantees could be used to ensure that responsibility went with ownership. He pointed out that Regional Committees were already being instituted within and between Member states for shared waters such as the North Sea.

**30.** In closing the discussion and debate **Snr Monteiro** invited **Mr Crooks (Ministry of Agriculture Fisheries and Food, UK),** as Rapporteur, to sum up the discussion. After this he finally thanked everyone for their contributions and the Speakers for their time and effort in providing the useful and stimulating inputs for this Session.

# INTERACTIONS BETWEEN ENVIRONMENT, POLLUTION, FISHERIES AND AQUACULTURE AND THEIR IMPACTS ON SOCIETY

# Keynote speech

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## Abstract

El Niño events are only well advertised examples of climatic interannual variations. Other climatic events are observed all around the world and often affect short-lived species like small pelagic fish. In some instances it is possible to understand and model the underlying processes responsible for variations in stock abundance and/or catchability. Some examples of modelling attempting to conciliate the tenants of the hypotheses of major environmental effects with the tenants of major impact of exploitation on the fish abundance are presented. If there is a lag between the environmental change and the effect on the stock, as in the case of pre-recruitment effect, the models allow a certain level of predictability. If there is no or only short lag periods, as in the case of catchability, one must rely on environmental predictive models, which are still rather unreliable despite some encouraging findings on lagged remote connections between oceans (Pacific and Atlantic ENSO events).

## Introduction

The evolution of marine species have enabled fishing resources to adapt to short-term and periodic (diurnal and seasonal) environment variations which can take the form of vertical and horizontal migration, reproduction strategies, etc. Concomitantly, fishermen adapted their fishing gears and strategies in order to maximise their yields in response to these periodic alterations in the environment and in fish behaviour.

Also observed but less predictable are interannual and decadal variations in the environment. Long-term environmental variations are usually of smaller amplitude compared to diurnal and seasonal variations, but they can greatly affect both abundance and catchability of the resources, even though we are just starting to understand the underlying ecological processes.The main debate at the end of the 19th century was to decide whether fishing activity had or had not a major influence on fish abundance. After a long debate on the causes of fluctuations in stock abundance (natural fluctuation *versus* influence of fisheries), which culminated in 1883 during the London Exposition, it was recognised that better knowledge was needed to manage the fisheries (review: Smith, 1988). This task was assigned to the International Council for the Exploration of the Sea (ICES). While the ICES overfishing committee, chaired by William Garstang, focused initially on the causes of stock abundance, the migration committee, chaired by Johann Hjort, paid attention to fish movements and the availability of fish to fishers. In 1907 Hjort (1908)

first suggested that fish age distribution be studied in order to understand the variability in catches.

A century later, after much investigation aimed at demonstrating the importance of the effects of fisheries, and after the development of sophisticated direct or indirect methods for measuring their impact and managing the fisheries accordingly, the debate has resumed for both pelagic (e.g. Beverton, 1990) and demersal species (e.g. Hutchings, 1996). There is no longer any doubt that fishing activities influence stock abundance, but the huge variations in stock abundance, from outburst of several hundred thousand tonnes to collapse, are more and more related to other factors that probably interact with the fishery. Among them, changes in environmental conditions and the modification of stock distribution are likely to play a major role. From 1983, at least six international symposia have been devoted to this topic and from the end of the 1980s the annual ICES meeting has had special sessions related to this problem. During the present decade, servile working groups (SCOR 98; GLOBEC WG) are tackling this same issue.

Interactions between the environment and fisheries can be direct or undirect. In the case of direct interactions, the fishing operations themselves depend on the environment. Typically this is the case of poor weather conditions disturbing either setting the fishing gears or detecting the fish concentrations, or simply preventing fishermen to leave the harbour. These extreme situations are unfortunately common, especially during some seasons of the year. Both fishermen and fishing industry suffer from this inconvenience and try to limit they negative effects by improving the technology in order to get rid of the weather conditions or by alternative activities or simply by a seasonal closure of the fishery. Nevertheless, during some years such periods of poor weather condition are longer or stronger than expected and, as a result, the whole sector of activity is affected. In the worst periods fishermen risk their own life in fishing in dangerous conditions in order to limit their economic loss due to bad weather, especially when the fishery is managed by strict limited period of access to the fishing grounds.

Undirect interactions between the environment and fisheries are more subtle and diverse than direct interactions. It is often difficult to distinguish between an effect of environment on the catchability of the resource and an effect on its abundance.

# Effect of the environment on abundance

Let us see for instance the case of the pelagic resources. This species are characterised by a high fecundity: an adult female currently spawn 100 000 eggs per year. In demersal species the fecundity is not so high, but still much more elevated (currently 10 000 eggs per year) than most of the terrestrial species. This is an evolutionary response to the dispersive environment in which fish eggs are released. As expected a huge mortality occurs in the first stages of life, which decline rapidly. At the age of recruitment, fishing mortality is often higher than natural mortality when the stock is currently exploited. Factors responsible for mass mortality in the early stages are numerous (predation, advection, and starvation) and often depends on environmental factors at small time and temporal scale. A small perturbation in the spawning area during a few weeks can result in a failure of cohort for many years in the whole fishing grounds. This kind of decoupling between scales makes it difficult the investigation of the effect of the environment on the stock.

While temperature often sets limits on the geographical extent of species distributions, in the recent literature it appears to be less important than upwelling processes and locations promoting retention of larvae in these advective systems. Such retention area — often located near the coast — minimise turbulent mixing of the water column (Parrish *et al.*, 1981; Bakun and Parrish, 1991). Recent work on circulation indicates that retention can occur in certain areas even when a wind-driven upwelling is fully developed, due to special topographical features which favour double cells of circulation (Graham and Largier, 1997; Roy, 1997). Bakun (1996) defined the "triad" of processes suitable for coastal pelagic fish reproductive habitat: enrichment (upwelling, mixing etc.), concentration (water column stability, convergence, frontal formation) and retention of ichthyoplankton within (or drift toward) appropriate habitat. In this triad, some factors are related to long-term habitat selection and others to the short term. Among those last ones, the current and turbulence play a major role, and optimal values of wind during the reproduction period are expected to provide a suitable compromise for larval survival (Roy *et al.*, 1992). As a consequence of optimal value of wind speed, its effects on the abundance is not necessarily linear and even not monotonic. Similar non-linearities are likely to exist for other environmental variables and we must make use of other statistical tools (e.g. general additive models) than the conventional ones to track these relationships.

Decadal variations in the environment become more obvious from the retrospective analysis of long environmental data series or reconstructed data series using proxy variables such as growth rings in long lived trees or stratification in polar ice.There is growing evidence suggesting that these long term variations in the environment are responsible for regime shifts in the ocean (Lluch-Belda *et al.*, 1989; Kawasaki, 1992; Bakun, 1998). The most obvious evidence of regime shifts are the switches in abundance between dominant fish species in the main upwelling ecosystems (e.g. shift between anchovy and sardine). Our predictability of environmental shifts is presently very poor. Despite some evidence of low frequency bands in the signal, there is little hope for reliable prediction in the future. Nevertheless decadal variations in the environment is in essence slow and highly autocorrelated. Marine resources appear to largely integrate the superimposed year to year variability, as far as switches in dominant species are concerned. Therefore, if regime shift is confirmed by further statistical analysis (in particular by an exhaustive comparative approach), there is hope for a certain degree of prediction of dominance between pelagic species once the shift has clearly started.

# Effect of the environment on catchability

In contrast to the lagged effect of environment on the abundance, the influence on catchability is usually immediate or shortly lagged. It can occur at different time scale, from circadian variation do interdecadal ones, and can affect either the type aggregation or the habitat selection.

## Circadian in catchability

The patchiness of pelagic fish distributions is known to change according to circadian and seasonal rhythmicity, but there are also some unusual examples of weekly variations due to exploitation and yearly variation.

In the Namibian purse seine fishery, Thomas and Schülein (1988) found circadian cycles in the catch frequency and catch per set of the different species. Similar examples are provided off Argentina by Matsumiya and Hayase, 1982. In the Senegalese purse seine fishery, the mean catch per set varies according to the time of day, with higher values early in the morning. This means that biggest schools occur early in the morning, at least if we assume that the catch per set is proportional to school size (Fréon *et al.*, 1996). If the circadian or seasonal fishing pattern is changing from year to year for external reasons (market, changes in target species, etc.), the consequences of circadian variability of the coefficient of catchability q on the mean CPUE will be a bias in abundance estimates.

Large predators (fish or mammals) are also able to split large schools into several small schools, less suitable for commercial fisheries. Predation on schooling fish is more likely to occur during twilight periods when stalking predators have an advantage over shoaling prey under low light levels (Pitcher and Turner, 1986).

## Seasonal changes in catchability

Seasonal variation of patchiness might influence catchability. In the Senegalese fishery, the mean catch per set of *Sardinella maderensis* displays a clear seasonal pattern, from 3 t $set^{-1}$ in winter to 6 t $set^{-1}$ in summer, despite similar body length composition (Fréon, 1991).

Many fish species choose to forage in different areas according to the season, and reproduction often occurs away from foraging areas. Therefore, if the fishery does not cover the whole area of the stock distribution, or if fishing effort is not equally allocated to the different sub-areas, then a seasonal component will appear in the CPUE.

Such situations raise the problem of a proper estimate of an annual index of abundance. Even if mean annual values of catch and effort are used in surplus models, the CPUE will give a biased indication of abundance variation because two assumptions are seldom met:

(a) the seasonal timing of migration must remain exactly the same from year to year (in particular, the time spent by the stock in the area accessible to the fleet must remain constant);

(b) the seasonal pattern of exploitation must also remain constant, particularly the yearly proportion of fishing effort allocated each season to the different fishing sectors and to the different target species in multispecific fisheries.

Nowadays, an efficient and objective procedure to deal with these problems of abundance estimation when the availability varies seasonally is to use 'deseasonalised' CPUE. Modern statistical software allows the incorporation of various effects in the general linear models (GLM; see recommendations in the last section).

## Influence of the lunar phase on catchability

Fish aggregations may also change according to the phase of the moon, probably in relation to the light intensity. These changes are generally associated with vertical migration and therefore habitat selection (review in Fréon and Misund, 1998). Nevertheless the influence of the lunar phase is not always observed, and when it is

significant, the phase associated with the highest CPUE depends on the species and the gear. In cases of demonstrated lunar phase effect, if there is any interannual change in the pattern of the fishery with respect to the lunar cycle (e.g. according to seasonal closure of the fishery), it could be suitable to take this cycle into account in a GLM procedure.

### Annual changes in aggregation

At small scale, the aggregative behaviour of the fish might change from year to year and this change can also be density-dependent or related to environmental changes that are not always identified. Let us see now these two situations.

Long-term changes in stock abundance of pelagic species are often associated with simultaneous changes in catchability, inversely proportional to the area occupied by the stock (Ulltang, 1980; Csirke, 1988), which could be a social aggregation effect. In contrast, change in catchability may occur without change in abundance when long-term changes in the environment influence the aggregation pattern (Mangel and Beder, 1985). For pelagic stocks exploited by purse seiners, the usual CPUE is computed using the time spent searching for schools. Evidently in such situations this CPUE will not reflect the range shrinkage of a stock, nor will it show variation that is related to abundance fluctuations, but only to change in the catchability.

## Interactions between environment and exploitation

One of the key-questions concerning stock assessment of highly variable resources is to know how the large variations in abundance are expressed in terms of density, or conversely whether the area of distribution is related to abundance. Swain and Sinclair (1994) found that the area containing 90% of the cod from the southern stock of the Gulf of St Lawrence was density dependent, in contrast to the core area (50% of the stock). They modelled fish distribution and proposed a figure showing two extreme cases of variation in fish spatial spread according to the biomass (constant density or density proportional to biomass) and a threshold of density used to define the exploited stock area (A).

Most indirect methods of stock assessment are based on density estimation because they use the CPUE as an index of abundance (e.g. surplus-production models) or as a tuning variable for ASA models. From a theoretical point of view, Fréon and Misund (1998) distinguish at least three main mechanisms of change in abundance in pelagic fish which will match better with one or the other of the extreme cases of change in density proposed by Swain and Sinclair. They also propose to relate these three mechanisms to some major changes reported in the major fisheries (not reported here).

**In the first case (Fig. 8.3a),** changes in biomass are mainly due to variations in the fishing mortality F. These variations can be related either to modifications in the nominal fishing effort E, or to changes in the catchability coefficient q in relation to changes in the environmental conditions without major change in the carrying capacity. But this contrast between a variation in F due to the modification of E or q is an oversimplification of a complex reality because in the first scenario we have:

$E\nearrow \rightarrow F\nearrow \rightarrow B_t\searrow$

(where $\nearrow$ and $\searrow$ represent increasing and decreasing values respectively) but the variability of q is also likely to occur because the decline of the biomass $B^t$ might increase the catchability (McCall, 1976; Ulltang, 1980; Csirke, 1988). This will create a loop in the process, sometimes responsible for the stock collapse:

$E\nearrow \rightarrow F\nearrow \rightarrow B_t\searrow \rightarrow q\nearrow$

$\quad - \leftarrow \leftarrow \leftarrow \leftarrow \leftarrow \downarrow .$

The social behaviour of fish is thought to be responsible for this increase in catchability because the population maintains a constant density, even when depleted, and therefore the stock area shrinks.

By contrast, in the second scenario (a2) the increase in catchability can be attributed to different mechanisms related to environmental modifications (V), such as changes in accessibility (e.g. modification of the vertical distribution owing to changes of the thermocline depth) or in vulnerability (e.g. modification of the avoidance reaction related to changes in turbidity):

$V\nearrow \rightarrow q\nearrow \rightarrow F\nearrow \rightarrow B_t\searrow$ (or reversal changes)

where $V\nearrow$ means an increase in favourable environmental conditions. In this scenario, there is less reason to suspect acceleration in the process leading to an increase in F than in the previous scenario, nor to suspect shrinkage in the stock area, even though it can occur in the case of prolongation of unfavourable climatic conditions. But an increase of the nominal fishing effort E due to higher catch rates can also create a loop in the process:

$V\nearrow \rightarrow q\nearrow \rightarrow F\nearrow \rightarrow B_t\searrow \rightarrow q\nearrow$ (or reversal changes)

$\downarrow \rightarrow E\nearrow \rightarrow - \leftarrow \leftarrow \leftarrow \leftarrow \downarrow .$

**The second case (Fig. 8.3b)** corresponds to a variation of the biomass first initiated by environmental changes, which modify its carrying capacity:

$V\searrow \rightarrow B\infty\searrow \rightarrow B_t\searrow$ (or reversal changes).

In general, this is associated with corresponding changes both in the area (A) of the habitat and in the density, especially in upwelling areas (scenario b1) which can extend according to the strength of the wind stress. Nevertheless, the possibility of a change only in density could be contemplated, with reversibility (scenario b2) or not (scenario b3). Usually the history preceding the collapse of such stocks — especially scenario b1 — starts with a period of increase in biomass owing to favourable environmental conditions, which usually allows large benefits and consequently investment in new boats and therefore a subsequent increase in the fishing mortality. Then, when the environment becomes unfavourable, the area of the habitat shrinks. As a result, the local density increases suddenly, which in turn causes an increase of catchability. Therefore the fishing mortality is high and the stock collapses:

$V\nearrow \rightarrow B\infty\nearrow \rightarrow B_t\nearrow \rightarrow E\nearrow\nearrow\nearrow \rightarrow F\nearrow\nearrow\nearrow \rightarrow B_t\searrow \leftarrow V\searrow$

$\quad - \leftarrow q\nearrow \leftarrow \downarrow .$

The difficulty of investigating such situations comes from the interacting influence on the stock of both fishing effort and environment. Some scientists argue that the fishery plays a minor role compared with the environment (Lluch-Belda *et al.*, 1989; Kawasaki, 1992; Cushing, 1995). Moreover, records of past history of some stocks from anaerobic sediments indicate large variation of biomass without exploitation (Soutar and Isaac, 1974, Shackleton, 1987, Baumgartner *et al.*, 1992, among others). Others claim that fishing mortality dramatically increases the probability of collapse when combined with unfavourable environmental factors (Beverton, 1990; Fréon, 1988; Hutchings and Myers, 1994; Pauly, 1995). Our purpose is not to enter into this debate, but to stress how in such a situation, habitat selection and social behaviour may interfere with the abundance estimations.

**The third case (Fig. 8.3c)** is an extension of habitat selection when a species starts to colonise new biotopes vertically and/or horizontally, resulting in an outburst of biomass. Two examples can illustrate this situation: the triggerfish *Balistes carolinensis* in West Africa (Caverivière *et al.*,1981; Caverivière, 1982) and the Japanese sardine *Sardinops melanostictus* (Watanabe *et al.*, 1996).

The reasons for these sudden changes in abundance, density and behaviour remain speculative, because in most cases no environmental modification was observed, or this modification was hardly related to the species' biology (e.g. the influence of salinity on triggerfish abundance). Nevertheless, in the reported examples, knowledge of the environmental changes was generally limited to a few parameters (mainly temperature and salinity) and the biology of the species was not completely investigated. Therefore it is still possible to relate this third case to the second one.

# Some attempts of modelling the yearly variability of catchability in relation to habitat selection

## Correction of abundance indices

In case of unusual extension of habitat, the first step is to compute relevant indices of abundance before modelling (except when the model does not intend to describe the stock abundance but only the CPUE as in the next section). If the changes in stock abundance occur without a trend in the spatial change in the stock distribution ("proportional density"), the mean CPUE will be proportional to abundance, provided that the fishing pattern remains the same and that no other biases. In contrast, in the case of change in stock distribution ("constant density"), even if the fishery area follows the extension and retraction of the fluctuating stock, the mean CPUE will not give a reliable index of abundance. In the case of strict constant density and no density threshold, the mean CPUE is expected to be constant. Under these conditions of density dependence, the stock collapse can occur without warning given by the CPUE analysis. But in practice the fishing effort is usually not randomly distributed and the CPUE results from the combination of the stock distribution and the fishing strategy. Simulations performed by Gauthiez (1997) who used the two extreme cases of density distribution of (namely "proportional density" and "constant density" and four models of fishing effort distribution illustrate this point.

Instead of using the mean CPUE as an index of abundance, it is recommended to collect geo-referenced data, in order to built spatio-temporal strata. The difficulty is then to get enough observation in the different strata. This is partially obtained by enlarging the size of the strata, but there then arises the problem of intra-stratum variability of the catchability, especially for highly aggregated pelagic species. The main problem is how to deal with the lack of data in strata where no fishing operations are performed. To obtain a consistent time series of the abundance index when the density is not proportional to abundance, it is necessary to revisit historical data and to make some assumption on the fishing zone not visited during low biomass periods. Assuming that the abundance index was equal to zero in these fishing zones is usually not realistic because fishers allocate their effort to a fishing zone only when the guess of yield is above an empirical threshold. Information external to commercial data is usually necessary to make proper assumption (e.g. acoustic surveys, trawl surveys).

## Modification of surplus production models

MacCall (in Fox, 1974 and MacCall, 1976) suggests a non-linear relationship between the catchability coefficient q and the biomass in the California Pacific sardine (*Sardinops sagax caerulea*) fishery from 1932 to 1950. He proposed the following equation — even though he had to remove three years of observations to get it significant:

$$q = \alpha B^{\beta} \qquad (1)$$

where α and β are parameters. Fox (1974), who introduced function (1) in a global production model to describe the depensatory regime in some fisheries, gave a wider audience for MacCall's findings:

$$dB / dt = h B_t (B_\infty - B_t) - \alpha B^{\beta} E_t B_t. \qquad (2)$$

Equations at equilibrium derived from this model were applied to the California sardine fishery for the period 1932-1955. The model fits the data reasonably well and a negative value of β allowed the collapse of the stock to be explained.

To take into account the influence of environmental factors on stock production, Fréon (1986, 1988) proposed a modification of the conventional surplus-production models. An additional environmental variables (V) have been inserted into the conventional models so as to overcome the failure to meet the assumption regarding the constant catchability, or to take account of the changes in the carrying capacity on the biomass. Three kinds of models have been developed according to the mechanism of environmental influence (Table 2): (1) influence only on the stock abundance, (2) influence only on catchability coefficient and (3) influence on both abundance and catchability. Let us see the interesting case of influence on both abundance and catchability, which can be related to an increase of the biomass associated with an increase in catchability and vice versa.

Let $B_\infty(V)$ be the function representing the fluctuations of $B_\infty$ owing to environmental factors, and q(V) the function representing the fluctuations of q; then equations (8.6) and (8.7) become respectively (Fig. 8.9):

$$CPUE_e = q(V) B_\infty(V) - q(V)^2 E / h \qquad (3)$$

$$Y_e = q(V) B_\infty(V) E - q (V)^2 E^2 / h. \qquad (4)$$

Therefore MSY and $E_{MSY}$ values will be functions of V:

$$MSY = [B_{\infty}(V)]^2 \, h / 4 \qquad (5)$$

$$E_{MSY} = B_{\infty}(V) \, h / 2q(V). \qquad (6)$$

Note that in such models, the CPUE does not pretend to represent an index of abundance because it is accepted that q is not constant (nevertheless the fishing effort must be standardised in order to take into account the variation of q owing to non-environmental factors, such as technological changes).

The functions q(V) and $B_{\infty}(V)$ are usually not precisely known and have to be chosen according to the data. Moreover, this choice must be combined with the choice of the conventional production model: linear (like above), exponential or generalised. The set of final equations according to the choice of the q(V) function and to the basic production model (linear, exponential or generalised) is available in the expert-system CLIMPROD (Fréon *et al.*, 1993). It helps users to select the model corresponding to their case according to different ecological criteria and not only to the best fit. It uses the past-averaging approach to deal with non-equilibrium situations (for both E and V) and a jackknife procedure assesses the quality of the fit.

In some instances, a substantial part of the biomass lives in a habitat inaccessible to the fishery (deep grounds, remote areas or zones subject to strong currents, shallow water, etc.) but the proportion of the biomass unavailable to fishers may vary from year to year, depending upon environmental changes which can affect the habitat selection. Laloë (1988) proposed two global production models taking account of this "inaccessible quantity of biomass". He applied them to the stock of *Sardinella aurita* of Ivory Coast and Ghana. The formulations of the models are derived from the conventional linear surplus production model. When only the second term of this equation is modified it becomes:

$$= hB_t (B_{\infty} - B_t) - qE(B_t - \alpha B_{\infty}) \qquad (7)$$

where $\alpha B_{\infty}$ is the inaccessible quantity of biomass.

The use of age structured models does not necessarily solve the problem of the difficulty to detect catchability trends as stressed by Stokes and Pope (1987) and other factor related to the environment (Fréon and Misund, 1998).

## Extraction of spatial and temporal variability from CPUE series

Nowadays, a common technique to limit biases due to spatial and temporal variability in CPUE series is the estimation of an annual abundance applying a general linear model (GLM). This is an old method, which is now usable on large data sets thanks to modern computing facilities. The common effects entered in the model are: year, month, fishing area, vessel type or category. Nevertheless, many other relevant effect might be incorporated in the model (e.g. environmental variable affecting the catchability, moon phase, period of the day) and their interactions. Nevertheless if any interaction involving the year effect is important, it will make impossible the evaluation of an unbiased estimate of the annual CPUE by the model.

# Risk and uncertainties

Fisheries management is the next step following stock assessment and it requires additional inputs not contemplated in this paper but that cannot be ignored: social, economical and political aspects, ecosystem management, trade-offs between fisheries management and management of other users of the sea or the coastal area (aquaculture, tourism, navigation, etc.). This makes fishery management a complex task which requires a close co-operation of a broad category of actors as underlined by Caddy and Mahon (1995). Marine ecosystems are by too far complex and fisheries systems too much complex to allow a full scientific understanding. Therefore there will never be enough information to manage fisheries without risk at all (Ludwig *et al.*, 1993). A major source of uncertainty is linked to environmental changes and human activities impacting the resources. There are growing evidences showing that heavily exploited stocks are more sensitive to environmental changes and more subject to collapse than underexploited ones. Recognition of uncertainty and its potential consequences has led to the adoption of the precautionary approach in the UNDC Rio Declaration and later the 1995 FAO Code of Conduct for responsible Fisheries. Other than MSY reference points has been identified (e.g. Caddy and Mahon, 1995). It has been recognised that we need to quantify better the confidence limits of scientific advises and the robustness of management systems to uncertainty.

For instance the Bayesian approach to stock assessment determines the probabilities of alternative hypotheses using information from the stock in question and from inferences for other stocks/species (Punt and Hilborn, 1997). It makes use of the collective historical experience of fisheries sciences when estimating the consequences of proposed management actions. The use of reserves or marine protected areas for management is an old method, common in terrestrial ecology but curiously limited for marine species. It recently has enjoyed a renewal of interest (Roberts, 1997). The limit of the proper use of this method is our poor knowledge of population structure (number of stock-units and nurseries, diffusion of eggs and larvae, migration pattern, natal homing, etc.).

# Discussion and conclusion

Marine science is relatively young compare to terrestrial studies. Physical oceanography is even younger than marine biology and the links between those two branches of marine science was strengthened only during the past two decades.

Marine species have evolved in order to get adapted to the predictable seasonal changes. They reproductive and feeding strategies match the seasonal cycles. In contrast the unpredictable interannual changes in the environment affects the species and is responsible for large variations in the abundance of the marine resources. The exploitation of these resources amplifies the effect of the environment and increases the risks of collapse. The consequences of the different temporal scales of environmental variability on the fisheries and the society are numerous, ranging from the risks of overexploitation, changes in the balance of the ecosystems, economic crisis of the fishing industry and finally the lack of food supply for the coastal communities.

Environmental changes can affect the fisheries either at the level of catchability or at the level of abundance of the resource, and it is not always obvious to distinguish between those two effects. The interaction between different time and space scales makes it difficult the identification of the processes linking the environment to the resources. Modelling these interactions must also take into account the effect of exploitation. Nevertheless, it can result hazardous on the long term due to our poor knowledge of the underlying processes. At present management of living resources cannot rely entirely on models but should also quantify the risks due to uncertainties related both to environmental factors and to our lack of knowledge.

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# Human activities affecting the coastal zone

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## The importance of coastal biological systems

- Constanza et al, (Nature 1997) argue that the goods and services provided by coastal ecosystems has a value of three times the global gross national product. This is one of the first attempts to assess the economic value of coastal systems. The data are necessarily preliminanry and whilst of importance questions must be asked as to whether the economic values given are realistic. For example is the most important function provided by coastal biological systems treatment of nutrient discharges? The other central questions relate to whether or not these clearly economically important goods and services can be provided by human influenced systems? Do degraded systems function as well as pristine systems? A key scientific question relting to the conservation of coastal biodiversity is, are all species necessary for efficient functioning of these systems? Most of the important services mentioned by Contanza et al are in fact provided by bacteria (nutrient cycling, detoxification etc) and occur in sediments. Perhaps this is where the focus of research should really be.

## The threats to coastal systems by human activities are:

- Loss of coastal habitats by reclamation of wetlands and estuaries.
- Fishing, (especially trawling) damages the seabed, but to what extent does this damage lead to reduced efficiency of nutrient cycling and contaminant detoxification?
- Eutrophication. We know the causes, but have we done enough to solve the problems? How will climate change effect the risks of eutrophication incidents? Are toxic algal blooms linked to eutrophication and to climate change? Although there are many claims of such links in fact there are powerful arguments that suggest that the frequency of toxic blooms have not increased over time, rather there are better observing systems in place today.
- Contaminants: Recent results suggest that heavy metals are no longer a major problem expecpt in limited areas. The key problems are with organic micropollutants and their accumulation in the Arctic due to the "grasshopper" effect of volatisation at low latitudes and precipitation at higher latitudes followed by renewed volatisation and precipitation until the final sink the polar regions.

- Introduced species are a major problem (e.g. the collapse of the fishery in the Black Sea due to the introduction of the ctenophore *Mneniopsis lledyii*) and are likely to be an increasing problem.

## Perceived and real problems

There is a need to distinguish between the two. Good examples of perceived rather than real problems are:

- Oestrogenic mimics and cholera and algal blooms. Whilst there is good evidence of hormone related changes affecting alligators in Florida and fish in limited stretches of some British rivers it is by no means clear that release of oestrogenic mimic hormones is a major environmental problem. Likewise the suggestion that cholera is spread along the world's coasts by attaching to phytoplankton is not borne out by the data. There is no evidence to substantiate the claim that the 1991 Peruvian cholera outbreak was due to transported ballast water with spread along the coast due to attachment to plankton. Scientists must give priority to real rather than percieved problems.

## Dealing with uncertainty

The greens criticise science for not dealing with uncertainty where human influences on the environment are concerned. I argue that science can deal with uncertainity and still make predictions. We have a sound scientific basis for hazard and risk assessment, but this is rarely applied. Likewise scientists know how monitoring programmes should be designed taking into account of Type-II statistical errors rather than Type-I errors. Yet due to financial constraints or ignorance such aspects are rarely taken into account in environmental management.

# Session report

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The Chairman opened the session, welcomed the participants and thanked the keynote speaker and provocateur for being present and to contribute to start the discussion. The audience was then introduced to the methodology that would be used in the session. First, P. Fréon would address the question of the impact of environmental factors on resources and fisheries, while J. Gray would act as provocateur. After the break, the roles would be inverted, with J. Gray tackling human activities affecting the coastal zone, and P. Fréon posing provocative questions. The audience was invited to join the provocative questions as they were raised, as well as to deliver written comments to the rapporteur. A couple of such comments were indeed received, but they will be treated anonymously, just as any other participation from the audience. The modus operandi adopted by the provocateurs and the chairman was that of stimulating the discussion immediately after each question was raised.

The keynote speech by P. Fréon is appended to this report.

The first provocative question was related to the **ability of Global Climate Models to make predictions at the scales required by managers**. How reliable are the predictions for the coastal seas of Europe, and what is needed to make the models predict what the managers want to know? While it was clear that models are still not capable of producing such answers, certainly not beyond a time scale of a couple of years, it was remarked that whenever a clear lag is identified between the environment and the response, it may not actually be needed that the models predict climate change in order to give an answer that may interest the managers. It was pointed out that some countries, like Norway, have indeed been using such approach to "predict" from one year to the next. The question of the applicability of predictions to adjust investment policy or management attitude (e.g. using fleets from other countries) did not receive an encouraging answer. Attempts have been made and revealed dangerous. On the other hand, the accepted 20-year lifetime of a vessel does not seem quite compatible with the 10-15 year time scale of a regime shift.

The main lesson to the management is probably "do not think of investment over long periods, and be prepared to shift from one resource to another".

When thinking of predicting climate change **effects on biodiversity**, one needs to know which critical levels of biological organization (other than fish) to consider. Apparently, it is not possible to disregard any level of organization, and the most important is to prevent the elimination of species. The debate is certainly open at lower levels. The mechanisms are unknown, may be genetically controlled, and may even be derived from learning. We are still quite ignorant of the interactions within the ecosystems, and may even ask what is an ecosystem? For instance, it is not known to what extent may one isolate the "coastal" ecosystem from the "terrestrial"

or the "marine" one. And it is also not certain that the "marine" ecosystem does not interact with the "coastal".

Fisheries management should be considered as a part of ecosystem management. While it is not yet enough debated what one means by "ecosystem Management", it was proposed that the management objectives should be that we should have mammals, birds and other life forms, and not specifically the fish. The interactions are complex and largely unknown. The importance of a particular "box" in the system may only reveal when a regime shift occurs, and the identification of key factors is not at all easy. Quite often, in variance analysis, links are identified that may be significant while still explaining a minor part (20-30%) of the variance. Conclusions are therefore to be treated with extreme caution, and management attitudes difficult to adopt.

Satisfaction was expressed from the audience that the question of the ecosystem in related to fisheries was finally addressed. However, since one cannot manage the ecosystem, it is mandatory to find out how realistic it is to approach the ecosystem from the point of view of fisheries management. A report of an ICES Working Group on effects of fishing on other marine living organisms was referred to have been considered in the role of ICES as an advisory board for fisheries management, and managers are willing to take it into account.

The basic question that needs to be answered is whether or not it is acceptable to risk a species on account of fisheries.

The issue of **risks and uncertainty** was the last topic of provocation before the brake, the specific question being that, although scientists do indeed deal with the topic, this does not seem to be clear for the public or the greens. This could be due to a poor understanding of "uneconomic growth", as one that does not take into account externalities (costs of effects of fishing other that the price of fish). While a view was presented that industry development always leads legislation, and therefore tends to neglect the externalities, in another view a comparison was made between the chemical risk assessment — where the worst case scenario tends to be modelled — and the way models are used in fisheries.

Although it was recognized the tendency to model the best (and not the worst) case scenario in fisheries, it was also pointed out that the risk/uncertainty approach in fisheries is still in its infancy: it aims at accepting a level of risk that does not compromise a certain level of stock exploitability. The calculations, however, are still largely made on a single species basis, and some progress has to be made in this context. The decisions certainly involve the level of funding allocated to marine research as a whole, and this has revealed unstable. Scientists and politicians need to jointly address the philosophical basis of management decision making. Scientific work and political decisions should become more compatible, perhaps by adopting "worst case scenarios" in models and "precautionary principle" when taking decisions.

If one wants to reduce the risk of damaging ecosystems, it is certainly necessary to adjust the fisheries not to affect the non targeted species. Less destructive, more selective, fishing methods should be encouraged. On the other hand, the effect of fisheries on the ecosystems is, to a great deal, ignored because there are virtually no trawl-free grounds. Some fishing free ground are, therefore, needed.

This topic served as a good bridge to the second part of the session, for which the keynote speech of J. Gray is appended. A relevant part of it called upon the concept of "Goods and Services" provided by coastal ecosystems, as presented by Costanza et al. (Nature, 1997), and the discussion that followed derived, to a great deal, from such approach.

At the very first provocative question, the issue of the establishment of strictly **Marine Protected Areas** was raised as a possible way of attempting to preserve biodiversity, since only 0.1% of the resources are within protected areas. The basic recommendation was to try to conserve habitats instead of looking at a species level. It was remarked that one is always looking at a mosaic where, quite often, the questions asked at the level of particular areas, or individual components, are left unanswered, while at larger scales significant answers could be found.

For some time then, the discussion was centered around the threats to coastal ecosystems by human activities. One such threat being trawling, a point was raise about its positive effects, like the increase in food web turnover, namely in benthos. There was no disagreement about a short-term increase in biomass due to trawling. However, it was due to opportunistic species, meaning that, although the protein is increased, this was not necessarily the kind of protein one was aiming at. The example of the North Sea was cited, where every square metre is virtually trawled at least once every year, with no obvious positive effects.

A comparison was made between trawling and the agricultural use of land, and a suggestion put forward for the definition of trawl protected areas for different periods, from 1-year or 2-years to a total trawl ban. In this respect, it was referred that zonal fishing management is already being practiced in the area around the Great Barrier Reef Marine Park, Australia, with a 3-year rest in each band — a solution that may be regarded as nearly optimum. Views were expressed encouraging all kinds of experimental approach to the problem. Indeed, the idea looks appealing, but not easy to implement: still comparing with agriculture, one must prepare to address the question of "fertilization", and bear in mind that hundreds of species are exploited at sea, only a few dozens are grown in land.

Another possible way of managing fisheries was presented also as an example from Australia (now from the south), where a number of fishing licenses were attributed in plots that are used in rotation. Limits may also be set to the amount of fish that may be caught in each plot.

**Marine Protected Areas** may be a good way to understand processes and mechanisms, as well as to assess changes and benefits of reduced fishing, informing fisheries management and conserving habitats. However, a dilemma is immediately raised: can such areas be subject to scientific experiments, that may indeed be clearly detrimental? Also, it will be necessary to quantify the costs imposed by such experiments on a commercial scale.

Some sceptical view claimed there is no evidence from European seas that Marine Protected Areas are necessary to protect marine biodiversity. How would protected areas be then compared with fishing areas? And how would different fisheries be considered? Controlling human activity at sea may be a better way of protecting marine ecosystems and fisheries.

The Protected Areas topic congregated most of the discussion after the break in the session, reducing to a minor level the attention of the audience to other points raised by the acting provocateur. These included the eventual cost of reduction of nutrient input on production of planktivorous fish, perceived vs. real problems, namely in the case of introduction of alien species and drastic management decisions (namely concerning escape fish from fish culture facilities).

A last item of provocation was adequate to sum up the session. It concerned the role of scientists in enlarging fully protected areas. A view was expressed according to which such role should include communicating with coastal users, and society in general, about the impacts which human activities have on coastal and marine ecosystems. It was considered as important that coastal users understand their personal responsibility for environmental impacts. Communication of the knowledge gained from scientific research is crucial towards such understanding, and requires attention, energy and resources. The establishment of marine/coastal Protected Areas is only part of the picture.

# IMPLEMENTATION

# INTEGRATED COASTAL ZONE MANAGEMENT: HOW TO MOVE FROM THEORETICAL CONCEPTS TO USEFUL APPLICATION

# Keynote speech

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## 1. Introduction

The concern over the sustainability of ocean and coastal resources is spreading worldwide and the response that gains growing recognition is that of integrated coastal management (ICM). Efforts for such management are also intensifying but, as yet, without satisfactory answers to all of its challenges. The examination of these challenges and approaches to confront them is the major objective of this essay. The following steps are taken: (a) review of the ICM thesis and praxis to establish its proposed scope and perceived challenges; (b) analysis of the four-part question *"integration for what-of what-by whom-for whom?"* to formalize the relationship between integration and coastal management dilemmas; and (c) development of a blueprint of *"how"* to implement an ICM that responds to this formalized relationship.

Epigrammatically, the whole analysis is founded on the premise that the "picture" of the "integration puzzle" counts more for the completion of this puzzle than the sophistication of the design of its pieces. Support is derived from the realization that ICM should not be expected to achieve sustainability simply because it aims towards a greater integration of coastal management (CM) elements. A number of factors determine the nature of the integration of CM and, thus, its outcome. Moreover, the interest must focus on the integration of the whole CM process that starts with the definition of a problem and ends with the implementation of a chosen solution. Attempts to integrate separate elements of this process are valuable but they do not completely respond to the challenge. The two most significant examples are the attempts for trans-disciplinary research of CM problems (see, e.g., European Commission, 1997a, and European Science Foundation, 1997) and the development of comprehensive information gathering mechanisms and instruments (see, e.g. Lipiatou, 1997; Engelen, 1997).

## 2. Thesis and Praxis of Integrated Coastal Management

Calls for modeling and planning the integration of all public policies including those for the environment go back to the 1970's (Davos, 1977; 1977-78; 1979a; 1979b). What prompted these calls was the growing awareness of the interdependencies among all social concerns and actions. In the early nineties, similar calls but with a focus on the coastal environment and resources became prominent with: (a) the Chapter 17 of the Agenda 21 action plan agreed at the Rio Summit (Coastal Resources Center, 1991) and (b) the recommendations of the council on integrated coastal management of the Organization for Economic Co-operation and Development (OECD, 1993). Comprehensive reviews of what ICM entails according to its

proponents and of efforts to implement it are given in Cicin-Sain (1993), Cicin-Sain and Knecht (1997), European Commission (1994 and 1997b), OECD (1993), and World Coast Conference (1993).

A representative definition of ICM is given in the report of the World Coast Conference (1993): *"integrated coastal zone management involves the comprehensive assessment, setting of objectives, planning and management of coastal systems and resources, taking into account traditional, cultural, and historical perspectives and conflicting interests and uses; it is a continuous and evolutionary process for achieving sustainable development"*. In the same report, this thesis is translated into the following main elements of ICM: cooperation through both horizontal integration (relating to the responsibilities of agencies at different levels of government) and vertical integration (relating to the responsibilities of different governmental sectors); recognition of socio-economic, cultural and ecological dynamism; extension of planning time horizon and harmonization of short/long-term goals; and arrangement of management responsibilities.

What this ICM thesis actually offers with a comprehensive acknowledgment of the interrelated dimensions of complexity of CM is a vision of *utopia*. A representative summary description of what is considered as the present *dystopia* is contained in the report of the European Commission on the progress of the Integrated Coastal Zone Management Demonstration Programme (1997) which discusses the diverse experiences of projects designed to comply with the ICM thesis. The major findings of these projects emphasized in the report are: the diversity of approaches; the diversity of administrative, legislative, environmental, physical and economic issues; the importance of the economic and social motives; the difficulty in finding a mechanism for involving the private sector; the significance of building mutual trust among actors; the need for a common language of ICM; the uniqueness of the issue of building mechanisms for interaction between administrative/sectoral layers; the importance of capacity building; and the importance of such additional issues as: enabling legislation; facility to control and regulate land use and activity; system of forward planning; system of property registration; mechanisms to facilitate participation of the general public; mechanisms of compensation and controlled – but compulsory – acquisition of property by authority; and activities and processes in the hinterland.

Having developed a vision of *utopia* and an understanding of the present *dystopia*, what remains to be examined is the road from *dystopia* to *utopia*. This road has not been as yet adequately mapped and discussed, however. It is true that certain suggestions regarding how this road can be traveled have been offered. For example, the report of the World Coast Conference (1993) proposes the following ICM tasks: objective setting; problem definition; analysis and planning; implementation of measures; operation and maintenance; and monitoring and evaluation. Similarly, the following sequence of interconnected actions is suggested in the report of the European Commission (1994): identification of issues and analysis; selection of programme goals; selection of 1$^{st}$ generation strategies and objectives; institutional design; formal adoption and funding; implementation through annual work plans; and evaluation.

These sets of actions are actually generic in nature, however (as a comparison between them partially illustrates). They have been borrowed from the generic literature of systems analysis and management and have led to positive results

primarily in the private not in the public sector. Moreover, they have not been associated with the particular terrain of the road to ICM and its obstacles. Thus, although they may appear to constitute a system for navigating the road to the envisioned ideal state of ICM, their capability to lead to the desired destination is suspect.

More importantly, the above-described dystopia relates primarily to the implementation of prevailing concepts of ICM. It does not directly reflect on critical CM dilemmas for which integration may be considered a better response.

# 3. Coastal Management Dilemmas and ICM Approach

In defining the challenges of CM and searching for the appropriate integration approach to address them, it is critical to remember two important realities. First, coastal management is a **collective** endeavor and as such, it faces a dual challenge regardless of who carries it out and by which approach. It depends on the cooperation of a multitude of stakeholders for the effective implementation of its decisions, while at the same time, it undermines such cooperation with the unavoidable conflicts its decisions generate among the different stakeholders' perceptions of their self- and collective interest. Second, in real life and in the public sphere where collective actions such as those for CM are chosen, decisions are not "made" by a single individual but negotiated among many stakeholders. The latter include governmental agencies (with competing or overlapping mandates), expert-scientists (with differing affiliations with competing theories, methodologies, information bases, and institutional interests), and other public and private stakeholders (with conflicting economic and other value interests).

To appreciate the ramifications, consider the following questions in relation to the above definition of ICM: Who is supposed to define the problem (issues for analysis) and set specific goals (objectives, strategies) for the coast and their resources? How can differences among the various stakeholders' objectives and their priority be harmonized in the context of a decision to adopt and fund an ICM plan? How is the integration and harmonization of sectoral policies to be achieved and by whom? Whose capacity to access, assimilate and evaluate information will dictate the design and availability of the collected information and coastal environmental indices? Will the objective of public education and citizen participation go beyond that of "assessing the political feasibility of certain alternatives", and educating the "uninformed" public about why the experts' decision or proposed action is the best one? How can traditional, cultural and historical perspectives really be taken into account? Finally who will decide which institutional structures (designs) are most effective and how could this effectiveness be defined, monitored, and evaluated? (Davos, 1998a). Different stakeholders may give conflicting answers to any of these questions and for none of these questions there exists a single answer that can be imposed as satisfying a universally accepted criterion of superiority.

It is these two critical CM challenges of "collectivity" and "negotiation necessity" and their ramifications (as reflected in the above questions) that define the need to **promote cooperation** among stakeholders as the major task of a new, **cooperative**

approach to ICM. Answering the four-part question of integration "for what-of what–by whom–for whom" assists the understanding of the dimensions of this task.

## 3.1 Integration For What

The sustainability of ocean and coastal resources has been set as the ultimate objective of ICM. Two ways by which ICM is expected to achieve this objective are: (a) the determination of "better" solutions to CM problems; and (b) the facilitation of "better" coordination of the implementation of chosen solutions. Hence, what constitutes "better" CM solutions and coordination of their implementation is important for planning and executing the integration of CM. Solutions can be judged as "better" either because of their greater compliance with certain normative criteria imposed by rational, theoretical analyses of CM problems or because they emerge as broader compromise choices among competing stakeholders after a participatory process of: (a) evaluating all feasible solutions; and (b) bargaining. The choice between these two ways of identifying "better" solutions is important for the effectiveness of CM, i.e., its ability to achieve targeted objectives within targeted time horizons.

Normative solutions, by their nature, need some form of coercion (usually legislative) in order to be implemented. However, the fact that calls for ICM are intensified and the concern over the sustainability of ocean and coastal resources is escalating despite a prolonged legislative effort to impose normative solutions, emphasizes that coercion does not lead to effective CM. The introductory discussion of this section implies why this is so by pointing to the contentious nature of CM issues and the dependence of the effectiveness of any solution on the cooperation of a multitude of stakeholders with competing interests. The alternative is a focus shift to cooperative solutions that can be chosen by voluntary agreements and/or bargaining.

Accordingly, integration should assist the CM process facilitate the collective evaluation of alternative solutions by all stakeholders and the ensuing negotiations instead of contributing to more comprehensive theoretical constructs of reality as the source of normative determinations of what solutions should be chosen. Moreover, integration should assist the coordination of the institutions needed for the cooperative choice of solutions and their implementation, not the harmonization of the coercive powers of existing governmental structures.

## 3.2 Integration Of What

The current definitions of ICM imply a whole encompassing integration. However, the enumeration of all the pieces of a puzzle does not suffice to complete it. The picture of the puzzle is also necessary. The picture provided by a collective CM based on cooperation, negotiations and bargaining highlights an integration of:

- The CM concerns and their priorities of all stakeholders, not just those of elite groups;
- The values that stakeholders associate with specific CM solutions not generalized traditional, cultural, and historical perspectives;
- The information needs of all stakeholders, not just the specialized knowledge that experts consider necessary to build and run theoretical models of reality;

- The conflicts among the choices of economic and other actors, not among the expert-recommended sectoral policies that governmental agencies adopt paternalistically;
- The institutions that assist bargaining and lead to conflict resolution, not the mandates of the existing agencies and institutions.

## 3.1 Integration By Whom

In line with the answers to the previous two questions, it is reasonable to suggest that the integration of CM must be the outcome of the stakeholders' debate and bargaining not of theoretical models of the whole ICM process, i.e., integration must be an ongoing process, not a normative prescription. Alternatively, integration should be the outcome of a *cooperative* ICM, not the objective of a *paternalistic* ICM.

It should be expected that within a cooperative ICM process, scientists, governmental agencies and other public and private stakeholders will still utilize analytical support models to gain needed information and enhance their understanding of the issues at hand. However, as can be derived from the discussion of the proposed new ICM praxis below, these models are entirely different from those needed by a CM process seeking to identify and impose "ideal" solution choices, as if such solutions preexist and are independent of human interventions. The analytical support models needed by a cooperative ICM assist the stakeholders but they do not supplant them.

The support for a paternalistic ICM emanates from the findings of positivist analysis of: (a) the threat of the *tragedy of the commons* associated with the exploitation by selfish stakeholders of common resources (Hardin, 1968); (b) the paradox of the *prisoner's dilemma* relating to individual rational strategies leading to collectively irrational outcomes (Dawes, 1973); and (c) the *logic of collective action* which suggests that unless the number of stakeholders is quite small, some form of coercion or some other special device is needed in order to make individual stakeholders act in their common interest (Olson, 1965). However, as it already has been mentioned, paternalistic choices of solutions for collective problems such as those faced by the management of coastal resources are being proven ineffectual (Davos, 1998a).

The alternative of cooperative ICM is implied by such calls as those of Principles 10 and 22 of the Rio Declaration (Center for the Study of Marine Policy, 1992), and is justified by an expanding literature reporting cases where stakeholders voluntarily chose cooperation in managing common resources, placing their collective interest above their self-interest (Berkes et al, 1989; Crance and Draper, 1996; Ostrom, 1996).

## 3.4 Integration For Whom

A straightforward answer to this question is "for all stakeholders". However, a number of issues must be addressed by a more comprehensive answer. First, the stakeholders may be the only "value arbiters" but are they the only "value holders"? An affirmative answer implies that society is only the sum of its members, i.e., society is an "organic chooser" of ends whose values and wants are simply the

"sum" of those of its members. However, those who believe, e.g., that future generations have a "stake" in the decisions of the current generation and that their values should also be taken into consideration, will disagree with this answer. The same applies for those who reject the "transcendence" foundation of our western value system in favor of that of "immanence", and who, thus, argue that the inanimate nature should be considered as a value holder as well (Tribe, 1976).

Secondly, the inequality of the current power distribution among stakeholders (economic, political, educational, cultural) raises the question of whether it should be of concern to ICM or be considered by it as an initial condition. A practical implication of this issue relates to the question of whether the values of all stakeholders will weigh the same in their integration or not (Davos, 1986). If the attempted ICM accepts existing inequities as initial conditions, it will have to cope with the obstacles to its implementation that will be erected by the growing number of those who associate these inequities with the issue of "environmental justice", i.e., the issue of an unequal distribution of environmental hazards among populations with differing economic and political power (Collin, 1992; Mohai and Bryant, 1992; Been and Gupta, 1997).

Finally, the resolution of the issue of whose values should be integrated does not end the debate because value integration is by itself a source of conflicts. How these conflicts can be managed is also subject to debate and requires integration of opposing viewpoints.

Currently, the broad application of a narrowly defined benefit-cost analysis for the evaluation of alternative CM solutions appears to address some of these issues. Only the values of stakeholders count, these values must be expressible in monetary terms, the power distribution and its impact on these monetary values is an initial condition, and the integration of values can be done by a simple summation since, under the given power distribution, conflicts are resolved in the "magic kingdom" of markets. The problem of this analysis is not so much with the moral and ethical basis of its hypotheses and limited view of the source and appropriate expression of values. The objections it invites relate more to the fact that its application implies acceptance of a paternalistic, quasi-rational resolution of some very contentious issues (Davos, 1977). ICM must offer, instead, the ability to integrate all views in order to maximize the voluntary acceptance of any final resolution of their conflicts.

# 4. Cooperative Integrated Coastal Management Praxis

Acceptance of the above arguments leads to the blueprint of a cooperative ICM praxis, highlighted-below. (The provided references to related literature offer a more comprehensive treatment.) In drawing this "picture of cooperation" as the guide for completing the "CM integration puzzle", emphasis is placed on the integration of the CM process, the analytical needs of this process, and related institutions.

Before proceeding, however, the distinction must be emphasized between the cooperation that the current definitions of the ICM thesis call for (refer back to Section 2) and the cooperation that the proposed cooperative ICM praxis tries to engender. The former is primarily forced upon the stakeholders by a paternalistic approach to CM that relies on legislative power to implement expert-recommended

solutions to problems defined by an elitist agenda. The latter is pursued as a voluntary endeavor to implement agreed upon solutions to problems defined by a pluralistic agenda. The advantage of voluntary cooperation can be established with the reasonable proposition that it is more sustainable than forced cooperation.

## 4.1 The Integration Of The Process

### *4.1.1 Stakeholder Registry*

The integration of the cooperative ICM process must start with the development of the most comprehensive stakeholder registry possible. Naturally, current communication technological capabilities limit the scope of integration to only those stakeholders who are active participants in the CM process, including individuals who seek a voice in various debate fora. Given the rate of technological progress, however, the time when the whole polity can participate in the CM process is not distant.

The stakeholder registry may take the form of a "stakeholder tree". The roots may refer to international stakeholders, e.g., nations or as in the case of the "Europe of Regions" the various coastal regions of the European Union. The branches may relate to regional stakeholders within each national setting. The leaves may refer to stakeholders from the various coastal communities within each national region. Finally, the twigs may incorporate the various groups and individuals within each coastal community.

Stakeholders of each of these "tree" classifications can further be grouped as, e.g., "governmental agencies", "other public stakeholders" (e.g., elected officials), "environmental scientists and engineers", "economic stakeholders" (e.g., fishermen, tourist operators, merchants, other service providers, industrialists, etc.), "environmental stakeholders" (i.e., members of environmental advocacy groups), "active individuals", etc. The purpose of any such classification (other than to facilitate the development of a comprehensive registry) must be to support the analysis of the impact of certain key stakeholder characteristics on stakeholder behavior, attitudes, and solution choices. (For an example of such analysis see Valcoast, 1997.) However, it will be a mistake to associate these classifications with camps expected to hold conflicting values, as, e.g., some may think is the case of "economic stakeholders" and "environmental stakeholders". (How such preconceived notions of value conflicts can be handled is discussed in the next section with reference to potential interest coalitions.)

Sources for this registry may be official documents, academic and research institutions, associations (e.g., commerce, manufacturers, fishermen, etc.) literature reporting cooperative efforts for CM, lists of participants in public debates, direct invitations to express interest in registering, etc. Comparisons of registries among regions or nations will also result eventually in more comprehensive stakeholder integration into the ICM process.

It must also be added that in building the stakeholder registry, the objective should be the identification of all sources of potentially different patterns of values (to be further elaborated immediately below). The attainment of statistically valid representation of various stakeholder cohort groups is not important because cooperative ICM is not aiming at the integration of all stakeholder values into a single

representative set of values. With a cooperative ICM, the focus is on how stakeholders holding different values can be induced to cooperate in the choice and implementation of a solution through bargaining and cooperative agreements. Hence, what is important for facilitating this inducement process is the knowledge of all differing values.

### *4.1.2 Value Tree*

The second most important step towards ICM must the development of a "value tree" that will synthesize all stakeholder concerns with CM. The roots of this tree can be associated with such major concerns as, e.g., environmental sustainability, economic development, public health, quality of life, equity, etc. The branches can represent such associated concerns as, e.g., environmental degradation and fishery sustainability (related to the root of environmental sustainability), employment level and sectoral diversification (related to the root of economic development), inter-generational and inter-regional equity (associated with the root of equity), etc. Additional sub-classifications of concerns can be represented as leaves and twigs of the value tree. Notice that the development of a value tree offers the opportunity to incorporate all notions of value, e.g., even those referring to the rights of future generations or inanimate nature. (Valcoast (1997) offers an example of a value tree for coastal communities). The integrative functions of the value tree are illuminated in the subsequent sections.

Issues raised in debates, relevant existing laws and regulations (international, national, and regional), and the literature are major sources of candidate components of a value tree. The final selection must satisfy certain principles for the value tree to be a viable instrument of ICM, e.g., relevance, comprehensiveness, completeness, operationality, etc. (Keeney and Raiffa, 1976). However, the most important principle should be the direct and proactive participation of the stakeholders in the final development of the value tree.

On first impression, the value tree may resemble the list of impacts of an "impact assessment matrix", the familiar basis of impact assessment reports. Nothing precludes this resemblance. The fact should be remembered, however, that the value tree is a systematic representation of stakeholder concerns that might or might not coincide exactly with precise impact specifications as determined by the sciences and engineering. For example, stakeholders are concerned with water quality but not all of them might be able to debate related policies according to such quality measures as BOD and DOD levels. A cooperative ICM must depend primarily on the "value tree" to guide the choice of impacts of alternative CM solutions that sciences and engineering must assess. On the other hand, a paternalistic ICM will be interested only in the "impact assessment matrix" as the foundation of expert-based analysis of its decision alternatives.

### *4.1.3 Value Integration*

The integration of values is the primary function of the value tree. This integration is a two-stage process. The first stage relates to the general value debate regarding the urgency of all social problems including those of CM while the second stage refers to the specific value debates on the desirability of alternative solutions of specific problems. In both stages, the integration focuses on the priority (weight of significance) that stakeholders assign to the concerns at the roots, branches,

leaves, and twigs of the value tree. Another focal point relates to the conflicts among these priorities, as it will be shown below (conflicts that will have been obfuscated otherwise with the use of an evaluation criterion such as benefit-cost analysis).

What necessitates this distinction between the two stages of value integration is the fact that stakeholders might argue for different priorities for the value tree concerns when they debate the urgency of problems and when they debate the desirability of specific alternative solutions. For example, it is reasonable to expect that most coastal stakeholders will argue for the urgency of the problem of "environmental sustainability" but when specific policies for "economic development" are debated, the same stakeholders may argue for a higher priority to be assigned to, e.g., "employment levels". This difference is not irrational. Consider the example of the concern over "water quality" which may be weighted as more important when "agricultural" or "tourism development" policies are evaluated instead of "transportation" or "educational" policies. (Valcoast (1997) contains the results of assigning priorities in the first case, the general value debate.)

### *4.1.4 Policy Integration*

The integration of all policies, including CM and economic sectoral policies, must also be performed in two levels. The first relates to the setting of the agenda, i.e., the process by which specific concerns gain prominence and exposure and thus become legitimate policy objectives meriting the attention of all stakeholders (including as always the policy legislating agencies). The development of the stakeholder registry and the value tree constitute necessary first steps of a "pluralistic" agenda setting process which is the only one that can engender cooperation (Davos, 1998a).

The second level of policy integration involves the assessment of the impact that all proposed policy alternatives have on each concern in the value tree. Such an assessment allows the evaluation of the interdependencies among all policies, which is necessary for their integration as well as for determining the desirability of each policy alternative.

### *4.1.5 Information Integration*

There is currently a proliferation of environmental databases and a preference for certain very sophisticated means of information gathering and analysis. (See e.g., Lipiatou, 1997; Engelen, 1997.) Undoubtedly, they are instrumental for scientists to obtain a better understanding of threats to ocean and coastal resources and to define the associated problems for the rest of the stakeholders. However, for the cooperative management of these problems, the needed information relates to the impacts of various proposed solutions according to the concerns of the value tree. This information must also be accessible to and assimilable by all stakeholders.

It is true that since the definitions of the concerns in the value tree might not coincide exactly with the scientific definitions of the impacts of solutions under evaluation, it might be difficult to assess these impacts. (Once more, consider the example of the concern over "water quality" and the its various scientific parameters, as e.g., BOD and DOD levels.) In such a case, other techniques than those utilized by related sciences should be applied. One such technique is the DELPHI method that enables the stakeholders to adjust their own estimates of impacts in light of information on

other stakeholders' average estimates and their variance (Linstone and Turoff, 1975).

This integration of information with a basic reference to the value tree also directs the integration of efforts for public education and the study of motives behind stakeholder arguments as two means of maximizing stakeholder voluntary cooperation in all CM efforts. Current attempts for public involvement and education, on the other hand, try to "manage" public participation in order to minimize its effect on decisions under consideration or assess the "political feasibility" of specific solutions (Portney, 1991).

## 4.2 The Integration of the Analysis

In light of the previous discussion, the analytical needs of a cooperative ICM process relate primarily to the assessment of the extent to which each alternative ICM solution will engender cooperation. This assessment requires the prior determination of each stakeholder's desirability for each alternative solution.

### *4.2.1 Solution Desirability Assessment*

A stakeholder's desirability for a solution is determined with the integration of the stakeholders' priorities for the concerns of the value tree, the impacts of each solution on these concerns and the stakeholders' desirability of these impacts. This integration is assisted by a variety of methods offered by the field of multicriteria (multiple objective) evaluation. (For environmental management applications see Davos, 1987; Davos *et al*, 1993.)

When the number of involved stakeholders is large, one approach to consolidate this task is to determine the priorities for the value tree concerns of all stakeholders but then, determine the desirability of alternative solutions for clusters (*potential coalitions*) of stakeholders with similar priorities (Davos, 1993).

A byproduct of this first analytical step is a measure of the need for more information and direction, obtained by assessing the *solidarity* of cohorts of stakeholders having similar characteristics (e.g., occupation, education level, etc.) or declaring similar affiliations with special interest groups, e.g., "fishermen", "labor and labor associations", "tourist and other service sector associations", etc. (Davos, 1993). Solidarity will be evident when there will be statistical compatibility among the priorities or desirability assessments of cohorts, or when identified potential coalitions contain stakeholders with a similar blend of special interest affiliations. Lack of solidarity points to a need for more information and directions for its interpretation.

### *4.2.1 Cooperation Assessment*

The potential cooperation in the implementation of each alternative CM solution can be determined by applying the tenets of *Core Theory* (Telser, 1994). According to this theory, stakeholders will be willing to cooperate in the implementation of a specific solution if and only if by doing so they can achieve at least as good an outcome as by acting alone — a condition referred to as *collective rationality*. Moreover, a stakeholder can join all other stakeholders in a grand coalition or only a number of them to form a single coalition, with each coalition placing a constraint on the

collective choice of a final solution. (For J stakeholders, there are a total of ($2^J$–2) possible proper subsets of the grand coalition.) With respect to the decisions that can be reached by a collective effort, those that are unacceptable to some coalition because it can do better for its members are categorized as "dominated" decisions. The set of all "undominated" decisions constitutes what has been defined as the "core" (Gillies, 1953; Shapley, 1953). The latter can be of course "empty" when no undominated decision exists, it may contain a range of undominated decisions, or it may consist of a single decision — e.g., the choice of a grand coalition of all stakeholders.

Hence, it is the "core" solutions that offer the advantage of cooperation and it is the determination of the core that provides the "picture" needed to complete the puzzle of the integration of CM. What remains to be discussed is the selection among the "core" solutions if there are more than one.

### *4.2.3 Solution Choice*

As was previously pointed out, for the real world public policy arena and, thus, for a cooperative ICM, the choice among "core" solutions is a matter of stakeholder negotiations. What the analysis can offer to these negotiations, in addition to determining the "core", is to provide information of the strength of support for each "core" solution that should be counterbalanced with ample "compensation" in order to be overcome (Davos, 1998b). Individual negotiations among groups of stakeholders in the case of an empty "core" can also benefit from this information on the strength of support for various solutions.

If negotiations are not feasible (for the reason, e.g., of widely spread impacts of solutions among many stakeholders), the choice of a solution ("core" or otherwise) must be made with criteria that promote cooperation or preserve stakeholder participation in a stable coalition. Such criteria are those of *fairness* and *justice*. However, since there is no normative theory of justice that is universally acceptable, a choice must be made among several related criteria with their merit inextricably linked to empirical considerations (Young, 1994; Zajac, 1995). (Lejano and Davos (1995) present an application blueprint of such criteria.)

## 4.3 The Integration of Institutions

Institutions reflect socially constructed systems of rules that generate regularities in people's behavior. Hence, the above-proposed integration of the ICM process and its analytical needs also provide a map for the needed ICM institutional integration. To recapitulate, the type of stakeholder behavior that the ICM institutions must focus on is: participation, negotiation, and cooperation, not obedience to "commands" of "followership behavior".

To nurture such behavior, ICM institutions must lead the stakeholders to: demand an open debate of all values as a means of exploiting the advantages of the growing diversity of interests, instead of accepting normative criteria as arbitrary referees of this diversity; seek the information that responds to their own concerns instead of attempting to interpret information generated for others' needs; seek the sustainable influence that coalitions can exercise instead of attempting to apply individual pressure to decision making authorities; and recognize that obligation to care for the commons does not limit freedom to pursue individual aspirations but reinforces it. In

particular for the governmental agencies among the stakeholders, ICM institutions must lead them to: accept that cooperative agreements are more effective in securing sustainability than "command-and-control" instruments; appreciate the need for redefining agency mandates to promote the above institutional objectives instead of simply trying to deal with the inertia of established organizational interests and accommodate marginal adjustments; redefine the role of science and engineering in order to distinguish their role as knowledge seekers from that of advisors and promoters of self-interest; and increase their sensitivity to the postmodern conditions of cultural and ethical development instead of defending stale traditions and ideologies.

Several recommendations offer more concrete guidance towards establishing such ICM institutions. For example, Seabright (1993) proposes such *formal* mechanisms as privatization of property rights, decentralization of incentives within common ownership and control, delegation of management responsibility to an agent so that participants are limited to a monitoring role. Seabright also suggests such *informal* mechanisms as making the future matter, by threatening, for example, the violators of present cooperative agreements with exclusion from the commons resource, instituting credible retaliatory strategies, and making cooperation history dependent by establishing memory preserving mechanisms. Crance and Draper (1996) suggest such strategies as *scope-reduction* (i.e., focusing on a distinct part of a larger problem); *phased segmentation strategy* (i.e., emphasizing that each individual's behavior will determine whether or not the management goal is reached); and *education on social values and responsibility* in order to enhance the value that an individual places on collective welfare above self-interest. Davos (1998) emphasizes the importance of four challenges. First, *creating optimism about the level of optimism,* i.e., increasing stakeholder optimism about the level of cooperativeness of all other stakeholders. Second, developing a *pluralistic CM agenda*, i.e., providing all stakeholders with an equal opportunity to develop the list of legitimate concerns regarding coastal sustainability. Third, facilitating a value discourse that covers both issues: (a) the *origin of values* (i.e., what constitutes a benefit and a cost and who should make this determination); and (b) the *application of values*, i.e. how all benefits and costs should be evaluated and how they should be integrated into a rule of choice). Fourth, paying attention to *information and empowerment*, i.e., reconsidering the modalities of the relationship between power and knowledge and the management of the conflicts they generate. Finally, Ostrom (1996) offers a systematic treatment of an institutional approach to the study of self-organization and self-governance in common-pool resources accompanied by an analytical framework.

# 5. Synopsis

Current ICM theses and praxes align with a paternalistic CM approach that calls for expert-based, rational analyses to recommend "best" solutions and for decision making authorities to adopt these solutions. This approach appears to be concerned basically only with the comprehensiveness of these analyses and the efforts of implementing their recommendations within established institutional structures. CM is a collective endeavor, however, and its effectiveness depends on the cooperation of its stakeholders. Moreover in real life, decisions on collective endeavors are not made by a single individual or agency but are negotiated among

many stakeholders. Decision making authorities negotiate among themselves because of their fragmented responsibilities or the diversity of their constituencies' interests as well as with power centers because of their dependence on them for their effectiveness. Scientists negotiate among themselves as well as with decision-makers because the limitations of their theoretical models of reality restrict them to indeterminate conclusions and advice. Power elites negotiate constantly their conflicting interests. All these negotiations can be contentious or cooperative. Only cooperative decisions have the inherent power to lead to sustainable outcomes, however.

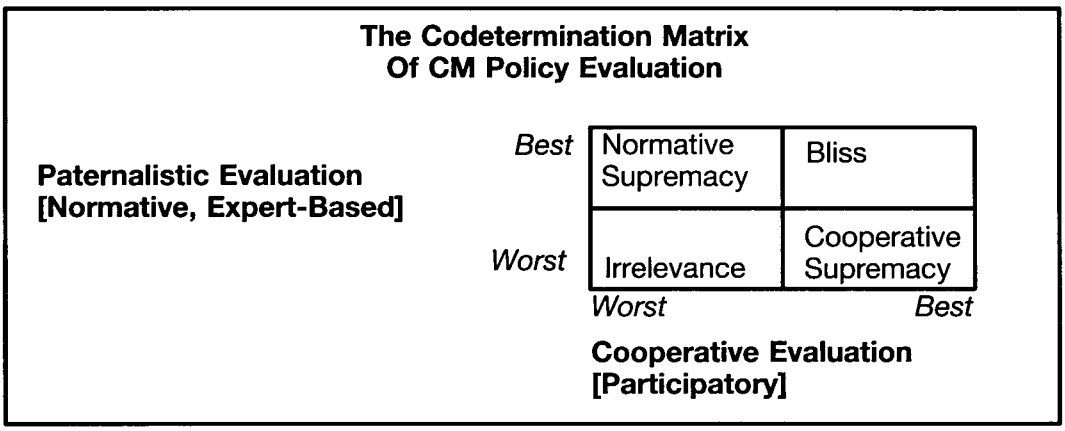
Consequently, the thesis of ICM must be more than a call for synthesis and comprehensiveness. It must delineate an integration that is appropriate for a CM approach that addresses these two realities of "collectivity" of CM and "negotiation necessity". Such integration is the one achieved by a cooperative CM approach. Specifics of its scope and nature were highlighted as answers to the four-part question "integration for what-of what-by whom-for whom?" Its implementation involves; (a) the compilation of the stakeholder registry and the value tree; (b) the assignment of priorities to the elements of the value tree by the stakeholders for the ordering of both CM problems and alternative solutions to specific problems; (c) the evaluation of alternative solutions according to their impacts specified by the value tree; (d) the integration of the information needs of all the stakeholders; (e) the identification of "cooperative" solutions that are preferred by all or groups of stakeholders as cooperative choices over acting-alone alternatives; and (f) the development of institutions of cooperation.

Despite the compactness of the foregoing discussion (necessitated by its forum), the responses it offers to the problems with the current ICM praxis (summarized in Section 2) are traceable. A single approach to and a common language of ICM is offered (cooperative ICM) that handles the diversity of issues (with the value tree) with a mechanism for involving both the private and public sectors (the stakeholder registry, the assignment of priorities to the value tree concerns, and the core analysis of alternative solutions), and with guidelines for setting up the appropriate institutions, thus, building mutual trust among actors (the whole approach is founded on this requirement). A conceptual response and guidance for the practical resolution of the additional issues of system of forward planning, mechanisms to facilitate participation, mechanisms of compensation, can also be found in the above discussion.

In closing, it must be acknowledged that the transition to cooperative ICM from the traditional paternalistic, normative one, requires time consuming and resistance generating adjustments. During this transition period, ICM can assist the choice of solutions with an analysis of the tradeoffs between the evaluation of alternative solutions by normative, paternalistic approaches and by participatory, cooperative approaches. This tradeoff analysis is depicted in the Codetermination Matrix in Figure 1 (Davos, 1988). As shown, solutions in the "bliss quadrant" make the issue of choice moot. In the absence of "bliss" solutions, those empowered with decision making authority will have to make the tradeoff between "normative-best" and "cooperative-best" solutions, i.e., among solutions along the diagonal quadrants. Upon reflection, this codetermination of ICM solution choices may be actually the ultimate integration, necessary for a post-modern society whose values become

volatile and ephemeral and whose interdependent problems tax the capacity of scientific approaches to model them and evaluate their tradeoffs.

**Figure 1: Codetermination of ICM policy choices**




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# Provocateur's statement

*Peter Burbridge, University of New Castle upon Tyne*

The concept Coastal Zone Management has been with us for more than 30 years. During this time there have been major advances in theoretical approaches to the management of coastal areas, including the nearshore marine environment, and in the planning and management of human activities. Principles and guidelines have been developed and there are many manuals to use in training people to conduct coastal management.

Despite these advances, we find that sustainable development of coastal areas and renewable resources eludes us in many parts of the developing and more developed regions of the world. This is leading to degradation of coastal ecosystems, loss of renewable natural resources, destabilisation of coastal communities and foreclosure of future development options. This suggests that there remain serious obstacles to the successful formulation, design and implementation of sustainable coastal management strategies, programmes and plans. Two of the main obstacles are:

1. Slow development of political will to put in place the sophisticated forms of governance required to deal with the complex ecological, economic and social relationships found in coastal zones. This may in part be due vested financial interests, or perhaps our failure to demonstrate that integrated coastal management can yield economic and social benefits that outweigh the political difficulties and fiscal costs of establishing effective coastal management;

2. A lack of scientific information concerning the functions of coastal ecosystems and the complex ecological relationships among terrestrial and marine systems. However, what is more important is the general failure to communicate the value of available scientific facts so that they can be used effectively by policy makers, planners and managers;

Which of these two major challenges, i.e. strengthening governance or strengthening the contribution of science to the process of developing integrated coastal management, should be given priority? In addressing this question we might stop and ask — can "science" play a major part in strengthening governance? It can be argued that better scientific information does not necessarily lead to the formulation of better policies, plans or resources management strategies. There are three basic reasons why we must consider this argument, namely:

1. The main emphasis within most coastal management theories and practices is placed upon integrating sectorial policies, plans and management strategies governing human activities in order to reduce conflicts and to improve economic efficiency. The environmental management of the ecosystems whose functions directly or indirectly support those activities is often considered too difficult and is largely ignored. The lack of attention given to these natural systems which generate the goods and services needed to sustain many human activities means that they will continue to be undervalued and it will be difficult to justify

the allocation of funds and human resources required to develop ecosystem based coastal management frameworks.

This also means that the value of the scientific information available concerning critical factors required to maintain the health and productivity of coastal ecosystems will also be undervalued. Under-valuation of coastal and associated marine ecosystems will also have a negative influence the allocation of funds for research.

2. Major investment will be required in both fundamental and applied research to fill major gaps in our understanding of how coastal and nearshore marine ecosystems function and how they are interrelated. Although such research could yield information of great significance to the natural sciences, there are inconsistencies in some forms of social science logic that constrain the interpretation of the social and economic value of ecological information and its significance for management purposes. One major example is the common practice of "discounting" the future economic and social value of resources. This means that we assume that resources available to future generations will be less valuable than they are to us today. Does this really make sense? With population growth and increasing scarcity of many renewable resources, such as fish captured in coastal seas which yield some 40 percent of the protein available to coastal communities, will not such resources be in greater demand and therefore be given higher value in decision making? If so, why do we continue to discount the future in such common decision making tools such as cost/benefit analyses?

3. Even where the natural and social sciences can prove more effective in informing the coastal governance system, the information provided may not be used rationally by those operating the system.

This raises two further questions. Is the fundamental challenge one of improving coastal governance or coastal science. Could we address both by placing more emphasis in the conduct of research to demonstrate the economic, social and environmental benefits to be gained from broadening the conceptual framework for coastal management to incorporate the ecosystems that sustain human development?

I would argue that unless the natural and social sciences can work more effectively together in demonstrating the essential role of coastal ecosystems in sustaining human activities, it will be difficult to have much positive impact on established governance systems and it may become impossible to sustain current demands for renewable resources. This will mean that current and future generations will lose valuable opportunities to advance human social and economic welfare.

# Report on the discussion

*Ekko van Ierland, Wageningen*

In the discussion Michel Cournaert mentioned that a European programme for integrated coastal zone management exists: Better Management of Coastal resources. Literature shows that most information for coastal management is available, but not always used. A programme is set up based on demonstration cases. A team of researchers works in many areas in Europe, including, about 35 cases. The programme is not focusing on case studies, but tries to integrate the various studies. A team of 6 researchers is studying the results, searching for 6 items: legislation; participation; information; EU policy; territorial and sectorial co-operation; technical solutions. Cournaert invited suggestions for contributions to the process of the demonstration projects.

Job Dronkers indicated the importance of distinction between Coastal management and Coastal Management research. Coastal Management research is intended to provide more understanding. A comparison of coastal management practices does not necessarily lead to good insight in the functioning of coastal systems and coastal ecosystems. Insufficient understanding is present of the processes to predict the development of systems. The question is how to make further progress in understanding the systems and analyse the fundamental processes. Multi-disciplinary approaches are therefore needed and a transdisciplinary research programme, in order to establish good interactions. This confirms the results of the Euro Conference in December 1997 in San Feliu in Spain of which a conference report is available.

Hartmuth Barth stressed the need to translate theoretical insights into practical research questions and projects.

Peter Burbridge raised the question of how to integrate existing knowledge and information. How to obtain better results and predictability? More important is to influence policy making and to influence policy making structures.

Climis Davos focuses on the need of integration of top down and bottum up as suggested by Burbridge. Scientist as stakeholders discuss the various options. Scientist are developing strategies to influence policy making, where scientists and policy makers have different concerns: Politicians should be reelected. Scientist want to make progress in scientific analysis.

Van Ierland indicated that good results are obtained by means of integrated assessment and integrated assessment models in other areas of complex policy making: typical examples are acidification and global warming, for which integrated assessment models have successfully been applied. Similar approaches can be used for integrated coastal zone management. Le Roy raised the question of how to weigh the values of different stakeholders. Decision makers can be asked to indicate the weights for the multi-criteria analysis in order to rank the various alternatives.

Van Ierland stressed that in many cases seemingly conflicting interests can be solved, either by means of new technologies or by better management or co-operative solutions. If necessary compensation or side payments can be used to stimulate co-operative behaviour.

Examples of successful integrated coastal zone management were given, ranging from the management of the Venice Lagoon (as indicated by Capobianco) to coastal zone management in developing countries and high tech management in the Netherlands. Burbridge gave examples from South Africa and the Asian region. Le Roy indicated that in Thailand major problems occurred in the planning of two deep sea harbours. Better site selection made it possible to avoid tremendous damage to ecosystems.

d'Ozouville from the European Science Foundation stressed that the Euroconference in December 1997 in San Feliu in Spain brought forward a large number of suggestions for research projects on integrated coastal zone management and that many initiatives are going on at the European level in EMAPS. It would be useful to have co-ordination of these initiatives and to develop activities for the Fifth Framework Programme.

Burbridge indicated that many lessons have been learned from the past, for example as documented in the report 'Enhancing the success of integrated coastal zone management', SIDA/UNDP, 1996. Information on EU and ESF initiatives is available on internet and further information exchange should be enhanced.

# Conclusions

- Many activities in integrated coastal zone management are ongoing at the national and EU level
- A need exists for participatory research in which stakeholders participate and detailed analysis of experience in existing projects
- The scientific challenge is to understand the processes in nature and society, and to obtain useful results for policy making. Without understanding of the processes and their interactions, no useful lessons for identifying policy options can be learned. this stresses the need for fundamental scientific research in order to obtain results relevant for policy making.
- Both socio-economic, social and natural sciences should be involved in coastal zone management research, participating in multi-disciplinary teams, working on various projects in EU.
- In future research projects risk assessment and decision making under uncertainty should play an important role, to analyse how risks can be reduced and how human activities in coastal zones change the risks of society. Scientific approaches (including concepts like hedging strategies, precautionary principle, safe landing) can be very helpful in understanding and solving these problems.
- Education for nature conservation and protection of biodiversity should be integrated in regular educational programmes, not only on visible aspects, but also on coastal zone management and aquatic ecosystems, including oceans.

- The opportunities offered by the Fifth Framework programme will be essential for enhancing scientific research and should be used to contribute to create understanding of the fundamental processes of coastal zone management and the land ocean interactions
- Dissemination of results is essential for having an impact on society and policy making. Dispersion of information and interaction with stakeholders is to be included in research proposals and should be an element in the selection procedure, as is already the cases in many programmes
- Important research topics will include the multidisciplinary analysis of tourism, fisheries, aquaculture and urbanisation in coastal zones and their impacts on biodiversity and landscape, and socio-economic impacts and the various trade-offs involved; detailed description are given in the report *Coastal Management Research*, Trans-disciplinary Euroconference, European Science Foundation, 1998, Strasbourg.
- Internet offers facilities to communicate on integrated coastal zone management and initiatives can be made to strengthen these opportunities.

# PREDICTABILITY FOR LONG-TERM COASTAL EVOLUTION: IS IT FEASIBLE?

# Predictability for Long-term Coastal Evolution Handling the Limiting Factors

*Michele Capobianco*

## Summary

*Predictability measures the reduction in uncertainty about one variable given knowledge of others using models of relationships.* Coastal Zone Management Tasks are normally undertaken in a situation of uncertainty that affects the predictability of long-term Coastal Evolution (and of any variable involved). The paper first introduces the problem of dealing with uncertainty in the context of Decision Making. This provides the framework for a first classification of the existing Limits to Predictability. The concept of "Window of Predictability" is then introduced. Recognising the importance of prediction in the context of impact and vulnerability assessment and the importance of models as tools to summarise the available knowledge, we aim at promoting a Model-Based Methodology for the Prediction of Long-term Coastal Evolution. The possibility of adopting Sensitivity Analyses and Monte Carlo Simulations as a way to formalise the identification of the Window of Predictability is than shortly discussed.

## 1. Introduction

The evaluation of long-term and large scale Coastal Evolution in response to both direct and indirect human interference's and to natural phenomena is an increasingly important issue in Coastal Zone Management. Such prediction would particularly assist impact and vulnerability assessment and contribute towards the definition of more effective policies and practices for Integrated Coastal Zone Management (ICZM) and for the sustainable utilisation of the Coastal Space. The prediction of the modifications that can occur to coastal morphology is thus particularly relevant for social and for economic reasons. It has however to be noted that Coastal Evolution is not only Morphological Evolution and Morphological Evolution is not only determined by sediment transport processes but also by the interaction with the local ecological system and by the interaction with the more general socio-economic system (EMAPS, 1998). Fig. 1 summarises the mechanisms that determine the driving forces.

Shoreline, as one specific variable of interest, and shoreline erosion, as one specific morphological process, are influenced by coastal processes resulting in offshore and longshore transport of sediments. Changing patterns in coastal storm climate can change the direction of sediment transport by altering the intensity and direction of waves incident to a beach. Shoreline erosion and the sensitivity to hazardous

storms are affected in a complex manner by coastal land-use decisions and by climate change and, conversely, can greatly affect coastal environmental quality.

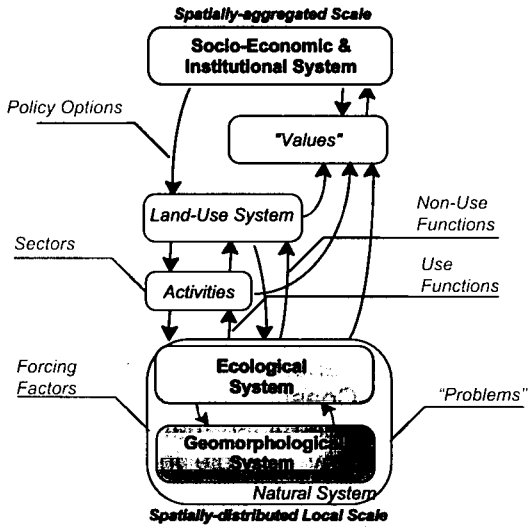



Fig. 1 - Mechanisms Driving Changes

Studies of global climate change and improvements in the predictability of climate variability are crucial for predicting and mitigating the impacts of shoreline erosion and hazardous storms. Local sea level changes (from subsidence of coastal areas from freshwater withdrawal, erosion, and movements of Earth's crust) could contribute to global effects. Of all the potential effects of global climate change, the effects of sea level rise have received perhaps the most attention, but other effects of climate change may be even more important. These include: the potential for increased storm intensity and frequency; changes in precipitation patterns and river flow; changes in sea-water temperature range and seasonality; alteration of coastal currents and upwelling, which affect temperature and nutrient supply; and modification of intermediate-scale weather patterns that affect winds, currents, and rainfall. Many uncertainties characterise such picture and affect the current degree of predictability of shoreline evolution.

The considerations that hereby follow can be considered for simplicity as being referred to long-term evolution of coastal morphology, however, in view of Fig. 1, they apply well to the coastal evolution in general.

# 2. Uncertainty in Decision Making

In decision theory and statistics, a precise distinction is made between a situation of risk and one of uncertainty. There is an uncontrollable random event inherent in both of these situations. The distinction is that in a situation of risk the uncontrollable random event comes from a known probability distribution, whereas ***in an uncertain situation the probability distribution is unknown and should be searched***. To understand the scope of the problem, it is necessary to differentiate between risk (sometimes referred to as "statistical uncertainty") and true uncertainty (sometimes referred to as "indeterminacy"). Coastal Zone Management problems suffer from true uncertainty, not just risk. One can think of a continuum of uncertainty where zero represents certain information, moving to intermediate levels representing information with statistical uncertainty and known probabilities (risk), and ending with high levels for information with true uncertainty or indeterminacy. Risk assessment has become an important guiding principle for environmental management but true uncertainty has yet to be adequately incorporated into environmental protection strategy.

Current approaches to environmental management, on the other hand, do not like uncertainty. The reasons for this are clear; the goal of management is to make unambiguous, defensible decisions, often codified as laws, regulations, and procedures. While legislative language is often open to interpretation, regulations are much easier to write and enforce if they are stated in clear and absolutely certain terms. But many scientific studies come to just conclusions in terms of probability (or conditional probabilities) because that is the nature of the phenomenon (and this is yet to come in long-term coastal morphodynamics).

Problems arise when coastal managers ask scientists for answers to unanswerable questions. When trying to enforce the regulations after they are drafted, the problem of true uncertainty about the impacts remains. As they are currently set up, most environmental regulations demand certainty. When scientists are pressured to supply absolutely certain answers, there is not only frustration and poor communication, but mixed messages in the media as well. Because of uncertainty, environmental issues can often be manipulated by political and economic interest groups (Funtowicz and Ravetz, 1995). Uncertainty about global warming is perhaps the most visible current example of this effect at large scale but, at a smaller scale, shoreline erosion can provide another example.

The "precautionary principle" is one way to deal with uncertainty. The principle states that rather than await certainty, regulators should act in anticipation of any potential environmental harm to prevent it. The precautionary principle is so frequently invoked that it is considered now as a basic normative principle of international environmental law. But the principle offers no guidance as to what precautionary measures should be taken. It "implies the commitment of resources now to safeguard against the potentially adverse future outcomes of some decision", but does not tell us how many resources or which adverse future outcomes are most important (Funtowicz and Ravetz, 1995).

In the context of Integrated Coastal Zone Management tasks, uncertainty plays a fundamental role during the *planning phase*. Particularly when the tasks require sequential decisions to be undertaken and when such sequential decisions can themselves represent a "stress" or an "impact" applied to the coastal area. Methodologies to formulate and solve sequential decision problems under uncertainty with continuous decision and/or random variables are increasingly being developed (Stonebraker & Kirkwood, 1997). More in general the tendency is that of developing some kind of propositional formulas according to their certainty or priority level, by assigning them lower bounds of necessity values.

# 3. Sources of Uncertainty and "Limits" to Predictability

In our case, uncertainty is introduced by the existence of "limits for predictability" that restrict the range of conditions that allow for the evaluation of coastal modifications. To make rational and informed decisions in Integrated Coastal Zone Management or while applying Environmental Impact Assessment procedures in the Coastal Zone, an evaluation of the limits to achieve predictability is therefore necessary. Moreover, definition of the limits to Predictability can contribute to Risk Assessment of Large Scale interventions. We distinguish:

- Intrinsic limits to Predictability
- Extrinsic limits to Predictability
- Technical limits to Predictability
- Organisational limits to Predictability
- Scientific/Methodological limits to Predictability

The ***Prediction of Aggregated scale Coastal Evolution*** at various spatial and temporal scales is discussed by De Vriend (1997); here we provide a more general framework. We do not discuss here the "amount of predictability" that is actually required by the Coastal Zone Management tasks, we leave to the actual coastal managers such definition during a later, more applied stage. However it is useful to focus the attention on two basic actions that might characterise the Coastal Zone Management tasks:

- Scenario evaluation, to evaluate, on the base of "what-if" type of questions, what could be the consequences of proposed actions;
- Forecast, to have some kind of anticipation of events that are likely to occur under present as well as future conditions.

## 3.1 Intrinsic Limits to Predictability for Long-term Coastal Evolution

We consider here those limits given by the intrinsic morphological behaviour of the Coastal System. Analysing the relationship between spatial resolution and predictability it is clear that while increasing resolution provides more descriptive information about the patterns in data, it also increases the difficulty of accurately understanding and modelling the formation and the dynamics of those patterns. There may be limits to the predictability of natural phenomenon at particular resolutions, and "fractal like" rules or "chaotic" dynamics that determine how both "data" and "model" predictability change with resolution (Falconer, 1990). The companion paper of De Vriend (1998) provides circumstantial evidence about the existence of intrinsic limits in coastal morphodynamics; no doubt that the same evidence can be given with reference to the other components of the coastal system.

What is important here is the recognition of such limits in order to avoid dissipating energy and resources to solve intrinsically unsolvable problems (i.e. the principle of indeterminacy) but also in order not to cause "error propagation" to occur when detailed process modelling is concerned.

## 3.2 Extrinsic Limits to Predictability for Long-term Coastal Evolution

We consider here those limits given by the uncertainties related with the forcing factors. Limitations concerning the evaluation of the possible long term changes of the wave climate and/or the possible modifications of relative sea level are well known. In addition we have to carefully evaluate those aspects in the forcing factor that are really relevant to long term coastal morphodynamics. In the same family of limits we should include those limits to the prediction of extreme events that are particularly significant for Risk Assessment.

Going backward in the cause-effect chain we enter the problems connected with climate prediction (and particularly the possible existence of long-term periods) and weather forecasting (and particularly the determination of the statistical character of extreme events). Care should be taken not to try to answer questions about Long-term Coastal Evolution that cannot be answered because of limits to the predictability of the forcing factors. Of course a possible simplification to the problem can be represented here by the "filtering capacity" of the coastal system that is however still subject to investigation (De Vriend, 1997).

## 3.3 Technical limits to Predictability for Long-term Coastal Evolution

We consider here those limits mainly given by our technical ability to describe the initial and the boundary conditions and to provide suitable information to describe what are the long-term and large scale changes for a given coastal system. We can include here the limits represented by the available measurement technologies, particularly those technologies suitable for long term measurements and those technologies suitable for large scale measurements and observations.

Suitable technologies to describe the complexity and the current state of the Coastal System are expected to provide a fundamental step toward the solution of such technical limitation (the adoption of remote sensing techniques and new generation of GIS). At same time the possibility to put in place and leave there technologies for the continuous as well as the event-driven monitoring (autonomous and "intelligent" monitoring systems) of the coastal changes can really provide an opportunity for the understanding of many long term processes that cannot otherwise be studied (e.g. cannot be recognised and studied in physical models).

## 3.4 Organisational limits to Predictability for Long-term Coastal Evolution

We consider here those limits given by lack of co-ordination in organising the available information about the forcing factor and the boundary conditions as well as those limits given by the lack of resources to collect the basic information. Even if the technology is potentially available, the organisations are often not there to collect and manage the available information, especially the information that is not directly "morphological" but potentially extremely useful for the evaluation of long term and large scale evolution of coastal morphology.

The possibility to assemble all the information that becomes available from any site around the World is something that should increasingly be considered in the future and is certainly like to be (see Woods et al., 1996 as an example). The possibility of networking and mapping information wherever available, the possibility to classify it according to coastal zone specific needs, and the possibility to "learn" from such information, can eventually provide enough experience to handle the variability of the forcing factors and the variability of the boundary conditions.

## 3.5 Scientific/Methodological limits to Predictability for Long-term Coastal Evolution

We consider here those limits given by our present knowledge and understanding of the long-term morphodynamic processes and by the present level of applicability of

the state-of-the-art knowledge on coastal morphodynamics. It could also be possible that the evaluation of long term and large scale Coastal Evolution is still, except for relatively simple situations, an "ill-posed problem".

The difference with respect to the Intrinsic Limits to Predictability is that in this case it is our knowledge and understanding, as well as our approach to use such knowledge and understanding, to introduce the limitations. These are likely to be overcome by the adoption of suitable alternative approaches still to be extensively investigated (see for instance Southgate and Capobianco, 1997) as well as by the adoption of alternative model formalisms like those based on fuzzy logic (Shen and Leitch, 1993).

# 4. The "Window" of Predictability

All such limits introduce serious uncertainties in the quality of the prediction of long-term Coastal Evolution that we can currently achieve at all the scales of interest and for any variable of interest (shoreline as an example). However, the existence of uncertainties cannot certainly be a justification for not undertaking any predictions, especially while planning interventions in the coastal zone. The central question here is "how to deal with existing limits" of Predictability for Long-term Coastal Evolution given the "amount of predictability" that is actually required by the Coastal Zone Management tasks (i.e. by the specific variable).

While the first two classes of limits "simply" need to be understood and recognised, the last three could potentially be ameliorated/changed by the adoption of suitable technical, organisational and scientific practices. The practical objective should be that of enlarging the "window of predictability" (Fig. 2 gives a qualitative indication) for the temporal scale and the spatial scale of interest and for the variable of interest. Thanks to the progress in scientific knowledge and to advances in information technology, models of coastal processes are now widely implemented and available. Furthermore they appear to have generally surpassed the availability of observational and experimental data with which to initialise, force and evaluate their behaviour and performance. The lack of data actually represents a limit for improvements in process understanding, especially on large scales, and inhibits the further development of models, both descriptive and predictive. The key to enlarge the windows of predictability is most probably in the integration between models and data (see Gerritsen et al., 1998).

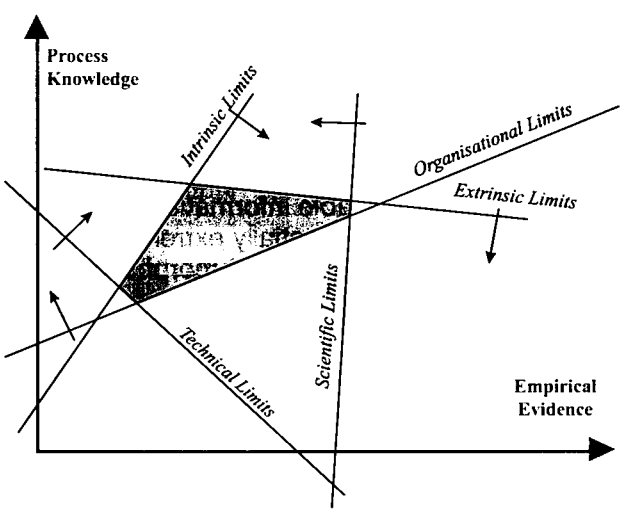



**Fig. 2 - The 'Window' of Predictability**

It has to be noted that the consequences of coupling ecological processes to a physical environment that has variability over a very broad range of space and time scales could be profound (see Dyer and Christie, 1998). There may be fundamental limits to predictability of ecologically relevant quantities in such a "chaotic" environment. What such limits are, if any, is an important question with substantial ramifications. It may not be possible to predict beyond a certain point in time what the effects of changing global environments are, because of the fundamental limits to predictability in the coupled physical-ecological systems of the Coastal Zone. It may be possible to predict some quantities (e.g., biomass), but not others (e.g., abundance and distribution of individual species). Perhaps there may be some guidance from more recent mathematical studies in non-linear dynamics.

For a practical evaluation of predictability, given a specific Coastal Zone Management task we need to focus on one specific variable at a time (shoreline is a well recognised example here), even if in general the variables of interest (or the "indicators") are certainly more than one, and serve more than one need and more than one user.

As far as the spatial dimension of Coastal Evolution is concerned, one can define spatial auto-predictability (*ap*) as the reduction in uncertainty about the state of a variable at a given point in space at a certain time, given knowledge of the state of the same variable at adjacent points at same time, and spatial cross-predictability (*cp*) as the reduction in uncertainty about the state of a variable at a given point in space at a certain time, given knowledge of the state of corresponding points at other times. *ap* is a measure of the internal (spatial) pattern in the data, while *cp* is a measure of the ability of a model to represent that pattern. Cross-predictability (*cp*) can be used for pattern matching and testing the fit between maps at different times. In this sense it relates to the predictability of models versus the internal predictability in the data revealed by *ap*. While *ap* generally increases with increasing resolution (because more information is being included), *cp* generally falls or remains stable (because it is easier to model aggregate results than fine ones). Thus, in principle, we can define an optimal resolution for a particular model (see De Vriend, 1998) that balances the benefit in terms of increasing data predictability (*ap*) as one increases resolution, with the cost of decreasing model predictability (*cp*).

These results may be generalised to all forms of resolution (spatial, temporal, and number of components) and may shed some interesting light on "chaotic" behaviour in systems. When looking across resolutions, chaos may be the low level of model predictability that occurs as a natural consequence of high resolution. Lowering model resolution can increase model predictability by averaging out some of the chaotic behaviour, at the expense of losing detail about the phenomenon (De Vriend et al., 1993).

# 5. Model-based Methodology for Predictability Evaluation

We do not enter here the explanation in details, however it is important to note that, regardless of the type of model that is adopted, and the type of technology and organisation that are employed for data collection and information handling, uncertainty "propagate" along the model links and the decisional chain. To have an

indication of the decisional chain, Fig. 3 summarises a model-based methodology to decide upon Coastal Interventions.

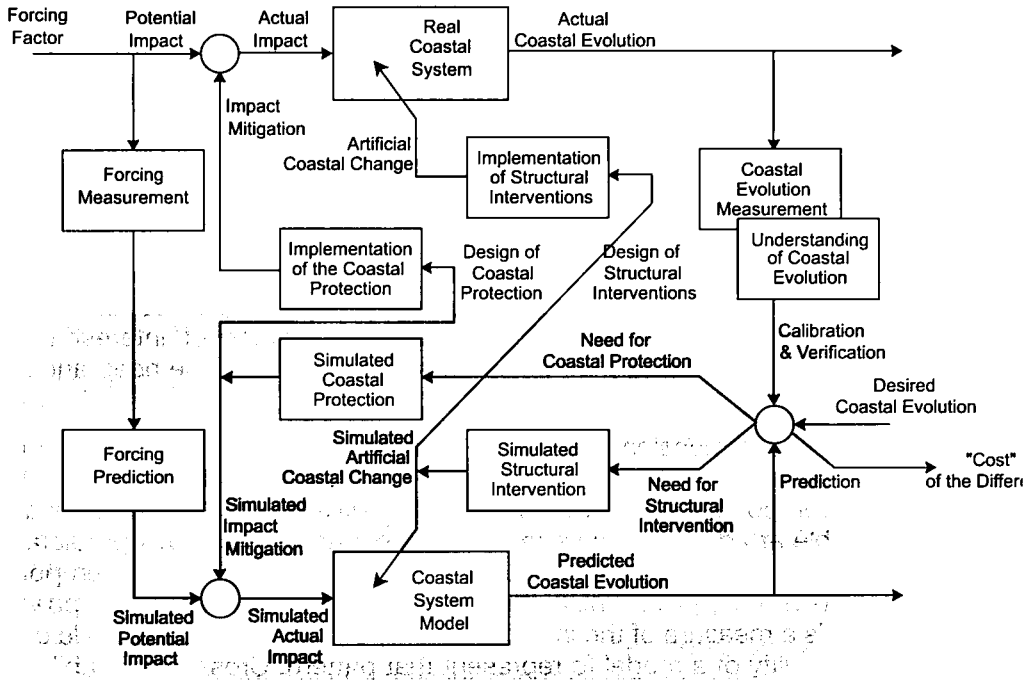



**Fig. 3 — Model Based Methodology for Coastal Zone Management**

Dealing with coastal protection, this has clear implications in the resulting mismatch between desired Coastal Evolution and actual Coastal Evolution (with possible social and economical implications). Such mismatch has, in ultimate analysis, a "cost". Same considerations apply to coastal development activities where the need to undertake Environmental Impact Assessment arises. Of course we do not only suffer from a lack of knowledge but, to a certain extent also from weaknesses in the formulation of the problems, especially as far as the risk associated with Coastal Zone Management is concerned. While from a scientific point of view the focus is on the prediction of Coastal Evolution itself, from a decision-making point of view focus is on the prediction of the "cost" of the difference between actual Coastal Evolution and desired Coastal Evolution. We expect that from the application of such schemes it will eventually be possible to address and represent uncertainty at least by identifying and quantifying the statistical characteristics of the prediction.

We basically classify the models that are available or potentially available on the basis of the relative degree of available data and available process knowledge (Fig. 4). In the case of Coastal Morhodynamics models, from such classification exercise we can roughly distinguish four large classes of models (see De Vriend, 1997): ***data-driven models***, or those models fully based on the examination of available measurements; ***behaviour-oriented models***, or those models also based on the qualitative observation about the behaviour of available measurements; ***pattern-***

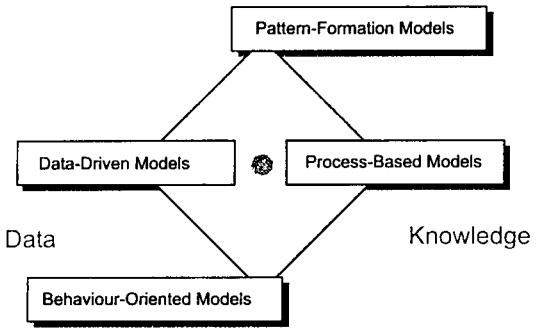



**Fig 4. - Classes of Models**

***formation models*** (or models of theoretical morphodynamics), or those models able to explain the mechanisms of formation of significant morphological patterns in the available measurements; ***process-based models***, or those models that, on the basis of first physical principles, can reproduce the available measurements. Such classes must of course be further referred to the specific class of problems the models are supposed to handle.

Given the classes of limits to predictability, the purpose of work is to assess the applicability of the four classes of model concepts, and of available models, to practical situations. On the other hand, given a certain "amount of knowledge" summarised by the four classes of model concepts, we would like to use such knowledge in the framework of the scheme of Fig. 3. The objective is that of carefully defining the capabilities and limitation of the so-called "predictive models".

From system theory, using the scheme of Fig. 3 and referring to the peculiarities of the models of Fig. 4, some interesting findings that can shed light on the practical feasibility of the prediction of long-term Coastal Evolution can be derived. ***Central to such an effort is the evaluation of the degree of uncertainty related with the prediction, and particularly with the time and space scale of such prediction. When such uncertainty exceed a certain threshold to be defined with reference to the specific application, than we can argue that the limit to predictability has been reached.*** Implicit to such consideration is however a number of purpose-specific, qualitative (and subjective) definitions.

# 6. Sensitivity Analyses for Uncertainty Assessment

Simulation modelling requires a large number of model parameters (calibration values) and input data. An important issue in modelling is the sensitivity of the model to variations in such parameters or data. Central to a model-based methodology for the prediction of long-term morphological evolution is the numerical implementation of the models. In this case, "a-posteriori", practical, ***Sensitivity Analysis (SA)*** can be used to evaluate how model output changes with changes in input variables, and uncertainty propagation can be analysed to examine how uncertainty in individual parameters can affect the overall uncertainty of the assessment. The basic method for sensitivity analysis requires the parameter to be varied in some predictable way, subsequently the model is run and the output recorded ***(Monte Carlo simulations)***. The output is plotted against the parameter value, and a regression analysis is performed to quantify the effect of the parameter on the results. The absolute sensitivity is given by the slope of the regression line while the relative sensitivity is the slope of the regression line if both the independent and dependent variables are standardised.

We expect that it is possible to investigate in such a way various aspects of the previously listed limits to predictability. In addition, from a more operational perspective:

- in the ICZM task, SA may help ***to identify critical regions*** in the space of the input parameters;
- in Scenario evaluation, SA may help ***to locate a few influential parameters***;
- variance based SA techniques are useful to ascertain if a subset of input may ***account for (most of) the output variance***;
- the previous point may be used for ***mechanism reduction*** (dropping or fixing non relevant parts of the model) and for model lumping (building/ extracting a model from a more complex one);
- SA may be coupled to optimisation/search algorithms; by identifying the most important parameters SA may allow ***to reduce the dimensionality*** of the space where the search is made;
- as a quality assurance tool, to make sure that the dependence of the output from the input parameters in the model has a physical resemblance and explanation in the case of behaviour-oriented modelling;
- to optimally allocate resources in R&D, by showing where is it worth to invest in order to reduce the model's range of uncertainty.

Different methods are generally adopted for varying the parameters in SA (see Capobianco & Otter, 1997). Whatever is the approach, it is worth noting that SA is applicable to variables with and without known probability distributions (i.e., frequency distributions are acceptable). Some tricky points are establishing the distributions of the input variables, designing a sampling strategy that will give reliable results in a reasonable number of simulations (typically on the order of 1,000), making sure we have examined enough simulations, quantifying the "true statistical distribution" of the output "errors".

Certainly we can benefit from the fact that the existence of "thresholds" around working points may make the model output some way more insensitive to variations of certain inputs or certain parameters; however this is something that is very difficult to be established a priori. At same time the existence of the same "thresholds" may cause large variations to occur from small modifications of the inputs if the working point is at the edge of rapid transition. The discrimination between such two situations should necessarily be the first action in the sensitivity analysis exercise and is directly connected to the issue of risk assessment. We need to tackle here one of the most important intrinsic limits in the present knowledge about coastal morphological systems, which concerns the role of extreme events on the short as well as the long term Coastal Evolution. Very little is known about the natural variability of coastal morphology; ***to what degree coastal morphology reflect any kind of "equilibrium conditions" or to what extent it essentially reflects transient behaviour induced by the dominance of low-frequency events?***

# 7. Discussion and Conclusion

**The scientific community should not underestimate the problem of the decision-makers** that, while undertaking short term decisions, often have to deal with large long-term uncertainties that limit the predictability of the consequences of such decisions.

**Work is needed to represent, qualify, quantify, and handle the limits to predictability** by making reference to the use of models for long-term Coastal Evolution. The adoption of models is central to the evaluation of the limits to predictability; the challenge is, however, to make the prediction itself less and less dependent upon the model. The objective is that of making the model utilisation less and less dependent upon the specific characteristics of the model (and more dependent upon the problem) by introducing, and using, principles and guide-lines for the systematic analysis and communication of the results they can provide. We formulate concepts of how to deal with our knowledge and representation of forcing factors (natural and human-induced influences), processes and outputs.

On-going activities to qualify Intrinsic, Extrinsic, Technical, Organisational and Scientific limits to Predictability must continue and should be integrated. It is probably premature to have a unique and robust prediction methodology but it appears to be reasonable to expect that, by developing new methodologies to handle the available knowledge at all significant spatial and temporal scales, by adopting technologies for long-term and large scale observation, and by investing in coastal-specific networking and information sharing, it will soon be possible to enlarge ***the window of predictability for many significant Coastal Systems and for a large number of significant Coastal Zone Management Issues***.

# 8. Acknowledgements

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# On the predictability of coastal morphology

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## Summary

Within the framework of definitions and development strategies which is given in the companion paper (Capobianco, 1998), circumstantial evidence is provided which indicates that there may be intrinsic limits to the predictability of coastal behaviour, and that a systematic investigation into the existence of such limits may be worthwhile. In order to improve prediction practice, a probabilistic approach to predictive modelling is proposed.

## Introduction

Coastal morphological changes take place at a variety of space and time scales, from small-scale ripple formation through to the evolution of entire coastal systems at historical and geological time scales. The predictability of coastal morphology over this wide scale range is not obvious.

The coast can be considered as a dynamical system, of which coastal behaviour is a manifestation. This includes changes in morphology, but also phenomena such as waves, currents and sediment motion. The dynamical character of this *coastal morphodynamical system* is constituted by the interaction of the water/sediment motion and the beach/seabed topography at various scale levels. Fig. 1 outlines this interaction.

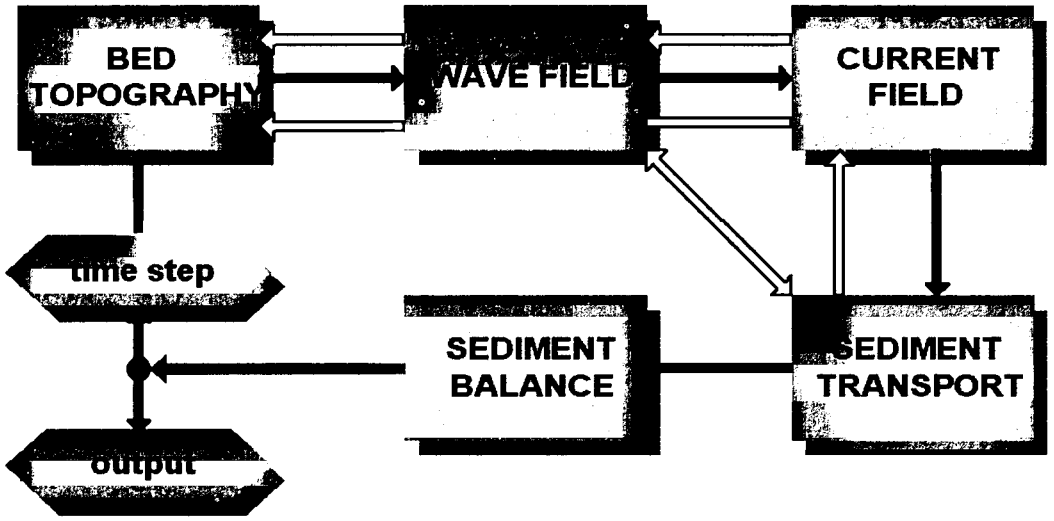



Fig. 1. Flow chart of the coastal morphodynamical system

In principle, a dynamical system can exhibit two main types of behaviour, viz. free and forced behaviour. The forced behaviour is due to an external forcing factor, e.g. storm waves. An example from the coastal domain is dune erosion. If the pre-storm topography of the shoreface and the dune front, as well as the soil mechanical properties of the sand body are supposed to be given, the erosion rate can be related directly to storm phenomena such as water level set-up, wave height, etc.

There is ample evidence that morphodynamical systems, even when approximated linearly, can also exhibit free behaviour. In that case, the system is linearly unstable and develops free modes which are unrelated to similar patterns in the external forcing. A relatively simple, but spectacular example is the formation of sandwaves on the seabed under the influence of tidal currents (e.g. Hulscher, 1996). These are wave-like features of a few hundres of metres wave length, up to some 8 m high, with their crests more or less perpendicular to the main axis of the tidal current. They evolve at a time scale of years. The tidal current field does not include any harmonic mode of this wave length. The only role of the tide is to provide enough energy to bring the bed sediment into motion; the internal dynamical interaction between water and sediment motion and bed topography does the rest. The occurrence of sandwave fields in the North Sea is clearly shown by depth soundings (see Fig. 2) and by SLAR-pictures (for instance, see the MAST-II project MAST^2).

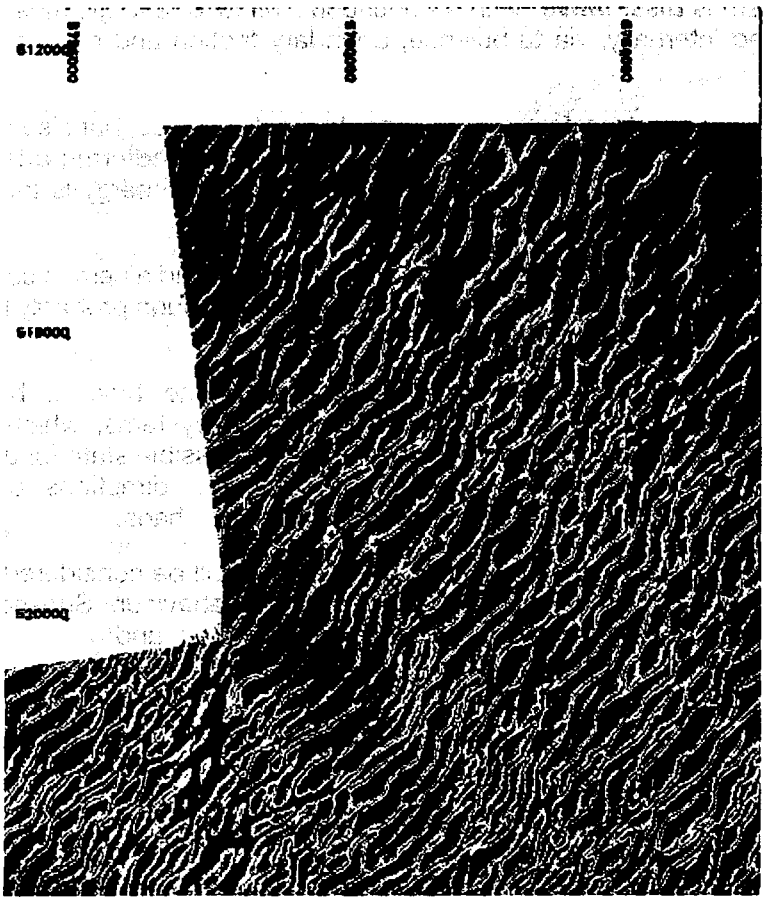


Fig. 2. Sandwave fields as observed near the Europlatform, North Sea (courtesy Rijkswaterstaat; Van Gool and Andorka Gal, 1996)

In the case of a linear system, free and forced behaviour are totally separated, but in nonlinear systems they will interact, whence they are more difficult to separate. Nonlinear free behaviour can evolve into very complex patterns, sometimes called coherent structures, or self-organized patterns. The nature of these patterns can be modelled in detail (cf. refined turbulent flow modelling; e.g. Lesieur, 1997), but they cannot be predicted in a deterministic sense, i.e. exactly where and when they occur.

The coastal morphodynamical system satisfies all conditions to allow for unpredictable behaviour in a deterministic sense:

- various essential components are ***highly nonlinear*** (e.g. flow inertia, bottom friction, sediment transport rate),
- the interaction between the system elements has a spatial dimension (e.g. non-local response of the water motion to its forcing, non-local relationship between bed shear stress and sediment transport rate); this means that, from the point of view of systems theory, the system is ***high-dimensional***, since each point in space represents a dimension,

- the system is ***dissipative***, with a continuous inflow of energy, most of which is dissipated internally, via turbulence, boundary friction and grain/grain interactions,

- energy is not only transferred from larger to smaller scales, but also from smaller to larger scales (wave-induced currents, small-scale bedform patterns influencing the larger-scale current pattern); in other words: energy is transferred ***up and down the energy cascade***

- it is to a large extent stochastically forced, since beyond a certain scale level the weather has to be treated as a stochastic variable (though probably not as white noise).

One must therefore expect the system to exhibit the type of behaviour of stochastically forced nonlinear dissipative dynamical systems, which includes a fractal structure of the system's state, more than one possible state for a given input (multiple attractors), vacillation ("hesitation") between directions of evolution, jumping between different states, or even deterministic chaos.

In the following, phenomena from various fields sites will be considered, which can be interpreted as manifestations of this kind of behaviour. Subsequently, the implications for further research, model development and model application strategies will be discussed.

# Fractal structure of wave-like patterns

The state of a dynamical system has a fractal structure if the same pattern occurs at a discrete series of scale levels. In the case of morphodynamical systems, we therefore have to be aware of the possibility of a fractal structure if the same topographical patterns show up at different scale levels, without forming a continuous spectrum.

First, we consider a well-known example of free morphological behaviour: sand ripples, on the beach, or in wind-blown sand, or at other places where a fluid moves at a sufficient speed over a loose sand bed. This entails the development of regular-looking patterns of small wave-like features, which, upon closer inspection, show strange anomalies, such as crest bifurcations and confluences, crest splitting ("eyes"), etc. These are typical indications of the system's nonlinearity: linear systems can only yield regular free patterns.

Strikingly, the sandwave pattern in fig. 2 has the same characteristics, but at an essentially larger scale. Again, we have a regular-looking pattern of wave-like features, with the same type of nonlinear anomalies.

At a yet larger scale, we find tidal sand bank patterns, with a wave length of typically 10 km, a height up to 75% of the water depth, and a time scale of evolution of centuries. Their crests make a sharp angle with the principal axis of the tidal current. Fig. 3 shows an example from the North Sea. Here, again, we see anomalies like those in the smaller-scale patterns.

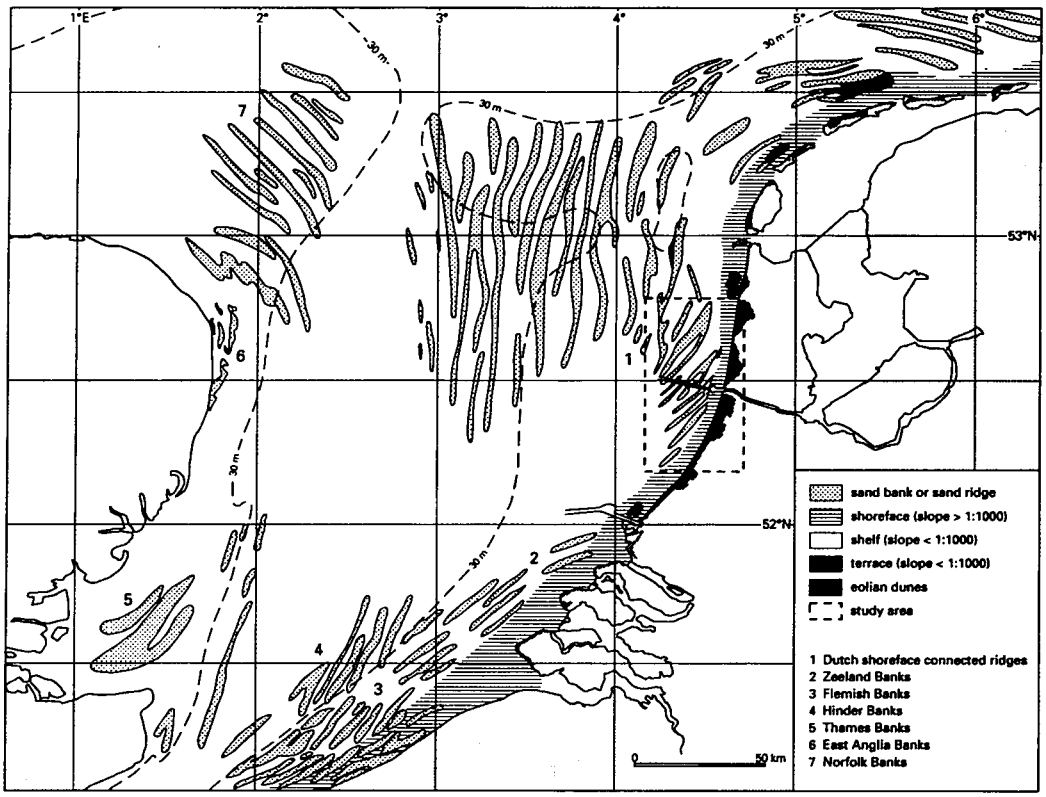



Fig. 3. Tidal sand bank pattern in the Southern North Sea (from: Van de Meene, 1994)

There is one other scale level at which similar features are found: that of the megaripples (wave length a few tens of metres, height typically 1 m, crest perpendicular the the predominant flow direction, timescale of evolution in the order of days).

The MAST-II projects CSTAB and STARFISH, which investigated the morphodynamical processes around Middelkerke Bank, off the Belgian coast, have shown that these patterns may well coexist, with megaripples "riding" sandwaves and these migrating up the slope of the bank (e.g. O'Connor, 1996).

Clearly, we don't have a continuous spectrum here, but rather a discrete series of wave-like topographical patterns. Although the formal proof remains to be given, this is probably a fractal phenomenon.

The seabed in shallow shelf seas may be an interesting (and practically most relevant!) playground for morphodynamicists, but it is different from the coast. The coastal equivalent of the above phenomena may be nearshore bar systems. There we see at least two distinct scale levels: the small-scale inshore bars which evolve rather fast and may look rather irregular, and the larger and slower nearshore bars, which seem to exhibit a more regular behaviour. Whether their patterns are similar

remains to be investigated. Moreover, the situation is much more open to dispute here, since they occur in areas with an essentially different forcing.

The same goes, *a fortiori*, for the so-called shoreface-connected ridges, which form the shoreward limit of the sandbank patterns in Fig. 3. One might be tempted to consider them as the next-higher-scale representative of the nearshore bar fractal family, but they probably are not, since they are tidally forced (Van de Meene, 1994; Falqués et al, 1998).

This illustrates the circumstantial character of the evidence. As long as the formal proof remains to be given, one should be aware of the possibility of other interpretations of the observed phenomena.

# Fractal structure of nearshore Profile behaviour

Probably the world's most data-rich coastal site, at least at the decadal scale, is the USACE's Field Research Facility at Duck, North Carolina. Both the inputs (wave conditions, water levels, etc.) and the output (beach and seabed topography) have been monitored extensively and consistently during more than a decade now, and a series of intensive field campaigns has revealed much of the internal dynamics of the coastal system there.

In the framework of the MAST-III project PACE, Southgate and Möller (1998) have investigated the fractal properties of the behaviour of a number of coastal profiles at this site. Using the so-called Hurst-exponent as an indicator, they arrive at the conclusion that the profile behaviour has a fractal structure and is uncorrelated to the input variations, but only within a certain time window. This window changes from 1-20 months for the beach and dune area, via 30-40 months between the inner and the outer bar zone, back to 1-12 months for the upper shoreface, i.e. the zone offshore of the outer bar (Fig. 4). Outside these windows, the profile behaviour is well-correlated to the forcing factors, but inside them one must expect self-organisation and limited predictability.

This confirms the concept of a *window of predictability* which was introduced in the companion paper (Capobianco, 1998).

# Multiple attractors

The analysis of the nearshore bar patterns observed at Duck by the ARGUS-video system (Lippmann and Holman, 1989) showed, after the first few years, a rather consistent pattern of delayed response to the wave energy input: during storms, a rapid stretching of the outer bar occurred, and during the subsequent periods of less energy exposure, the pattern tended to become gradually more three-dimensional, up to a well-developed crescentic bar system (Lippman and Holman, 1990). Upon the impact of a few extreme storms, around 1990, however, the behaviour changed drastically: it became much more irregular and thus it has remained until now, even though the input conditions have not changed essentially since the beginning of the observation period (Lippmann et al., 1993).

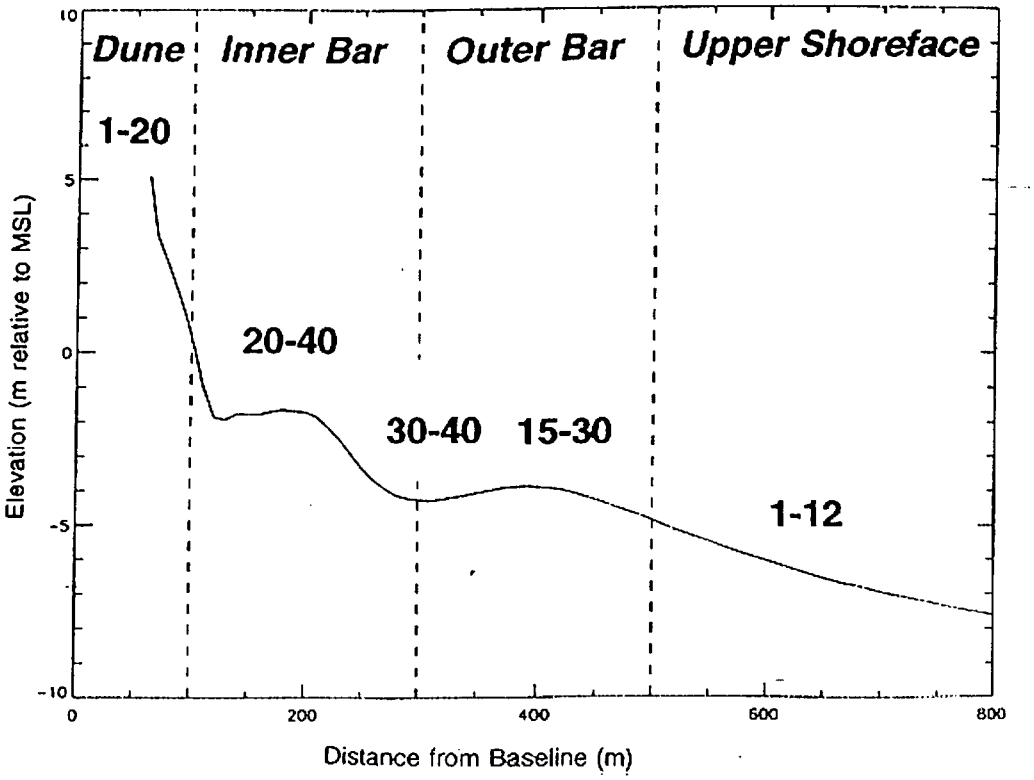



Fig. 4. Time-windows (in months) for fractal behaviour of the coastal profile at Duck, NC (from: Southgate and Möller, 1998)

A possible interpretation of this observation is the existence of more than one attractor state. The storms apparently pushed the system from one attractor "basin", representing the regular behaviour described above, into another, representing the more irregular behaviour.

Another indication of multiple possible states stems from an EOF-analysis of the JARKUS-data for the Holland coast (Wijnberg and Terwindt, 1995). This extensive dataset covers more than 25 yearly records of the cross-shore profile every 250 m along the entire coast of the Netherlands. The analysis revealed the existence of distinct "provinces" in the interannual behaviour of the nearshore bars. They differ especially in the return period of the outer bar, and in its migration speed. They are separated by surprisingly narrow transition zones, sometimes consisting of large engineering works (e.g. the entrance of IJmuiden harbour), sometimes without any obvious trigger.

The occurrence of these "provinces", which can by no means be related to longshore variations in wave climate, tidal motion or sediment properties, might be interpreted as as if bar behaviour be a matter of extrapolation from the past, such that accidental differences determine where the system goes (cf. the development of a language in two isolated areas). This would mean that bar formation would be an initial value problem, which is not quite likely, because of the ubiquitous spatial

interactions. Another interpretation might be that the co-existence of different lines of evolution is associated with different attractors.

# Vacillation and jumping

So far, little evidence of vacillation has been reported, but this may just as well be due to the fact, that a clear picture of the attractor states is still missing. It is rather difficult to assess whether a system is "hesistating" between two attractor basins if one is not even aware of the existence of the latter.

Plant and Holman (1997) analysed the location of the crest of the outer bar at Duck. This shows a number of very sharp transitions, which cannot be attributed to similar variations in the forcing. This also indicates that the bar behaviour is strongly nonlinear and cannot always be related to variations in the input.

Presumably, the longshore coherence of bar systems is not always very strong and easily interrupted. This seems to be confirmed by an observation near the pier at Duck (Plant, pers. comm.), where the bar behaviour at either side of the pier sometimes gets disconnected, develops in different directions and then, during some event, locks in again. The pier is known to cause a pronounced rip current, which apparently suffices (under certain conditions) to separate the bar evolutions at either side of it.

# Research implications

The basic knowledge which has been incorporated in predictive mathematical models concerns mainly small-scale processes (waves, currents, sediment transport). Based on the above circumstantial evidence, we must consider the possibility of intrinsic predictability limits. Hence it is not obvious that these morphodynamic models can be integrated through to essentially larger scales, if only we have a big enough computer and a robust enough numerical scheme.

Small-scale process research, however valuable in its own right and for small-scale modelling, may therefore be insufficient to improve our predictive capability at larger scales. In order to be sure, we have to investigate the coastal system for the existence of intrinsic predictability limits. If they exist, we must find ways to overcome them.

One way to trace predictability limits is a nonlinear stability analysis of the mathematical model which is supposed to describe the system. As stated before, it has been shown extensively that the onset of many coastal morphological phenomena can be explained from the inherent instability of the system's free behaviour (e.g. Hino, 1974; Blondeaux and Vittori, 1990; Damgaard Christensen et al., 1994; Hulscher, 1996; Falqués et al, 1997, 1998; Schuttelaars and De Swart, 1998). As yet, only few of them have been extended to the nonlinear domain (e.g. Vittori et al., 1998), but this has to be done in order to arrive at amplitude evolution models which can be analysed for predictability.

The existence of predictability limits is widely accepted for the input (weather) and for the lower scale levels (turbulence, grain motion). There one has also found the recipe to overcome them: aggregation over the scales at which the behaviour

becomes unpredictable. Since the models are nonlinear, this automatically leads to residual terms, which have to be expressed in terms of the agrregated state variables. In the case of turbulence, this has led to a wide range of turbulence closure models, in the case of grain motion to empirical relationships between the gross sediment flux and mean flow properties.

Another way of aggregation is behaviour-oriented modelling, a combination of empirical descriptors of observed behaviour (e.g. the equilibrium profile shape) and some elementary conservation laws (e.g. for sediment mass).

# Implications for model development

For coastal morphological model development, this may imply that a cascade of models is needed, each at a different aggregation level and with different state variables. Each lower-level model may be used to "feed" the parameterizations and closure submodels at the next higher level (upscaling), and each higher-level model may provide large-scale forcings and constraints for the next lower-level model (downscaling).

A recent application of this idea is the suite of morphological models which was used to investigate the effects of the planned extension of Rotterdam Harbour: a process-based 2-D area model for the short-term effects (up to 5 years), followed by a 2-D quasi-equilibrium model for the next 50 years, and a semi-empirical box-type model for the next 250 years. Each of these models feeds on the one at the next lower scale.

Moving to a higher scale level requires aggregation over certain space and time scales, but usually it also implies a shift of the model bounds (interaction with a larger area and new processes). A short-term prediction of beach evolution, for instance, can do without including the dune area and its vegetation, a long-term prediction cannot.

In any case, a straightforward extrapolation from first physical principles only will be very difficult, if not impossible. Data are indispensable, for model conceptualisation and fitting, as well as for model validation. Since the interest in operational forecasting of coastal behaviour is less well-developed as in the case of weather or ocean wave forecasts, we must keep on emphasising the importance of consistent long-term monitoring schemes, also with novel techniques. Remote sensing, for instance, seems to be ideal for monitoring pattern evolution in shallow water with a decent current.

The above cascade of models must enable us to cover the wide range of scales which is needed for engineering and management purposes. It touches upon the concept of *appropriate modelling*, i.e. choosing the model combination which is the most suitable to provide the information required, with maximum control of the robustness and accuracy of that information. Other research issues in this domain are the propagation of errors through a compound model (cf. De Vriend, 1987), identification of the principal sources of uncertainty, risk analysis, etc.

# Implications for model application

Single model runs are typically associated with a deterministic approach and hence unsuitable for the prediction of coastal morphology. They don't give any information on the robustness of the conclusions to be drawn from their results. The alternative is a probabilistic approach, combined with a quantifiable measure of skill. Both are standard practice in the use of models for weather forecasting, for instance.

Yet, a probabilistic approach is far from widely accepted in coastal morphodynamic modelling. For 2-D area models, there is an excuse: computers are not yet fast enough to make probabilistic modelling, e.g. via multiple runs in a Monte Carlo setting, practically feasible (Brøker et al.'s (1996) top-of-the-line model of the Thyborøn Inlet, for instance, ran at 50% of real time for a single run). We therefore have to accept that these models should primarily be used to get insight into the morphodynamic processes in the given situation (a very useful application in its own right!).

Nonlinear one-line and multi-line models, however, and probably also coastal profile models, must be ready to move to a probabilistic approach. Therefore, it is time to start building up experience with this type of approach. No doubt, this will raise new research questions, but we have to begin somewhere.

The development of measures of skill for coastal morphodynamical models has not yet received much attention. Yet, this is an essential step on the way to professionalising the use of these models, especially for prediction purposes. If we fail to convince the end-users of the quality of the information we produce, this type of modelling has no future.

# Conclusion

There is circumstantial evidence of the possible existence of intrinsic predictability limits of coastal morphology within the scale range which is relevant to coastal zone management. This should suffice to dedicate an appropriate research effort to either identifying these limits, or to showing unambiguously that they don't exist.

In the meantime, we should keep on trying to enlarge the window of predictability where this is constrained by scientific or technical limits, and to overcome the organisational limits where these are constraining our possibilities.

Predictive modelling of coastal morphodynamics should move to a probabilistic approach, in order to have an indication of the robustness of the information derived from the model results, and to cope with the possible existence of multiple attractors, which a single run will never reveal.

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# Summary and conclusions of the session on "predictability for long-term coastal evolution: Is it feasible?"

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1. Integrated Coastal Zone Management (ICZM) needs to anticipate the effects of current and potential natural and human processes. It should respond to the various processes effectively and without delay, with the overall aim of maintaining anthropic functions and using coastal resources in a sustainable manner. This means that there is a need for "predictions" of coastal evolution. Expanding economic activities along Europe's coastline require not only an adequate management preservation of water quantity and quality but also the active housekeeping of riverine and marine sediments. Beach resorts, marina's, reclamation projects, land-fill, natural habitats, all want their share of a pool of sediments which is decreasing due to relative sea-level rise. In the past coastal erosion was the result of a natural phenomenon that could not be opposed; at many places coastal villages have been abandoned and rebuilt landwards. With present coastal defence techniques, in particular nourishment of the coast with sea sand there is an alternative. Economic investments and revenues in the coastal zone tend to impose the choice of defending the coast and maintaining the coastline. As a result, the natural adaptation of the coastline is stopped, and the coastal profile may evolve away from equilibrium. To what extent is this evolution sustainable; how long can we continue playing around with sediments; does the coastal sediment budget impose limits that cannot be exceeded; can coastal sand management be optimised? These questions were underlying the scientific presentations and discussions of the session on "Predictability for long-term coastal evolution". It was mentioned that the scientific community should not underestimate the problem of decision-makers who, under pressure of short-term interests, have to deal with large long-term uncertainties that limit the predictability of the consequences of their decisions.

2. The first question raised during the session was: predictability of what? Which features of coastal evolution are of interest? For coastal authorities, the features of coastal evolution of interest depend on the scale of management. For instance, change of small scale features will be less important for management at the coastal zone scale. From a scientific point of view the prediction limits are different, depending on the type of coastal features under consideration. In general, the predictability time scale is getting shorter if the spatial scale is getting smaller.

3. The general outline of the session was designed as follows:

- different types of coastal features are distinguished according to their spatial extent (for instance, ripples, sand-waves, bars, sand-banks, beach and shore-

face slopes, inlets, coastal cells, delta's), and for each type the question is posed:

- over which time interval can its evolution be predicted (autonomous evolution or response to external forcing);
- how far can the predictability limit be pushed ahead (up till an eventual intrinsic predictability limit);
- and for this, which are the most critical issues for research, technology and organisation that should be resolved.

4. Predictability limits cannot be pushed ahead indefinitely. Due to the non-linearity of the physical processes and due to the great number of degrees of freedom of the system, the behaviour may become subject to "deterministic chaos". This means that after some sufficiently long time interval no unique direction of evolution can be defined. This time interval is called the "intrinsic predictability limit". There is evidence, both from theory and from observations, that such limits exist.

5. Coastal features can be ranked according to their spatial scale and we may consider for each feature the overall dynamics corresponding to this scale. A general rule seems to apply, saying that the intrinsic predictability scale increases with the spatial scale. This means that the dynamics of large scale structures cannot be derived in a deterministic way from the dynamics of the constituent smaller scale structures. In this case, the only way to push the predictability limit further requires the development of new dynamic description for the next aggregate scale level.

6. From the presentations it was concluded that there is still much progress needed in scale-aggregated models for practical prediction of long-term coastal evolution. Intrinsic predictability limits are not yet explored in a systematic way. In practice, models are still considered as less reliable for long-term prediction than extrapolations from long-term data sets. Of course, in extrapolation procedures implicit assumptions are hidden on long-term dynamics. There is a risk that this is not always fully recognised.

7. New observation techniques and new statistical methods and probabilistic approaches have become available which are powerful tools for analysing the complex behaviour of coastal systems from morphological data sets. Application of these methods emphasises the importance of long term morphological data sets for understanding and predicting coastal behaviour.

8. Another important development is the combined use of data and models. With integrated data-model systems existing data sets may be completed and enlarged. More precise information on extremes and other statistical quantities can be obtained from subsequent statistical analysis of these synthetic data sets. By adjoint modelling techniques and by sensitivity analyses, the most important error sources for predictive modelling can be investigated. These techniques provide a tool to focus research on the reduction of prediction uncertainties in a systematic way. It was concluded that great improvements in predictability could be achieved through further refinement of model techniques. Besides, improvement of predictability also depends on equipment and on technology development for measuring sediment transport and morphological change, both in situ and by remote sensing.

9. Insight in the basic nature of sediment transport processes is far from complete yet. There is great uncertainty, for instance, whether the most significant transport takes place in the water column or along the bed. The net transport is often only a small fraction of the gross transport, which changes direction and fluctuates both at small and at long time scales. Hence, the net long-term transport is difficult to measure and to model. In addition to physical processes, biota also plays a role; for fine sediments this role is very significant, but not well known. A lot of work still has to be done for a better understanding and description of sediment transport, which is crucial to improve the predictability of coastal behaviour.

10. A better understanding of the possible uncertainties related with the forcing factors should be achieved. Here we have to face, for instance, problems connected with climate prediction (and particularly the possible existence of long-term trends and periodicities) and weather forecasting (and particularly the determination of the statistical character of extreme events). Coastal managers should also consider uncertainties related to future human interference with coastal development.

a. In conclusion, a programme for future research should encompass the following elements:

b. investments in technology development for integrated measuring campaigns, which provide better information on morphological processes at different spatial and temporal scales; a special effort should particularly go toward long-term continuous and event-driven measurements and large -scale synoptic observation;

c. refinement of model techniques and statistical data analysis methods — and, in particular, data-model integration methods — to quantify and reduce the uncertainty of morphological predictions;

d. contribute to long term monitoring programmes, to better understand the role of low-frequency phenomena and of long-term trends and periodicities on morphological evolution;

e. development of aggregated-scale models to overcome intrinsic predictability limits related to constituent processes at smaller time and space scales;

f. co-ordination of European efforts in this field trough sharing of equipment, data, instruments and models, in order to enhance the quality and efficiency of this research;

Looking at the applications in the context of ICZM, predictability for coastal evolution should also consider interactions with the economic and social dynamics of the coastal system.

# Analysis and prediction of long-term beach evolution using advanced statistical methods

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## Background

The need to predict long-term beach evolution has increased in recent years as engineers and practitioners respond to the demands from society of project designs that target environmentally sound solutions and sustainable development. Thus, techniques and models are required to determine the long-term behaviour of a beach. In theory, knowledge of the governing equations at small-scale would be sufficient to derive the long-term behaviour; however, uncertainties in the formulation of the governing equations and lack of sufficiently detailed knowledge of boundary and initial conditions in general prevent such an approach. Instead one often has to resort to statistical methods to extract and predict beach evolution characteristics using available long-term data sets. A number of advanced techniques has recently become available that are useful for determining complex spatial and temporal morphological patterns and their dynamics. Two main classes of techniques for data analysis and simulation applicable to long-term beach evolution are principal component analysis and nonlinear dynamics. This paper discuss several such techniques and their application to the analysis and simulation of long-term beach behaviour.

## Data employed

Several long-term data sets encompassing beach profiles of high resolution in time and space together with wave measurements were compiled, analyzed, and used for simulation. For example, data sets from beaches at Duck, NC, Ocean City, MD, Oregon Inlet, NC, and Sylt Island, Germany, were employed. In all these cases complete beach topographies were available, except from Duck where surveys from four lines were used (instead very high resolution in time). Some of these beaches were subject to engineering activities during the measurement period making it possible to assess the effects of such activities on the beach response. The time periods of the data collection ranged from 5-15 years.

# Results

Empirical orthogonal functions were used to detect characteristic patterns in time and space for the measured topographies at the above-mentioned sites. Signals from engineering activities (short- and long-term) could be distinguished from individual storms and effects induced by large-scale features such as shore-attached shoals. Thus, long-term patterns could be detected and identified in all the data sets indicating the possibility of predicting beach evolution over the time scales investigated. Beach response and incident waves were correlated using canonical correlation analysis, employing both offshore and local wave conditions. A predictive model was developed based on these correlations and validated against measurements from Duck. The results showed promise for predicting bar formation and movement based on the local wave properties predicted by a numerical model. Singular spectrum analysis (SSA) was employed to reconstruct the dynamics of beach topography change. Long-term patterns characterizing the variation in time were identified, again indicating predictability of predominant long-term morphological features. Simulations of the profile evolution was also performed using SSA and the Duck data.

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# The Role of Parametric Modelling in the Study of Sea Level Extremes

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Parametric modelling has been extensively developed and applied within the MAST II project NEPTUNE [1994-1997] which was concerned with developing a new methodology for modelling the statistics and impact of NW European coastal extremes. The methodology was based on parameterising the full scale numerical model chain used to represent the physical processes linking storm weather with the consequential impact on a coastal structure. This involved modelling the generation of waves and surges offshore and their transfer to shore. The DNMI 6 hourly gridded digital data set for North Atlantic covering the period 1955-1994 was used to provide the reference wind and air pressure data for the study. The full scale model chain involved use of the models HYPA [GKSS], CSX {Proudman Oceanographic Laboratory] and HISWA, SWAN [Delft Hydraulics] to simulate the generation and transfer of combined wave-tide-surge levels to shore for each of forty selected extreme coastal storm events. The results were then used to investigate the use of parametric modelling schemes to replicate the results and preserve the input-output identity of the parent models. The method of Empirical Orthogonal Components [EOF] was used to decompose the wind fields into simple parametric form and System Identification [SI] techniques were used to develop appropriate linear time-invarient models to replicate the wave-tide-surge modelling chain. The parameterisation schemes were tested extensively using field measurement data sets available over a 13 year period at a number of offshore stations in the Southern North Sea.

The work has shown that such numerical schemes are computationally viable and provide a remarkably fast and efficient way of simulating point specific or spatial time series of sea state to a good accuracy — based directly on digital meteorological data input e.g., a 40 year time series of waves can be selectively generated using an SI model calibrated using a small number of total event data. The calibration can be made using modelled or measured sea state data and the availability of increasingly longer time series of global wave data derived from satellite altimetry and SAR presents interesting alternatives. This opens a new range of possibilities for researches requiring either selective or long continuous time series of sea state parameters. However, it places emphasis on the central importance of digital meteorological data and it's use as a reference standard; as well as the methodology of model parameterisation employed.

This paper will describe and illustrates the model parameterisation process with reference to NEPTUNE results and will outline the perceived evolution of the process set against a unified global digital meteorological data set. The paper will also discusses some of the difficulties and key issues which would arise in moving it forward towards more popular acceptance.

# Coastal Evolution — extending short term simulations

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## Objectives

1. To identify how modelling and monitoring capabilities need to be developed and combined to provide estimates of coastal — nearshore sediment exchanges.

2. To consider limits to long term predictability.

## Approach

Traditionally shoreline evolution has focused on coastal engineering aspects of the response of beaches to waves. This focus has recently been extended to include coastal-nearshore sediment exchange, reflecting concerns arising from acceleration in: climate change (sea level and storminess), offshore aggregate extraction, steepening of cross-shore slopes, adoption of soft-defence strategies (inc. beach nourishment) and recognition of large-scale interdependencies.

Such large-scale sediment exchanges cannot be measured directly and the longer-term impact on bathymetry may only be evident in shallow water. Thus models are required, linking dynamical simulations of tide, surge, wave and turbulence to 'dispersion' modules representing the erosion, transport and deposition of a range of sediment types. The associated dynamical coupling of model components and subsequent evaluation against observations emphasises the need for a Pre-Operational modelling approach. Monitoring is required to verify the sediment algorithms locally and the integrated depth changes in areas of rapid accretion/ erosion.

In the MAST III programme PROMISE, the North Sea was adopted as a focus because of the existence of forecasting systems for: tides, surges and waves. Wave models were adapted for fine-scale application in near-shore shallow regions. Likewise the turbulence models were developed to incorporate wave-tide-surge interactions. Extensive data sets were then assembled to assess these various modules independently and overall.

# Results

Parallel applications of the above models in the MAST II programme SCAWVEX have indicated that existing models accurately simulate both currents and waves in the near-shore zone. Likewise the interaction between these parameters can be reproduced together with their impact on turbulence intensity and locally re-suspended sediments. Thus the dynamics and associated erosion, deposition and suspension of sediments can be accurately simulated (at least at such low sediment concentrations). Longer term (and thereby larger scale) simulations of sediment transport are bedevilled by the chronology of sediment availability and the resultant evolution of bed form etc. Likewise there are inaccuracies in specifying meteorological forcing and 'initial'

bathymetry.

# Conclusions

Accurate shorter term simulations of near-shore suspended sediment concentrations have been achieved. However the longer term changes in bathymetry are calculated from successive differentiations in time and in space of these concentrations. Hence accurate simulation is much more demanding — especially since the availability of sediment for resuspension is dependent on chronology. Ensemble simulations with appropriate perturbations of initial conditions, forcing conditions, prescribed coefficients etc. can be used to test whether morphological simulations converge to provide stationary stochastic variability or diverge widely. Long term persistence of beaches, estuaries and shorelines (within seasonal/ decadal envelopes of variability) indicate the likelihood of the former. Conversely, occasional dramatic changes suggest that such stability is confined to a limited range of parameter variability. The recently developed capabilities in monitoring bathymetric evolution (especially inter-tidal) should provide datasets for assessing both the deterministic and stochastic aspects of associated simulations.

# Data model integration — a necessary approach to integrated modelling to extend and underpin predictability

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## Objective

(1) To identify and quantify the uncertainties and weaknesses in the process components and data elements in sediment and morphological modelling by means of formal data assimilation techniques. (2) To improve the information and forecast by optimizing the combined use of modelling, in-situ and remote sensing data. (MAST-III/PROMISE; BCRS/RESTWAQ).

## Background

Large-scale sediment behaviour on shelf seas and the net exchange with the coast are the result of the combined action of wind, waves, tides and interaction with the bed across different scales of time, space and depths. While descriptions for the different process mechanisms exist, albeit with varying levels of validation and robustness, the combination of the various processes in a description of (net) sediment transport and morphological change on longer time scales is still rather qualitative. Our limited understanding of the processes of interaction across scales and the observational difficulties is recognised. The approach adopted here uses formal data assimilation techniques to identify and quantify the impact on the prediction of the net transport or sediment exchange, of possible uncertainties or errors in the various elements of the total process description and inputs. The same holds for natural variability. Based on this insight, the level of predictability can be improved by addressing the weakest links in the process descriptions and data sets. This rigorous analysis approach is necessary to really extend predictability for complex integrated processes. The approach moreover provides quantitative information on the confidence with which such predictions should be treated.

## Results

Results focus on the sensitivity of a North Sea scale sediment transport model w.r.t. meteorological, hydrodynamic and wave parameters as well as empirical coefficients in the formulation of the erosion and sedimentation processes and sediment inputs such as dumpings, coastal erosion and riverine inflows. The model

performance is evaluated by comparing the computed concentrations and transports with observed data derived from NOAA/AVHRR reflectance imagery in combination with in-situ observations.

# Conclusions

The results sofar show the relative importance of hydrodynamics, waves and specific sediment processes and their inputs on the simulated net transport. Vice versa, this provides the information on the respective requirements to obtain a net transport prediction of a certain accuracy or robustness.

# The response of Mudflats to tides, weather and sea level

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Intertidal mudflats and their backing saltmashes protect many coastlines with the minimum of coastal defence structures. The cohesive sediment supports very productive specialised ecosystems that respond to both the covering by water and exposure; to hydrodynamic and atmospheric forcing. There is a complex interaction of sediment, biology and physical processes with feedback particularly affecting the erosion properties of the surface mud. For instance, the presence of a surface diatom layer enhances the sediment cohesion and thus increases the erosion threshold, whilst the characteristics of the diatoms depend on the sunlight and the moisture content of the mud, which is itself a control on erodability. As part of the MAST III project INTRMUD, an interdisciplinary field experiment was carried out on mudflats in the Humber Estuary to examine the interlinking of the processes. Synchronous measurements were taken at four stations across the mudflats of the tide as it flooded and ebbed across the flats, with measurements of current velocities, salinity, temperature and sampling for suspended sediment concentrations, carbohydrate and pigment. Because of the presence of elongated shore-normal ridge and runnel bedforms, measurements were taken during exposure to explore crest to trough differences, and how these may effect preferential erosion and deposition. Measurements of the changing moisture, organic, EPS (extracellular polysaccharide) and chlorophyll contents of the surface mud were completed.

The maximum velocities and concentrations occurred in shallow water during both flood and ebb, and the highest values were at the mid point of the flats where the bedforms were best developed. The direction of the maximum sediment fluxes appears to be responsive to the wind induced wave amplitudes, but were in the flood direction during calm periods, as was expected from the flood dominant tidal asymmetry. There were differences between the mud characteristics across the mudflats, with higher moisture and organic contents at the landward stations, 150% and 11% respectively. There are also differences between the ridges and troughs of the bedforms, with softer sediment in the troughs, though these differences varied significantly throughout the zone of bedforms. This implies that deposition and erosion can preferentially occur there. However, the ridges are probably more exposed to wave action.

It is concluded that, under a scenario of increasing storminess, erosion of the mudflats is likely to predominate at mid-flat levels, turning a convex depositional profile into a concave erosional one. Increasing temperature or exposure duration may increase the production of mucal films helping to bind and stabilise the mud. Increasing sea level will preferentially cause deposition on the salt marshes, but if landward progression of the marshes is prevented, loss of sediment offshore may result. The overall budget of the mudflat-salt marsh system is also likely to depend

on changes in the sources of fine sediment external to the immediate mudflat system.

Comparison of the results with measurements also being carried out in other areas as part of the project will enable quantification of the processes and clarification of their generality in different mudflat types.

# Large Scale evolutions of the Aquitaine coast

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## General Background and scientific objectives of the research

The Aquitaine coast is located in the bay of Biscay on the Atlantic french coast and is made of two uninterrupted stretches of sandy coasts (total of 240 km long) lying on both sides of the Arcachon tidal inlet. Landwards, the whole sandy beach is backed by the coastal dune system artificially built up 150 years ago to " stop " dune migration landwards. This dune system is 15-20 m high (peaking at more than 100 m at dune du Pilat) and 100-200 m wide. The overall coast is globally eroding and the beach and dune systems are slowly migrating to the East at an average speed of 1 to 2 m/year.

An analysis of the global evolution system has been performed in order to be able to predict the long-term evolution of this stretch of coast. Such a prediction is needed for legal reasons in order to prepare protection plans against natural hazards.

## Overview of the research work and preliminary results obtained

The work was based on field measurements including historical records and regular monitoring of the evolution of the dunefoot position since 1967. Additional data have also been obtained from detailed aerial surveys at a scale of 1 in 5000 for the Gironde coastline. The tidal inlet of Arcachon bay plays also a key role here and its evolution has been regularly monitored. Hydrodynamic and sedimentological data have also been collected.

Rythmic features have been identified at several space and time scales. Fluctuations of the dunefoot position are large-scale features which look very similar to longshore sand waves oberved along the dutch coast. An overall gradient of the erosion rate was inferred from the data as well as peaks of erosion located every 45/50 km (main peaks) and 20/25 km (secondary peaks). The celerity of these peaks, moving southwards, has been estimated to 0.5/1 km/year. It has been correlated with the duration of the migration of the outer sand banks of Arcachon tidal inlet which was estimated to be about 80 years.

# Main conclusions

From the previous analysis, long-term cycles of erosion/accretion have been observed making performance of classical protection schemes including hard structures very variable. A long-term understanding is now necessary before implementing any new defence scheme.

The results of this research are a first attempt to provide such an understanding.

# Inland beach migration and predictability of change in the northwest coastal zone of Portugal

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## Abstract

1. The northwest coastal zone of Portugal is situated between the estuary of the Minho river in the north and the Serra da Boa Viagem-Mondego cape in the south.

2. Some coastal segments are subject to rapid inland beach migration, by coastal erosion, at least since the XIXth century (in particular the coastal segment where is located the town of Espinho), and others present some stability, even after storm periods.

3. In the coastal segments with fast inland beach migration, coastal defence structures (groynes and revetments) have groynes andin front of the revetments.

4. The contrast of behaviour between different coastal segments is notorious. This has resulted in trying to find its causes and to accept the human incapacity to neutralize them, in so far they derive from Global Change (climatic changes and answers to the processes related to the instability of the structure of the Globe).

5. Research data (sedimentology, geomorphology, geochronology and neotectonics) about the paleoenvironments that have succeed each other, in the present coastal zone, since the Upper Pleistocene and Holocene till the present is demonstrated, in order to show that the coastal zone has always been unstable, and hence at environmental risk and a hazardous area.

6. The current explanation for coastal erosion (sediment retention behind river dams, greenhouse effect, sand mining, trampling, etc.) are discussed and it is presented the need to consider other factors and causes (marginal tectonic deformation, sedimentary stocks in nearshore and offshore, etc.) is presented.

7. The prediction assessment of coastal erosion implies that many coastal segments will continue to be subject to an acceleration of inland beach migration. From a decision-makers point of view, this will result in an artificial protection option of those coastal segments. Decision makers are still convinced that they are thus protecting the coastal populations and their livelihood from environmental disasters This will continue till the moment when they begin to realise that population retreat is the best option to protect people from inevitable coastal disasters. The question remains: will this prediction be right?

# INFRASTRUCTURE FOR RESEARCH ON BIODIVERSITY: WHAT DO WE NEED?

# Earth is a marine habitat and marine biodiversity matters

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## Abstract

The awareness of scientists, society and government that *marine* biodiversity is indispensable, vulnerable and an enormous resource is finally beginning to be appreciated. Biodiversity is not about species numbers, nor is it about fisheries– or any other single aspect. Biodiversity is about "connections", i.e., we know that biodiversity itself affects ecosystem function but we don't actually know *how*. The main challenges to understanding these connections are hampered by a series of mechanistic bottlenecks– and breaking these bottlenecks can be achieved by providing the necessary scientific and political infrastructure. Bottlenecks include lack of balance between descriptive aspects and question-driven aspects of biodiversity studies, loss of taxonomic expertise, non-transferable paradigms between the terrestrial and marine realms, and general fragmentation of research effort. Infrastructure for research in marine biodiversity that will help to break through these bottlenecks includes new technologies such as remote sensing *sensu lato*, DNA methodologies, advanced informatics on Web-sites, standardization of survey methods and protocols that will facilitate cross-comparison/integration of data sets. Most important is the need for clear operational terminology and specific formulation of research questions.

## Introduction

The United Nations Conference on Environment and Development that met in Rio de Janeiro in 1992 raised world awareness of the importance of biodiversity and its impending loss, yet the major international initiatives that followed did not include the oceans as a principle target for biodiversity research. Such glaring short-sightedness regarding a domain that represents 71% of the planet Earth is hard to believe, but it happened. Over the past five years a number of international organizations and consortia of individual scientists have been working hard (and with some success) to get marine biodiversity research included within (inter)national research agendas (*Global Marine Biological Diversity* 1993, *Marine Laboratory Networks* 1994, *Understanding Marine Biodiversity* 1995, and *A European Science Action Plan for Marine Biodiversity* 1998). Hallmarks of these documents are that they specifically identify critical scientific questions that must be addressed– not just science policy.

The awareness of society and government that *marine* biodiversity is indispensable, vulnerable and an enormous resource is finally beginning to be appreciated. In economic terms marine ecosystem "goods" and "services" have been estimated as equal to the global annual GNP (Constanza et al. 1997). While this recognition and valuation is heartening, the scientific realization that we actually know very little about marine biodiversity as compared with *terrestrial* biodiversity also comes as a rude wake-up call. Marine resources are being lost before they have even been discovered– and lost before we understand their contribution to marine ecosystem function. As terrestrial creatures ourselves, we have had the interest (?) and the technological means to investigate aspects of the marine realm for a relatively short while (say 50 years as compared with at least 200 in terrestrial systems). The task ahead is thus a big one.

Here it is argued that studies in marine biodiversity require a careful balance between descriptive and experimental approaches, i.e., systematics and monitoring based studies on the one hand, and process and experimentally based studies on the other. The latter approach is expected to elucidate the ways in which biodiversity modulates ecosystem function– the so-called "mechanism" or "how" question. Below, I identify four major bottlenecks to the study of marine biodiversity and discuss the infrastructure needed to break these bottlenecks.

# Bottlenecks

## The problem of definitions and balancing descriptive *and* experimental approaches

The multidisciplinary nature of research in marine biodiversity can make professional communication (or cross-talk) difficult. Each discipline carries with it traditions and scientific perspectives that necessarily emphasize different aspects of biodiversity as well as scientific approach. Conceptually, we can readily define biodiversity as the collection of genes, species, habitats and ecosystems. But in practical terms, it is often difficult and contentious to translate such a comprehensive notion into specific questions, whose answers must promote the synthesis of principles needed for understanding ecosystem function and sustainability. Ecologists, geneticists, biogeochemists, modelers, taxonomists are, in their way, "blind men examining the elephant". In my opinion, these differences most often translate directly into value judgements about what kinds of data and what kinds of questions are important. Biodiversity research is not "taxonomy" any more than it is "fisheries", "global change", a "foodweb", "computer model" or "ecosystem goods and services". Glib labels do much damage because, in fact, one does need to know what species are present, in what mix, how they function, how they interact and how they can be sustained. Biodiversity research is, in fact, about "connections"– and humans interfere with these connections.

## The taxonomic abyss

Over the past decade, new marine species (mammals: Brownell et al. 1995, invertebrates: Funch & Kirstensen 1995), new phyla (prochlorophytes: Chisholm et al. 1988), new domains (Archaea: Woese & Olsen 1986) and even new marine

ecosystems (deep sea benthos: Grassle & Maciolek 1992) have been discovered. These examples are dramatic and underscore our relative ignorance about the basic diversity of marine life (especially as compared with terrestrial systems) and highlight the need to reevaluate our taxonomic perceptions. By analogy we can compare our description of the taxonomic aspects of marine biodiversity to contemporary genome sequencing projects, which are also explorative and descriptive. Still, we implicitly accept that the discovery/descriptive phase of these projects will be followed by a synthetic one in which mechanism and function will be elucidated.

While it seems incredible that taxonomic knowledge of marine organisms lags so far behind our terrestrial knowledge, if one thinks for a moment, it's not really so surprising. Humans are designed for a terrestrial world, not a marine world. Human interest in marine organisms has traditionally been less and the technological means to investigate marine systems is relatively recent. For example, subtidal studies involving scuba diving have only been conducted for about 30 years. As a consequence, most standard marine floras and faunas do not include the subtidal because at the time they were written, scuba diving was not a research tool and dredged material was generally of limited value. Species that have been reported as rare in shallow waters often turn out to be abundant just a few meters further down. Examples in the pelagic are even more dramatic. Characterizing the deep sea by dropping equipment from ships is like describing a tropical rain forest by snagging organisms with a hook from airplanes. Availability of deepsea ROVs and and other new technologies are rapidly changing the traditional view of the open ocean as a "desert" (Ryther 1969). Prochlorophytes, which are responsible for a substantial portion of global primary production, were discovered in this "desert" only a decade ago. Just this year, an unidentified mesopelagic jellyfish was collected at 885 m off the Bahamas (Mills and Carlton 1998). Seemingly unimportant by itself, the ubiquitous removal of top finfish predators and the general tendency to fish further down the food chain, may be causing a shift in species balances in which fish are replaced by predatory jellyfish such as this one. Small size and simple morphologies (taxonomic anonymity as well as functional anonymity) must not be mistaken for primitive and/or unimportant. These properties have hindered progress using traditional morpholgical methods. With molecular techniques (i.e., DNA methodologies), it is now possible to critically and reliably identify marine species (including cryptic species and introductions), track species, and make assessments of dispersal. What we are learning from these investigations (taxonomy, phylogeny, biogeography and population genetics) is that levels of diversity and its compartmentalization are far more complex than previously supposed. Notions of basin-scale gene flow, taxonomic homogeneity and "global species" are rapidly falling away. The bottleneck here is that taxonomic expertise is either falling away or is already gone. Exceptions are in fishes, marine mammals and a few other traditionally well-studied groups such as diatoms and molluscs. But what about marine prokaryotes, marine algae and some of the more exotic invertebrates?

## Establishing *connections* in order to understand how biodiversity modulates marine ecosystem function

Life in the marine domain is fundamentally different. The water column is three-dimensional, continuous, and spatio-temporal scales are sometimes orders of magnitude different from terrestrial ones. Life history variation is greater and

common in marine organism so that population dynamics are necessarily different. Currently existing models (if they exist at all) that link mechanisms, that in turn shape and maintain biodiversity in relation to ecosystem function are still generally inadequate to explain current and projected, future function.

*A priori* "forcing" of terrestrial paradigms to marine ecosystems is one of the most important bottlenecks inhibiting progress at the process/mechanism level. While many principles do appear to be universal many are not. It has become axiomatic, for example, that marine species diversity is highest at the equator and attenuated towards the poles since this is the general pattern observed for terrestrial organisms (Clarke 1992) and based on a few case studies of marine molluscs (Stehli et al. 1967). As it turns out, polar depauperacy is mostly an historical artifact (see Gray 1997). Early studies were limited (for logistic reasons) to the Arctic, which is relatively species poor as a consequences of the last glacial episodes. Recent studies of the Antarctic provide a sharply contrasting picture that may be more generally applicable. Crame (1989) hypothesized that recent climatic cycles have acted as a diversity pump, concentrating taxa in *high* latitudes; and that frequent fragmentation and recombination of the distribution of shallow water marine invertebrates, due to the advance and retreat of continental ice shelves, may also have promoted speciation. The point of this example, is that many generalizations become "blind spots" in marine biodiversity research because they are simply not questioned.

Marine and terrestrial food webs provide a second example of non-transferable paradigms. For pelagic marine populations, the lowest trophic levels are phytoplankton and autotrophic bacteria, all characterized by small physical size, high numbers, and short generation times. Top predators are the largest in size and have the longest generation times. In most terrestrial systems the structure is opposite (Steele 1991) e.g., lions are smaller than their prey. The significance of these differences is that high level carnivores often play key roles in structuring marine biodiversity yet are exploited heavily by humans as food. In terrestrial systems, herbivores generally play this role. Moreover, a greater number of higher trophic-level species are exploited in the sea than on land with cascading effects down the food chain which we still do not fully understand. The previously mentioned example of the unknown mesopelagic jellyfish and pelagic fisheries illustrates this.

Scale is yet another nontransferable paradigm that must be carefully evaluated in the marine context. The spatial (or temporal) scale of a variable is defined as the distance (or period) over which it is relatively unchanged. Ecological time scales may correspond to years in terrestrial systems whereas the same events in a marine system may occur in days or months. At the spatial level, the scales over which various process occur are poorly known for practically all marine ecosystems yet are essential to the development of models of sustainability. Oceanographic and biogeographic studies (particularly those employing molecular genetic methods) demonstrate conclusively that the oceans are far from being homogeneous. Rather, oceans are a complex, three-dimensional mosaic of environmental compartments each with a measurable combination of abiotic and biotic characteristics. In a very practical context, both the spatial and temporal scale over which ecological processes take place in the oceans are mostly at odds with the spatial and temporal scales of human exploitation and geo-political boundaries. This is significant

because human pressures on the sea are growing rapidly. It is currently estimated, for example, that about 60% of the world's human population lives within 100 km of the shore.

Ecological redundancy and ecosystem resiliency are also related to areas with unique parameters in the marine domain. What is the critical minimum biodiversity necessary for the system to function? If species are removed, at what point will the ecosystem be unable to recover? Are keystone species involved? We have some ideas about these levels for terrestrial systems, but we simply do not know where the threshold levels lie for biodiversity, as a modulator, in marine ecosystems (Naeem et al. 1998).

### The fragmentation of research effort

Individual and national research efforts are critical, but they can only go so far because the scope of the questions is so large that only a concerted effort will lead to a workable answer. This relates in part to expertise and in part to biologically irrelevant political boundaries. Ocean boundaries are not so easily delimited as those for geo/political states (Mills and Carlton 1998).

The fragmentation bottleneck was highlighted recently in a review of marine biodiversity research projects in EU member countries. Warwick et al. (1996) concluded that of the 473 European projects covering the five *Diversitas* programme elements, marine biodiversity research was extremely fragmented with respect to geographic areas being studied and the distribution of projects over the five research foci. The skewness extends to the organisms being investigated, the geographic areas and the themes themselves. Taxonomic and monitoring projects accounted for 65% of the research. Within these two *Diversitas* foci, >90% focused on animal studies (70% on fisheries) whereas plant studies accounted for <10% and prokaryotes <1%. This unbalanced approach clearly reflects human interest rather than biological reality. The remaining 35% of the projects covered the other three *Diversitas* foci, i.e, ecosystem function, modeling and conservation. In the geographic context, the Wadden Sea, Baltic Sea and portions of the Mediterranean have received most of the attention, whereas more general coastal areas, notably the Atlantic coasts of Spain and France have received relatively little. This is surprising because the larger number of endemics would be expected to occur along these coastlines as a consequence of the last glaciations. Fragmentation further inhibits progress because much of the accumulated data cannot be synthesized (for a variety of reasons) into a larger context– either at the theoretical or applied levels.

## Infrastructure

### 1. New technologies

Remote sensing *sensu lato* includes everything from space satellites (SEAWIFS) to underwater probes (side scan sonar and remotely operated vehicles (ROVs)). Robotics equipped with real time video and options for virtual reality are presently available but not used to their fullest potential. Combined with sophisticated programs such as Geographical Information Systems (GIS) EuroGOOS, remote

sensing capabilities can be significantly expanded and provide a means for understanding spatial-temporal scaling questions. Fixed-position buoys and other seafloor instruments must also be considered, especially for long-term baseline monitoring. Advances in micro-electronics, miniaturization of equipment, and remote-links to researchers make these approaches far more tractable than even a decade ago.

Molecular biological (DNA) methods ranging from comparative DNA sequencing to fingerprinting and probe development can be used for identification, population tracking, population modeling, systematics and functional gene expression. Molecular data also provide a bridge between many disciplines (e.g., molecular ecology) which facilitates collaboration on common questions. Some examples include tracking migration routes and feeding grounds, coupled with genetic structure and social behaviour in humpback whales (Valsecchi et al. 1997), homing behaviour and population differentiation in reaction to post-glacial colonization in Pacific salmon (Small et al. 1998), and in studying the breeding system and dispersal capacity in benthic marine algae (Wattier et al. 1997).

Information management/informatics and accessibility via interactive World Wide Web-sites are essential. Coupled with standardized data collection protocols and sampling designs, the capacity for synthesis will be greatly enhanced. Availability of real-time data, databases for complex image patterns, DNA sequences/alignments (GenBank), multi-media identification keys (LINNEAUS), use of neural network keys and species inventories at all scales can be integrated with GIS. CD-ROM formats can also be produced.

## 2. Standardized methods and protocols

Comparison of data sets is often impossible owing to differences in experimental design and choice of data (e.g., Clarke 1992). While this cannot always be done, some standardization of methods and protocols for data collection and handling needs to be established. This could be done in a formal way through the EU usng a modular approach tailored to the specific question. This would facilitate analysis and integration of large-scale data sets (of all kinds) among scientists from different countries. Use of nested designs are important for scale issue questions but also enhance statistical analysis. Clear operational definitions of terms are also important, especially with respect to more abstract terms like habitat, system, and population. Coordination of marine laboratories and institutes can be further enhanced by calling upon already existing networks such as MARS (Network of European Marine Research Stations), LOICZ (Land Ocean Interaction in the Coastal Zone) as well as by interactive Web-sites described above.

## 3. Clarity and specificity of the research questions

The question must always dictate the approach (field survey, experiments, models) and methodology, and all too often the tendency has been to do just the opposite. Moreover, proposal guidelines, whether at the national or EU levels, are often vague. In one sense generality of guidelines provides flexibility and creativity, but in my opinion, it also promotes fuzzy science with no real chance for synergism. Below is a sample of some of the core areas/questions that can provide significant insights into

the way in which biodiversity modulates ecosystem function. More details on specific questions can be found in the *European Science Action Plan* (1998).

Effects of fragmentation on natural populations (both natural and anthropogenic) are not clear. Is there a minimum threshold population/community size? Determination of this would require controlled, long-term field and mesocosm experiments. Linked to this are questions around ecosystem resiliency (i.e., recovery insurance following disturbance), species redundancy (How much biodiversity can be removed without causing a crash or major change?), and the role of keystone species (are they even present?) in relation to stability and productivity.

The temporal and spatial scales over which various processes occur are poorly known for practically all marine ecosystems yet are essential to the development of models of sustainability. One example has to do with the connections among life history traits (often complex in marine organisms), dispersal, genetic differentiation and its consequences for population structure and compartmentalization. Understanding genetic structure of populations in space and time permits identification of stocks and the magnitude of gene flow. Are stocks genetically depauperate? Are there source stocks and if so, where are they? Development of molecular markers for identification, mapping and monitoring are key as are nested sampling design.

Models of marine food webs and interactions between food web structure and biogeochemical cycles needs refinement. Species have complex interactions (competition, predation, parasitism) among themselves and with their environment (temperature, water motion, food supply). As biodiversity flucuates (both quantitatively and qualitatively), we need to know how ecosystem function and resiliency will be affected. Good (=predictive) models require good data. Therefore, quantitative information on composition, dispersal of marine species, genetic diversity, spatial and temporal scales is imperative for establishing parameters of the model.

Systematic/taxonomic studies of under-represented phyla and lineages needs special consideration, as does the need to investigate putative "global species" (particularly zoo- and phytoplankton). Here I will argue that methodology does play a key role. Specifically, the use of molecular methods in combination with more traditional taxonomic tools is essential, especially for small and morphologically nondescript entities. As to choice of taxa, the current emphasis on fisheries- related animal taxa at the expense of plants (<10% of the research) and, especially, marine prokaryotes (<1% of the research) is simply unsound with respect to biological importance of the different groups.

## 4. Establishment of a few selected habitats

It is not possible to look at everything in every place. Therefore, a select number of "flagship" sites should be chosen across the geographical range of Europe (from the Canary Islands to Svalbard and from the Azores to the Eastern Mediterranean). For these, the biodiversity characterization should be as complete as possible. Less comprehensive surveys at larger scale (using standardized methods) could be targeted separately. Where taxonomic problems are serious, they should be given extra attention. Deeper habitats (beyond the inter- and shallow subtidal) must be included. In the past, the deep habitats have been ignored because of technical considerations. Now, new technologies make investigation of seascape compartmentalization tractable. The reason for wanting to have this sort of comprehensive

inventory of information for a few sites is that it: 1) provides baseline descriptive and functional information that is essential for future comparisons; 2) allows for a limited number of fine-scale studies (competition, predation, recruitment, succession, disturbance, etc.) to be conducted in a uniform manner; and 3) provides a standard set of measurements that can be compared across the different sites.

### 5. Long-term support

Government stamina for long-term studies is essential. The return on investment measured as knowledge about how marine biodiversity modulates ecosystem function will be directly proportional to the time course of the work. Some questions may be answerable within a 2-3 year period favored by most funding agencies, but most are not. For example, community-level, ecological research should span 2-3 lifetimes of the dominant species. Where temporal scale is long, cumulative data sets covering a decade or more are needed.

Technical and scientific horsepower are available– and time is potentially available if sufficient political will combined with financial support can be obtained. One potential solution is to look for matching funds from private foundations in Europe. This would have the dual effect of softening financial strain while raising public awareness and participation. One example of this approach is currently under consideration by Hewlett-Packard Foundation (USA) involving a consortium of some west coast marine scientists. The proposal under consideration involves a US$15 million-dollar grant in perpetuity to study, preserve and manage marine ecosystems along the 2000-km-long California coast.

## Conclusions

The desire for comprehensive models that *connect* genetic variation at the population level to dispersal processes that *connect* particular species assemblages with functional performance, *connect* scaling processes, and make predictions of global change beyond certain biodiversity thresholds are still a grand challenge requiring a multidisciplinary effort. In any case, a greater understanding of these relationships can only be achieved by collaboration at the European/ international levels that can *connect* the mosaic of regional diversity patterns within larger latitudinal and longitudinal gradients.

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# Provocateur's report

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What is biodiversity? Obviously it is more than the mere number of species in a certain area, but:

In what way does biodiversity research differ from classical floristic and faunistic inventories in various types of habitats, ecosystems, regions etc?

Today we probably think about biodiversity in terms of the total pool of genetic information. This means that we are not only dealing with diversity based on the classical species concept, but also the specific genetic information in populations of a species.

Now, what is research on biodiversity? Is it mapping biodiversity, documenting species, how abundant a species is, populations sizes and the genetic differences among populations?

Or do we mean research dealing with the concept of biodiversity, I. e. what it is, how it could be measured, what it means for the ecosystem, in what ways it is important for Man etc.

If it is the former we need to engage in a large scale mapping of marine ecosystems down to the population level and including measuring genetic variation. This is certainly an enormous task even for more conspicuous and well known species, such as fish or macroinvertebrates, but for bacteria and "phytoplankton" it is an Herculean task. Can it be done and is it worth the effort?

Should we invest in a Biodiversity equivalent of CERN or EMBO, or is it better with a much more loose network? Is it necessary to direct international research money, e. g. from EU, directly to such efforts, or can national programs be sufficiently encouraged, financed, staffed and coordinated?

Obviously biodiversity is changing all the time, both naturally and above all today anthropogenically. Is it thus necessary to engage in some kind of paleobiodiversity research and is this feasible? If we put a large effort into quantifying present biodiversity, will this information be obsolete in a few years due to natural variations, global change and more regional anthropogenic influence? And how does present biodiversity relate to the pre-industrial revolution situation etc?

For the special case of marine biodiversity we have the obvious problem of the unconfined nature of the habitat and thus the possibility of large scale movements of organisms, sometimes aided by man.

Being a scientist I do not believe much in large centralized and bureaucratically controlled research efforts. I also doubt the feasibility of e. g. a European marine

biodiversity mapping program with their own laboratories staff etc. Obviously some kind of coordination on at least a European scale is needed, but this could be achieved through some more loose network initiatives (which probably already exist).

I suggest, however, that resources are allocated to some specific areas, where concentrated efforts are obviously needed and could give much return in the form of new knowledge:

1. Research on marine "bacteria" using modern molecular biological methods. Here we are still very ignorant and do not know what there is in terms of genetic variation or even who is doing what, e. g. in the pelagic environment.

2. Research on genetic variation among "phytoplankton" and especially what this means in terms of toxin production, bloom formation, response to eutrophication etc. Harmful algal blooms appear to be a continuously increasing problem, in spite of efforts to control pollution and eutrophication. Too little is known with respect to the genetic variation within phytoplankton species.

3. Research on the effects from commercial fisheries on marine biodiversity. Fisheries is one of the holy cows of the European community, only surpassed by agriculture. Marine overfishing has most likely profoundly changed food chains by eliminating keystone species. The consequences of fishing ourselves down the marine food chains have recently been discussed in Science, but we know too little in spite of the enormous economic implications. There must be much more cooperation here between traditional fisheries biologists and marine ecosystem scientists and theoretical ecologists as well as geneticists.

4. The relation between eutrophication and biodiversity is still poorly known. Obviously anoxic enclosed basins have a very low biodiversity, but what about the more delicate balance in the littoral and pelagic zones due to changed competitive relations caused by an increase in certain essential resources, such as nitrogen and a decrease in others, such as silica. From terrestrial ecosystems we know that increased nitrogen addition decreases biodiversity. Is this the case in marine systems too?

5. How does the introduction of cultivated fish affect genetic variability and survival of the species in the long run? Artificial rearing of fish until a certain size from a limited number of parents and under completely artificial growth conditions may be disastrous for wild fish stocks, e. g. with respect to resistance against diseases.

6. Introduction of foreign (exotic) species. This is thought to occur e. g. through ballast water. Several new species of bloom forming and harmful algae may have been introduced into European waters during recent decades. There are also new species of macroalgae, medusa etc, which causes tremendous impacts on native organism communities. However, little systematic research has been done. From terrestrial ecosystems we know that exotic introductions are only second to habitat extinction of species.

7. How does long-term accumulation of sub-lethal doses of persistent organic pollutants affect species diversity? Not only PCBs, DDT etc, but also toxins produced by certain phytoplankton species are know to have long-term effect, such as e.g. okadaic-acid which is a liver tumor promoter. These toxins can be found in mussels but also in fishes. How do these toxins affect mammals higher up in the

food chain (seals, whales) and commercial fish stocks (which are already threatened by overfishing)?

8. Which are the genetic and ecological effects of the dispersal of introduced species and genetically modified organisms (GMO)? The use of genetically manipulated organisms (such as fish) in aquaculture may increase in the near future. Escape of these GMO_s might have consequences for reproduction and genetic variation in natural populations.

9. Species that live at the limits of their distribution may become genetically distinct through isolation. How genetically different are these species? We know that eg Zostera marina in the Baltic Sea was resistent against the disease that caused extermination over large areas of the northern Atlantic in the 1930-ies. In the Baltic there may be genetically distinct populations of a large variety of organisms which are also found in more marine areas of the N Atlantic. Such differences, e. g. with respect to the blue mussel, Mytilus edulis, need to be documented.

This are some examples of biodiversity problems/research issues. As resources are obviously limited, we need to concentrate on the most urgent problems. Which are these?

# Rapporteur's Report

*Carlos Duarte, CEAB/CSIC*

Following an introduction of the subject by the chairman (Dr. Carlo Heip), providing a definition of biodiversity, its hierarchical structure and the formal context or this research, a keynote address was delivered by Dr. Jeanine Olsen (see text attached), to which was replied by the provocateur, Dr. Edna Graneli (see text attached). Lively discussions, with participation of over 50 scientists in the audience, followed each of the speakers. The presentations and the discussion provided a clear consensus on what the main priorities in the research agenda should be, and what infrastructures are needed to effectively address them. This consensus is summarised below.

The decimation of marine biodiversity is clearly perceived, both by society and the scientific community, to be a threat to the sustainability of the oceans. Not only the present state of marine biodiversity is subject of concern, but the future of marine biodiversity, under a scenario of climate change and increased human pressure on marine ecosystems (FAO estimates that the deficit of marine food, the difference between demands and supply, will be about 10 — 40 million tons by year 2010). This perception, reflected in many scientific documents and international conventions and declarations, has, however, led to different priorities for action, pointing to a gap between the priorities identified by the scientific community and those perceived by society. Moreover, even within the scientific community there is considerable controversy as to what the priorities for research should be. The net result is that research efforts remain fragmented, and the mobilisation of the scientific community at the European scale to address the grand challenges of research on marine biodiversity has not yet been realised. The main bottlenecks hindering progress were identified to be:

- The absence of a truly interdisciplinary approach to the study of marine biodiversity, which should extend beyond the different disciplines within biology (molecular biology, taxonomy, systematics, ecology) to encompass all aspects of marine sciences (geology, geochemistry, physics, chemistry, etc.). Instead of co-operating, the research programme has been characterised by disagreement between scientists with different backgrounds as to what the priorities should be.
- The lack of a clearly phrased question that would allow the design of effective research strategies. This absence has opened a gap between the interests of scientists and those of society, resulting in a poor mobilisation of resources. Moreover, the absence of a clearly formulated central question has resulted in the proliferation of small-scale research efforts, leading to a fragmented approach, in contrast to the synergy of efforts and resources, which must encompass at least the European dimension, required to effectively address the key issues.
- The absence of prioritised research agendas, which have been formulated too broadly, resulting in exceedingly vast requirements of resources, which have rendered these research plans non operational.

- The existence of a poor knowledge basis from which relevant research can be formulated. This derives from the fact that scientists have been able to sample directly marine biodiversity for only one generation, so that the expertise is often lacking in key fields and the paradigms and basic patterns remain largely undescribed.
- The absence of a coordinated research programme, at the European scale to address the main challenges for the sustainability of marine biodiversity. Yet, it is clearly recognized that the efforts required and the scale of the problems are of such a large magnitude that progress can be only attained through coordinated research with a clearly defined European Dimension.

It was felt that such bottlenecks would be largely overcome by the definition of a central question, providing the grand challenge to mobilise resources and efforts towards the core of the problem. The discussion allowed to identify this question as:

**To predict the role of marine biodiversity in the regulation of marine functionsand the array of services these functions provide to society** (climate and gas regulation, pollution abatement, nutrient cycling, prevention of coastal erosion, food and raw materials, etc.). The research needed to address this question would allow:

- The development of an interdisciplinary, multiscale science, for the marine functions affected impinge on all fields of marine science and all levels of biological organisation (molecular, species, and ecosystem).
- The description of the basic large-scale pattern of the distribution of marine biodiversity in Europe, allowing the empirical test of concepts and models of the regulation of marine biodiversity.
- An emphasis on predictive power, leading to the quantitative knowledge demanded, as a basis for decision, by society.
- An experimental approach, for the predictive models and hypotheses must be tested at relevant scales before being used as a basis for decision making.

Once the central question that should guide research on marine biodiversity at the European scale has been identified, an action and implementation plans are needed to guide the efforts. The European Commission and the European Science Foundation should take leadership in the formulation of this agenda. In fact, the European Science Foundation has already, throughout its European Marine and Polar Science Board (EMaPS), released a position document that outlines the basis for the European dimensions of the marine biodiversity issue, and lines out the key priorities that ought to be addressed (EMaPS, 1998). There are, however, clear issues that are already emerged as main bottlenecks for progress and that must be addressed through actions on infrastructure:

**Issue 1:** *Marine biodiversity can only be addressed by an interdisciplinary community, contributing the full spectrum of disciplines involved.*

Infrastructure actions required:

- Support for taxonomic know-how as a basic infrastructure for research in biodiversity. This support should include training activities, calibration workshops, and the development of networks and electronic data bases, accessible by all scientists concerned with marine biodiversity.

- The development of new curricula, at the under- and postgraduate level, tailored to endow the students with the array of skills required to address marine biodiversity (molecular tools, taxonomy, systematics, ecology, geology, etc.), leading to a more "horizontal" training designed to this end.
- The organisation of EuroConferences specifically designed to bring together scientists addressing marine biodiversity from different perspectives in order to generate the needed synergy.
- The development of Experimental Interdisciplinary Workshops, where scientists from different background are brought together to exchange "hands-on" experience using contrasting approaches. These workshops will be most useful if structured around biodiversity "hot spots" (e.g. the Alboran Sea — the biogeographic boundary between the Mediterranean and Atlantic; Greek hydrothermalism, border between eastern and western med, very species poor Baltic, etc. ).

**Issue 2:** *Predictive power of marine biodiversity knowledge remains small (qualitative at best), and is of very limited use as a basis for decision making.*

Infrastructure actions required:

- Development of, presently non-existing, experimental ecosystems, where experimental tests of hypotheses and models can be conducted at the relevant scale (ecosystem scale). Because the consequences of decision making on marine biodiversity impinge on the conservation of species and ecosystems, any models or rules to be applied must be tested to satisfaction under natural conditions before use. These facilities must consider the needs for proper replication and controls, considering that such controls must comprise "business as usual" conditions, i.e. including human actions as legitimate components of marine ecosystems.
- The development of "Ecotrons" (i.e. large-scale experimental facilities where full artifical ecosystems can be set up, e.g. Montreal's Biodome, Lisbon's Oceanary) for experimentation on marine biodiversity under scenarios of future climates, and conditions.

No such facilities exist in Europe at this time.

**Issue 3:** *The basic large-scale patterns of marine biodiversity in Europe are not known, because their study requires co-ordinated use of resources.*

Infrastructure actions required:

- A network of marine research stations allowing the synoptic, standardised sampling of marine biodiversity across broad geographic ranges and the establishment of a network of well chosen flagship sites for long-term in depth study of marine biodiversity.
- The mobilisation of research vessels over Europe to run large-scale meridional and zonal transects to provide the basic description of large-scale patterns of marine biodiversity in European waters.
- The better use or new development of better instruments for synoptic sampling and adequate observation using remote sensing techniques for the upper water column and the sea floor.
- The development of standardised protocols and methods, through workshops.

**Issue 4:** *A large gap between the perception of priorities of politicians and managers, on the one hand, and scientists, on the other, has been a key issue preventing progress in marine biodiversity research..*

Infrastructure actions required:

- Dissemination activities are essential, through the education of the general public (from the school level on), managers and politicians on the nature of marine biodiversity and the goods and services it provides and the reasons and consequences of its change. Sustainability of marine biodiversity ultimately depends on public awareness, and this can only be built up with the help of scientists. The dissemination of results from EU projects to the general educated public should be a standard requirement for projects.
- Demonstration programmes, where the link between marine biodiversity and sustainability of marine ecosystems is made explicit, are needed to transfer knowledge from science to society.
- Electronic open conferences on marine biodiversity, such as on-going activities, are needed.
- The involvement of industry and the private sector on research on marine biodiversity is essential, for the private sector is expected to be amongst the main beneficiaries of this research, and because many of the business activities dependent on the sea are directly dependent on the sustainbility of marine biodiversity.

# References

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# LARGE-SCALE PROJECTS: SUCCESS AND DIFFICULTIES IN SCIENCE AND MANAGEMENT, INTERDISCIPLINARY RESEARCH, INTERNATIONAL COOPERATION

# Large-scale research projects: a challenge for marine sciences in Europe

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## Abstract

Within the specific programme Marine Science and Technology III (MAST III), a special area, A3, has been devoted to the study of Regional Seas. This domain has been given a relatively small amount of funding compared with the overall MAST III programme (36 MEcus for A3, approximately 15% of the total budget of MAST III). Four regional seas have been identified in the Work Programme: the Mediterranean Sea, the Baltic Sea, the North West European Shelf, and the Canaries-Azores-Gibraltar area. For each of these regions, one large-scale research project has been selected by the European Commission following the call for proposals. It should be recalled that research projects managed by the European Commission are based on a contract between two partners, the European Commission on one hand, the different research teams involved in the project on the other hand. The total cost of a project (including science and management expenses) is equally shared between the EC and the group of scientific teams from different member states. One of them acts as coordinator for the group. The contract implies an obligation of results. The four large-scale research projects funded within the area A3, Regional Seas, receive a European contribution between 7 and 11 MEcus for a duration of nearly three years, their total cost varying between 12 and 20 MEcus. Large-scale research projects can be defined by (1) a certain size (more than one hundred of scientists involved, Community contribution at least 7 MEcus devoted to science and management), (2) the interdisciplinary aspect of the research programme, (3) the choice of a specific marine area and finally (4) the simultaneous use of standardized methods at the scale of a marine basin or a group of adjacent basins. The different features of large-scale research projects are then discussed in general terms, including specific problems such as national allocation of ship-time and better use of large oceanographic facilities as well as general questions such as interdisciplinarity versus multidisciplinarity or quality and output of the science community in Europe. The advantages and disadvantages of large-scale research projects are then discussed. One interesting feature is the scientific dynamics of those projects compared to smaller ones. In some cases, large-scale research projects appear to promote a stronger coordination between Community and Member States scientific policies. In a sense, they contribute to the renown of european science abroad.

# Introduction

When I was asked to prepare the key note addrss for the session on "Large-scale projects: success and difficulties in science and management, interdisciplinary research, international cooperation", I first envisaged as equally important questions the two topics included in the title, i.e. "Large-scale research projects" and "International cooperation" and I tried to analyze and discuss both concepts. These first steps and further discussions with Dr E. Lipiatou and others convinced me that it would be much more clear to concentrate my talk on "Large-scale research projects: success and difficulties in science and management, interdisciplinary research" as commonly understood within the European Union Framework Programme, in particular within MAST 2 and MAST 3 specific programmes. The main reason for this choice comes from the fact that Large-scale research project, as any other european research project, are founded on the basis of a contract, including European Union funding for research tasks and project management; this is not the case with international cooperation, where joint research projects are rather rare and, when they occur, receive most of the funds needed for research through national channels. There is at least one important exception to that remarks in earth sciences, the international Ocean Drilling Programme in which the major part of the cost of a given project, let me say a given "leg" at sea, is provided to the chief scientist as ship-time and drilling facilities from the different national contributions. This organisation mainly results of the common use of a unique -at this time- and highly expensive research tool needed by a large international community of scientists. Consequently, I decided to limit my talk to the first half of our session, Large-scale research project: success and difficulties in science and management, interdisciplinary research.

# Some peculiarities of European R&D programmes

European Union Framework Programmes (the 4th FP is coming to its end and the 5th is in its very infancy) have some some basic peculiarities. Firstly, there is a contract between the European Commission and the coordinator and other contractors of R&D projets. This originates from the fact that European Union R&D, in its very beginning (late 70's and early 80's), focused on industrial research and was mainly operated by industry laboratoiries, in the field of information technologies. In environmental sciences such as marine sciences, this procedure is generally well accepted, even if scientists have some problems when negotiating with European Commission staff, especially for questions of long delay between the approval of a project by the programme committee, the signature of the contract and the first allocation of funds from the Euroepan Commission to the coordinator. A second basic feature is very well known by european scientists, but probably not so clear for scientists from abroad. It concerns the European Commission funding rules. There are two different main procedures for sharing the total cost of a project (including cost of management and of scientific and technical activities) between European Commission and the national "entities" to whoch belong the different research teams involved in a project: — On the basis of an equal part ot the total cost (50/50) when analytical accountancy systems exist in those entities; — On the basis of 100% of the marginal cost where no analytical accountancy system occurs.

The equal sharing of the total cost between European Commission and a given research public organisation from any Member State can be accepted by both parties only if the scientific priorities of the European Commission call for proposal are more or less in line or coordinated with national priorities. The coordination between European Union and Member States R&D policies is explicitly written down in the European Union Treatise. Since 1995, a procedure has been set up. This point is of special importance when considering allocation of national ship-time for a European Union project, taking in account the pressure of national oceanographic cruises. A third basic point establishes clearly the boarder line between international cooperation -where usually no obligation of means or results occur- and European Commission R&D projects. To be clear, one should add that allocation of European Commission funds through periodic payments is directly linked with the respect of these obligations.

# Birth of large-scale research projects

Large-scale research projects can be achieved following two different procedures, the "top-down approach" and the "bottom-up approach". The top-down approach has been developed in industrial research programmes such as Information Technologies, in the framework of the "cluster" concept. The European Commission plays a leading role, selecting a group of small projects that can combined in a large-scale project. Between others, the question of the choice of the grand coordinator for the cluster can be a difficult one, depending on the level of competition between the various individual teams associated in the small projects. On the other hand, the bottom-up approach requieres much more preparation work between research teams before submitting the final proposal. Reciprocally, a large-scale project proposal prepared within the budget limit of a call for proposal (which means that all teams agree to regulate their own financial need) is a well balanced project that will probably reach most of its goals. The role of such bottom-up large-scale research projects for building-up regional scientific communities is obvious. Between those two opposite approaches, a wise use of selection criteria could also help to promote unusual collaborations between disciplins without imposing a top-down approach which might dangerously limit innovation; for instance, at least one research team in marine ecology and one in socio-economics could be required for a given project.

# Pragmatic definition of a large-scale project

In the case of MAST 2 and MAST 3 programmes, regional seas research was deliberately organised in "targeted" or "focused" projects. Two targeted projects were included within MAST 2. They were generally considered as successes by the scientific communities. Consequently, when discussing MAST 3 regional seas are in the European Committee for Science and Technology (CREST), the main difficulty was to limit the national ambitions to a reasonable number of targeted projects. Four regional seas projects were finally decided by the European Union: Mediterranean Sea, North-east Atlantic, Baltic Sea and Canary-Azores-Gibraltar Sea. Four projects have been selected: Mass Transfer and Ecosystem Response (MATER, for the Mediterranean Sea), Canary Island, Azores, Gibraltar Observation (CANIGO, for the Canary-Azores-Gibraltar area), Baltic Sea System Study (BASYS, for the Baltic Sea) and Ocean Margin Exchange (OMEX, for the North-East Atlantic). A comparison

between the four on-going projects enables to propose a pragmatic definition of a large-scale research project. Four different criteria can be identified: the size (whatever the unit be), the interdisciplinary aspects, the choice of a specific marine area, the simultaneous use of standardize methods by different laboratories. When discussing the size of a project in terms of number of scientists involved, the question of full time versus part time has to be seriously considered. The total cost and the amount of the European Commission contribution are probably more precise parameters. As a minimum, the large-scale research projects of MAST 3 involve more than one hundred scientists and the European Commission contribution amounts from 7 to 11 MEcus. A gross evaluation of the interdisciplinary aspect could come from the number of scientists belonging to the different oceanographic sciences. As said earlier, the full time versus part time question makes it difficult. A better indication should come from the analyses of scientific papers signatures's. There lies the actual boarder between disciplins, and the difference between multi- and interdisciplinary research. I was not in the position to achieve such a task. The two other criteria do not need to be discussed in detail. To come back to interdisciplinarity, we oceanographers have to face a major challenge between physical oceanography and biogeochemistry on one hand, and marine biology and ecology including living resources, on the other hand. In a recent and excellent book on the "Ocean machine", a french physical oceanographer wrote that upper levels of biological production can be neglected when looking at global carbon budget in the ocean, because they are negligible in terms of organic carbon content compared with the primary pelagic production. That is true, but one can also starts from higher production levels and living resources, and delete most of large-scale physical oceanography... Interdisciplinary oceanography is more than that. A practical tool to promote interdisciplinarity is the matrix approach as developed for instance in the MATER project. Each scientific disciplin is leaded by one scientist, and is shared between the different geographical sites under study; for each site, a scientist acting as local leader organizes the work of the various scientific teams. An interesting point is the opportunity to exchange scientific teams belonging to the same disciplin from one geographical site to another, providing a better standardization of data.

# Oceanographic cruises

One of the major problems met with by the coordinators of large-scale research project is the question of achieving the oceanographic cruises that are required for their projects. I remember the first european discussion about point when preparing MAST 2. At that time, the coordinator had to do his best to convince the national communities involved in ship-time allocation that his european project was at least as original and good as any other national projects... Why should any national scientific community agree to allocate ship-time to a European project? Four different reasons can be underlined:

— The national funding mechanism give a chance to european projects as well as national ones,

— The scientific quality of the projects is the major critrion used by the ad hoc committees,

— The national renown, specially when the coordinator of a project belongs to the country where he applies for ship-time,

— The european project is in accordance with national priorities; this point has been underlined earlier.

This last point, which can also be expressed as a strong coordination between European Union and national scientific policies, is probably very important for the future. So, it has been decided for MAST 3 that a small part of the budget (5% of the total budget of MAST 3, i.e. 11 MEcus) will be used to facilitate and guarantee the access to national oceanographic vessels. This mechanism should not be sufficient in the future.

# Other questions

Some questions that coordinators of large-scale research projects would probably consider as important ones have not been extensively discussed in this general presentation. A few of them are listed below:

— Management of large-scale research projects; is there any synergetic aspect, or, on the contrary, is the burden heavier than in several small projects of comparable budgets?

— Do large-scale research projects provide better opportunities for training young scientists in other european countries?

— Do large-scale research project give a wider renown to european marine sciences?

— Do they help European Union to take part as such in large international programmes (what about a Euro-RIDGE, or a Euro-WOCE)?

— Are socio-economical sciences more easily involved in MAST 3 large-scale research projects than they are in smaller ones?

— Is the averga duration of a large-scale research project appropriate with the scientific and technical goals?

These and a lot of others are probably be better discussed within the specific lectures on the large-scale research projects of MAST 3. Of course, a key point is still undetermined: would the next programme in marine sciences and technology, whatever its name, keep on with the concept of large-scale research project, or would it change the rules of the game that we have been playing for years? The answer shall come in the next months, when the decision of the thematic programme on Energy, environment and sustainable development will be adopted by the European Council. In my opionion, large-scale research projects should be maintained, provided the necessary rotations and renewal of teams be promoted.

# Mediterranean Targeted Project II-Mass Transfer and Ecosystem Response (MATER): Managing a Regional Seas Project is a unique experience and a task on its own

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The MTP II project has been structured in a way that will best facilitate the acquisition of scientific information and its subsequent dissemination. One of the MTP II-MATER focal points is the existence of a coordination unit consisting of both a scientific coordinator and a project manager. A matrix-like structure has also been established combining scientific topics and disciplines within various geographical areas, ecosystem modelling and an efficient data management network. The latter is organised around a data manager in close cooperation with a Data Quality Group, and a network of National Data Centers corresponding to the operational and geographical organisation of the project.

During the first 18 months of activities in MATER and according to the work plan specified in the Technical Annex, intense measurements of physical, biological, chemical and sedimentological processes have been undertaken. To date, shiptime has reached X days (41 oceanographic cruises) and a complete system of information management and dissemination has been set up.

At this stage, a preliminary assessment of the advantages and problems arising during the implementation of large scale projects is attempted by:

1.the scientific coordinator presenting the overall project management and structure, and

2. a scientist directly involved in both field and laboratory work reporting on the daily scientific activity.

# CANIGO: a regional sea project

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CANIGO (Canary Island, Açores, Gibraltar Observation) is a project financed by the MAST Programme under the area A.3 of Marine Science. It is an interdisciplinary project which total cost is around 12.5 MECUS and the European contribution is over 8.5 MECUS. The project brings together 45 research laboratories, including a JCR from the EU, one institution from Israel and other one from Switzerland. The project will last 38 months and at the time of the MAST DAYS will be in its 20th. month.

For the time being (let us knock on wood) the project is coming along with not major problems. We think that, beside the work, the effort and the good disposition of the researchers involved, the reason of this suave progress lies in several causes and in the components that constitute CANIGO.

The way the consortium of partners was formed and the parallel and jointly development of the research lines, in the pre-CANIGO phase, was fundamental for laying down the proposal and for avoiding friction between partners during the contract negotiations and later, during the execution of the project.

The scientific structure of the project -distribution of the work in 4 subprojects, establishment of 4 subcommittees related to infrastructure and data management, and the composition of the Steering Committee (SC)- keeps everybody informed about the progress and vicissitudes of the project; and it allows a rapid answer to any mishap. Scientific guidance and coordination are carried out by the SC, which assure the achievement of the tasks and the interaction between participants through diverse mechanisms. The SC will ensure the integration and synthesis of results through the pyramidal hierarchization of task and deliverable responsibles. An appropriate balance of decision capacity and level of executivity has been established between the SC and the Coordinator.

A Data Management Subcommittee that reports directly to the Coordinator provides interface between partners and data managers assuring data sharing and proper advice. The identification, acquisition and processing of remote sensing data is the labour of a particular subcommittee. The Modelling Subcommittee ensures compatibility between models and interaction between modellers and observationalists.

A very important component of the project is cruises. CANIGO shiptime adds up to more than 12 months. The consideration of some partners in CANIGO with access to their own ships or national ship agencies and their willingness to provide shiptime have been crucial for the project. A Ship Subcommittee that reports directly to the Coordinator will provide information about cruises to achieve an optimal use of shiptime.

Financial management has a different structure to that of the scientific one. To ensure a effective and fast distribution of funds a national net was organized. From the ECUS account of the coordinator funds flow to four contractors that will distribute the funds between the partner of its own country, irrespective the subproject they belong to.

Finally, a continuous and open flow of information and advice between the Steering Committee and the MAST office has been very beneficial indeed.

# BASYS - Baltic Sea System Study Added value to regional efforts in system analysis?

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Marine science in the Baltic Sea has a long tradition reaching back for more than 100 years and thus this intracontinental brackish water body is regarded as on of the best investigated marine ecosystem in the world. In the last 50 years international cooperation in Baltic Sea research has been unparalleled despite the times of the 'iron curtain'. Several Baltic wide joint research projects have been carried out such as the Baltic Year (1969 –1970) and a Patchiness Experiment (PEX 1986). Many bi- and multinational projects have been conducted in the various subregions of the Baltic Sea. Finally, since 1979 an international obligatory environmental observation programme is in operation to monitor possible adverse effects of human activities and to provide the background for mitigation plans.

Why then an large scale project as BASYS, particularly as there is another large project BALTEX which is on of the five continental-scale experiments of GEWEX?

The pitfalls an caveats of a large scale project: These occur already in the planning phase, if a system analysis of a large sea is envisaged. Neither a top-down selection of partners nor a bottom-up approach can prevent from overseeing some of the best expertise in the numerous research fields needed for a system approach. When a project like BASYS is understood as a focussing instrument for various regional approaches to efficiently fill gaps of knowledge field work and synthesis work will be needed. Consequently within the period of 3 years the project cannot be completely synchronised, e.g. the new field results will only marginally included into modelling activities. This may appear as lack of cooperation, albeit the added value in a longer period will be considerable. The tight task structure of a large project and the number of tasks, which is requested, reduces the activity of the coordinator strongly to a formalistic rather than a scientific affair. Further, the strictness of the deliverables-system considerably cement the scientific approach for 3 years and novel approaches as a consequence of the ongoing work are restricted as well as are fulfilment of arising needs in various subprojects.

Added value and success: These are fortunately more numerous than the caveats. System analysis require a multinational approach. A uniform funding umbrella offers a greater advantage to a binding approach than the collection of various national fundings. A regional project like BASYS is an excellent information tool which collects and makes available information in marine science far beyond the project activities. Further data collected and scientific tools will be public domain after the project's end. The unequivocal scientific merits of a large scale project are that marine research can be elevated on a system level and the necessary temporal and

spatial scales can be included. The interdisciplinary aproach, even if not seen directly between all participating senior scientists, allows to approach the same problem from different angles, e.g. the comparison of system variability from historical data, high resolution proxies from sediments and modelling. Thus, during the work of the project new groups are emerging which garantuee added scientific value. Another important merit is the training of young scientists who learn to interpret their specific results in a wider ecosystem frame work. Finally, the transfer of expertise between the participating countries will raise the quality of marine science in the respective region considerably.

Albeit the merits far outweigh the caveats scientific progress may be improved. Examples from the BASYS project will be given and discussed.

# A comparison of four large UK and MAST projects, emphasising OMEX; science, relevance and management

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The EU MAST project Ocean Margin Exchange (OMEX) is concerned with physical processes and the full range of biogeochemical processes involved in fluxes of energy and matter between shelf-sea and ocean. In three phases (1993-96, 1996-97, 1997-2000) it has involved about 50 principal investigators (PIs) with a full cost of about 20 MECU. Comparisons are made with three other projects: the UK North Sea Project (NSP; shelf-sea interior physics, suspended particulate matter - SPM — and primary production on seasonal time scales; 1987-1992 et seq; 30 PIs; 16 MECU) and Land-Ocean Interaction Study (LOIS; fluxes from river catchment to continental shelf edge, emphasising nutrients and SPM; 1992-2000 in total; 100 PIs; 40 MECU) and the EU MAST project Processes in Regions of Freshwater Influence (PROFILE; physics, SPM and microbiology in shelf seas near the coast; 1990-1996; 15 PIs; 5 MECU). The two-way comparisons in size and (inter) nationality help to reinforce and separate out the effects of scale and different management approaches.

All the projects involve measurements at sea, remote sensing, interpretation, modelling and model development. Advanced technology was used, but little technology development per se. All the projects also included physics, SPM and biology at least to the extent of primary production. Excepting PROFILE, they also included chemistry and sea-bed studies. Thus they were broadly multidisciplinary in approach as well as in the scientific subjects studied.

The management effort increased with size. In the case of OMEX, the management team comprises the co-ordinator, a near-full time manager and assistance, advised by a Steering Committee. This Committee comprises sub-project leaders. In OMEX I these sub-projects were disciplinary: physics; biology; biogeochemistry; benthic; air-sea exchange. Now they relate more to experimental approaches: temporal evolution, systematic survey, benthic, explicit approaches to integration; however, discipline coverage is retained in the Steering Committee membership. Data management was recognised at an early stage as a big issue, and was secured by a MAST II supporting initiative, now as part of the project. Other activities to aid management and integration have been necessary informal bilateral co-operation, sub-project meetings at typically 6-month to yearly intervals, and an annual meeting where all PIs are strongly encouraged to present their work in plenary session. Working together at sea proves a powerful integrator and community builder. Ultimately, models synthesise the science.

Scientific successes and achievements in OMEX include: automated provision of satellite imagery (including near-real-time transmission to the ship); estimates of lateral exchange at the margin; estimates of primary production, its controls and the

contribution of dissolved organic carbon; comparison of vertical fluxes through the water column; inference of fast-and slow-sinking particles and a lateral contribution to the fluxes; a finding that little organic carbon is buried; developments of physics and biology models.

Management achievements include an integrated and almost complete data set, easily accessible (now on CD-ROM), community building and many scientists trained at all levels.

Advantages of the management structure in OMEX have been economy, lack of bureaucracy, direct contact between the co-ordinator and all partners (on the one hand) and between the co-ordinator and the MAST office (on the other). There have been corresponding disadvantages: strain on the co-ordinator and manager, and a sub-structure not "natural" to the science. In OMEX-I the disciplinary components did not foster interdisciplinarity, which is much improved by the present sub-structure. However, much effort is now devoted to integrating the experimental approaches.

By direct contact with the co-ordinator, all partners are aware of the common schedule and organisational aspects, so that formal aspects of reporting and timing of deliverables have not been detrimentally affected by project size. In part this has been helped by a less synthesised reporting format than is usual in normal-size projects. This factor and the science-discipline structure of OMEX-I have been detrimental to direct communication between partners, especially in different disciplines. Another factor reducing synthesis was the number of partners whose work was not very directly contributing to a single unifying theme.

It is suggested therefore that management of a large-scale project is feasible if there is a strong unifying theme, e.g. estimating the ocean margin carbon budget from flux contributions; all partners should be able to relate their work to this theme. Other factors for feasibility may be: a management structure corresponding with a natural partitioning of the scientific activity; corresponding specific attention from the start, to the interfaces across any such partitions; time and flexibility for the project to develop interactions between partners and any sub-components of the whole project, and to evolve the structure. OMEX has a large and rather complex need for ship time and would have been more successful in aligning these needs with availability, and accommodating necessary work together, if it were not simply dependent on available national contributions.

All the projects considered were genuinely interdisciplinary, eventually. The large scale is necessary to provide a wide range of specialist skills (the principal reason for the large number of partners in OMEX). Size is obstructive, however, if a sub-structure by discipline is interposed. Working together at sea is a great help to interdisciplinary science, via both consistent data sets and interaction between scientists. Computer model "frameworks" to couple modules of different disciplines, and frequent project meetings sustained over several years, have also fostered interdisciplinarity. Social science aspects were not formally part of any of these four projects, but discussion of this aspect of applying the results was actually greatest in the two UK projects. This probably relates to their location and science objectives, but also reflects the extra challenge in the European arena of linking a marine scientist in country A with a social scientist in country B.

International co-operation has not proved a bigger problem in the larger project OMEX, except for the ship-time provision. The large projects have all been very "visible" outside Europe, and in particular have won US scientists' admiration for their integrating character. The common use of English as the language of science has helped.

All the projects have had limitations to the scope, despite their size. OMEX has had to focus on one location at a time, although there is a great variety of ocean margin contexts to compare. The pioneering science and organisation have been hard to estimate in financial terms; the common experience of remaining limitations is evidence that there are marine science problems where such large-scale projects are necessary to achieve the interdisciplinary coverage and results required.

Other conclusions are that flexibility and lesser management remain in favour of smaller projects. Management structures should not be arbitrary or disciplinary, but align as far as possible with any natural (e.g. experimental) components and allow for interchange between them. Integration of larger projects is inherently more difficult and carries a larger management overhead in proportion. All the projects have needed more than five years and extensions beyond this initial planned duration, to realise full scientific success. Technological developments have also caused delay. Nevertheless, the questions and problems tackled by all projects have proved long-term and their relevance is undiminished. PROFILE has a follow-up "exploitation" project COHERENS and LOIS is using models developed in NSP, PROFILE and OMEX. However, all large projects have achieved good scientific results, developed techniques for working at sea and modelling and notably built new communities of scientists and provided valuable data sets. The latter are of great and lasting value when brought together with the scope of a large project. Large scale is not per se an agent of inspiration. However, it does provide the scope for interdisciplinarity, via full discipline coverage, and for the comparison or synthesis between contrasted domains that may be the particular benefit of the MAST programme.

# The joint West- East- European EROS project on the North-western Black Sea: a difficult road to a scientific and human success story

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EROS (European River Ocean System)-Black sea is the first large scale EC-project bringing together scientists of eastern and western Europe. It was launched in 1994 for a 2 year pilot-phase and extended (after the usual submission/evaluation procedure) for an additional 2 year-period. Western institutions (18 EC including 2 JRC and 1 SWZ) were funded by the Environment and Climate Programme for a total of 2.25 MECU; eastern institutions (8) by the PECO/INCO-Copernicus and PHARE Programmes and INTAS organisation for a total of 1.2 MECU. The project will end in July 1998. The final symposium will be held in Ispra (Italy) hosted by the EI-JRC on 13-15 June 1998. The 60 abstracts received today and the attendance of representatives of the sister NATO-Turkish project are evidences of the success of the EC-project. However the road was long and difficult.

## Why a large-scale project on the Black Sea?

The Black Sea, with its unique features, such as being the largest enclosed catchment basin receiving freshwater and sediment inputs from rivers draining half of Europe and parts of Asia, represents an extreme example of deterioration of the coastal and marine environment in Europe. It was chosen as the best pilot site to understand and predict the complex interactions between human activities and the marine environment owing to its great sensitivity to human disturbances. The Black Sea ecosystem has indeed experienced several changes during the last decades, driven by human perturbations in the coastal ecosystem itself and in the drainage basins of the rivers discharging to it.

Ultimately the project objective is the hierarchical development of coupled physical-mechanistic biogeochemical models describing biogeochemical transformation and ecosystem change along the Danube river-Black Sea aquatic continuum in response to natural and human-induced perturbation. When completed it will constitute a valuable tool for answering the following environmental questions:

What is the time needed for a given ecosystem to recover after a voluntary reduction of nutrient loads to the coastal area?

What is the buffering capacity of the ecosystem to nutrient reduction?

What is the synergy between human-induced changes such as eutrophication, overfishing and introduction of exotic species leading to ecosystem destabilisation?

The EROS approach was designed to benefit from cultural differences by combining more traditional observational approaches based on the analysis of existing data and modern technology.

# What were the major difficulties?

The major difficulties above all encountered during the implementation phase of the project were due to lack of communications with eastern countries (no E-mail in 1994), language barriers for both communication and drafting, hierarchical organisation of eastern research, economical and cultural differences and contrasting scientific approaches. These had as major consequences the effect of slowing down the start-up of the project. This was further exacerbated by the strong lack of co-ordination between the funding programmes leading to a 11 month-delay for the starting date of eastern participants with the related confusion about field work planning and scientific reporting. Superimposed were problems related to transfer of funds, overheads taken by eastern banks, bankruptcy.

Field research had to face the lack of availability of research vessels, Custom and Excise problems and general insufficient funding

# What has been solved and how

A triple coordination: global, scientific and local, seconded by a steering committee, including 8 members of western and eastern representatives, was set up. This has been decisive for the successful organisation of field work by making possible the chartering of marine, coastal and river boats. Furthermore, the local coordinator had a deciding role in solving problems of money transfers.

E-mail connection supported by the GEF bureau (UNEP) at Istanbul had a major role in managing both science and administration and in stimulating collaboration and data exchanges between participants. The latter was mainly initiated by joint one-month cruises which had as additional positive effects a decrease in language barriers and scientific mistrust.

Last but not least, coordination between the two EC funding programmes improved during the second phase of the project, both for starting and reporting dates.

# Main achievements

In spite of the difficulties encountered, EROS completed a tremendous amount of field work by conducting several cruises on smaller research vessels and boats in the Danube river and delta as well as 4 one-month cruises aboard the large Ukrainian RV ' Prof Vodyanistky '. Due to the declining economy this well-equipped ship, as most of Russian and Ukrainian research vessels, is now used for commercial exchange. EROS was the first research project to charter her for

scientific purposes. Since then, RV ' Prof Vodyanistky ' is being regularly chartered by other international projects in the region but also in the Mediterranean Sea and Atlantic waters. Joint field cruises were the catalysts for scientific exchange, training, comparison of approaches, and transfer of expertise. These scientific merits were re-enforced by the organisation of 2 International symposia and 2 cruise workshops.

# Conclusion

EROS-Black Sea is now coming to its end. It has been highly successful in spite of the amount of technical and funding problems that had to be faced during its implementation. For EROS participants, however, this end is coming too early and is very difficult to understand with respect to the financial and the scientific investment made in this project.

In the opinion of EROS co-ordinators who were at this stage perhaps too much involved in administration and too little in science, such a large-scale project needs a long-term funding effort. Too much time has had to be devoted at first to implement the project.

# Mechanisms for Collaboration Between EU and US — Large Program Examples

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Large programs, involving participants from several organizations, are an effective way to foster international collaboration. EU nations and the US have long collaborated in such projects. The US Navy has been happy to participate in many of those, both as performers (through our laboratories) and sponsors (among our university grantees). This paper will show examples of such large programs, describing their planning, performance, analysis and follow-up. One example will be for Rapid Environmental Assessment that involved a major field program in the Mediterranean. A second example will be a collection of individual investigators working together on the topic of nearshore dynamics. The key ingredient in both examples was the existence of common interest and genuine desire to cooperate as equals.

Past collaboration between EU country scientists and those working with Navy programs has largely been ad hoc. This may yet be the best mode for the future as the only partners that need be involved are the scientists and engineers actually doing the work. However, as more formal partnership mechanisms evolve for EU-USA concord, it may be appropriate to explore planned associations, where longer tern collaboration can be established. One example of such could be in the area of ocean prediction, where common interest and capability lie in such areas as predictability and real time environmental analysis.

The US Navy interest in marine science and technology covers the spectrum from basic research through demonstrations. The fields of interest include process understanding, modeling, prediction and measurement. Much (but surely not all) of our current interest has moved from the open ocean to coastal regions where many of countries of the EU have had long standing interest and experience. Potential collaboration could be with academic research we support through our Office of Naval Research (ONR), between our Naval Research Laboratory (NRL) scientists and related colleagues in EU laboratories and/or universities, and/or with our Oceanographer of the Navy and related EU activities. ONR's International Field Office in London, ONR Europe, can interface with all of these organization, who collectively invest $500 Million, annually in marine science and technology.

# U.S. Academic and Funding Agency Experience in Planning and Implementation of Large Cooperative Programs Involving European Scientists With Suggestions for Improvement

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With the signing of a bilateral agreement between the EU and USA for cooperation on science and technology in December 1997, the way is open for discussions of potential new approaches for collaboration between major funding agencies on both sides of the Atlantic, focusing on ocean and coastal research. Over the past decade, many formal and informal arrangements have developed, particularly in the area of Global Change research. Formal scientific collaborations have been forged through organizations such as the International Council of Scientific Unions (ICSU), and intergovernmental organizations such as the World Climate Research Program (WCRP), and the International Council for the Exploration of the Sea (ICES). At a very general level, informal liaison has been maintained by the International Group of Funding Agencies (IGFA). These efforts have met with varying levels of success. Within the USA, federal funding agencies responsible for marine research, such as NSF, ONR, NOAA and NASA, often collaborate directly to issue joint announcements for funding opportunities, and organize joint review and funding mechanisms to achieve the goals of the programs. Most international collaborations (the International Ocean Drilling Program being a notable exception) are characterized by independent announcements, review mechanisms, funding decisions and out-of-phase timing for initiation, funding and concluding of programs.

There are several ongoing and planned programs in the North Atlantic and adjacent coastal regions — such as GOOS, CLIVAR, GLOBEC, TASC, LOICZ and the development of data assimilation and prediction capabilities, including in connection with the North Atlantic Oscillation. We should discuss mechanisms whereby funding agencies in North America and the EU can develop joint strategies to optimize pan-Atlantic review and funding of such programs. The Ocean Sciences Division of NSF is prepared to present a template of how such activities could work. Based on scientific areas of mutual interest a small pilot or demonstration project might be initiated.

# RESEARCH POLICY

# MARINE RESEARCH AND POLICY INTERFACE: LINKS, INTERDISCIPLINARY COOPERATION AVAILABILITY OF RESULTS, CASE STUDIES

# Taking research to policy making

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## Communication of science

As with all scientists, marine scientists use a specialised language to talk to their peers. In the 1980's they met the challenge of communicating between different disciplines within marine science with the evolution and funding of multidisciplinary research programmes. By the 1990's the communication challenge had evolved further with the increasing need to communicate their work, results and hypotheses to the public, to administrators and to policy makers (Fig 1.) To do this successfully specialised languages need to be adopted and evolved in co-ordination with increased education and understanding. This wider audience is beginning to include social scientists and economists who also have their own specialised languages. The challenge for the new millennium could be to include these groups in effective communication of science.

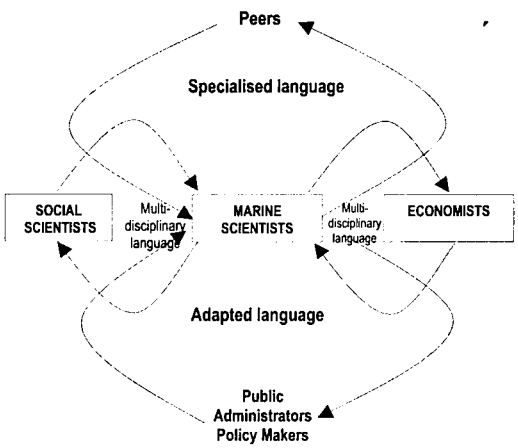



*Fig 1. The Voice of Science – the language changes with different groups*

To communicate our science we need to be aware that the scientific process and the perception of the process by non-scientists can sometimes be different. We need to ensure that the public understands that Science by nature evaluates and debates the interpretation of existing

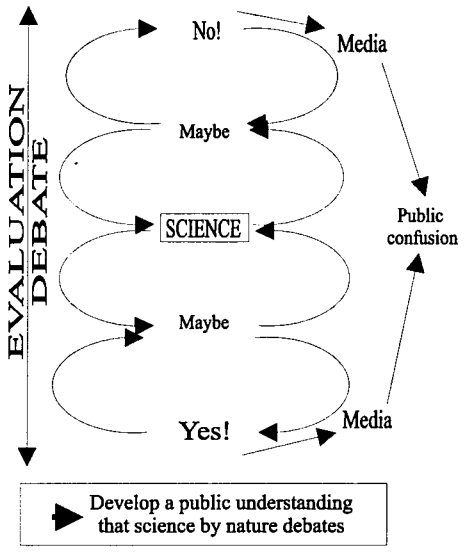



*Fig 2. The Perception of the Scientific Method*

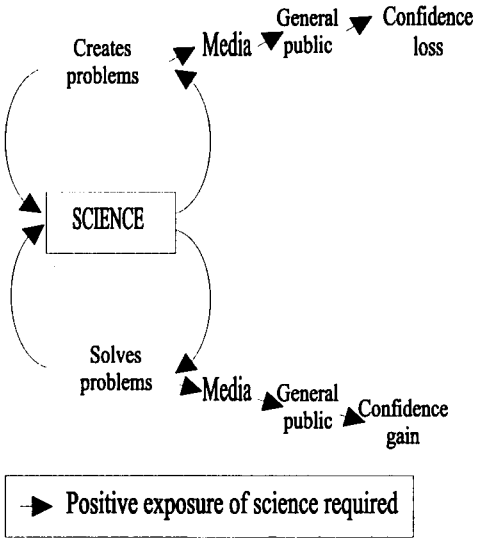



*Fig 3. The Public View of Science*

knowledge. However, outside the scientific community, the perception of science can be very different. For example, the demand from the public can lead to probabilities or improbabilities being misconstrued as facts and "yes" or "no" answers. This can lead to scientists being perceived as "disagreeing with each other" and can lead to public confusion and loss of confidence. While Science deals in probabilities, the public, administrators and policy makers want certainties. Perhaps, we need to develop a better public understanding of Science and its methods. In some countries, the media exposure of scientists can fluctuate considerably such that on one occasion they may be seen as the perpetrators of a disaster and on another occasion as saviours (Fig 3). We need a more positive and balanced exposure of science and scientists and a movement away from the generalised and characature-scientist we see exposed in our media.

# Information flow

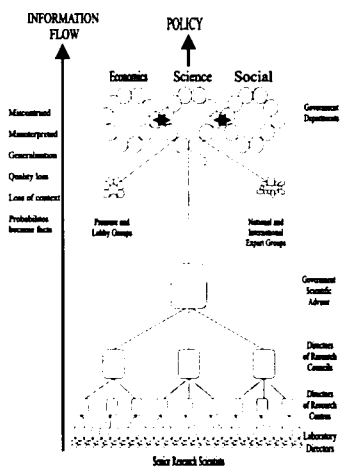



*Fig 4. Scenarios of Information Flow to Policy Makers*

The method of information flow from research scientist to policy makers is also an important consideration. Some strategies may be hierarchical with information flowing up the hierarchy (Fig 4). This method may lead to a change in the quality of information through generalisation, loss of context, misinterpretation, misconstruction and probabilities becoming facts during the processes. The formation of expert groups and committees (Fig 4) from all hierarchical levels is a method often used to feed information directly to policy makers as is the placement of individual experts on government committees or indeed of having government ministers from a science background in office. Pressure and lobby groups are other methods of influencing policy. It may be a useful exercise to model how Science has influenced policy and the strategies adopted to do this at local, national and international levels.

# Research funding and strategies

Research budgets are competing with other government expenditure and are under increasing scrutiny. Scientists are increasingly required to justify their research through deliverables such as wealth creation, product production and well being. This can shift the science base towards more short-term, specific, applied research and away from the long-term, creative and pure research (Fig 5). The reasoning for this seems to be that applied research will deliver results and rewards quickly, which is a justification used by both governments and industry for investing in this area of research. However, there are arguments countering this because many major discoveries come from long-term and more open, pure research from which large financial rewards can be gained. A balanced strategy incorporating and valuing both

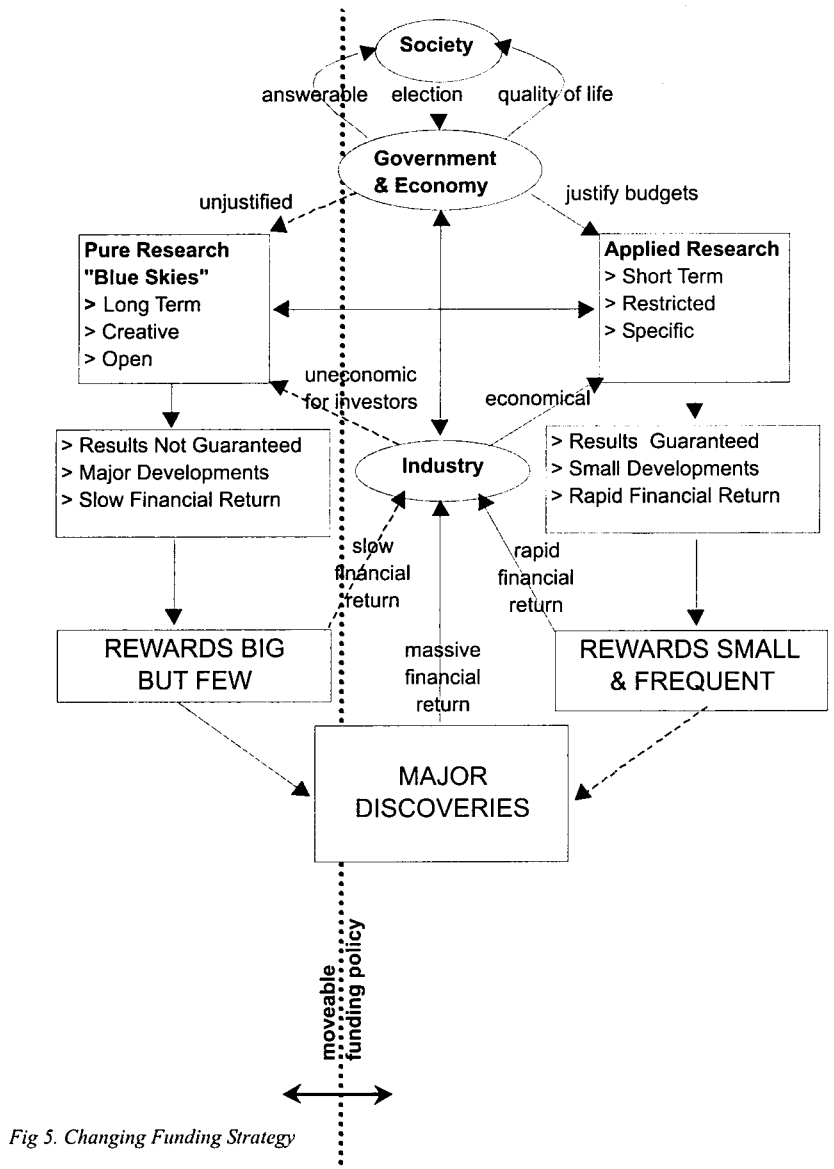



*Fig 5. Changing Funding Strategy*

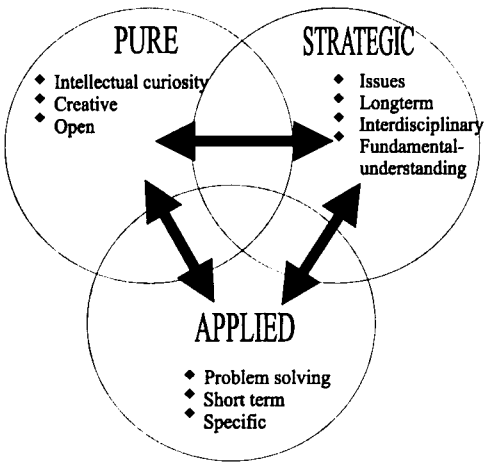



*Fig 6. Interactions and Overlaps between Researc Strategies*

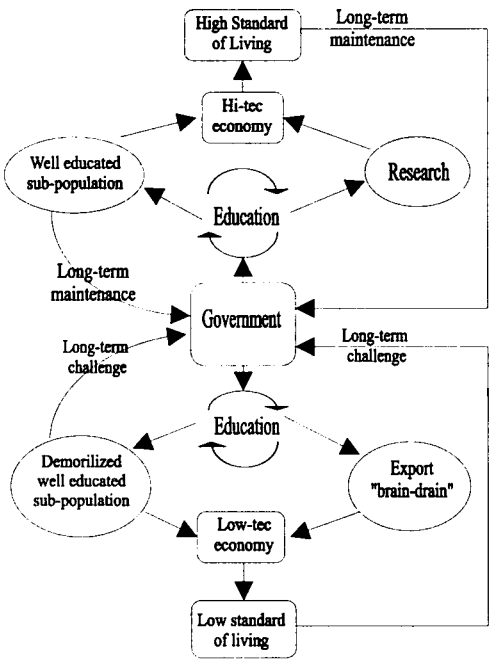



*Fig 7. Importance of Research to Economics, Society and Government: Potential Scenarios*

research strategies would seem to ensure both short- and long-term gains. To this end, perhaps we need a better appreciation that applied and pure science are not at conflicting polar ends of a research strategy continuum but are rather approaches to science with substantial overlaps and interdependencies (Fig 6). For example, strategic research, (which is driven by issues, is long-term and aims at a fundamental understanding of the topic), relies on and contributes to both pure and applied research and also plays an important role in the overall research strategy for nations. A well-balanced research strategy is of key importance in creating and maintaining a Hi-tech economy, a high standard of living and well being of the populous living in well managed sustainable environments (Fig 7). Two scenarios that may arise showing the role of research in society, economy and government of a nation are depicted in figure 7. One involves an educated population but no investment in research with subsequent "brain drain", Low-tech economy and low standard of living and demoralised population. The other involves a well-educated population and investment in research resulting in a Hi-Tech economy, a high standard of living and a population with "well-being" content to maintain the *status quo* at government level.

# Implementing policy

Achieving an appropriate change in policy is a great and often lengthy achievement but it is not the end of the road. Rather it is just the start of the journey, as we also need to look beyond policy making and examine how policy is implemented and the success of its outcome. This requires appropriate legislation, funding, communication and education, monitoring and assessment of success (Fig 8). Scientists must play a role in this crucial cycle in order to ensure its successful completion.

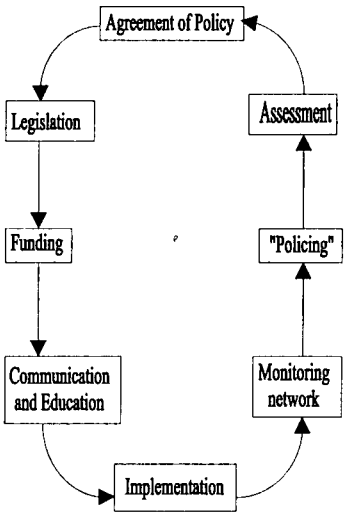



*Fig 8. Implementation of Policy*

# The reduction of nitrogen: the Swedish coastal waters case study

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During the 1960-ies there was a fierce "limiting nutrient controversy" in North America. This debate was fueled by the claim from some scientists and the detergent industry, that carbon, not phosphorus, was limiting algal production in lakes. Thus efforts to reduce phosphorus in sewage and detergents would not counteract eutrophication. The controversy was resolved through whole-lake fertilization experiments. These showed beyond doubt that phosphorus was the key element in lake eutrophication. The debate did not appreciably affect Sweden. Here an administrative decision was taken that municipal sewage treatment plants should have efficient (>90 %) phosphorus reduction facilities. A large proportion of the Swedish urban population is now connected to such treatment plants. This applies both to cities with a lake as recipient for the sewage, as well as cities where the sewage is discharged directly into coastal waters. It was assumed, without much scientific support, that marine and brackish water recipients would react in the same way as lakes to reduced phosphorus loading. Results with respect to lakes have been quite encouraging. Trends of increasing algal biomass and reduced water transparency during the 1960-ies and 1970-ies were in many cases reverted. In the center of Stockholm, salmon can now be caught routinely by sport fishermen in the outlet of lake Mlaren to the Baltic. However, in Swedish coastal waters the situation deteriorated in spite of the substantial investments in advanced sewage treatment. During the end of the 1970-ies, serious signs of overfertilization appeared both in the Baltic proper and in the Kattegat. Such symptoms were e. g. deep water anoxia, mass mortalities of benthic animals, algal blooms and substitution of brown algae with slimy green algae. The public reacted strongly to the situation. In the beginning of the 1980-ies more than 70% of the Swedish voters appointed environmental problems as the most important political issue in the coming elections. A large research program on eutrophication of the Baltic and the Kattegat/Skagerrak was launched by the Swedish Environmental Protection Agency and was realized during the second half of the 1980-ies. Both laboratory and field experiments indicated nitrogen, not phosphorus, as the most limiting nutrient for phytoplankton biomass accumulation. Based on these results an ambitious program aimed at a reduction of nitrogen discharges to coastal areas was initiated. The goal was a 50 % decrease in the (anthropogenic) nitrogen loading to targeted areas by 1995. A similar goal was set in e. g. Denmark. In contrast to phosphorus, sewage only contributes a minor fraction of anthropogenic nitrogen entering coastal waters. A large part originates from diffuse sources, e. g. agriculture and the transport sector. Large scale efforts are now being implemented with the aim to reduce nitrogen leakage from agriculture and to increase retention of nitrogen leached from terrestrial ecosystems. Among these measures can be mentioned construction of wetlands, restoration of streams,

better storage facilities for manure and changes in fertilizer applications and crop rotation. The goal of a 50 % reduction has, however, not (yet) been achieved. Eutrophication symptoms, e. g. blooms of both toxic and non-toxic algae, seem to be increasing, not decreasing, in many Swedish coastal areas. The reason may either be that nitrogen loading does not control algal growth, or — more likely — that the system reacts slowly due to large internal stores of nutrients and a long hydraulic residence time. In addition, nutrient loading to Swedish coastal to a substantial extent originates from sources in other countries. Ever since the beginning of the 1980-ies there has been strong opposition against nitrogen control from a small but very active minority of scientists. They maintain that nitrogen reduction measures are a waste of money or even have detrimental effects by provoking the blooming of blue-green algae. It has been very difficult to reach consensus among scientists and environmental managers. Very little research money has been available in Sweden or elsewhere for a critical testing of the marine limiting nutrient controversy. This is unfortunate given the multi billion dollar investments made in sewage treatment plants and other measures to reduce nutrient loading to coastal waters.

# Atmospheric inputs into Northern European Seas: Socio-economic aspects of possible solutions

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## Abstract

High concentrations of PCBs, pesticides, other persistent organic pollutants and heavy metals were measured in the Baltic Sea and the North Sea in the 1970's and 1980's. These observations, carried out by research teams mainly in countries around these seas, were then related to unwanted environmental effects, such as reproductive failure and behavioral abnormalities for various species, incl. seal, otter, and some kinds of fish and birds. Rate of eutrophication of the seas was also growing due to increasing loads of nitrogen.

The above observations within national studies have resulted in the initiation of interactions between natural scientists and policy makers. International conventions on the protection of the Baltic Sea (HELCOM) and the North Sea (OSPARCom) have been established with a major goal to define sources, transport pathways, fluxes, and control policies for pollutants causing the above mentioned environmental effects. It was concluded that the atmosphere is an important pathway for several nutrients and toxic compounds reaching the Baltic Sea and the North Sea. More than 50% of nitrogen, and between 20 and 50% of toxic pollutants enter the above mentioned seas by atmospheric deposition. For some of these chemicals the atmospheric load was found higher than environmentally acceptable, thus the action was expected to be taken. Major point sources of emissions (so-called "hot spots") and emission regions have been defined with the help of atmospheric models.

Action to be taken by policy makers required evaluation on how serious is the threat posed by anthropogenic load of nutrients and toxic pollutants to the studied seas. This evaluation should always be made in terms of ecology, environmental and health effects, economics, and quality of life. An extended interdisciplinary cooperation of experts is needed in order to perform such evaluation. In the case of HELCOM and OSPARCom decisions have been made to reduce the loads of several pollutants by as much as 50%. In the next step of international interactions in the Baltic Sea and the North Sea, an implementation plan has been prepared with the aim to propose various emission reduction scenarios. A cost-benefit analysis of environmental policies, prepared by both natural scientists (benefit part) and economists (cost part) is the core of emission reduction scenarios. At the beginning of the 1990's a cost-benefit analysis was approached for the Baltic Sea with the support of financial institutions, such as the World Bank and other regional

investment banks in Europe. Conclusions and recommendations have been prepared with respect to emission reductions at various "hot spots" in the region.

Implementation of the above mentioned conclusions and recommendations is a responsibility mainly of governments of countries in the region. In some countries, financial mechanisms have been established in order to help implementing the recommendations of emission reduction. A few member countries of the Paris Club have agreed to convert a part of Polish foreign debt (most of them by 10%) to support activities aiming at the reduction of pollutant discharges in Poland. Reduction of releases of pollutants to the Baltic Sea is one of 4 major priority programs of EcoFound foundation in Warsaw, established by the Polish Ministry of Finance (at present National Treasure) to manage the financial resources originating from the eco-conversion of the Polish debt abroad.

# Interactions between chemical monitoring and regulatory policies: Western Mediterranean and Black Sea case studies

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The marine environment is recipient of an increasing variety of xenobiotics from land-based sources of pollution. The fate of xenobiotics in the marine environment is largely dependent of the physico-chemical properties of these products. A small fraction of xenobiotics introduced in the marine environment is recaltritant to degradation processes and it can be accumulated into sediments which act as archives of marine pollution along the historical record.

In this presentation, different chemical classes of persistent pollutants that allow to trace pollution sources such as agriculture, industrial and urban into the marine environment are introduced. Some of these chemical classes have already banned such as DDTs, branched anionic surfactants (ABS) or replaced for other classes of more environmentally acceptable compounds (esterquats ——> quaternary ammonium salts) or are subjected to regulation such as PCBs, TBTs etc. The determination of these chemical probes in environmental compartments allows different time-scale information increasing from recent (seawater and biota), mid-long term (sediments). Therefore, the effectiveness of changes in regulations can be assessed by monitoring chemical probes in the different compartments according to their temporal information needed.

The former approach has been applied along the EROS-2000 project of the EU (MAST, ENVIRONMENT) in the western Mediterranean and Black Sea. Historical trends of these chemical probes is used to reconstruct the pollution history and to assess the effectiviness of changes in regulations.

# Managing nutrient fluxes and pollution in the Baltic: an interdisciplinary simulation study

*Prof. R.K. Turner, CSERGE*

This interdisciplinary paper reports the results of a study into the costs and benefits of eutrophication in the Baltic Sea. A large multidisciplinary team of natural and social scientists estimated nutrient loadings and pathways within the entire Baltic drainage basin, together with the costs of a range of abatement options and strategies. The abatement cost results were compared with clean up benefits on a basin-wide scale, in order to explore the potential for international agreements among the countries which border the Baltic. The environmental benefits valuation studies (contingent valuation method) were undertaken in both Sweden and Poland and results were 'transferred' to other Baltic countries. Most countries would seem to gain net economic benefits from the simulated fifty percent N & P reduction policy.

Costs and benefits from reducing the nutrient load to the Baltic Sea by 50%, millions of SEK/year

| Country | Reduction in % | Costs | | Benefits | | Net Benefits |
|---|---|---|---|---|---|---|
| Sweden | 42 | 5,300 | 20,723 | (11,591) | 15,423 | (6291) |
| Finland | 52 | 2,838 | 10,799 | (6046) | 7,961 | (3208) |
| Denmark | 51 | 2,962 | 12,376 | (6929) | 9,414 | (3967) |
| Germany | 39 | 4,010 | 8,369 | (4687) | 4,359 | (677) |
| Poland | 63 | 9,600 | 11,631 | (5899) | 1,761 | (–3701) |
| Russia | 44 | 586 | 3,488 | (1769) | 2,902 | (1183) |
| Estonia | 55 | 1,529 | 418 | (212) | –1,111 | (–1317) |
| Latvia | 56 | 1,799 | 583 | (291) | –1,216 | (–1508) |
| Lithuania | 55 | 2,446 | 923 | (468) | –1,523 | (–1978) |
| Total | 50 | 31,070 | 69,310 | (37892) | 38,240 | (6,822) |

Note: Figures in brackets are for benefit figures which assume zero wtp of non-repondents.

# Research and policy issues related to fisheries management

*Elisabeth Vestergaard, Danish Institute for Studies in Research and Research Policy, Aarhus*

Case: Danish fisheries, main focus on the Baltic island of Bornholm

A main characteristic of the Danish fleet is that most vessels shift in annual circles between different fisheries in terms of species, waters and catching methods. There is no ecological basis for large single species fisheries like in more northerly waters, nor any basis for multispecies fisheries like in southern waters. Instead, there is an intermediate situation with a fair number of species that require a flexible fleet and a combination of strategies to allow for all year fishing. Throughout the years, the flexibility of the fleet has at the same time been the fishermen's pride and also ensured the best rentability for the individual fishermen. The Common Fishery Policy and the way it is enforced by the Danish authorities has had severe consequences for the cornerstone in the organisation of fisheries as Totally Allowed Catch (TAC) and licences easily conflict with the organisation of fisheries diminishing the possibilities for the hitherto strategy of flexibility and adaptability to changing circumstances.

The island of Bornholm can be seen as a mini laboratory for fishery research: For years the fishing sector has been crisis afflicted, in addition one finds here conflicts with the fishing control, dissatisfaction with the regulation system, conflicts between different fishing enterprises from various places within Denmark, with other EU nations and especially with third countries (the other Baltic nations).

With an outset in Danish cases the paper will investigate relevant management systems and point to preconditions to consider when drawing such systems in order to make them well functioning.

Finally, trends in modern society will be outlined with the focus on 1/ changed relationship between primary producers and civil servants (:the state) and 2/ the consequences of the emerging consumer society for primary producers.

# Large-scale research for the protection of the deep ocean

*Hjalmar Thiel, Alfred-Wegener-Institut für Polar- und Meeresforschung*
*D-27515 Bremerhaven, Germany*

During the last three decades the use of the deep ocean became a target between technological developments, commercial exploitation and environmental protection. Metalliferous resources, i.e. polymetallic nodules in the Pacific and Indian Oceans and the metalliferous muds of the Red Sea were explored, radioactive wastes and munitions have been dumped, and the disposal of sludges and carbon dioxide into the deep sea have been discussed. The verification of these large-scale actual and potential penetrations into the "inner space" needs careful consideration by oceanographers. No ethical argument can be brought forward against the use of this part of the sea as long as Man exploits the terrestrial sources. Large-scale disturbances demand large-scale monitoring and precautional research for environmental impact assessments in the deep sea, a co-operative and international challenge for oceanographers.

The lecture will summarise the various uses of the deep sea, ongoing large-scale impact experiments, and the need for future impact studies. It will draw attention to the New Law of the Sea Convention, the United Nations Seabed Authority and other policy-making organisations.

The presentation will be based on the report "Environmental Risks from Large-scale Ecological Research in the Deep Sea. A Desk Study."

# Dissemination and exploitation of results from basic RTD. The Way of CPMR: Networking and co-operation with scientific organisations

*Jean Pierre De Loof, Directeur, Délégué aux Affaires régionales (IFREMER)*

When correctly transferred to adequate users, the results of many oceanographic researches are of main interest to economic and social sectors. Such are those involved in living resources' exploitation (fisheries and fish farming) as well as environment conservation and management (tourism, harbours, maritime transportation). Improvements in marine technology are also of great interest to manufacturers in connection with sea resources' exploitation. Its obvious that local and regional authorities of coastal zone have specific feelings in this matter as they are in connection with various social groups and worrying about conservation and development of local activities.

But what means correctly transferred and who are the adequate users? That is the general question of dissemination and exploitation of scientific results.

In the maritime field, CRPM, thanks to its large representation in maritime regions and to its efficient organisation, offers to scientists very good opportunities to improve the dissemination of their results to social sectors and towards policy makers.

In that sense, initiatives have been taken to settle co-operation agreements between CPMR and research organisations – first with IFREMER in November 1994 and recently with ICRAM in October 1997.

The final objectives are:

to improve communication between people of different cultures as

— policy makers, (politic body and administration officers),

— policy beneficiaries (or so expected) as fishermen, fishfarmers, tourism operators, maritime companies, etc.

— scientists whose advises or information have influence on making political decisions.

to take into account interactivity of such typology in the programming of research.

to offer better opportunities to exploit results of researches, thanks to better understanding by non scientist.

The method includes improving co-operation between research organisations themselves, involving local and regional research organisations, networking between research organisations and maritime regions involving social groups directly concerned.

Thanks to DGXII and DGXIV support, some primary attempts have been achieved to organise such a network. So, from RECORMED** network experience, after a first meeting at Brussels (April 29, 1996), and a second at Palma de Mallorca (February 27-28, 1997) devoted to biology and fisheries, our working group can give its first conclusions.

CPMR is committed by DGXVI to assume the follow-up of 26 projects concerning Coastal Zone Management. These projects are parts of LIFE, PHARE, TERRA and Interreg-IIC programmes. CPMR will be in charge of dissemination and exploitation of the results of these 26 projects, in connection with the 120 region members of its organisation.

# DISSEMINATION AND EXPLOITATION OF RESULTS FROM BASIC RTD: HOW TO DO IT BETTER?

# Keynote speech

*Kaj Riska, Professor of Arctic Marine Technology, Ship Laboratory, Helsinki University of Technology*

## Introduction

The dissemination and exploitation are in many cases treated together because it is implicitly thought that once scientific results are disseminated, they are also exploited by somebody. It is like wild berries in forests; once they are there, always somebody goes and picks them. This is not the case for scientific results. Before the dissemination i.e. making others aware of your results and exploitation i.e. making somebody use your results, can be discussed, distinction should be made about the different aims present.

When confronted with the question: Why to do scientific research? answers vary widely depending on the point of view. The general aims of scientific research may be divided broadly into four different goals:

(1) Science per se to the scientific forum,

(2) Increase of the awareness of the public about the interconnections of matters in our physical, biological or economical surroundings

(3) Support for decision making in governmental organizations and enterprises and

(4) Exploitation by the industry and the society in general in developing innovations, products,

services etc.

All these aspects have to be and are in the following analyzed differently.

## Publication

The basic avenue for publication of scientific results for every scientist is to present articles in distinguished journals about the results of her/his work. When a scientist wants to publish a quick news release, a paper in a scientific conference is the commonly used avenue. At best, these publications are read only by a small group of scientists working in the same field. The abundance of scientific journals and conferences makes this group even smaller than the practitioners of the subject matter. Thus the question of reaching even the scientific community has arisen. Publication is not dissemination.

That scientists should publish their results, is clear because otherwise no scientific critisism leading to improvement is possible. The question is, however, that larger dissemination of results could lead to quicker advancement of science. Here no direct answer about enhancing dissemination can be given. The best way for wider

circulation of the results is to make a plan for structured dissemination. Most of the research organizations publish their own news bulletins. This is a place to advertise your research results to colleagues and publish the references where your work can be found. The conference papers are more informative and thorough than just the news bulletins. All the facts and methods used reaching the conclusions are to be published in a scientific journal. EC could stimulate the news releases by publishing a newsletter from each scientific programme.

At present it is not easy to put your research in perspective because the scope of science is enlargening rapidly. It is, however, necessary that the context of the research is clear especially if the target of the research is to be lucid. Leafing through scientific journals leaves the reader many times baffled; the article at hand can be understood i.e. all the text makes sense but what is really achieved is obscure. Other way of stating this is that data is published often but knowledge is more difficult to come by. Here scientists have something to learn, we tend to keep our own aims that self evident that we do not explain these to others.

The word deliverable is important in discussing the dissemination. Putting together a report or submitting a paper to a scientific journal is not really delivery of results. The delivery means that somebody takes the results. Many times the publication is a value *per se*, not that people read the article. Naturally science citation lists emphasis the delivery aspect but they also highlight the topics which are in fashion and in the mainstream of research.

# Publicity

The scientists are not good communicators towards the general public. One of the main reasons for this is that all fields of science have developed their own vocabulary which does not open easily to the layman. Above some other reasons for this have been noted. Scientists are often surprised when they note what aspects of their results interest the public. Usually it is not the newest result the scientist has achieved but more the general insight into the subject matter. Here it is also indicative that in the Finnish main newspaper the weekly science part is titled: Science and Environment. People are interested in things which influence their view on the world.

It is instructive to write an article to a newspaper. The way the reporters mutilate your nicely structured exposition is often a chock. In a scientific article the problem is first defined and the paradigm explained. The definition of the methods and boundary conditions is also important in the beginning. The results then emerge after a thorough analysis. Newspaper articles are written in a contrary order. First the results is stated and then a little of the analysis. Finally the problem might be defined. Here it is anyway important that you catch the interest of the reader. For a scientific paper in a scientific forum the interest is taken as granted.

The lack of interest in the general public have turned many scientists hostile to the press. This, however, is not the correct response. Better is to try to see your results from the perspective of a man from the street. Here the university teachers and professors are in a good position, they have to explain their results to students and this way test their reasoning. The best test here is to stimulate interest of non-scientists.

The publicity aspect is extremely important for fundamental research. It is nowadays considered self evident that scientific results have a potential for exploitation. In case of fundamental research that is not necessarily the case. Here then the publicity is the only avenue towards larger impact of your results. The public is very interested in such non-exploitable results as human evolution, microbes on the Moon, extra-terrestrial life forms or deep sea fish species. The scientist has only to tell about these in an interesting way. For the public the scientific caution means that the story is not interesting.

# Communication

The most difficult task for a scientist is to make his/her results to have an impact for decision making. The urge to have an impact on decision making is directing many times the choice research topics. This way problems which are considered more important and results which are considered to have more value are at least implicitly preferred. The research related to the climate change, greenhouse effect or ozone layer is deemed more important than some other topics. This preference towards the orthodox subjects is well accepted and endorsed by the EC or national research programmes. This can lead also to selection of topics or approaches which are unfruitful.

Universities want to emphasis their independence from the shifting currents in the society. Earlier this was easier as the funding was not questioned but nowadays more and more funding is tied to the likely impact the results of a research project. The answer to a scientist's critisism for this is that the curiosity driven research will lead the focus of the research astray. Here communication about the aims of the research is important and especially the willingness of the scientists to come and present the results in workshops and other discussion for a where the audience consists of different groups of people. This should lead to fruitful debate.

Here EC could stimulate the interaction between scientists and others by arranging workshops where scientists present their results and future research direction is discussed. Also support for training of scientists will enhance the communication of results and should thus be favoured.

# Exploitation

Once scientists have done all the measures towards good communication and dissemination, the exploitation of the results is still not a necessity. The exploitation of the scientific results means that someone uses the insight created to a specific problem. This flow of results from basic research towards the product development may be described as an innovation chain. The exploitation of results in industry must be organized according to the innovation chain where the basic research is at the root of a chain leading to a marketable innovation through development in the industry. The organizations doing basic science (universities) are not necessarily good in passing the results forward — there is a need for applied science organizations like universities of technology, research institutions (VTT in Finland, TNO in Holland etc.) to be more active.

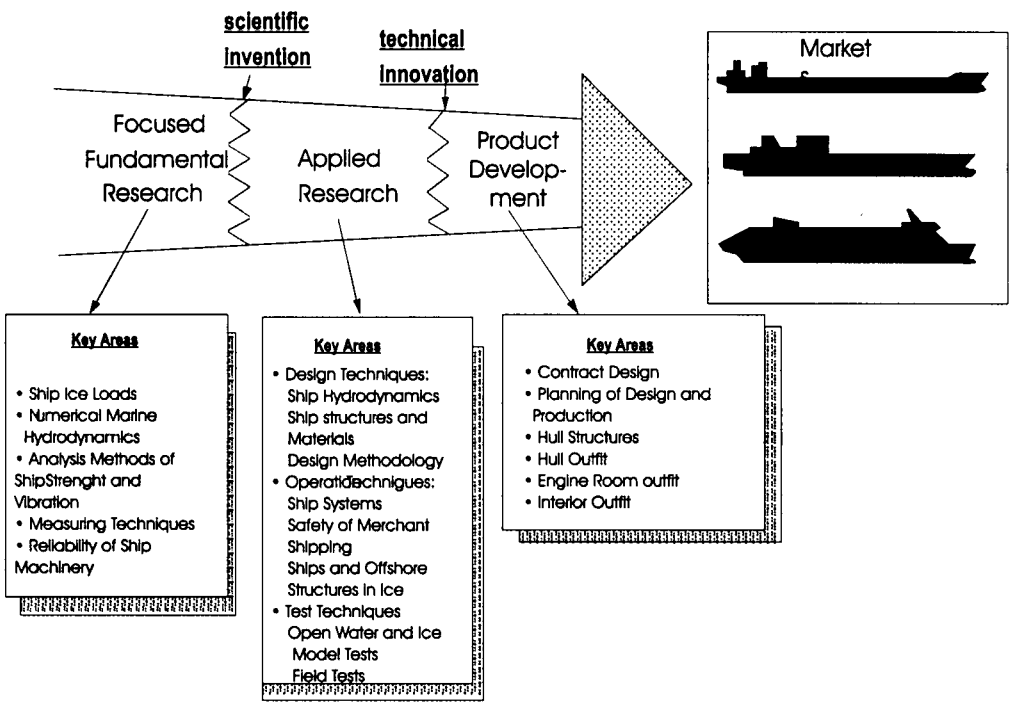



Fig. 1. An example of the innovation chain, the ship technology related research in Finland.

The concept of innovation chain puts the exploitation of research results in a very compact and logical form. This route to a specific application from the basic scientific invention is not this direct; only in hindsight it can be distinguished at all. In many cases the time from the invention to commercial application has taken several decades. The needs of product development are often and usually very direct. The scientific results are needed immediately; there is no time to wait for scientists to complete their work. This balance of long term research and short term needs is very difficult to solve. One answer is to sow that much that some meaningful results emerge constantly. This view is many times taken by the universities. Governmental and EC funding mechanisms take a more direct point of view by guiding the research.

The whole exploitation matter is hinged around the fact that scientists should be able to recognise the potential of their results and this way foresee the applications. This requires active cooperation with the those who apply the results as the scientists do mostly analysis and design or development work requires synthesis. The active cooperation makes these two approaches acting in different direction more comprehensible to each other.

The active exploitation policy requires that projects geared for exploitation should be organized vertically including organizations from basic science to product development and the final users. Only when all partners in a project have a role

towards the final product which in this kind of projects should be quite clearly defined, can the work along the innovation chain be speeded. Science projects could still be organized horizontally so that scientists share work.

# Conclusion

The exploitation and use of the research results could be stimulated by some EU-actions. Scientists must be convinced that dissemination is important. Stimulation towards this might be that the science reports are published in some series arranged by EU. Also publicity could be assisted by some centralized actions from research programme offices. Projects should be stimulated in reserving money for dissemination. MAST-office could give some training and/or practise for exploitation of the results. There could also be some kind of reward in or a follow-up towards proper exploitation of results.

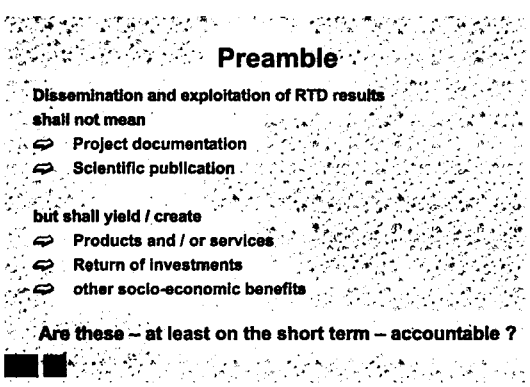
# Provocateur's report

*Klaus D. Pfeiffer, HYDROMOD Scientific Consulting, Germany*

Following the key-note lecture which amongst other topics reflected on the role of the scientists in dissemination and exploitation of basic research results along the innovation chain from the point of view of an applied scientist, the provocateur brought some more industry and SME related issues into the discussion. These however, reflected the sight of a service provider with often very close links to applied and basic RTD activities mixed with personal experiences arisen from developing and managing a SME on the "learning by doing" basis. Its roots came from a marine academic institution and a considerable part of its corporate profile was developed by exploiting and applying results and methodologies from basic marine sciences. Although these opinions might neither be fully representative for the overall area of exploitation and dissemination of results from basic RTD nor reflect the general view of the industry on this subject they might have provided some hints for "how to do it better".

## 1. Provocative Statements

The statements presented arose from the role of a discussion meeting's provocateur to polarise opinions and thus and stipulate a lively discussion. As a discussion basis one ought to agree that dissemination and exploitation of results and technology arising from basic science and research shall neither mean standard or project-related documentation nor classical scientific publication. The first comprises just proper project work and the latter is an obligation of every scientist and the research community's internal quality control of his work. Exploitation and dissemination must extent far beyond and shall mean in particular:




- Transforming results of basic research into marketable products and services;
- achieving return of investments into science by strengthening industrial competitiveness, market position and thereby launching re-investments into basic research;
- creating socio-economic benefits by working up scientific results, data or prototype technologies in such a manner that they are transparent and usable for administrative and / or operative issues;
- attracting the public and convince the tax payer in beneficial use of his money.

Enhanced focus and awareness on exploitation and dissemination of RTD results is a rather new component and objective in RTD programmes and this certainly needs an adaptation and learning phase for all sides involved – programme managers, scientists, dissemination professionals, industry and users. Although all sit in the same boat and know whereto sail with it but the mix of the crew, the distribution of their individual roles and the selection of course, speed and the propulsion system seem to be still in a somewhat experimental phase.

And there remains a rather big problem for the controllers – is it possible – and if yes – how to account and validate the success of exploitation and dissemination activities? This appears on both product and sales levels keeping in mind the length of the innovation chain but, moreover, for the indirect socio-economic impacts and benefits.

## 1.1 Basic RTD versus industrial products and services

If one looks on interests and requirements of both science and industry several differences and contradictions can be identified which – at least on the first glance – appear quite difficult to solve and overcome. The nature of science on the one hand is driven by widening the horizons of mankind's knowledge and thus must have a wide range of freedom and liberty. On the other hand industrial activities – at least these of the "non-monopolists" who cannot effort to conduct own basic RTD and maintain brain trusts – have strictly adhere to market and Client's demands and are bound by constraints of resources, achievable remuneration and capital assets. Whereas science has to operate in an open minded environment industries' marketing and dissemination is always a critical balance between disclosing and withholding relevant background information.

**Contradictions**

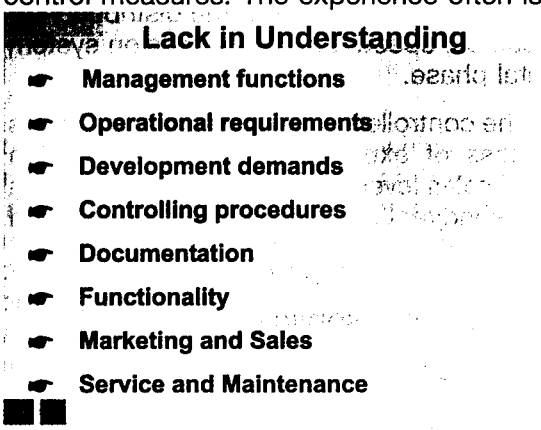
| Interests of science | Interests of industry |
|---|---|
| Freedom of science | Market dictate |
| Knowledge driven | Capital driven |
| Open | Competative / Confidential |
| „Unlimited" | Demand oriented |
| Unique | Series / Multiplication |
| Fully funded | Partially / not funded |
| Low risk | High risk |

Industrial involvement in basic RTD projects can be supported by subsidiary funds of up to 50% of the project costs. This forces concentration on issues and topics which guarantee return of investments and give prospects to achieve earnings and to fund future RTD within commercially foreseeable periods. This does not appear for scientific institutions who usually have their public institutional or infrastructural funds and often receive 100% of project related RTD costs supplementary. Finally, there appears a certain difference in risk. Failure of a basic RTD project having proven a wrong direction or approach still might still yield considerable socio-economic benefits. Fault of industrial – especially SME – RTD commitments usually ends up in bankruptcy.

Industrial RTD is one measure to increase competitiveness and efficiency but others reveal to standardisation and multiplication of products and as much as possible repeated sales of once developed products with the lowest possible grade of modification. This requires certain measures which are not or very poorly – if not at all – developed in the scientific community. Well proven industrial project manage-

ment, controlling and operation procedures are barely implemented in scientific and especially academic institutions.

Perspective developments often fail due to lack in documentation and quality control measures. The experience often is in the head of the developing scientists who are usually PhD students or post-graduates on time contract. If these leave the institution it is often impossible to set-up following activities on the level which has been previously achieved already. On the other hand lack in understanding and application of such procedures often hampers co-operation between industrial and scientific teams and may cause different expectations, requirements and assignment of priorities within a RTD project.




Further, the difference between a basic scientific development which usually comprises a unique laboratory prototype operable by the developing specialists themselves and a fully functional, qualified and repeatable product or service is enormous. If these basic and mainly technical issues have been solved and overcome and a serial-ready prototype has been developed the real matters in exploitation are just at the beginning. These goes far beyond scientific objectives, interests and expertise and includes activities like proving long-term operability, sustainability and quality, set-up and operation of demonstration and reference applications which are essential for successful sales later on as well as working up the market and preparing production, sales, technical support and maintenance.

## 1.2 Constraints and hampering criteria for exploitation and SME involvement

The following reveals in particular to the marine research technology market which has its own peculiarities (this does not mean that these do not appear for other markets but this goes beyond the experience of the author). This special and non-mass market is strongly dominated by the public sector who is involved and dominant from end to end (i.e. from specification of programmes and research contents through funding and conduction of basic and often also applied RTD activities towards application, implementation and purchase of products and services). On the one hand, these who provide basic input to define and specify RTD programmes and directions are often identical with or heading these institutions and research teams who conduct basic RTD activities. On the other hand their links to, networking and interfacing with both potential end-users, manufacturers and exploitation professionals are often poorly established. Thereby the full scale of exploitation potential might not be recognised.

The public sector as market and Client is bound to planning schedules, time scales and related financing issues which often cannot be brought in line with both time scales of RTD project and thereto linked requirements for exploitation. This appears

especially after the funded RTD or demonstration phases and for post-project exploitation when someone else has to pay the bill for implementation, purchase or application.

Many programmes headed by the key-players in marine science or being the only Clients for implementation specify useful or necessary developments and try to stipulate industrial and especially SME involvement. However, provable and accountable answers to questions regarding the market potential – in concrete the future budget assignments for implementation and purchase of successful developments – remain unanswered at all.

**Some Typical Constraints**

- **Inertia of the public sector (planning, finance)**
- **Competition between public and private sect.**
- **Large overlapping activities**
- **Limited home-market potential**
- **Lack of risk and venture capital**
- **Lack of networking**

Nowadays more and more "competition" between the public and the private sectors both in exploitation of RTD results and on the market are observable whose looser due to lack of fundamental and basic funds and requirement to apply full cost calculations is obvious.

The European home markets for exploitation and implementation of marine technology are rather limited and often dominated by national preferences and interests. Often qualification possibilities for products and services as well as chances to implement demonstrators are missing. Lack of such essential references are certainly not the best basis to acquire Clients on export markets.

Finally SME involvement is considerably limited by the commonly known constraints in capital assets and lack of venture capital, financing and insurance possibilities for export risks.

## 1.3 The role of SMEs

SMEs can play a key-role in dissemination and exploitation of RTD results. They have the required flexibility and often more courage to enter into higher risks and can survive in small identified niches. For several reasons beyond the scope of this presentation, these characteristics are seldom found at large enterprises. One of the reasons for success of some SMEs in European Commission RTD programmes might be their long-term engagement in "non-direct profitable" activities which elsewhere financial controllers, business consultants or share-holders would have cancelled right from the beginning. However, the amount of SMEs who have therefore suitable corporate profiles, the necessary independence and backing are rather limited.

In any case, SMEs need guidance and support on different levels as their capital basis, own RTD funds and acquisition possibilities of supplementary financing are strictly limited. The same appears for their capability and constraints in transnational and world-wide marketing, sales and maintenance support. This reduces their sustainability in conduction of the end-to-end process of exploitation with own forces and resources. Thus the risk of failure of SME engagements in exploitation is a factor to be kept in mind.

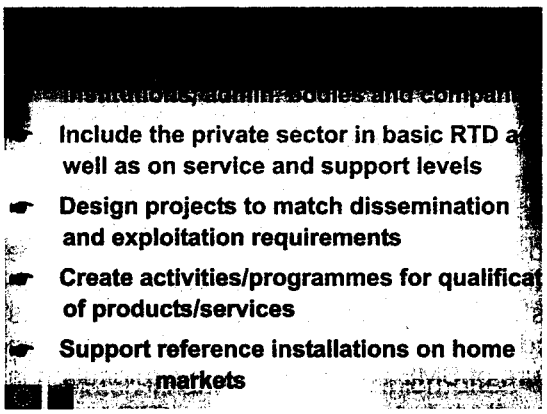
## 1.4 The role of programme and project controlling and administrations

Programme defining and managing organisations and administrations as well as supporting committees, members in reviewing panels and individual project controllers play an important role in support of dissemination and exploitation of RTD results. Only they can define objectives of programme and related Terms of References, Calls for Tender and evaluation criteria which facilitate an exploitation and dissemination friendly environment. By this they have a strong influence on the composition of project teams and assignment of functions and liabilities. Further by various complementary measures they can create and conduct a variety of activities supporting dissemination and exploitation activities and thus can support these as an end-to-end process. This creates – especially for SMEs – new co-operation and networking platforms, development chances, marketing possibilities and other direct and indirect benefits which they can barely achieve and maintain on their own.

However, it should be kept in mind that exploitation and dissemination is still in the initial phase and comprise recently stipulated activities of a longer-term complex process. As already depicted above, results and return of investments are difficult – if not impossible – to account in short and by means of simple cost-benefit ratios. Finally, one has to realise that exploitation of basic RTD results have require large efforts and thus have considerable costs. Commercial exploitation is always a venture with high risk of failure for all parties involved. Reflections and expectations on this being issued from time to time from "safe staff positions ashore" sometimes tend to overestimate the exploitation potential and possibilities or underestimate therewith related costs, efforts or risks. Some even appear quite far out of bounds from conditions encountered in the "rough and stormy seas of market reality".

# 2. Recommendations for "How to do it better"

It is quite simple to pack aforementioned critics and deficiencies in a series of provocative statements, throw them on the floor and then lean back on the podium without giving at least some accompanying ideas for improvements. As most of these where picked up in the following discussion and several aspects appeared in the conclusions as reported by the Rapporteur, they are depicted here in brief only. Certainly they contain no extraordinary new ideas but summarise ideas to increase efficiency in dissemination and exploitation. Several of them can be found in objectives and goals of existing and future RTD programmes or reflect related intentions and topics.




On the relatively short-term these comprise programme or even project-related measures to support and stipulate dissemination and exploitation. Intensified networking, co-operation, communication and exchange of knowledge between scientists, users decision and policy makers plus manufacturers and / or service providers is an essential step.

Besides better understanding of views and objectives of the different groups involved, RTD activities can be defined in a more exploitation suitable and application oriented manner. This must not necessarily mean restrictions in freedom and goals of fundamental and basic research.

Stronger incorporation of SMEs in accordingly defined RTD projects as research consortium partners or service providers will improve both future exploitation possibilities as well as qualification of RTD results being already in advanced exploitation or even commercially applicable state. Complementary project possibilities aiming on further qualification of exploitable results by means of prototype and reference installations beyond basic RTD and unique developments will strongly support their implementation and marketing potentials.

In the longer run and on higher decision and policy making levels the general "environmental conditions" for SMEs can be improved. Such flanking measures could aim in particular on strengthening their financial and marketing capabilities, supporting access to potential Clients in the public sectors of foreign countries and on diminishing of development, marketing and export risks.

# 3. Conclusions

Over the past ten years the development of dissemination and exploitation activities and their successive implementation in European and national RTD projects has considerably increased. The MAST Programmes appear as a classical example to track evolution of exploitation and dissemination objectives and activities over the past decade. In MAST I exploitation and dissemination appeared to be a factor of minor relevance and project-related major involvement of SMEs was at least uncommon if not impossible to realise. MAST II supported already several projects with SME participation. Some were even initiated and managed by SMEs and incorporated strong exploitation objectives. Further, several MAST II supporting initiatives comprised enhanced involvement of the private sector and most of them aimed on dissemination and exploitation of basic RTD results. Within MAST III exploitation and dissemination was fully implemented in the Terms of References and SME participation are quite as common. Looking towards the 5$^{th}$ Framework Programme these tendencies appear to go on with intensified incorporation of activities and components stipulating exploitation and dissemination. Many technologically oriented RTD programmes and projects on national levels almost world-wide appear with similar objectives.

However, exploitation and dissemination of basic RTD results is still in the implementation and experimental phase. All parties involved have to learn from each other and have to respect their individual strengths and weaknesses. There is a large potential to harmonise contradictions and incompatibilities and to optimise approaches and methodologies. These are iterative processes which may also include misdirection and require corrective actions based on positive experiences successively gained. Management and operation in basic RTD activities might likely change towards more optimised and efficient procedures which also supports exploitation in parallel or later on. This will open new chances and aspects in co-operation between science and industry. Clients as well as programme and funding administrations will for sure face risks and experience failure of the one or other exploitation measure. Companies may encounter painful experiences both in over-

or underestimating exploitation potentials and some of them will not be able to cope with related requirements or even vanish from the market.

In overall, optimised dissemination and exploitation of basic RTD results and the presently implemented or foreseen measures provide great chances for better co-operation between scientists, decision and policy makers, public and private users, developers, manufacturers and service providers. This will yield optimised utilisation of RTD results, resources and funds, create public awareness and increase support for decision and policy making. Further science and competitiveness of industry will be strengthened and thus bears a large potential of direct and indirect benefits for all parties concerned.

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# Rapporteur's report

*Órla Ní Chéileachair, Irish Marine Data Centre, Marine Institute, Ireland*

The discussion topics raised by the key note speaker and provocateur set the scene as between them they outlined issues from the perspective of the fundamental research, through to the more applied aspects of research and requirements of exploitation activities. They described a range of target audiences including scientists, industry, general public and government bodies, all of which have their own specific requirements in terms of how they can respond to, use and benefit from research results. The Key Note Speaker dealt with four main points: publication, publicity, communication and exploitation of scientific results. The Provocateur outlined similar issues concentrating on the contradictions, lack of understanding and constraints between the private and public sectors and steps towards improvement. As the detail is provided in the accompanying papers, I will give just a brief summary of the talks, followed by the main points raised in the following discussion session.

## Discussion Papers

### How well does the scientist manage the dissemination, communication, publicity and exploitation of research results?

While scientific papers are traditionally the main 'scientist to scientist' forum for dissemination of results, given the specialist nature of the research journal and limited target audience, 'Scientific publications can not be considered real dissemination or exploitation of research'. Neither is project documentation as they do not target the other potential users in the private and public sector.

Publicity and communication of results by the scientist are often not effective as scientific caution and specialist vocabulary can mean that 'scientists are not good communicators'. Communication can also be hampered by a dichotomy in 'appeal factor' in the type of research that both the scientist, general public and the policy makers consider as 'good research'.

Exploitation of results needs to be part of a focussed process or 'Innovation Chain' which channels results of fundamental research into the areas of applied research and product development. Such exploitation activities should give some form of social and economic benefit or return of investment. In general, the scientist does not easily migrate along this 'Innovation Chain', though it is important that they recognise the potential of their results and have a role in identifying possible applications and products.

### Operational environment of fundamental Science versus the operational environment of the Private Sector

Fundamental science contradicts in many ways the basic operational requirements of industrial and commercial markets. Fundamental research is a knowledge driven activity financed by the Public Sector with fairly open 'funding opportunities', which contrasts with the capital driven, demand orientated nature of the Private Sector. Further more, the industry wants to keep competitive advantage by restricting information while the scientists in contrast need to publish their research results. This Public Sector funding not only enables fundamental research but is also a user and main client of the research products. This again differs with the commercial environment which is either only partially funded by the Public Sector or not at all. However, Public Sector funding does have constraints such as the comparative inertia of the Sector, the lowering of market potential where similar systems are developed for overlapping activities (lack of focused marketing) and the general lack of risk and venture capital.

Operating in a commercial market also requires high efficiency and strict timing control in terms of project management, operational requirements, product production, sales and maintenance.

### How can we do it better?

Steps to improve exploitation and dissemination should include the implementation of an exploitation policy which defines a vertical structure to include organisations from basic research to product development and the final users (e.g SMEs, industry, Government Bodies), or at the least, stipulates strong networking between scientific institutes, administration bodies and the Private Sector. The inclusion of the final users in the early stages of project design would better facilitate the exploitation and focused targeting of the end-products.

Certain actions could be carried out by the Commission to convince the scientists of the value of dissemination and exploitation activities. Such actions could include a series of scientific reports, centralised publicity programmes, reserving finance for dissemination, training and follow-up actions in terms of exploitation of results.

Increased flexibility in terms of supporting external and mixed funding should be allowed and more options for outsourcing, particularly of dissemination and exploitation tasks, should be explored. Other mechanisms to be reviewed included the introduction of risk and venture capital. Marketing is another area that needs to be strengthened in terms of evaluating products and services, supporting reference markets nationally and well as exploring back-up markets in non-EU states.

## Discussion Session

Comments were expressed by scientists who had varying levels of involvement in exploitation and dissemination activities, several SME representatives, Government Body representatives, and a couple of non-EU participants who had experience of other funding strategies or initiatives for promotion of exploitation activities. While the discussion included a range of opinions from the floor, in general the audience returned to seven core points.

## Difference between dissemination & exploitation?

There was a distinction made between dissemination and exploitation activities. Dissemination may create awareness of research results but may not result in direct exploitation. The 'value' of dissemination then depends on how valuable this awareness is. Exploitation is a more measurable index of 'value' as it creates value when the results are 'used' and should ideally bring about some form of social or economic benefit.

Scientists are under a constant pressure to publish scientific papers. It is also their main forum of dissemination and essentially provides a means to quality control their work and to transfer their expertise. However, this is a quite limited form of dissemination as it targets only a small user group limited to scientists specific to a specialist research area.

## What is the role of Scientist?

A scientist can be involved in dissemination and exploitation activities but only up to a point. Their involvement to a certain level is necessary to ensure that their expertise and acquired knowledge is applied in the interpretation of the research results and in helping to identify the exploitation potential. After that, the multiple skills and expertise to effect exploitation and dissemination activities in a competitive environment are too demanding and place a range of roles and responsibilities on the scientist that they are ill equipped to handle. In short, the scientist does not migrate well along the innovation chain. This view was expressed in general by several scientists within the audience, as well as by other participants who have expertise in the more applied side of R&D and in the product and services area.

## What is the role of EC in terms of dissemination and exploitation?

Various views were expressed with regard to the role of the European Commission in terms of exploitation and dissemination. One suggestion discussed was whether the Commission should centrally facilitate dissemination and exploitation activities. Several responses were returned to indicate that the Commission should not have direct control but could facilitate such activities to varying levels ranging from provision of advice, stipulating end-user (e.g. SME) involvement, putting in place initiatives for applied R&D and 'incentives' for interaction with end-users as well as cross-linking between activities on a national as well as EU level. The main response from the Commission was that the project consortium should be constructed in a way that it can effectively handle dissemination and exploitation activities.

## Structure of Project Consortium

One of the key problems in handling the dissemination and exploitation of results is the composition of the project consortium. As mentioned previously, there was a common view that the scientist is not equipped to handle the range of communication, marketing, management and business skills that are needed to effect the exploitation (i.e. use) of results. As an example of this, a reference was made to Oceanology '98 where it was found that only MAST projects who had industrial partners were present at this major international forum for marketing and

promoting products and services. Hence, there is a need to include in the project consortia, specialist expertise who have the necessary skills to carry out and better target dissemination and exploitation activities. Be it through the project consortium or otherwise, there must be some mechanism that will facilitate the accessing of these skills to better effect the 'use and communication' of results to a targeted audience be it the industry, Government or General Public.

### Conflicts between fundamental research and the private sector

The discussion of how to strengthen the consortium structure raised again questions on the mechanism of involving commercial companies and resolving conflicts in management, timing, confidentiality and research demands between fundamental research and end-user needs. Again, it was suggested that the Commission stipulate end-user involvement in the funding programmes and review the structures and conditions which would make projects more 'SME' friendly. The need for fair competition between the Public and Private Sector was also raised.

### Post-Project Exploitation & Dissemination Activities

Concern was expressed with regard to the lifetime of exploitation activities versus the lifetime of the research project. Several comments from the floor reflected the fact that such activities can extend far beyond the 3 years lifetime of a typical MAST project and that there is a need to maintain continuous partnerships which can build on and harness exploitation potential. It was suggested that there are two stages of exploitation and dissemination activities. The first occurs within the life time of the project to ensure that the results of the research are produced in a form that is focused on its eventual 'use' or benefit, the second stage builds on the output from the first stage and actively disseminates and exploits those outputs in the medium to long term.

### Design of Project

There were some comments that it is difficult to sometimes identify potential products until almost after the results have been produced, that the start up time of a research project is slow and that project timing can clash with industrial needs. In response to this, the Commission emphasised the need to design the timing and focus of the projects to ensure that results or products are produced that can be carried to a further stage of dissemination and exploitation and that a good consortium should work towards some form of continuous partnerships.

## Conclusion

The need for dissemination and exploitation activities arises from the need to better direct and maximise the 'benefit and value' from scientific research in practical and measurable ways. To do this, the flow of results or 'innovation chain' between the originators of the research and those who can use or benefit from those results has to be strengthened.

It is also essential to recognise that there are many potential audiences that can benefit from results, including not only the industry and the scientific community but

also policy makers and the general public. However all of these potential 'users' require their own appropriate dissemination and exploitation strategy that will allow them to make 'use' of the results.

Consequently, research projects will have to look to the 'fitness to purpose' principle, and design and focus their project to ensure that what they produce can be effectively and easily used by a target audience.

Where is the scientist in all of this? Well, unless he or she can clone and re-train themselves successfully, the scientist does not have the training, time or interest to take on the range of roles that effective dissemination and exploitation requires.

However, this capability to successfully disseminate and exploit will somehow have to be accessed, and taking from the Commission's response, the current emphasis will be on a careful and strategic structuring of the project consortium and project design to ensure that these capabilities can be met.

It is important to identify and plan for the use of the research results and potential 'end-users in the design of the project. It is extremely helpful to include the end-user in the project consortium, to better focus and exploit research results. There are again however issues here to be resolved, particularly with the conflicts of the private sector to keep a competitive advantage and the need to ensure that state of the art research and innovation are not hindered by the need to turn around 'products'.

Finally, the inclusion of exploitation and dissemination activities in the area of research is relatively new and there is a learning curve ahead. It is important that we look at and learn different mechanisms for dissemination and exploitation as they will vary according to the different potential users that exist within both the private and public sectors. It is important to remember that the results of scientific research should benefit not only the industry but those who make policy decisions about our environment and the man in the street who actually foots the bill.

# MORE VALUE FROM PROJECTS THROUGH QUALITY ASSESSEMENT OF NUMERICAL MODELS AND DATA AND INFORMATION MANAGEMENT

# Keynote speech

*John Wallace, Marine Informatics, 64 Harcourt St., Dublin 2.*

## 1. Introduction

While significant progress has been made in recent years in the area of data and information management, there still remains a reluctance by some scientists to whole heartedly participate. With the hope of at least encouraging some of the sceptics to take a closer look, I will present the merits of data and information management in the context of the creation of value. This paper is presented in three main sections — firstly I will consider the concept of research value and some of the problems in realising our full potential, I will follow with some discussion on data management and its role and finally I will deal with the more specific issue of QA in modelling and its role in enhancing value.

## 2. The value of research

Accepting that the specific objectives of research may vary from project to project, I believe that the general underlying purpose of all research is to create value where value is considered in much more than just monetary terms. This creation of value involves three stages:

- Firstly the acquisition of knowledge which happens by doing research and which forms the foundation for value creation.
- Secondly, the dissemination or the making available of this knowledge through publications or other medium creates a potential value.
- Thirdly and arguably most importantly, the use or exploitation (not necessarily commercial) of this research-generated knowledge achieves value.

While this use or exploitation may be as varied as inclusion in an educational curriculum, its use as input for other research or even full commercialisation, if it does not take place then no value has been created and the underlying objective of the research has been not achieved.

The scientists who are responsible for research are key players in this value creation and they achieve their goal to varying degrees of success by linking what I see as the two resources that should matter most to them: their knowledge and those who would use this knowledge.

If we look a little closer at the theory of value creation and the linking of the knowledge creator and the knowledge user, we see that according to traditional thinking, the process is grounded on the idea that every value creator, in this case every scientist, occupies a position on a value chain. Upstream suppliers, usually other scientists, provide technology or information in the form of papers, data sets or advice as inputs to their work. The scientist doing the research then adds value to

these inputs by incorporating them in his or her own experiments and analysis and subsequently once new knowledge has been acquired it is passed downstream in a similar manner to the next scientist in the chain. Seen from this perspective scientists achieve success by developing expertise and designing projects which position them on the value chain where they have the right scientific expertise to create value potential and where this potential is realised because there exists a requirement for their knowledge.

In modern science however, this understanding of value is a little outmoded. Increasing competition for funding, changing research priorities and new technologies are creating new opportunities on one hand and new uncertainties and risks on the other. Traditional research areas which have offered value creating opportunities for many years maybe losing significance while areas which may have seemed peripheral in the past turn out to be the key opportunities of the future. In such a changing environment the concept of considering a scientist with a position on the value chain which may suggest some stability is less appropriate and he/she is perhaps better considered as a player in a constellation of actors. Within the constellation, these actors provide an atmosphere of knowledge and information through volumes of publications, conference lectures and speeches and more recently through media such as CDROM or the World Wide Web. Consequently, an atmosphere charged with value potential exists from which value is created when scientists seek out appropriate pieces of knowledge and information that will serve as inputs to their work and their value creation activities.

# 3. The difficulty in achieving value

Just as the creation of value involves three stages — knowledge creation followed by dissemination and finally exploitation, so to under these three headings are there problems found.

## Knowledge Creation

While research projects vary in subject, style and size, if considered in their simplest form, knowledge is created through two activities –

1. The gathering of inputs including previous research results and knowledge, existing data or new data.
2. The analysis and manipulation, by experts, of these inputs to achieve their project objectives.

A significant problem identified in this situation, which in many cases diminishes the potential for knowledge and ultimately value creation, is in the difficulty associated with sourcing sufficient quality inputs. A recent study of 426 European Marine scientists revealed that more than 80% of scientists use data from third party sources as inputs for their work and more significantly, 35% indicated that their work would be significantly enhanced if they had better access to additional existing data. Only 3% indicated that access to additional data would be of no benefit. The principal reason cited for not using more existing data was the difficulty associated with finding it.

Knowledge dissemination

There are two aspects of current knowledge dissemination practice which diminish the potential for creating value:

Firstly, a limitation exists in relation to the effectiveness of traditional methods for knowledge dissemination and in particular with the traditional scientific journal. The exponential growth of scientific journals in recent decades is making it more and more difficult for a scientific reader to find and seriously read all that may be of value to them. As a consequence it is also becoming more and more difficult for the scientist to target their published work at all the would-be users who could create value from it. By way of illustrating the size of the problem consider that the number of scientific papers being published annually has been doubling every 10-15 years for the last two centuries [Price]. In many fields, this growth accelerated over the last fifty years to a doubling every ten years or less. The "Chemical Abstracts" journal, for example, which deals with physical and biological sciences as well as chemistry, doubled in size every ten years from 1945 to 1980 when it reached 475,000 abstracts per year. This growth rate for this journal slowed to about 550,000 abstracts per year by the mid–1990's. By simple extrapolation it is determined that more than 6.7 million abstracts have been published in this journal between 1950 and 1980 and more surprisingly over 50% of these were published during the 1970s.

The second problem in the area of knowledge dissemination is that the scientists or the creators of knowledge are often excessively selective in choosing content from their recently acquired knowledge for dissemination. Having created the knowledge scientists often distil it and, as might be expected, when disseminating this knowledge they focus on the pieces that they perceive to be the most innovative and therefore most valuable. However in doing so, it is often the case that other potentially valuable pieces of information that were acquired during a project are never disseminated and consequently never achieve their full potential value.

### Knowledge exploitation

Just as a piece of research often starts with taking inputs from other work, the knowledge disseminated at the end of a project is intended for use as an input in some other future work. Consequently, the problems a scientists encounters with sourcing inputs are the same potential problems for a would-be user of his or her data when disseminated. Information regarding the existence of the data and information must be distributed widely and should be comprehensive enough for the would-be user to easily assess its suitability as an input for new research.

# 4. Data and Information Management

While there are many aspects to data and information management and variety of approaches when implementing, the overall objective is simple – it is *to maximise the potential for the utilisation of data and information.* Furthermore, since the utilisation of knowledge and information is the key to value creation another way of looking at the objective of data management is *to maximise the potential value of research data and information.*

This objective is achieved most effectively through four data management processes and gains additional value from a fifth. These processes will achieve greater awareness of the data and information, achieve better data quality, allow

easier assessment of data, easier access and finally easier integration with other data. They are described as follows:

## Data awareness

It is only by using the knowledge and information from a research project that value can be achieved and without an awareness of the existence of knowledge and information, it cannot be used. As already mentioned 42% of 426 scientists recently indicated that the primary reason for not using more existing data as an input for their work was that it was too difficult to locate its source. Achieving a greater awareness of information and data is an essential element of good data and information management. A part from scientific publications this can be achieved through numerous existing mechanisms including the European Directory of Marine Environmental Data (EDMED), national data catalogues, information centres or on the WWW.

## Data Quality

Proper data management should begin in advance of gathering any data, especially in relation to planning for quality. The implementation of quality assurance procedures for the collection and handling of data is essential. Quality control will be used to ensure the assurance procedures are achieving their objectives. If quality procedures are implemented at the data collection stage they will greatly enhance the chance of "right first time" data gathering and thus save on resources and enhance the value creating potential. Interestingly, the aforementioned study of data management practices among European scientists revealed that more than 58% of all respondents do not practice quality control according to a documented procedure.

## Data assessibility

In this context is important to distinguish between data assessibility and data accessibility. The accessibility relates to the getting at the data and is discussed below, whereas the data assessibility involves a potential data user making a judgement on different aspects of the data as to its suitability for his/her application. In a situation where a scientist may encounter a number of sources of knowledge and information, it is important that he/she can evaluate the data for quality and its applicability without delay. To do this there must be appropriate metadata available which will inform the potential user where, when, why and how the data and information was collected. Proper metadata should remove any ambiguity regarding the data and allow the user to establish whether it is suitable as an input in his/her research activity. In a situation where a potential user cannot establish the suitability of a data set the appropriate professional action is to discard it and in doing so, possibly miss an opportunity to create value from what could be an ideal data set. In reality it would appear that scientists are willing to accept significant uncertainty, running the risk of erroneous conclusions which in my view are worse than never creating value as they create negative value. Interestingly our recent survey established that less than 18% of scientists provide what they describe as comprehensive metadata and less than 50% were confident that a third party could use their data without their assistance.

## Data accessibility

Once a user has established that a piece of information or data is suitable and will meet their requirements the next task is getting it. In a worst case situation an owner of the data may not make it available. The reasons for this vary from they themselves see further opportunity to create value for which would be jeopardised by its release to simply that they feel threatened by the concept of another scientist creating value with their data when they could not. In this situation data management in itself cannot help. However, in a situation where the data is made available there still remains a number of problems with accessibility including those with formats and storage media.

## Data integration

A bonus through the practice of data management lies in the increased ability to integrate data sets from different sources and thus enhance value. By way of example consider the data sets used to produce the maps shown in figure 1 below which were compiled by integrating data collected on different campaigns over six years.

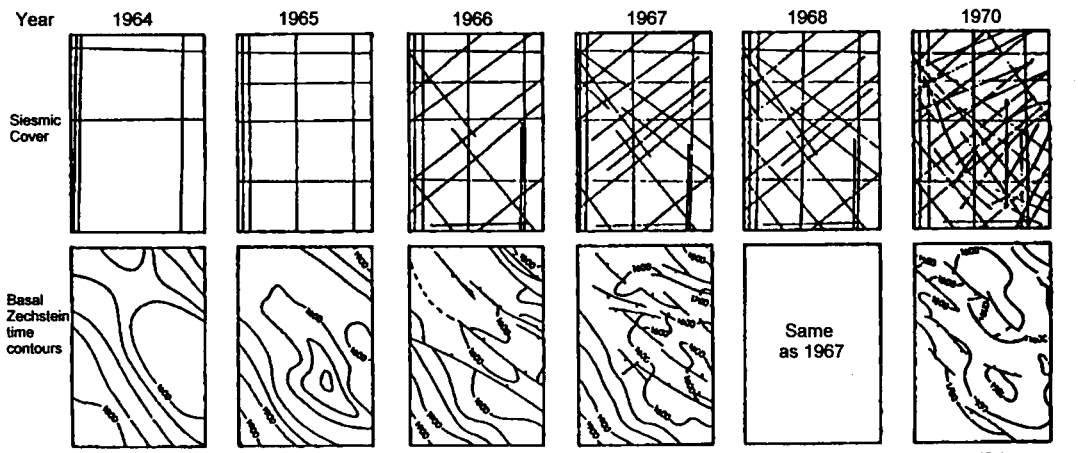



Figure 1. Seismic grid history from the North Sea, the West Sole gas field. Shooting dip lines in 1966 identified faulting. This was used as an input for subsequent work and all follow-up surveying was reoriented to investigate the nature of these faults. The resulting interpretations alter significantly. (after J.T. Homabrook. 'Seismic re-interpretation clarifies the North Sea structure'. Petroleum International, April-May 1974)

In a situations like this it is clear that the value of the sum of the individual data sets is greater than the sum of the individual data set values.

# 5. QA of models

Much of what I have already presented in general terms applies to the development and application of numerical models. If we consider the development of a model in value terms then it is appropriate to consider it in three stages:

- The objective of the first stage is to understand the process that is being modelled. This will usually involve expert scientists (physical, biological or chemical as required) who will gather inputs most probably by combining existing sources of knowledge and information with new data they will collect. They will analyse these inputs and using their expertise will arrive at an understanding of the process to be modelled. They will then disseminate this to the next stage in the process, thus creating value potential.

- The second stage involves the model development and will achieve value for the first stage by taking the knowledge acquired and mixing it with new inputs such as existing models to form a new set of inputs. The team responsible for the model development, which maybe the same as for stage 1, will use these inputs to develop a generalisation, algorithms and tools which will be validated and verified. Once this has been achieved successfully they will make the model available, thus again creating value potential.

- The third and final stage in the model development value chain is the model application. The model will be applied to a specific situation by combining it with other inputs such as site specific boundary conditions. The results of its simulations, once made available will again be a source of potential value which will be realised once used as in input to some other activity such and planning decisions or further research.

In all of these stages there is a clear requirement for a transfer of knowledge and information from one stage to the next. The consequence of poor quality at any of these stages will clearly negatively effect the project value. If the data and information used in stage one is of unknown quality or erroneous then, at best, the experts will waste time establishing its quality and at worst they will fail to achieve an accurate understanding of the process. If this is passed to stage 2 or if other data of poor or unknown quality are introduced then again, at best time will be wasted and at worst a model will be developed that only appears to represent the natural processes. If passed to the final application stage it is likely that a faulty model or the introduction other data of poor or unknown quality then again at best it will prove costly to rectify and at worst the information disseminated which will act as input for another activity and so on until a problem is eventually discovered.

# 6. Conclusions

The creation of value from research, which is the objective of all research, is only achieved by achieving knowledge creation, knowledge dissemination and finally subsequent use or exploitation of this knowledge.

In order to increase the value from projects, it is therefore necessary to increase the use. This is achieved by taking steps to improve the awareness of data and information and by improving data quality, data assessibility and data accessibility all of which can be achieved through tried and tested data management practices.

# Provocateur's report

*Herman Gerritsen, WL|Delft Hydraulics, 2600 MH DELFT, NL*

The arguments why a research project is valuable and what contributes to its value and its value creation, will vary with the perspectives that parties may have: politicians, funding and monitoring organisations, researchers, potential users of research output, general public. Part of this is determined by the image that a research topic has within the context of the needs and interests of society as a whole. Its perceived value may therefore change with shifting priorities in politics and in society as a whole.

In the present session we should rather focus on objective project value and on value as in "value for money": how to assure that the proposed research not only leads to (added) value, given a clearly defined and accepted description of this value, but more strongly — also maximises this value, while keeping cost within limits.

So, we have to realise that there is a need for a joint definition of project value, and of the how we can quantify and mutually compare the bits and pieces that contribute to value.

In doing this, we are guided by the general considerations and objectives for making available EU research funds, roughly summarised as: improvement of our understanding of natural processes and analysis of human activities and needs, in order to promote a sustainable and efficient society, while at the same time increasing European economic competitiveness.

## Human capital management

- In projects, human capital is the major item of value per se; and the pivot of value creation.
- Participation of junior partners or less experienced parties and the related educational/ training component contributes to project value.
- Value adding to human capital within a project implies more than oral exchange of results of research in progress at project meetings. Its effectiveness can be increased by:

(1) exchange of data and written material during the project and

(2) temporary secondment of juniors to a partner institute

# Information Management

- Information, acquired knowledge and in general project output which is not available in written or digital form and is not easily accessible for assessment, cannot be verified and subsequently used by others. Because of this, it is no information, knowledge or project output and has no value whatsoever.
- Periodic accounting through 6-monthly management reports detailing project progress, unforeseen problems and measures taken, is an essential tool for partners to reassess the state of the project activities, keep the project on course and optimise project results.
- Research reports, the web and ftp are key tools for active exchange of information between partners and to passively inform external interested parties.

# Data and Data Management

- Collected and processed field data has value only if accompanied by the meta data information describing the relevant collection characteristics and the processing and QC information. This enables third parties to assess its quality and suitability for future use.
- Data management is an end-to-end process, required to insure integrity (version control!) through the processing cycle and the simultaneous use of the data-in-process by partners.
- Data management is completed by making available to appropriate data banking authorities — on suitable media and with appropriate dissemination / exploitation conditions -, of data and related documentation enabling assessment and use independent from project partners.
- Data is a specific and non-generic end product per se with a given time and space label.

# Modelling

- Value of modelling is determined by the intrinsic modelling quality and the accessibility of information on the claimed quality of model and modelling.
- The value aspects applicable to modelling essentially depend on the type of modelling, or the stage in the modelling cycle
    - Stage 1: *Conceptual modelling* — the establishing of hypotheses about a set of observations — will lead to a tentative process description or data fitting, taking into account data inaccuracies and uncertainties. Its value lies in a comprehensive scientific publication, open for review and use by peers.
    - Stage 2: *Generalisation* to a process description or model valid for sets of independently sampled data. A description of the rules and the verification on the data sets in the form of an (scientific) publication creates the value. Its

value is both scientific and societal — for researchers and e.g. policy makers

- Stage 3 (for complex or integrated process descriptions): translation into a *computer-based model code*, including verification and validation. Enter the concept of an information generating tool, useful for both process research and more commercial use, i.e. a direct economic value, and public and commercial exploitation potential.
- Stage 4: *Model applications*, to generate information in the form of model-based data sets (hindcasts, forecasts). Value for society as a whole; public, commercial exploitation.

- Without an explicitation of Approximations and Assumptions in all stages, and of their impact on the status of the model (functionality and applicability; accuracy, robustness, model quality is undefined.
- Without a sensitivity analysis, model quality cannot be defined.
- Verifications and validations are explicit (open ended?) activities to chart a model's quality.
- Timely explicitation, sensitivity analysis, and validations lead to early detection of weaknesses and inconsistencies, and so improve the modelling quality, while keeping cost within bounds.
- Statements on the quality of a Stage 3 or 4 model application are without value if they do not include information on the required and actual uncertainties in inputs and parameters.
- In integrated modelling, QA of the various model components is crucial to control integrity and quality of the whole system.
- In an integrated model, the later modules determine the required (read: optimal) level of complexity and accuracy of the upstream modules, which increases the value/cost ratio.
- The proposed Guidelines for model documentation largely address the above issues and are an effective tool in QA of the modelling activity, leading to much better defined and higher quality of the resulting models.
- A Model is a *generic data or information generation tool* which is not limited by given time and space labels.
- A Stage 3 or 4 quality model is a complex knowledge or information generation tool, with much encapsulated knowledge and high level of added value, and as such has a recognised economic value for research and public / commercial exploitation.

# MIND: a practical and effective way forward in QA of modelling in FP5

The "Guidelines for Model Dissemination in MAST projects", adopted by the Mast Committee for Modelling Co-ordination in 1997, provide the basic elements of QA and Value Enhancement in modelling within EU — funded and other projects.

A practical means to structure and make explicit the essential information on a model and model development that interested parties need for assessing model characteristics and usefulness prior to actual use, is the itemisation contained in the Appendix to the above Guidelines.

It is proposed that such documentation (Model INformation Documentation: *MIND*) be completed for all modelling activities and model development in EU projects. The *MIND* should be a living document, growing in detail as the project develops, and be updated regularly, e.g. as annexes to Annual Science Reports. While at the proposal stage it largely details proposed model characteristics and modelling approaches, throughout its life cycle these are replaced by realised properties and characteristics.

Besides facilitating the information exchange between partners on the state of modelling during the project, at project completion *MIND* provides a useful external document that can be annexed to the Project Final Report, which is ready for dissemination. Depending on type of modelling, a final document of some 20 — 40 pages can be envisaged:

## Model Information Documentation (*mind)*

MIND should contain the following structured information items:

1. Originator(s), Contact person; name, institute, address
2. Purpose of the model: research, prediction, simulation, forecast, hindcast, operational, design/decision support, control, etc.
3. System or object which is being modelled: local sea, marine structure, a specific part of the coastal zone, etc.
4. System aspects that are modelled (functionality). Claims and disclaimers about aspects which the model represents.
5. Model type: deterministic/mechanistic, black box, stochastic, hybrid, etc.
6. Conceptual model (abstraction from nature): ecology, physics, chemistry, hydrodynamics, thermodynamics, etc.
7. Spatial structure: lumped or distributed, 3-D, 2-D, 1-D, 0-D, etc.
8. Resolution: time scales, spatial scales, etc.
9. Mathematical description: rules, algebraic, statistical, ordinary or partial differential equations, stochastic/deterministic, etc.
10. Algorithmic implementation, stability conditions, numerical techniques, etc.

11. Software implementation: language, hardware, etc., operation systems, library dependencies, etc.
12. Qualifying descriptions regarding initialisation, boundary conditions and other model parameters. Ranges and default values.
13. Model responses with a qualifying description; worked out test examples.
14. Verification studies.
15. Validation studies.
16. Calibration studies and sensitivity studies.
17. Glossary of terms (variables, subroutines).
18. References

# Rapporteur's report

*Jacob Steen Møller, Director Marine Environment Division, Danish Hydraulic Institute*

## Introduction

The Rapporteur's report (revised version) will reflect the presentations and the discussion and it will express the impressions of the Rapporteur. In order to make the report easy to read the discussion will be resumed according to topics rather than chronological.

## Organisation

The panel consisted of the following: a Convener, a Chairman, a Key Note Speaker, a Provocateur and a Rapporteur. The meeting convened at 14.30 on 26th May 1998, a 30-minute coffee break was held at 16.30 and the meeting adjoined at 18.00.

The Convener of the meeting was Martin Bohle-Carbonell of the Commission. The Chairman of the session was George Pichot, MUMM, Belgium. The Key Note Speaker was John Wallace, Informatic Management International, Ireland. The Provocateur was Herman Gerritsen, WL/Delft Hydraulics, The Netherlands. The Rapporteur was Jacob Steen Møller, Danish Hydraulic Institute, Denmark.

The Chairman gave a short introduction to the subject and the Key Note Speaker gave a presentation following the lines of the written contribution included in the present volume. Following the Key Note speaker, the Provocateur gave a short presentation of his views on the matter and opened the discussion with the floor. After the coffee break, a short resume of the discussion was given by the Rapporteur and the Provocateur sharpened his views and invited to a dialogue with the floor. 10 minutes at the end of the session were spent on a resume of the discussion by the Rapporteur.

## The Key Note Speech

John Wallace's speech took its basis in a model for the production of value from projects: The value from projects derives from the transformation of knowledge through IT-management and QA management to the exploitation of knowledge.

The role of the scientist in this process is to be part of a knowledge chain where observations and data via publications are utilised by other scientists in the combination with new data to form new knowledge that again is used by new scientist, etc. In each of the processes in the chain there is the risk of loss of information. Improved IT and QA management are means to reduce this loss of information.

In the traditional scientific community the knowledge chain is made up of the scientific publications. In the present day community the chain takes the form of a web where each scientist sits in the middle and utilises the knowledge and information from a variety of sources. The www is one of the conveyors of information that illustrates this development.

The exponential growth in publications poses a challenge for the scientists. How do we best extract the knowledge from the enormously growing amount of information? One of the ways to reduce the loss of information in the knowledge chain and at the same time reduce the problem of information congestion is via improved QA and especially via the use of good meta data which ensures that information and data is traceable, accessible and assessable.

# The Provocateur

Herman Gerritsen challenged the concept of universal value from projects. We have to realise that the value of a project is defined by the stakeholders interests, therefore the value of a project may be looked upon differently by the scientist, the public or the funding agency. It is thus important to agree on how to evaluate the value before the question of improving the value can be answered. He suggested adopting the EU policies as criteria for value of EU sponsored projects, but emphasised that also other stakeholders contribute to most EU projects.

The most important means to improve on project outcome were according to Gerritsen:

- Improve the human capital
- Improve IT management
- Improve data management
- Improve model documentation

Gerritsen also emphasised that any discussion on model quality should relate to the various phases of a typical model development:

1. Conceptual (identification and description of general relationships)
2. General (mathematical formulation of general relationships)
3. Generic and Predictive (numerical model)

He suggested that rather than introducing rigorous QA procedures a living "model document" should follow the development and application of the model. The model document should contain:

- Description of model type (deterministic, statistical, hybrid)
- Stage of model (conceptual, general, predictive)
- Assumptions behind model and the concrete application
- Sensitivity of model to uncertainties in model parameters and boundary conditions
- Verification (of mathematical/numerical solution)

- Validation (of actual application, related to calibration)

Description of the "model document" concept is given in the Provocateur's written statement included in this volume, and in the IAHR-document "Guidelines for documenting the validity of computational modelling software", June 1994 (IAHR office, P.O. Box 177, 2600 MH Delft, The Netherlands).

# The Discussion

Following the Key note and the Provocateur's statement a discussion took place. The following topics were discussed:

- Quality assurance of field data
- Quality assurance of models and modelling
- The knowledge and information explosion

## Quality assurance of field data

Pichot presented a stunning example of the importance of QA of data. In an OSPARCOM action participating countries were asked to compile data on marine pollutants. Due to poor QA between 2% and 81% of the available data was cancelled depending on country and parameter. Such large data loss expresses not only a waste of effort but it also presents a managerial and funding problem. How justify funding for monitoring programmes with such poor results?

Wallace and several members of the audience expressed that key elements in ensuring maximal value from field data are to enhance data awareness amongst the data users. EDMED forms, Data Centres, Publications and the www are means to achieve this awareness.

Wallace further stressed that meta data quality is of crucial importance for the value of data, in this he was strongly supported by the panel and by the audience. Meta data must ensure the accessibility of data and that it is easy to assess the quality and applicability of the data.

Bohle-Carbonell briefly summarised the elements of the EU policy regarding marine data management:

1. Apply the best international standards regarding observational data
2. Apply the best international standards regarding models and modelling

Regarding 1. he felt that a growing number of projects fulfil the goal, whereas the goal was not met for modelling.

In conclusion most participants were of the opinion that much has already been gained in improving data management and QA. The general principles have been agreed and much work is already being done.

## Quality assurance of models and modelling

The audience and the panel in general agreed to the staged description of modelling as presented by Gerritsen.

Members of the audience expressed that rather than comparing the QA and management for models with the similar activities for data, models should be envisaged as research instruments. For such instruments QA and documentation is an integrated feature which quality is judged at the market rather than via standards. No general consensus was reached regarding this point. It was, however, generally agreed that the most advanced models represent a commercial value, which will influence the motives to publish details of the umerical programming model.

Peer review was suggested by the audience as a tool to improve modelling quality. Against this view was argued that very often it is difficult, if not impossible, to find a qualified reviewer for modelling papers.

To enhance the value of the models and the modelling Bohle-Carbonell and members of the audience expressed the need to improve the formalised information on model and modelling quality. As a response to this Gerritsen referred to the Model Document mentioned in his statement, drafted by the MAST committee for modelling coordination. He emphasised that model documentation is a very comprehensive activity, which seldom generates academic recognition. Because of the non-academic character, model documentation often takes place in the commercial domain outside EU research programmes. A full and comprehensive documentation and validation of generic predictive models should perhaps be left outside the domain of EU's RTD programmes and left to the commercial institutions in the same way as measurement instruments' performance is documented by the producers.

## Knowledge and information explosion

Several from the audience raised the problem of information congestion or pollution. The audience and the panel agreed that it is indeed a problem that the amount of information and knowledge is dispersed at such large amounts that it becomes difficult to extract all relevant information for any research topic. No consensus was reached as to how this problem could be solved. One problem in condensing the vast amount of information was expressed in the quote by Wallace:

"just as the beauty is in the eye of the beholder, the value of information is in the hands of the user"

It was agreed that the importance of the user and the use of the data for the value of the data show that QA of data is not a standardised activity. The QA is task driven. In many cases, the final QA can only be done by the data user and not by the data provider or data banker. This fact strongly emphasises the importance of good meta data.

Møller suggested that the amount of data and information grow with such a pace that data reduction in the form of deleting data not likely to be analysed is becoming necessary. This viewpoint was strongly rejected by several members of the audience and the panel. The general consensus was that all data should be kept in accessible databases.

# Conclusion

The discussion meeting agreed in general on the principles and actions taken by the Commission regarding field data management and QA of data.

The discussion meeting agreed in general to the need for improved QA and dissemination of models developed as part of RTD programmes. No consensus was reached regarding how to achieve this goal. It was suggested that introduction of modelling practices as expressed in a living "Modelling Document" deserves to be investigated further.

# FUTURE MARKETS FOR SME's: OPPORTUNITIES FOR PARTICIPATION IN THE EU RTD PROGRAMMES

# SME Participation in the 4th European Union Framework Programme for Research and Technological Development

*R. J. Smits, European Commission, DGXII, SME Coordination Unit*
*in cooperation with Vertica Oy, in consortium with: Yellow Window NV and Zenit GmbH*

## Introduction

### SMEs: A key part of Europe's industrial fabric

SMEs (*) are the powerhouse of Europe's rapidly evolving economy: they make up 99.8% of all the EU's enterprises, provide 66% of its jobs, and account for 65% of its business turnover. Over the last five years, they have been responsible for more than 80% of jobs created. While some SMEs are helping larger firms to be more competitive by acting as sub-contractors, others are making a greater and greater contribution to innovation in rapidly evolving sectors such as multimedia, software development, biotechnology and environmental technologies.

Today, SMEs are facing the increasing globalisation of their markets and the need to develop or have access to new technologies if they are to remain competitive. The shared-cost Community RTD programmes give them the chance to both internationalise their network of business and research partners and improve their technological base.

### How do SMEs take part in the 4th EU RTD Framework Programme (FP4)?

SMEs can take part in FP4 in two main ways:

- Like any EU legal entity (large company, university or research centre), they can join a *Collaborative Research project, in* which each partner carries out part of the research effort and shares the results with the others. The Commission supports such projects by funding 50% of the costs incurred by each partner.

(*) For the Technology Stimulation Measures, Small and Medium sized Enterprises (SMEs) are companies who employ no more than 500 employees, have an annual turnover of no more than 38 MECU and are no more than 1/3 owned by an organisation larger than an SME (unless it is a financial investor).

- They can benefit from the Technology Stimulation Measures for SMEs (TSME), implemented by 9 specific programmes, which offer two pathways specifically for SMEs:
    * Exploratory Awards allow SMEs to benefit from EU funding (up to 75%) for preparing a better research proposal (be it for Collaborative or Co-operative research).
    * Co-operative Research (CRAFT) projects enable groups of SMEs which have similar technical problems, but lack the means to do research, to engage third parties (called "RTD performers") to carry out research on their behalf. The Commission will share with the group of SMEs the cost of the research by funding up to 50% of the total project costs. The RTD performers will be fully paid for the work performed, but the results of the research will be owned by the SMEs.

## A mid-term review

Two years after the launching of FP4, it was decided to assess the participation of SMEs for the years 1995 and 1996. A co-ordination committee was set up, involving staff from the various programmes and Directorates General. This group of EC staff gathered the information needed to gain an overview of SME participation in FP4. Four studies were launched in early 1997:

I A postal survey among the 4,000 SMEs who obtained a contract under FP4 in 1995-96. 1,314 SMEs answered the survey, representing 1,599 project-participations — this is a 30% response rate;

II An analysis of the reasons for which proposals under the TSME were deemed ineligible (source: desk analysis of internal EC documents);

III An analysis of the reasons why many rejected but good quality proposals under the TSME were not re-submitted (source: 21 National Focal Points (NFPs) and 100 SMEs who led such good quality rejected proposals);

IV An analysis of the reasons why SMEs who prepared an Expression of Interest, or were recommended to do so during the EU supported Euromanagement action, did not finally submit a proposal (source: 22 NFPs and 92 SMEs which took part in the Euromanagement RTD action).

This report presents the main results arising from the various studies and highlights the main conclusions.

It has been prepared by an external service provider who assisted the European Commission, particularly as concerns the postal survey among SMEs participating in FP 4.

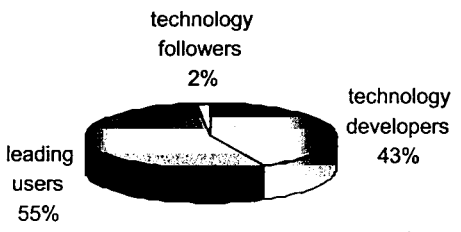
N.B. It should be noted that this report relates to the experience of SMEs in the years 1995 and 1996. Therefore, the impact of the specific efforts undertaken by the European Commission as of the middle of 1996 to drastically reduce evaluation delays and implement the TSME in a more user-friendly way are not fully considered.

# Executive Summary — 12 key features

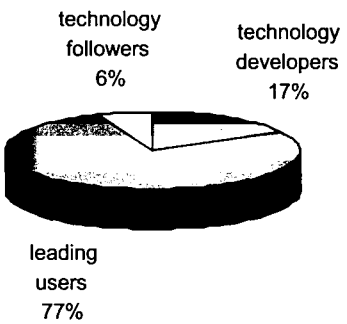
## 1. Different project types attract different types of SMEs

The Collaborative and Co-operative RTD actions of the European Community attract different types of SMEs. "Leading technology users" dominate co-operative actions, while "technology developers" prefer collaborative RTD actions.

**Collaborative RTD**



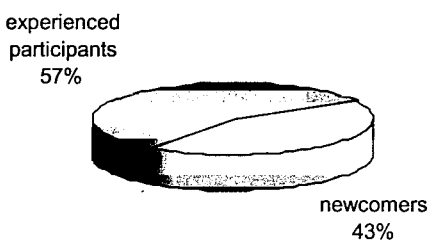

**Co-operative RTD**



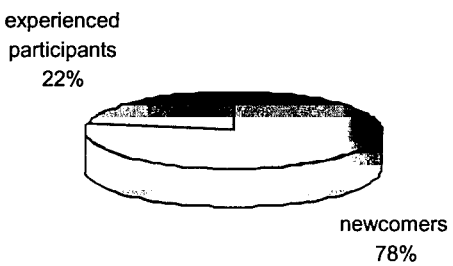

## 2. FP4 is reaching new SMEs

Nearly two-thirds (64%) of all SMEs participating in the 4th Framework Programme are newcomers. For co-operative research this proportion rises to nearly four-fifths (78%).

**Collaborative RTD**



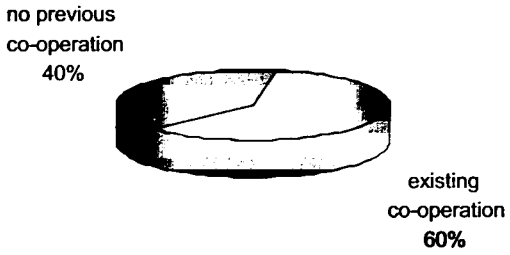

**Co-operative RTD**



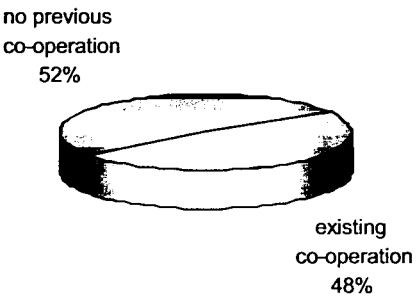
## 3. FP4 creates new partnerships

Nearly half of all SMEs participating in the 4th Framework Programme had never previously co-operated with any of the other companies or organisations that forms part of their consortium.

**Collaborative RTD**



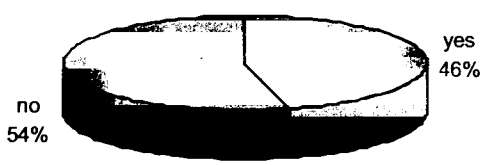

**Co-operative RTD**



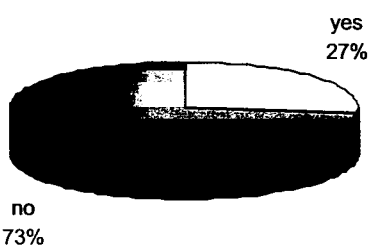

## 4. FP4 offers SMEs a way into joint RTD

Over three-fifths (63%) of SMEs participating in the 4th Framework Programme had never participated before in regional, national or multinational (Eureka, COST) R&D co-operation programmes.

**Collaborative RTD**
**Participated in Programmes other than EC**



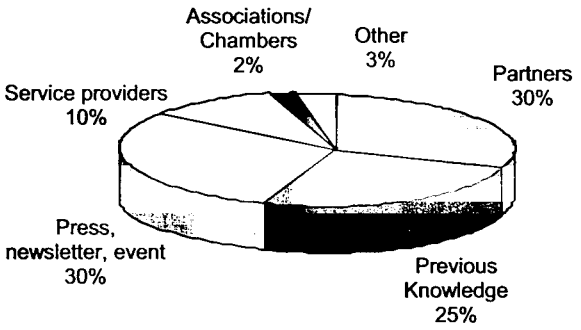

**Co-operative RTD**
**Participated in programmes other than EC**



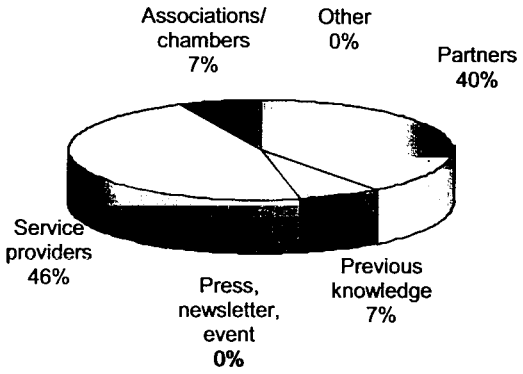
## 5. SMEs get general information from partners and service providers

Partners are the main source of general information for newcomer SMEs, and are also an important information source for newcomer SMEs who are leading a collaborative research project. Leaders (newcomers) of CRAFT projects most often obtain their information from intermediary service providers.

**Collaborative RTD**
**Newcomers – project leaders'**
**Source of first information**

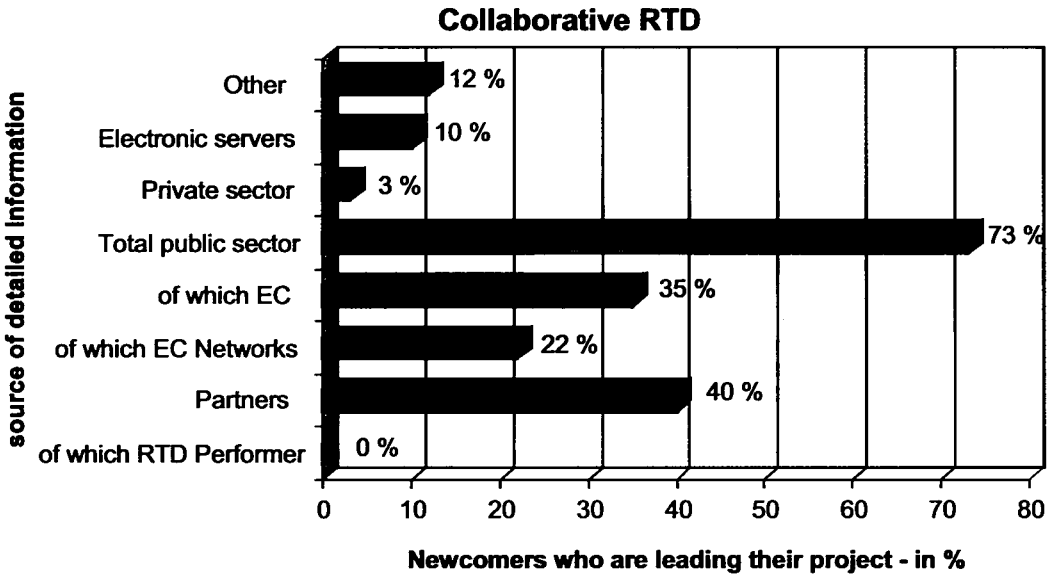


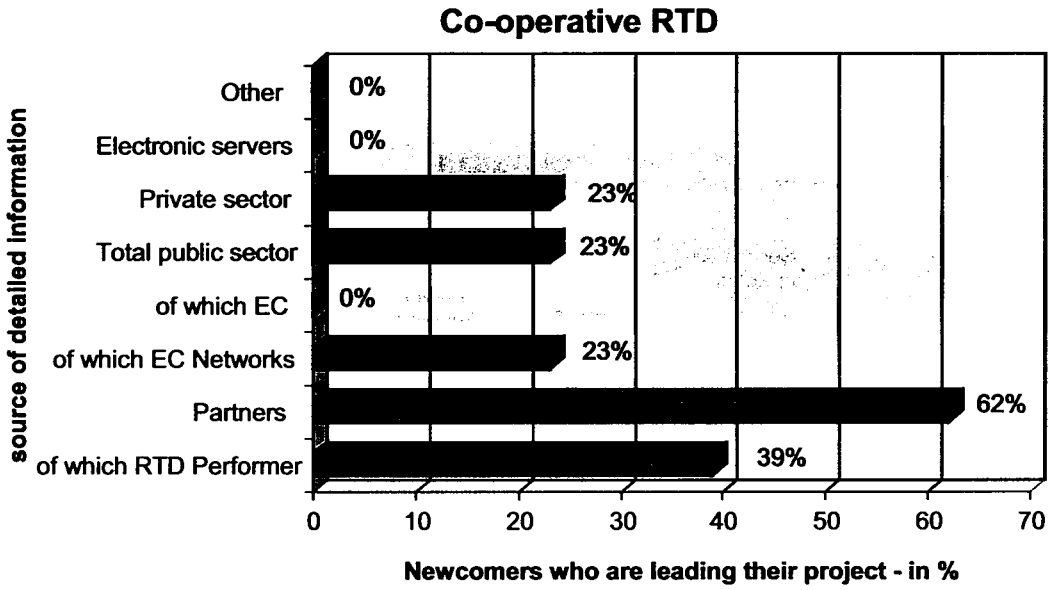

**Co-operative RTD**
**Newcomers – project leaders'**
**Source of first information**



## 6. The EC and its support networks play an important role for informing and assisting project leaders (newcomers)

Partners are the main source for obtaining detailed information and assistance. For newcomers leading collaborative research projects, public sector sources (including the EC) are the most used external source. Newcomers leading CRAFT projects rely more on RTD performers and EC support networks.

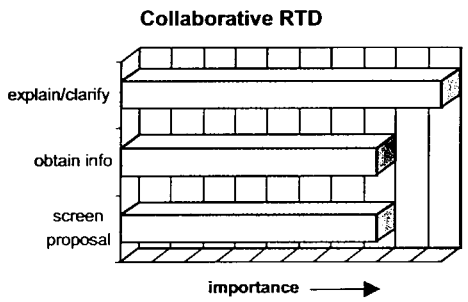


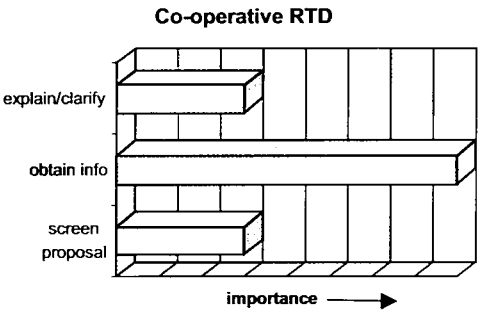



## 7. SMEs mostly require 3 sorts of help

The most important assistance services for newcomers are:

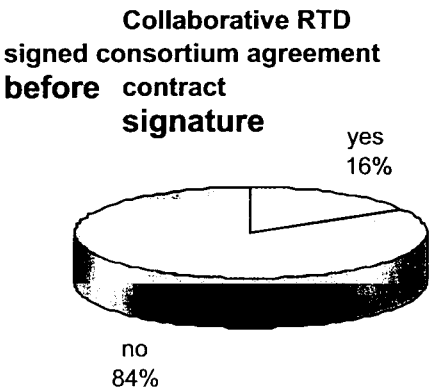
- Getting contacts / names for obtaining additional information
- Explanation / clarification of the official documents
- Checking the quality and eligibility of the proposal

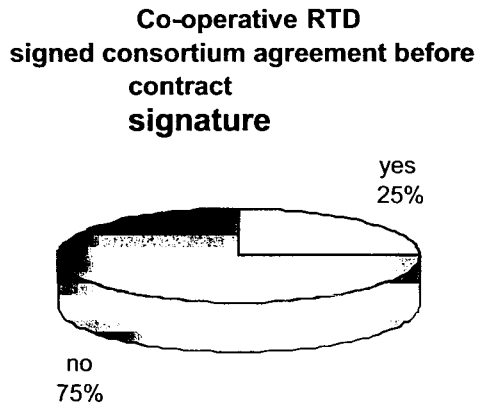



## 8. SMEs often underestimate the importance of addressing legal and intellectual property issues.

Nearly half of the participating SMEs do not sign a consortium agreement at all. Only a small minority (less than one quarter) had agreed a formal consortium agreement before they signed contracts with the EC.

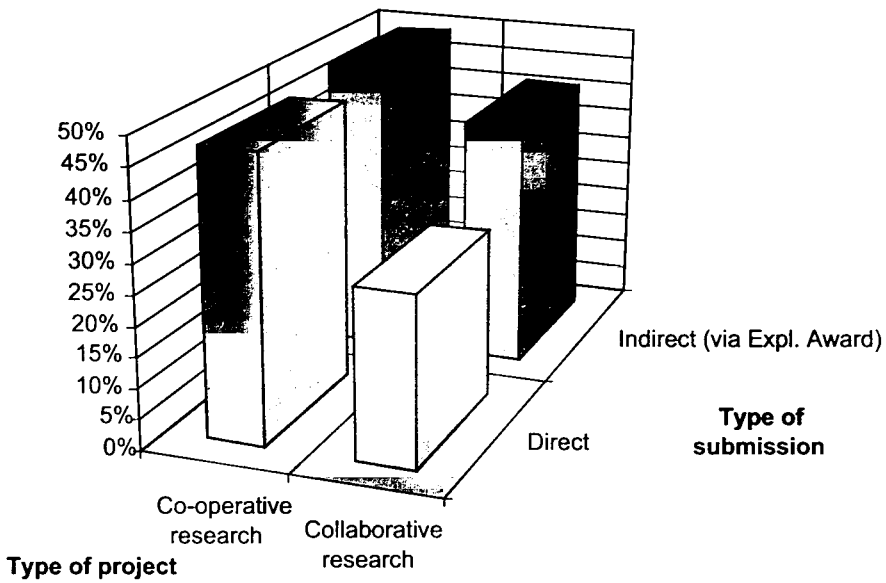


## 9. Exploratory Awards make a difference

The Exploratory Awards are an effective instrument to help SMEs to prepare proposals. They result in increased selection rates for collaborative RTD projects and allow newcomer SMEs to prepare good quality CRAFT projects.

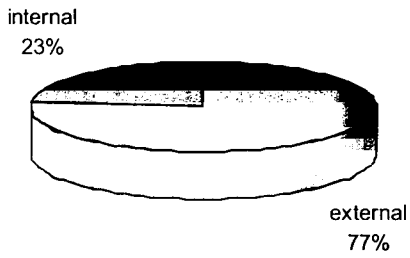
**Selection rates of participating SMEs by project type**



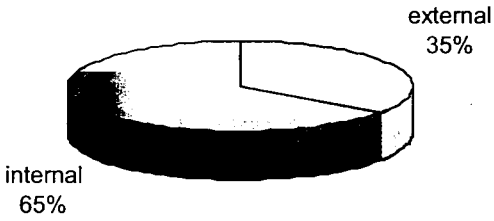

## 10. CRAFT's procedures are user-friendly

Barriers to participation in the Community RTD Framework Programme can be internal to SMEs (lack of management time or of internal resources) or external to them (delays in evaluating proposals, complex procedures, low selection rates). The new procedures introduced in the CRAFT action have reduced the relative importance of external barriers.

**Collaborative RTD**
**Relative weight of "important" barriers**

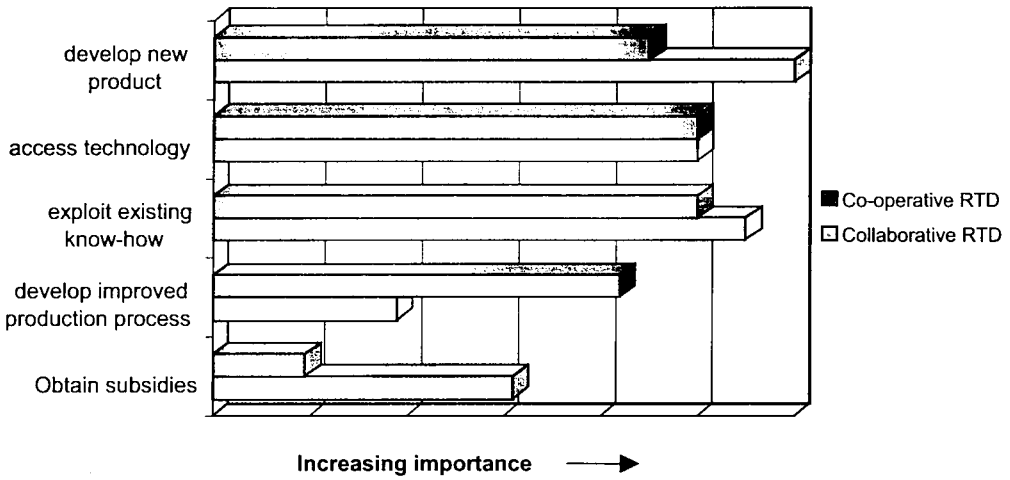



**Co-operative RTD**
**Relative weight of "important" barriers**



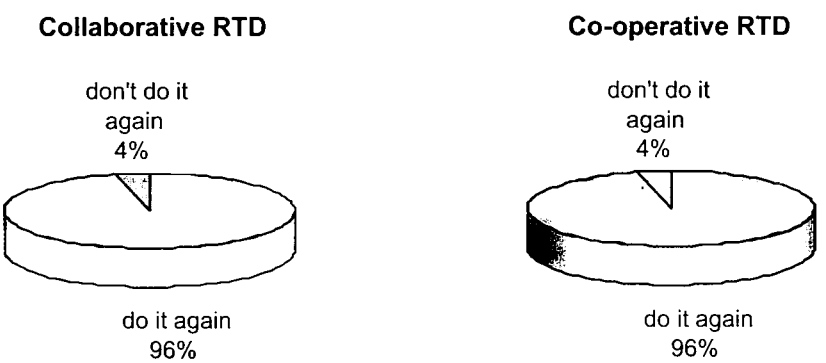
## 11. FP4 helps SMEs to innovate and develop transnational partnerships

Besides the development of transnational partnerships, SMEs see as the main benefits of their participation in the Framework Programme the development of a new product or process, access to state-of-the art technology and the exploitation of existing know-how. EU funding alone is not considered to be a main reason for participating.




## 12. FP4 users are satisfied

In general the satisfaction rate of SMEs participating in the Framework Programme is very high. Almost all would do it again.



# 1. SME Typology — the 3 types of SMEs

The main purpose of this part of the report is to consider the targets set for the EU RTD Framework Programme. Research programmes exist to stimulate the processes of innovation and research in the EU, not to aid SMEs in particular. Nevertheless, SME participation is considered important for various reasons and is being monitored and promoted. Research programmes are only of interest to a minority of SMEs and various studies have been done in the past on how to segment the SME population.

In practice, the survey that was conducted among the SMEs participating in the 4th Framework Programme provides a description of the different types of SMEs that are currently taking part.

In this final report are covered:

1. some of the key results, particularly in relation to the types of SMEs participating and the benefits as they are perceived by them;
2. some conclusions.

## 1.1 The 3 types of SMEs

To analyse the results of the survey, the participating companies from the sample have been grouped into 3 categories as follows:

1. technology developers (33 %)
2. a. leading technology users with sufficient R&D capacity (31 %)
   b. leading technology users with insufficient R&D capacity (31 %)
3. technology followers (4 %)

These categories are based on an opinion of IRDAC in 1988 (*), and a study carried out by the European Commission (**). These studies estimated that 1% to 3% of the EU's industrial SMEs were Technology Developers, some 10% were Leading Technology Users, while the rest were Technology Followers.

(*) Opinion on the creation of a European Co-operative Research Action for Technology (CRAFT), IRDAC, November 1988

(**) Evaluation study of co-operative/collective research for SMEs at European level with specific reference to the CRAFT scheme of the BRITE-EURAM II programme, EC, March 1994

**Table: Type of SME by Project Type (percentages)**

| | Exploratory Awards | CRAFT | Collaborative Research | TOTAL |
|---|---|---|---|---|
| Technology developers | 22 | 17 | 43 | 37 |
| Leading technology users | 69 | 77 | 55 | 60 |
| • with sufficient R&D | 29 | 27 | 32 | 31 |
| • with insufficient R&D | 40 | 50 | 23 | 29 |
| Technology follower | 9 | 6 | 2 | 4 |
| TOTAL | 100 | 100 | 100 | 100 |

**Table: Alternative typology of SMEs by Project Type (percentages)**

| | Exploratory Awards | CRAFT | Collaborative Research | TOTAL |
|---|---|---|---|---|
| Technology developers | 22 | 17 | 43 | 37 |
| Leading technology users | 69 | 77 | 55 | 60 |
| • with R&D Department | 19 | 24 | 22 | 22 |
| • without R&D Department | 51 | 53 | 32 | 38 |
| Technology follower | 9 | 6 | 2 | 4 |
| TOTAL | 100 | 100 | 100 | 100 |

- The two tables above show that the criterion 'sufficient' or 'insufficient' R&D capacity, as it is perceived by the respondent, is the main determining factor in a choice to participate in a Collaborative or a Co-operative project. SMEs which feel they have insufficient R&D capacity prefer to take part in CRAFT actions.
- The presence of their own R&D department is the main factor explaining the characteristics of their R&D activities (i.e. interdisciplinarity, international dimension, long-term/short-term orientation, tendency to outsource RTD activities...).
- The fact that an SME is active in a high, medium or low-tech sector is less of a determinant.

*Collaborative and co-operative RTD projects attract two distinct groups of SMEs*

## 1.2 Key characteristics of the 3 types of SMEs

*A. Technology Developers:*

- Participate more in collaborative than in co-operative research projects, participate more often in more than one project and tend to be leaders;
- Are more often small companies (40% of those with staffs of <10 are technology developers, against 23% of those with >250 staff);
- Are mainly to be found in the following sectors: high tech industries, ICT services and R&D services (together these categories account for half of the technology developers);
- However 2% of the technology developers are from the so-called low tech manufacturing sectors (against 9% from these sectors in the total sample); and 35% of consulting and engineering companies are technology developers;
- Are younger companies than the average of the sample (33% are less than 5 years old, against 24% of the full sample);
- Are more often spin-offs from universities/research centres (23% of all technology developers against 13% of the overall sample), but not from large companies (slightly less often than the average);
- Are investing significantly more in research: 75% of all companies investing more than 20% of their turnover in R&D are technology developers;
- 84% launched a technologically new or improved product in the last year;
- 68% launched a technologically new or improved process in the last year;
- Large numbers of very small service companies are technology developers. They will capitalise on the result of their research through high margin services or through the design and engineering of products (instruments, machines);
- Technology Developers tend to have a more global approach to RTD sourcing and are more long-term oriented. This suits the requirements of EU research projects, which involve multinational consortia and are of a pre-competitive nature.

***Technology developers** are smaller and younger companies coming more often from high-tech sectors. However, they can be found in all sectors and all sizes of companies: from high tech sectors to small (engineering) consultancies working for lower tech industries*

*B. Leading technology users:*

- Leading technology users participate more often in co-operative R&D, particularly those technolo-gy users with insufficient R&D capacity. This last category includes most CRAFT project leaders.
- 59% of the companies were created more than 10 years ago.
- They invest on average 11% of their turnover in R&D.

- Two out of three companies launched a technologically new or improved product in the last year.
- One in two launched a technologically new or improved process in the last year.
- One in three has experience with RTD programmes outside the EU RTD FP(against 50% for the technology developers).
- Come from both manufacturing and services, with a smaller presence from the high tech manufacturing sector, and from R&D services.
- Leading technology users think in the short-term and tend to source their R&D locally. Participating in a CRAFT project is often their first experience of a multinational, pre-competitive RTD collaboration.

***Leading technology users** are more established companies, and can be found in all sec-tors. They invest less in research than technology developers and are also less innovative*

*C. Technology followers:*

- Prefer co-operative to collaborative research projects. They tend to be partners, except in the case of Exploratory Awards, where 29% of them have taken the lead.
- Have the oldest average age of the three types (64% older than 10 years).
- 70% invest less than 5% of their turnover in R&D.
- Two out of five companies launched a technologically new or improved product in the last year.
- Two out of five launched a technologically new or improved process in the last year.
- For nine out of ten, this is their first experience with EU RTD.
- Only 17% have participated in RTD programmes outside the EU FP context.
- Are more often from low tech manufacturing sectors, hardly ever coming from high tech sectors, and much more rarely from service industries than from manufacturing industries.
- Technology followers focus on the short-term and use local partners. Few of them participate in EU RTD projects

***Technology followers** are mainly active in lower tech manufacturing sectors. Their research and innovation activities are very low in comparison to the two other types*

## 1.3 Newcomers to EU RTD

SME Participants in the EU RTD programmes can be split as follows:

- Experienced leaders: have experience both as leader and participant; have sent in a lot of proposals and have taken part in more than one project in the past.
- Experienced partners: have taken part in more than one project, but never as leader, nor do they have the capacity to act as leader.
- Newcomer leaders: companies without experience which are the leaders of their consortium.
- Newcomer partners.

The table below is an attempt to group the participants according to the groups defined above.

**Table: split by group and by project type in %**

| | Exploratory Awards | CRAFT | Collaborative Research |
|---|---|---|---|
| Experienced leaders | 3 | 2 | 22 |
| Experienced partners | 10 | 20 | 36 |
| Newcomer leaders | 51 | 12 | 5 |
| Newcomer partners | 35 | 66 | 37 |

*64% of the total sample are newcomers to EU RTD, 87% of Exploratory Award participants and 78% of CRAFT participants are newcomers*

## 1.4 The collaboration gap

Co-operating with others, whether they are other SMEs, RTD performers or large enterprises, is often a barrier for SMEs considering taking part in EU RTD programmes.

The various studies confirmed this fact, and it even appears to hold true among the group of the SMEs which are already participating in EU RTD:

- Only one out of three SMEs who have developed an innovative product in the last 3 years, did it by co-operating with external partners;
- As regards process innovation, only one in four of those who innovated this way did it in co-operation with external partners;
- Nearly half of the participating SMEs had never previously co-operated with any of the other companies or organisations that are in their consortium. This is more often the case for CRAFT SMEs (52 %) than for collaborative research or Exploratory Awards (40 %);
- Getting names/contacts of potential partners is the fifth most important service sought (for all three types of projects).

Still, most of these SMEs had previous collaboration experience:

- two out of three had collaborated with external partners for commercial or marketing activities;
- four out of five had collaborated with an external partner on a private basis for undertaking common or contracted RTD activities, before they were involved in EU RTD.

*European RTD generates a huge number of new collaborations throughout Europe*

# 2. Participation modalities and Programme procedures

This part of the report discusses issues linked to the ways open to SMEs to take part in European RTD programmes.

No project launched under FP4 had been finished at the time of the survey, so this report can only cover the first part of the project cycle. It touches on issues such as: programme priorities, eligibility criteria, procedures for selection and contracting (IPR), project preparation and management.

## 2.1 Programme priority areas

Sixteen percent of both Exploratory Award and CRAFT proposals are deemed ineligible, and for 1 in 5 of them, the reason is that the proposal is 'not in line with programme priorities'. This is the second most frequent reason for which Exploratory Award proposals are refused and transferred to another programme, and the third most frequent in the case of CRAFT proposals.

National Focal Points have identified this issue as one of the main barriers that SMEs face (ranking it as 4th most serious).

However only a minority of the SMEs taking part in the programmes have identified this issue as an important barrier. In fact slightly more respondents (even newcomers) consider this difficulty as unimportant than consider it important.

A possible solution to this problem is to have all proposals for TSME pass through a single entry point, which would route them to the right programme before evaluation.

This procedure would have the advantage of reducing delays; at the moment proposals are often significantly delayed because they are switched to the next evaluation cycle.

The introduction of a single entry point would thus address two problems:

- a communication problem: there would no longer be the need to build awareness for each programme separately, but only for EU RTD as a whole;
- ineligibility problems and/or delays resulting from submission to the wrong programme.

*Setting priority areas in specific programmes limits SME participation:*

- *A more bottom-up approach would allow SMEs to submit projects more in line with their own priorities*
- *A single entry point for SME proposals may facilitate SME access to EU RTD programmes and reduce the number of ineligible proposals*

## 2.2 Eligibility criteria

Some programmes use additional criteria to focus participation in their programme on specific profiles of SMEs.

*Industrial programmes*

The sample contained a very large proportion of small companies which, although classified as service companies, offer services only to one or a few manufacturing sectors. This characteristic applies to a wide variety of types of SMEs: some are more engineering oriented, others are consultancy companies, while others are difficult to classify. They are frequently companies who develop and sell know-how within a specific manufacturing sector. These companies are often highly specialised (e.g. a two-person company developing specific instruments), but have no manufacturing activity, and have therefore been categorised in services.

Sixteen percent of the sample are companies in the sector 'consulting and engineering' (excluding the ICT service companies), and most of them are small companies.

This situation could be ameliorated by abandoning the criterion 'manufacturing SME' used in some of the programmes.

***The insertion of additional criteria, such as the one on 'manufacturing SME' used in some of the programmes, hampers SME participation and excludes an important segment of potential EU RTD participants (i.e. service companies)***

*Specifically for CRAFT*

There are at the moment a set of criteria for CRAFT projects which aim to ensure that proposals are 'balanced'. These include criteria on the sharing of the work and of the funding among the SMEs and the RTD performers.

In practice, this set of criteria is responsible for 30% of the ineligibilities of CRAFT proposals.

***The many eligibility criteria designed to ensure 'balanced' proposals are considered as necessary, although they limit flexibility and hamper participation of some partnerships***

## 2.3 Arrangements between consortium partners

- A small majority of SMEs signed a consortium agreement, usually only after signing the contract with the European Commission.
- This proportion is significantly higher for CRAFT consortia.
- Three out of four SMEs/project consortia have an exploitation plan.
- Only one-third of consortia which include SMEs have legally protected their research results.

- Assistance with legal issues is consistently one of the least important/least used types of assistance, although, for proposals submitted under the TSME, it is the service for which SMEs are most ready to pay.

*SMEs often underestimate the importance of addressing legal and intellectual property issues*

## 2.4 Delays between the submission and launching of a project

| | Preparation | EC evaluation | Signed contract |
|---|---|---|---|
| Exploratory award | 6.0 months | 4.9 months* | 3.5 months |
| CRAFT | 5.8 months | 6 months* | 5 months |
| Collaborative Research | 4.6 months | 4.8 months | 4.6 months |
| Overall | 5 months | 4,9 months | 4,4 months |

* In 1997, these delays have been consistently reduced to 13 weeks for all TSME proposals.

On average, it takes 5 months for an SME to prepare a proposal. a further 5 months for the evaluation process, and then 4 ½ months for contract negotiations. This average figure hides a minority of situations where the duration is much longer. In particular newcomers who are leaders take on average 20% more time than experienced partners to prepare a proposal.

Differences among programmes are significant.

The problem of the delays between the submission of a proposal and their approval is the second most important difficulty reported during the survey among participating SMEs.

SMEs which have already taken part in more than one project attach significantly more weight to this difficulty than do newcomers.

Differences by type of project and SME type are small: between 1 in 4 and 1 in 5 of the SMEs consider this difficulty as very important.

*Time to market is critical for SMEs. Therefore the time between submission of a proposal and launching of a project should be reduced to a minimum*

## 2.5 The barriers to participation and their relative importance

Opinion of **SMEs** taking part in EU RTD **for the first time**:
*(basis = postal survey among SMEs participating in EU RTD. The order of the statements is based on the ranking by the full sample. The table gives the ranking for newcomers only – 1 being the most important, 7, the least important)*

| | Expl. Award | CRAFT | Coll. Research |
|---|---|---|---|
| 1. The requirements to prepare and make a proposal are too complex | 1 | 2 | 1 |
| 2. Delays between submission of proposal and approval are too long | 4 | 5 | 4 |
| 3. Investment in time and money to prepare the proposal is too high | 4 | 4 | 3 |
| 4. Management time is not available | 3 | 2 | 4 |
| 5. The risk of not being selected is too high (high competition and low approval rate) | 2 | 5 | 2 |
| 6. Limited resources to actually perform R&D activities | 4 | 1 | 6 |
| 7. Limited resources to actually exploit the project's results | 7 | 7 | 7 |

Opinion of **NFPs** on the importance of the different barriers:

*(basis = postal survey of NFPs)*

1. Lack of time/resources/management skills
2. Too long delays for procedure + project results
3. Collaboration gap (difficult to share information, to define RTD need,...)
4. Finding a partner
5. Priorities of EU programmes don't correspond to SME technological needs

Opinion of **SMEs** who were recommended to submit a proposal but failed to do so:

*(basis = telephone survey of 92 SMEs)*

1. Lack of time/resources/management skills (22 %)
2. Collaboration gap (difficult to share information, to define RTD need,...) (20 %)
3. Finding a partner (20 %)
4. Too long delays for procedure + project results
5. Lack of assistance

Barriers should probably be grouped as follows:

- 'General' barriers affecting a majority of SMEs

- those affecting a smaller group of SMEs

General barriers can further be subdivided between:

1. Internal barriers linked to the SMEs: lack of availability of management time, limited resources;
2. External barriers linked to EU RTD, e.g.:
   - The complexity of the requirements to prepare and make a proposal
   - Investment in time and money to prepare the proposal is too high
   - Delays between submission of proposal and approval are too long

All other barriers are always valid for at least a small group of SMEs.

*Most SMEs lack expertise and management time to prepare lengthy and complex proposals. Simplifying the submission of proposals and reducing delays between submission and project launch, would lower barriers and allow an increase in SME participation*

# 3. Information and Assistance

The purpose of this part of the report is to cover the issues linked to information and assistance services to SMEs interested in taking part in the EU RTD Framework Programme. This is done mainly through a selection of some key results as they were identified through the different studies.

## 3.1 First information source

Table: The first information source for newcomers in % (L = Leader — P = Partner)

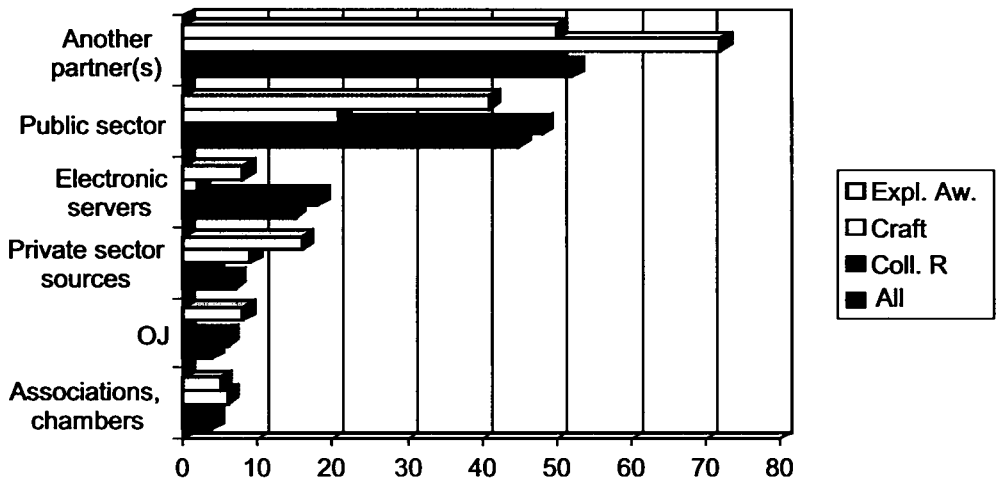
| | | Expl. Award | | CRAFT | | Coll. Research | |
|---|---|---|---|---|---|---|---|
| | | L | P | L | P | L | P |
| 1 | was contacted by a potential partner | 23 | 74 | 40 | 80 | 31 | 68 |
| 2 | did not need to be told, because had previous knowledge | 12 | 11 | 7 | 3 | 25 | 16 |
| 3 | read about it in a newsletter / magazine | 10 | 3 | 0 | 4 | 11 | 4 |
| 4 | was informed directly by a service provider | 23 | 5 | 47 | 4 | 10 | 3 |
| 5 | Participated in an event | 7 | 4 | 0 | 0 | 10 | 2 |
| 6 | was informed by industry association or Chamber of Commerce | 7 | 1 | 7 | 5 | 2 | 2 |
| 7 | read about it in the Official Journal of the EU | 2 | 1 | 0 | 0 | 5 | 1 |
| 8 | read about it in a specialised / technical magazine | 7 | 1 | 0 | 0 | 3 | 1 |
| 9 | read about it in the general press (newspaper / magazine) | 3 | 0 | 0 | 0 | 0 | 0 |

*Most SME participants are newcomers without previous experience or knowledge of the EU RTD FP:*

- *Partners are their main source of information*
- *Leaders, especially of CRAFT projects, depend more on service providers*
- *Industry associations and chambers of commerce play a significant role for newcomers involved in CRAFT projects*

## 3.2 Sources of additional information

Chart: Sources of additional information by project type in %




Notes:

- Public sector sources include: the EC, National Governments, NFPs, IRCs, EICs
- Private sector sources include: private consultants (mainly), banks, other service providers
- OJ = the Official Journal of the EC

This chart confirms the overall importance of 'another partner' as source of information, and the difference in profiles between collaborative and co-operative research:

- for collaborative research, other partners (50%) and public sector institutions (48%) are equally important sources of additional information, and electronic servers (18%) play a significant role;
- for co-operative research, partners are the dominant source with 70% of the respondents mentioning another partner as source; public sector institutions, although second in importance, are used much less often (21%), and electronic servers are used only marginally (2%);
- Exploratory award project participants fall between the profiles of collaborative and co-operative research, but nearer the collaborative research profile.

Leaders also use different sources depending on the project type, but the order of importance varies:

— For collaborative research projects, public sector sources predominate and the EC is the main single source used;

— For CRAFT projects, RTD performers and EC support networks play the main role;

— For exploratory awards, leaders depend most on the public sector, then on EC support networks, with partners being only the 3rd most important source.

*Information and assistance needs are satisfied by different sources depending on the project type and the partner role in the project:*

- *Partners are the main source overall, but only CRAFT project leaders use them the most.*
- *Public sector sources (EC, EC support networks) are the sources most used by other project leaders*

## 3.3 Use of external assistance services

Chart: SMEs in their first EU RTD project (newcomers) -

Use of external assistance, by type of project and leader/partner in % *(Source = study Part I)*

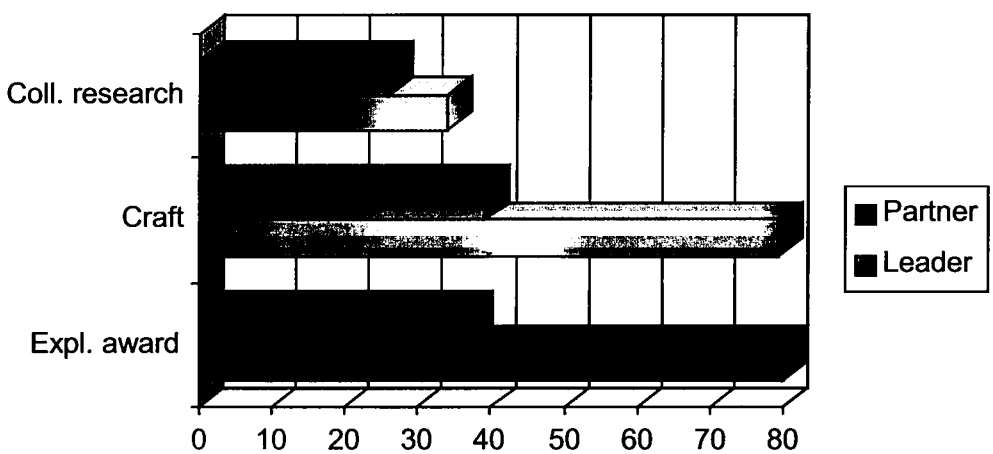


Table: SMEs new to EU RTD — Use of different types of assistance in the proposal preparation — in percentage of the total sample per project type

| Type of assistance | Expl. Award | CRAFT | Coll. Research |
|---|---|---|---|
| Explaining / clarifying the official documents (rules, forms to fill in,...) | 79 | 82 | 74 |
| Checking the quality and eligibility of the proposal document | 80 | 80 | 62 |
| Getting contacts / names for obtaining additional information | 59 | 64 | 63 |
| Providing services linked to the drafting of the proposal document (writing part or all of the proposal document) | 61 | 56 | 43 |
| Pre-screening of proposals by the European Commission services | 36 | 26 | 24 |
| Getting names / contacts of potential partners | 49 | 59 | 43 |
| Partner search services: finding partners that would complement your consortium | 51 | 41 | 33 |
| Consortium agreement | 24 | 49 | 42 |
| (Business) plan for the exploitation of the project's results | 21 | 36 | 27 |
| Advisory services linked to the research programme and activities | 37 | 39 | 21 |
| Advisory services linked to the intellectual property rights | 21 | 28 | 15 |
| Advisory services linked to market research / information | 23 | 26 | 16 |
| Legal advice | 18 | 26 | 24 |

*Explaining rules for participation and checking the eligibility of a proposal are the most used services for all project types:*

- *Partners under the TSME use assistance for partner search more than those in collaborative research projects*
- *Partners in CRAFT projects use assistance for preparing consortium agreements much more than partners in other types of project*

## 3.4 Which service provider?

Based on the frequency of use, the main service providers used by SMEs are (in descending order of frequency of use):

- Research service providers. These are mainly research centres, but some are universities. Most of these research service providers will actually be a partner in the consortium;

- Consultants (most often from the private sector);
- Another enterprise which is member of the consortium;
- The EU sponsored networks (NFP, IRC and EIC);
- National government institutions.

Some additional comments:

- The most frequently used type of service provider is:
  * a research centre for newcomers to collaborative and co-operative research projects;
  * a private consultant for leaders of co-operative and collaborative projects, as well as for SMEs that received an exploratory award.
- The EU sponsored networks (NFP, IRC and EIC) are used more frequently by SMEs participating in co-operative research projects or preparing their proposal with an exploratory award. SMEs preparing collaborative research projects will more often contact national government institutions.

The proportion of companies who did not use external services because they did not know where to get assistance is low (3%).

*SME proposers know where to get assistance as 'Lack of information and assistance' does not appear to be a barrier they consider important*

## 3.5 Pre-screening of proposals

Pre-screening of proposals is a service provided by some of the programmes, and is appreciated by SMEs.

Technology Stimulation Measures (TSME) can also be considered to offer pre-screening, as there is a permanently open call for proposals, and proposers of rejected proposals are encouraged to re-submit their proposals for the next evaluation.

The issues at stake are extremely important:

- Screening of proposals is a service that is appreciated when it is available from programmes.
- The systematic use of such a screening service would significantly reduce various problems, particularly that of ineligibility, and would improve the quality of submissions ("incomplete forms" is the main reason for ineligibility of CRAFT proposals, and the third most frequent cause of ineligibility for exploratory award proposals).
- Screening could also be a way to provide direct assistance to newcomers preparing a proposal, or to put them in contact with service providers that can assist them in solving problems identified during the screening.

The pre-screening of proposals by the European Commission is perceived as the second most important service by SMEs participating in collaborative research

projects. It is fourth in importance for SMEs from CRAFT or exploratory awards projects.

Services that are perceived as most important by newcomers are:

- Checking the quality and eligibility of the proposal document (equally for all types of projects)
- Getting contacts / names for obtaining additional information (less important for CRAFT, but critical for newcomers who are leaders)
- Explaining / clarifying the official documents (rules, forms to fill in,... ) (more important for CRAFT than for collaborative research)

These are also the three types of services that were most often effectively used by SMEs from the three types of projects.

*Pre-screening of proposals is a service that can have a positive impact on SMEs' qualitative and quantitative participation*

## 3.6 The role of RTD performers

Research centres, and to a lesser extent universities, who become partners of SMEs in CRAFT consortia, are the dominant source of information and assistance:

- Leaders of CRAFT projects most often use a research centre as a first source of information, but significantly less often than their partners: 29 % against 39 %.
- Half of CRAFT project leaders have as an additional source of information a research centre or a university that is a partner in their project.
- 1 in 4 of the leaders of exploratory awards had a research centre or university as a source of additional information.
- Research centres (who are a partner) are by far the most important source of assistance services for CRAFT SMEs, and they are the second most important for exploratory awards.

Private consultants also play an important role, particularly for exploratory awards, but also for CRAFT:

- Private consultants are perceived as the service provider more frequently used by SMEs with an exploratory award.
- The second most important source of initial information on EU RTD for CRAFT leaders are private consultants with 24%, but this source is hardly mentioned by their partners (3%).
- Consultants from the private sector are the most important source of external services for CRAFT leaders (based on the frequency of use).

*RTD performers and private consultants play a major role in the preparation of projects under the TSM*

## 3.7 Support networks

The second most important reason for the ineligibility of an exploratory award proposal is that it does not conform with the programme priorities, and must be transferred to another programme. This is also the third most important reason for the ineligibility of CRAFT proposals.

Training of the support networks might help solve this type of problem as well as others identified.

*Training of support networks and service providers in general can improve the average quality of proposals*

EC Support Networks play a critical role, especially in helping newcomer-leaders of proposals to be submitted under the TSME to understand if their projects can be supported by the EU RTD programmes.

The actual services provided by the different support network members are quite different. Although it is quite obvious that every organisation should be left free to devise its own service policy, it makes sense to agree on a number of services that should be provided in all countries/regions.

For 11 out of 23 NFPs, contacting rejected proposers is not part of their policy.

In two countries, all TSME rejected prime proposers were contacted.

Examples of activities undertaken by members of the Support Networks are:

- systematically contacting all the leaders of rejected proposals;
- systematically contacting all the partners of rejected proposals;
- systematically contacting all the leader/partners of approved exploratory awards.

*There is a need to define minimum standards of service to be provided by support networks*

# 4. Costs and benefits of participation

This chapter summarises some of the key findings which relate to the themes addressed in the three first chapters.

It covers the costs of preparing a proposal, the benefits of participation and also the barriers to participation.

Finally, this chapter will also review the degree to which the qualitative objectives of the Technology Stimulation Measures for SMEs have been achieved.

## 4.1 Cost for a company of preparing a proposal for a research project

**These are estimated as follows:**

Table: Cost of participating in kECU

| PROJECT TYPE | FP3 (1) | NFP (N=15) (2) | LEADER COST (3) | PARTNER COST (3) |
|---|---|---|---|---|
| Exploratory Award | 2.5 | 3.5 | | |
| CRAFT | 20 | 21 | 24.5 | 8.5 |
| Collaborative RTD | 20 | 23 | 24 | 13 |
| CRAFT or Collaborative RTD via Exploratory Award (4) | — | — | 28.5 | 14 |
| Consortium Agreement | — | 4.5 | — | — |

Sources of the information and comments:

(1) Evaluation study of co-operative/collective research for SMEs at European level with specific reference to the CRAFT scheme of the BRITE-EURAM II programme, EC, March 1994

(2) Opinion of NFPs based on a postal questionnaire. This estimate is valid for a Leader SME

(3) Average cost mentioned by participants in 4th FP projects (postal survey)

(4) The same average costs for SMEs which received an exploratory award. Although not explicitly mentioned, this may be presumed to include the cost of obtaining the award.

**Important remark:**

The figures above have their limitations because of the sources of the information and the way it was collected. They provide interesting estimates only for the costs of individual SMEs. Extrapolating these to full consortia would be wrong as no data is available to actually do this exercise.

**Conclusions**

- The actual cost to an SME to prepare a proposal varies extremely widely: it ranges from a zero cost for SMEs whose partners do all the work, up to more than 100 person-days.

- 15% of the sample of respondents claimed that they did not spend a single person-day on their proposal.
- According to the survey results, the preparation cost is twice as high for a leader as for a partner. This is the case for those SMEs which prepared their proposal using an exploratory awards and for collaborative research (28 k <-> 14 kECU and 24 k <->12 kECU respectively). The difference is even higher for CRAFT leaders whose cost is nearly three times the cost for a partner (24.5 k <-> 8.5 kECU).
- Exploratory award recipients exhibit a tendency to spend more on preparing their proposal, although the difference is probably explained by the inclusion of the costs of acquiring the award itself. Another reason may be that these SMEs are mostly 'newcomers' (85% of them) which have no experience of participation in EU RTD. Looking at the differences among partners and leaders, the difference between exploratory award and collaborative research is less than 1,500 ECU for partners and slightly more than 2,000 ECU for leaders.
- Exploratory award recipients spend more on fees, essentially to external service providers, which means they are using the cash received. The average of fees paid is 7,000 ECU against 2,000 ECU for collaborative research. Nevertheless the number of person/days spent is only marginally lower than for collaborative research (48 against 53 person/days for the leaders).
- Exploratory awards allow SMEs to increase their selection rate when they present collaborative research proposals (this rises from 28% to 41% when using an exploratory award). Although no similar impact is noted for co-operative research projects presented in 1995-96 (the average selection rates were of 47% for direct submissions and 49% for CRAFT proposals resulting from exploratory awards), exploratory awards are mostly used by newcomers, allowing a completely new category of SMEs to participate in EU RTD projects.
- CRAFT projects cost as much to prepare as a collaborative research project for the leaders, but the balance of the costs is different: less time is spent by staff of the company (38 against 53 days for the leaders) and much more is spent in cash, both on fees and on other (e.g. travel) costs: three times more on fees and nearly twice as much on other costs.
- The cost for a partner in a CRAFT project is significantly lower than it is for a partner in a collaborative research project.

*The exploratory awards are an effective instrument to help SMEs to prepare proposals.*

## 4.2 The benefits of participation

Ranking of benefits or reasons for participation given by respondents to the postal survey, as they are perceived based on their experience up to now.

| Benefit | Expl. Award | CRAFT | Coll. Research |
|---|---|---|---|
| 1. Develop a new product | 1 | 1 | 1 |
| 2. Exploit existing know-how | 4 | 3 | 2 |
| 3. Access technology or skills | 2 | 2 | 3 |
| 4. Improve company image | 9 | 5 | 5 |
| 5. Increase the company's international exposure | 6 | 5 | 4 |
| 6. Better knowledge of end-user needs | 8 | 8 | 7 |
| 7. Network to open new markets | 5 | 7 | 5 |
| 8. Obtain subsidies | 7 | 9 | 8 |
| 9. Develop an improved production process | 3 | 4 | 9 |
| 10. Better knowledge of competitor's strategies | 11 | 10 | 10 |
| 11. Better knowledge of supplier's strategies | 11 | 11 | 11 |
| 12. Access to processes and products that satisfy ISO and EU (CEN/CENELEC) standards | 10 | 12 | 12 |

*Besides developing transnational partnerships, most participants agree that EU RTD projects allow them to progress in the development of new products:*

- *TSME participants also access new technology or skills and improve their production processes*
- *Collaborative research partners also use projects to exploit their know-how and network to open new markets.*
- *Receiving funding from the European Commission is not SMEs' main reason for taking part in the EU RTD programmes*

The table below is based on statements about SMEs' experience of taking part in EU RTD.

The scores in the table show the degree to which the respondents agree with the statement mentioned, whereby: 1 = 'don't agree at all', and 5 = 'fully agree'.

| Statement | E.A. | CRAFT | Coll. |
|---|---|---|---|
| It allows us to share the investment with partners and the EC | 3.7 | 3.9 | 3.8 |
| It allows us to share the research-related risks with partners and the EC | 3.8 | 4.0 | 3.7 |
| It allows us to strengthen our technological capacity | 4.0 | 4.0 | 4.0 |
| It increases our chances of obtaining additional financing (from venture capitalists or banks) | 3.2 | 2.9 | 3.0 |
| Participating in a European R&D project is good training for our staff in project management | 3.4 | 3.2 | 3.6 |
| Participating in European R&D is interesting for the money only | 2.2 | 2.2 | 2.0 |
| The chances of getting a proposal approved are too low | 3.2 | 2.9 | 3.2 |
| The delay between submission of proposal and actual start of the project is much too long | 3.6 | 3.4 | 3.6 |
| Preparing a proposal document is easy | 2.3 | 2.3 | 2.3 |
| The forms used to present proposals are extremely difficult to fill in | 3.0 | 3.2 | 2.9 |
| Our company had not expected such a high level of bureaucracy | 3.3 | 3.3 | 3.2 |
| The opinion I have of the European Commission has significantly improved | 3.3 | 3.3 | 3.4 |
| Participating has helped in creating new and long lasting co-operation links with foreign companies and organisations (internationalisation) | 3.5 | 3.5 | 3.8 |
| The approval of the project by the European Commission improves the credibility of the project related activities (towards the public sector, our bank, the general public etc.) | 3.6 | 3.4 | 3.6 |

*Respondents agree that taking part in an EU RTD project allows them to:*

- *Share the investment and RTD related risks between partners and with the EC*
- *Strengthen their technological capacity*
- *It is confirmed that EC funding alone is not the main motivation for participating*

### 4.3 Would they participate again?

96% of respondents say they would participate again in a EU RTD programme in the future.

By type of project the 'yes' percentages are:

- Exploratory Award: 93 %
- CRAFT: 96 %
- Collaborative Research: 96 %

*Almost all SME participants would participate again in EU RTD programmes*

# LIST OF ABBREVIATIONS

CEN: Comité Européen de Normalisation

CENELEC: Comité Européen de Normalisation Electrotechnique

CRAFT: Cooperative Research Action For Technology

DG: Directorate General

EC: European Commission

EIC: Euro Info Centres

EU: European Union

FP4: 4$^{th}$ EU Framework Programme for Research and Technological Development (1994-1998)

kECU: 1,000 European Currency Units (ECU)

ICT: Information and Communication Technologies

IPR: Intellectual and Property Rights

IRC: Innovation Relay Centres

IRDAC: Industrial Research and Development Advisory Committee

ISO: International Standards Organisation

NFP: National Focal Point

OJ: Official Journal of the European Commission

R&D: Research and Development

RTD: Research and Technological Development

SME: Small and Medium Sized Enterprise

TSME: Technology Stimulation Measures for SMEs

# Provocateur's report

*Dr. Sabine Herlitschka, BIT, Austria*

All over Europe there are 17 millions Small and Medium sized Enterprises (SME). They account for

- 99,8% of the European companies,
- 66% of European employment, and
- 65% of business turnover.

These figures demonstrate, that SMEs are the basis of the European economy. Therefore, they are important target groups for national and Community policies.

BIT — the Austrian Bureau for International Research and Technology Co-operation — is the national information and service centre for European and international RTD programmes, initiatives and actions. In its daily work, BIT is stimulating and supporting SMEs in preparing their transnational research and development activities. Based on that insider experience, the following issues will be discussed with the representatives of the European Commission:

- The relevance, effectiveness and efficiency of the European RTD programmes for SMEs,
- Target groups of European RTD funding schemes,
- Services provided by European networks for information and advice,
- Results archived and problems faced during the last years,
- Major hurdles and major benefits for SMEs,
- Possible future improvements of European research and technology programmes dedicated to SMEs.

In the coming years, SMEs will have a crucial role to play in coping with major international economic and social challenges. Therefore, it is an important issue for policy and service actors, to provide an adequate framework for the successful development of SMEs in Europe.

# Rapporteur's report

*Cliff Funnell, Barnham*

After the Keynote Speech by Robert Jan Smits, which dealt with the Technology Stimulation Measures for SMEs (TSMEs), the Provocateur, Sabine Herlitschka, posed questions to the Session Chairman, Hendrik Tent, relating to the general participation of SMEs, i.e. not necessarily confined to SMEs involved in the MAST area.

Her first question asked about the philosophy behind the support of SME's in Europe. Mr Tent explained that SME's have common problems that can be solved by transnational collaboration. He also suggested that European collaboration would or could assist in the development of common European standards. Geoffrey O'Sullivan (Irish Marine Institute) agreed that cross-border collaboration will create European cohesion.

In response to the Keynote Speech, Franz Van Dongen (OCN) remarked that a company with 500 employees would be viewed as a very big company within the marine sector and that such a definition was not valuable to this sector. Mr Tent agreed and, in his personal view, such definitions of SMEs was unhelpful because each sector is different. In the textile industry, for example, a company of 250-500 is considered small. He would therefore prefer a level of flexibility.

Franz Van Dongen felt it important to look at the statistical evidence of SME participation and views within different sizes of SME, for example, 5-10, 10-20 employees. Jean van Sinderen-Law, University College, Cork, commented that very small SMEs need more support than larger companies in the preparation of proposals. Robert Jan Smits agreed that different sectors have different priorities so we need to be flexible.

The Provocateur's second question was that there were 14,000 SMEs participating in FP4, however, there are 17 million SME's in Europe. She asked whether the Commission was satisfied with SME participation.

Mr Tent's view was that the Framework Programme should not be viewed as a permanent subsidy scheme. He believed that zero participation was, in fact, the ultimate objective. With regard to the specific question he was is not certain of the actual demand in from SMEs in these schemes. Robert Jan Smits said that in fact 90% of SMEs are not actually potential participants, although he believed that there was still a large potential for growth in SME participation.

A participant opined from the floor that whilst FP5 was being presented to be about "solving solutions", many SMEs were "solution providers" for which the structure of FP4 was more relevant. Mr Tent did not agree. He said that for SMEs, FP5 would provide more of an open system with a "bottom-up" approach. CRAFT would also be horizontal across all Programmes and not necessarily relate to any specific Key Action.

Bernd Kassler, GKSS, asked for verification that the approximate cost of preparing proposals could be between 15,000 and 20,000 ECU. Mr Smits agreed, but explained that the Exploratory Award had been set at 45,000 ECU because it also included the costs of a research feasibility study, market research, etc.

A participant asked how we could attract "technology followers" to Programmes. Mr Tent believed that this had to be the responsibility of Member States through National Focal Points and not centrally by the Commission as each has different needs, cultures, etc.

John Wallace, Informatic Management International, was concerned about the perceived drive to larger projects in FP5. Mr Tent explained the importance of larger strategic projects rather than groups of unrelated smaller projects that together did not meet the overall strategic objective of the Programmes. However, he believed that small projects were also important within FP5, whilst large projects could be difficult to manage.

Geoffrey O'Sullivan pointed out that awards to SMEs should not be seen as a subsidy, but both an investment and part of a wider policy to assist SMEs to become more competitive.

Ms Sinderen Law asked whether there were any guidelines as to SME contribution in CRAFT projects. She claimed that some Programmes insisted on a cash contribution, while others did not. Mr Smits stated that there were no differences in such guidelines between Programmes, however, he believed that some cash contribution was preferable due to the difficulty of the Programme Management auditing in-kind contributions.

Ms Silvana Vallerga, the Italian MAST Committee member, believed that SMEs are usually more efficient that large companies. She asked whether the EU could undertake a cost/benefit analysis of the participation of large against small companies. Mr Smits felt it was important to have more concentration of projects with clear priorities.

It was asked from the floor whether there was an ideal balance between SMEs and institutions. Mr Smits replied that there was no "ideal" project. He re-emphasised that SMEs must always take the lead in Co-operative Research Projects and that RTD Performers were acting in a contractual role.

Franz Van Dongen commented that he believed that within FP5 it was difficult for SMEs to identify their role. He believed that the role of Thematic Networks was, therefore, very important. Klaus Pfeiffer, Hydromod, thought that it was also important to remember that SMEs provide a role as service providers, e.g. project management, data management, etc, within large collaborative research projects.

Geoffrey O'Sullivan asked about the objective of the SME scheme, i.e. was it to solve technological problems or to help SMEs? Mr Smits replied that there was not a specific SME programme. The Stimulation measures only have the objective of assisting SMEs to participate in the Framework Programme.

The Provocateur commented that there were internal barriers for SMEs in preparing a proposal for the Framework Programme, e.g., limited management time. She asked whether the scheme was too complicated for SMEs. Mr Smits said that this was recognised and demonstrated the importance of Focal Points in this area.

The Provocateur asked whether there were any plans to cope with the delays in project selection. Mr Tent responded that there have been examples of long delays and that this was not acceptable. However, he believed that what is important is that SMEs are aware of the level of delay, i.e. if it is known that it will take 4 months, then SME's should be notified.

John Wallace asked whether there were to be any changes in FP5 in relation to ownership of IPR? Mr Smits replied that IPR will continue to be owned by SMEs as they are funding the research. The RTD Performers are acting only in a contractural role.

Geoffrey O'Sullivan reported that within the Marine Science and Technology sector many SME's were very small, sometimes as small as two employees, with significant technological capability. It was important that we do not ignore these companies. Christos Fragakis was adamant that such schemes must not be used as a subsidy. He added that in the early stages of the Measures it was true that very small companies were not successful because of their size, however, as a consequence, evaluation panels were encouraged to be more flexible.

Ms Silvana Vallerga felt that what had been achieved in relation to the success of increased participation of SMEs in MAST had been a "miracle" in view of what had previously happened. She then asked about the role of the Horizontal SME Programme in FP%. Mr Smits explained that Horizontal Programmes only provide the tools for SMEs to participate in the vertical programmes e.g., providing a single contact point to provide support and back-up.

Christos Fragakis then presented statistics on the participation of SMEs in both the full MAST Programme and the Technology Stimulation Measures.

This was followed by a presentation on the role of SMEs in the MAST Programme by Cliff Funnell, the UK National Focal Point. He started by providing an overview of the European Marine Science and Technology industry. He explained that it was made up of the following:

- Survey Companies/Underwater Contractors
- System Manufacturers
- Sensor Manufacturers
- Technology Providers
- Software Providers
- Consultants

Operating in the following market sectors:

- Defence
- Offshore Oil & Gas
- Telecommunication Cables
- Seabed Survey
- Oceanography
- Marine Science

He also commented that a study in the UK suggested that the annual market for marine survey services, excluding seismic survey for hydrocarbon exploration, was nearly US$2 billion and that against the other sectors, marine science was a relatively small market, against the other sectors in which SMEs operated. It was also the case that the major turnovers were in survey companies rather than manufacturers who supplied these companies with the appropriate tools. As a result the major operators were predominantly large multinationals, e.g. in the survey industry, Fugro and Racal Survey, however, of approximately 200 manufacturers, approximately 90% were SMEs, whilst the larger manufacturers were large electronics and/or defence manufacturers. In addition, there were approximately 300-400 SMEs supporting the manufacturers and operators as technology/service providers.

These SMEs were primarily technology-based, many of which have "spun off" from universities and research institutes, and as a result there are a high number of PhDs/ M.Sc. A UK study undertaken by Cliff Funnell Associates and supported by the Commission as a Technology Stimulation Measure, identified that out of a sample of 40 SMEs, 40% employed at least one PhD. Furthermore, within the sector, a manufacturing company with 50 employees was considered very large, whilst most companies employed between 5 and 25 staff.

As a consequence, the strategy in the UK was to be very proactive, with Focal Points contracted from the private sector. Within MAST a number of tools were used, including the production of promotional literature; the organisation of seminars and workshops; visits to companies; the provision of a telephone/email/fax helpline; close contact with Commission officials and constant feedback on the progress of proposals; continuing dissemination of information and visibility of the Focal Point to ensure recognition, identification and access.

Experience as a Focal Point had helped the Rapporteur to identify a number of issues. Within Exploratory Awards these included:

1. What is an SME? – e.g. university companies, privatised national institutes with no shareholders, etc
2. The problems of finding SME partners without a good network of National Focal Points.
3. The problem of SMEs being aware of ongoing research or "state of the art" in academia.
3. The difficulty of persuading SMEs to clearly state research objectives in proposals for "pre-competitive research" for fear of being seen to be "near market".

There were also a number of issues relating to Evaluation, for example:

1. The inconsistency of evaluation panels
2. The expertise of evaluators in relation to specific technologies and knowledge of industry
3. The production of consensus reports
4. The time delays before contracts are negotiated

Within CRAFT the issues included:

1. The lack of financial incentive to SMEs in CRAFT projects
2. The fact that RTD Performers can be obstructive or try to influence too much the research scope or try to lead projects themselves.
3. The fragmentation of the marine S&T sector can make it difficult to identify even a small group of SME proposers.
4. The structure of Marine SMEs in terms of being technology providers means that many projects are hybrids, i.e. SMEs want to participate in the research.

The following suggestions were made to improve the SME Measures for the Marine S&T sector.

# Network of Focal Points

Commission to provide support to national Focal Points, but not prescribe activities

Select Focal Points that understand the sector and can assist in partner search

## Exploratory Awards

It is crucial that proposals emphasise "research objectives" but that Evaluators should be realistic about SME's knowledge of "ongoing research". Although SMEs are usually aware of competitive technologies and market issues, subject to the latter, in-depth knowledge of academic research programmes can be left to the Exploratory phase.

The priority of SME schemes should be to improve "industrial competitiveness" not necessarily to be at the forefront of science and technology.

Exploratory awards should be transferable across FPs, otherwise, there is a long delay between the last and first calls of each FP.

## Co-operative Research

Focal Points should monitor exploratory phase to ensure SMEs are implementing the project and preparing for Stage II, i.e. collaborative and co-operative research.

support travel and subsistence expenses of SME sponsors in CRAFT projects

allow SME-only shared-cost RTD projects

## Evaluation

Ensure that consensus report provide information/feedback that is useful to SMEs

allow Commission to act upon small changes without requirement to resubmit complete proposal, e.g. same Experts to look at resubmissions (by post?)

In discussion the following major issues were discussed:

The need to simplify procedures in processing applications and preparing contracts.

The importance of adequate contacts and networking. Resorting only to the Internet is definitely not sufficient to identify partners in this sector.

The costs to the lead SME in co-ordinating and managing a co-operative research project.

The need for flexibility in evaluating proposals. If a project is worthy of support, but shows some weaknesses, it should be possible for the Commission to seek clarification or improvements without the need to resubmit. The evaluation panel could deal with this by post/telephone/fax.

Very small companies (of less than 5 employees) should not be presumed to lack research capability.

The TSME (Technology Stimulation Measures for SMEs) in FP4 has led to an increase in the number of SMEs participating in collaborative projects. This has shown the success of the measures.

There is a need to recommend TSMEs in FP5 as soon as possible to ensure a greater time opportunity for SMEs to undertake Exploratory Awards and submit proposals for both collaborative and co-operative research.

# THE FIFTH EU RTD FRAMEWORK PROGRAMME (FP5): A SESSION OF INFORMATION AND QUESTIONS

# How will the machinery work?

*Martin Bohle-Carbonell*
*European Commission, DGXII.D*

The fifth EU Framework Programme slowly is taking shape. Since months EU-Member States and European Parliament agree step by step on its essentials taking up proposals made by the European Commission or asking for amendments.

Making the 5th Framework Programme operational implies to agree on more than its scientific-technical content. Cooperation mechanisms with the EU-Member States, participation rules and selection criteria which all have to be agreed too. Participation rules will describe what are minimum requirements of the composition of the partnership, what costs are allowed, what kind of resources the partnership has to have, who has the property rights to the results and what are the Community's own interest? Discussions on these and related matters are in full swing since early 1998 and consensus is emerging. Thus following main strokes of the emerging picture can be identified.

1. For the 5th Framework Programme the Community interests are defined as:
   - contribution to competitiveness
   - support to EU policies
   - implementation of S&T cooperation agreements
   - contribution to job creation
2. The participation rules spell out:
   - The consortium shall have the skills & resources needed to execute the planned RTD.
   - Half of the eligible costs required to execute the RTD will be paid by the European Union.
   - The consortium has the property rights to the results — if results are used!
   - Exploitation priority is for project partners.
   - The consortium has the obligation to disseminate the results- if results are not used!
3. Selection criteria will be used to find RTD-projects which will implement the 5th Framework Programme. In this view selection criteria are more embracing than scientific and technological excellence, which however is the bedrock for each acceptable project. These criteria include:
   - European added value
   - Social objectives / Citizens' concern

- Sustainable development
- Innovative nature of the RTD
- Dissemination & exploitation potential of the RTD

European added value, thus the specific benefits of executing RTD at the level of the EU, is sought to be obtained if the project

- either has a critical mass in human & financial terms through trans-national complementarity
- or contributes to implementation of EU policy
- or addresses problems pertinent on the Community level

Social objectives or Citizens' concerns are considered to be taken into account if the expected results of the project are:

- either improving employment
- or promoting quality of life and health
- or preserving the environment

Sustainable development is facilitated by a project if its results

- either enshrine growth prospects
- or improve competitiveness
- or foster S&T-progress with prospects for dissemination & exploitation in medium or long term

4. The scientific-technical content of the 5th Framework Programme is build on key-actions and clustering of projects targeting one and the same RTD- topic. Network of projects — "from basic to demonstration" shall emerge. Inter-project and inter-programme cooperation will be required which will develop bottom-up around joint calls and joint project life. Focused, regular calls — described in "road map" which is part of the work programme shall allow to subscribe less frequent and to target better. Contract negotiation which shall include an element of adjustment of a proposed project to its environment shall allow that key-actions and project cluster target one and the same RTD- topic.
5. External evaluation based on common criteria and common quality indicators for project life cycle management will provide the basis for this. Taking up the selection criteria as listed above the quality indicators are five-fold:
   - S&T excellence
   - Community added value
   - Social objectives / Citizen's concern
   - Economic development and S&T prospects
   - Management of RTD project
6. Drawing on the foregoing it shall be stressed that a consortium for a successful EU-project shall have a project which "targets beyond S&T" and shall have a

partnership which addresses "user involvement". The main tool to identify whether a consortium targets beyond S&T and involves users will be its plan for dissemination & use. This plan will be required at the proposal stage and will be subject to evaluation. During the life of the project this plan shall develop into the Technology / Results Implementation Plan for the post-project period. The Technology / Results Implementation Plan

- is a contractual part of the final report
- committing the partnership to post project reporting on exploitation / dissemination activities
- and will be monitored for its implementation

7. The 5th Framework Programme will build on consortia having a strategic view for:
   - its own development leading to direct exploitation activities
   - their partner's development leading to understanding of the partner's exploitation interests / interests in the project
   - their RTD-environment leading to early and enhanced dissemination activities of the project in order to foster their working environment in the long run

It may be a closing summary to encourage subscription to a call if you and your partners:

- build a consortium having a strategic view;
- address a problems in an innovative way;
- add value by acting on the EU level;
- meet Citizens' concern;
- are ready to exploit or use or disseminate your results.

# Report of discussion session

*Raquel Goñi, Instituto Español de Oceanografía, Palma de Mallorca*

This session developed in four distinct phases. In the first, the head of the Marine Science and Technology (MAST) Programme, J. Boissonnas, gave an overview of the current status of the Fifth Framework Programme (FP V) of Community research. In the second phase, MAST staff member M. Bohle-Carbonell described the rules of implementation and management of the FP V, emphasising the modifications introduced with respect to FP IV. Next, the provocateur – G. O'Sullivan from the Institute of Marine Research (Ireland) draw attention to a number of problem areas in FP IV concerning its overall conception, objectives and implementation as well as marine science and technological research specifically. In the fourth phase, the audience expressed the main concerns and doubts of the scientific community as it prepares to participate in FP V.

## Status of the Fifth Framework Programme

The Framework Programme is the instrument of EU research policy and as such, it is a policy document not a science plan. FP V is based on the principles of scientific and technical excellence, relevance to EU policies, and European added value. At present, the structure of FP V is defined up to the level of the specific programmes, without the detailed contents of the work-programmes being yet finalised. FP V has been conceived to respond to socio-economic and competitive needs of the EU and in its structure aims at concentrating research efforts to address relevant problems at the European level.

The common position on FP V adopted by the Council of Ministers on 12 February 1998 contains four Thematic Programmes — equivalent to the specific programmes of FP IV — and three horizontal programmes. The Thematic Programmes are:

1. Quality of life and management of living resources
2. User friendly information society
3. Competitive and sustainable growth
4. Preserving the ecosystem.

The horizontal RTD activities are grouped in the following three programmes:

1. Confirming the international role of Community research
2. Promotion of innovation and encouragement of participation of SMEs;
3. Improving human research potential and the socio-economic knowledge base.

The Thematic Programmes will comprise the following activities:

- Key actions: Cluster of problem-oriented, applied, generic and basic research activities directed towards a common European challenge or problem.
- Generic research and technological development: Activities that will complement the key-actions by supporting the maintenance and development of scientific capabilities and enabling technologies.
- Research infrastructure: Activities to promote optimal use of existing research infrastructures, rationalisation and cost-effectiveness in the development of research infrastructures through international cooperation.

The fourth Thematic Programme "Preserving the ecosystem" – introduced by the Council on 12 February — contains a dedicated marine science Key Action: "Sustainable marine ecosystems". In spite of this, marine science and technology research opportunities covered by the current MAST III and FAIR programmes must be looked for in at least four Key Actions throughout three Thematic Programmes:

- Theme 1 — Key action: "Sustainable agriculture, fisheries and forestry, including integrated development of rural areas".
- Theme 3 — Key action: "Land transport and marine technologies"
- Theme 4 — Key actions: "Global change, climate and biodiversity" & "Sustainable marine ecosystems".

# Implementation of FP V: The machinery

The rules laid out for the implementation of FP V are best understood having in mind the spirit of FP V: to move forward from basic to applied research in order to increase the benefits derived by society from Community research. The implementation of FP V will rest on three mechanisms: participation rules, selection criteria and programme management.

## Participation rules

To participate in RTD actions of FP V, no changes will take place on the required *minimum number of participants*. However, in FP V the Commission intends to examine more carefully the *financial resources* of the partners to carry out the project successfully. Also, in the new programme, *property rights* of the partnership will be reinforced – with the clarification made- "as long as results are exploited". Finally, to participate, the proposal must address questions of *Community interest*, taken to be those which: a) contribute to increasing the competitiveness of the European industry; b) support Community policies and science and technology agreements, and c) contribute to job creation.

## Selection criteria

In FP V, for a proposal to be "good", it must be more than scientifically good. This means that, in addition to scientific and technological criteria, the following criteria will be applied in selecting proposals for funding: a) European added value, b) social

objectives and citizens' concerns, c) sustainable development, d) innovative nature, e) dissemination and exploitation, and f) fundamental ethical principles. In the discussion session, attention was placed on the first three.

a) *European added value* is a core criterion that has been reinforced in FP V. It will be measured at three levels: 1) achievement of complementarily or critical mass in human and financial resources through transnational co-operation; 2) contribution to the implementation of EU policies; and 3) the proposal addresses a problem/question of interest at the Community level. At least one of these points must be satisfactory addressed for the proposal to be selected.

b) *Social objectives and citizens' concerns* or "what does the layman gain from this project". The measuring stick here will be the extent to which the proposed research contributes to: 1) improving employment; 2) improving health and quality of life; and 3) preserving the environment. Again, at least one of these objectives/concerns must be satisfactorily addressed for the proposal to be selected.

c) *Sustainable development* understood as the degree to which the proposed research: 1) improves growth prospects; 2) increases competitiveness; and 3) offers good prospects for dissemination and exploitation of results in the medium or long term. At least one of these conditions must be met by prospective projects. In this connection, emphasis was placed on considering early on who will be the user or users of our RTD work and what is beyond its immediate industrial or scientific application.

## Management and execution

*Performance* of FP V will be assessed annually by an external-monitoring panel. To facilitate assessment of performance, *benchmarks* will be identified ahead of time. *Programme Committees* will perform overseeing of implementation of FP V at the level of Thematic Programmes. Therefore, Programme Committees in FP V will have a more general role than in FP IV. For each Key Action, *work-programmes*, or scientific programmes, will being prepared, in turn *External Advisory Groups* (EAG) will assist in their implementation.

As in previous framework programmes, *calls for research proposals* to fulfil the scientific objectives laid out in the work-programmes will be published throughout the life of FP V. As a novelty, the intention is to publish more frequent and focused calls. The goal of this more targeted approach – or the so-called "road maps" — is to allow researchers to prepare better proposals and to reduce over-subscription. The dates of publication of these calls will be known well in advance. A first indication of this calendar should be available in August.

External experts will *evaluate research* proposals. A set of quality indicators — regarding criteria such as Community added value, social objectives, economic development and quality of management — will assist experts in evaluating proposals. For selected proposals this quality indicators will be used to monitor the project through its life. To achieve co-ordination of research and development activities, during the *contract negotiation* process, every project will be "adjusted to its environment", which means that, if appropriate, it will be integrated in a cluster of connected projects.

With regard to the proposal *dissemination and exploitation plan*, it was made clear that this plan will be closely evaluated and that a good plan should lead to a "technology/results implementation plan". This technology/results implementation plan will be a contractual part of the final project report and envisage post-project reporting on exploitation and dissemination.

Finally, the importance of inter-programme co-ordination in marine science and technology research was acknowledged. Tools being considered for achieving co-ordination are networking or clustering of projects, joint calls and joint project life.

# Summary tip: What makes a proposal good

In FP V, a good proposal must demonstrate: a) the strategic view of the partners; b) an innovative approach to attain the objectives; c) the added value for the Community; d) that it meets citizen's concerns; and e) willingness and ability to disseminate and exploit results. Of course, all of these without foregoing scientific and technical excellence!

# The plight of the provocateur: What is wrong with FP V

The provocateur raised a number of objections the relevance of which was reinforced by concerns voiced by the audience along similar lines. Regarding the conception of FP V, a strong complaint was expressed that FP V was a *step back* in the progress towards an integrated marine science and technology programme of Community research. This fact was deeply lamented on the light of the need to understand and treat in a holistic manner the wide array of interrelated processes and uses taking place in the marine environment and along its boundaries. Furthermore, the *dispersion of marine science and technology research* over three Thematic Programmes and over at least four Key Actions was criticised for the problems of management and co-ordination it will entail. The dangers of double funding or, conversely, those posed by interesting research projects falling through the cracks of this patchy map were exposed. In this connection, the provocateur disagreed with the Commission in that, relative to FP IV, FP V does not provide focus for, he said, it contains, if differently organised, the *same long list of research priorities*. Some members of the audience also voiced this view. Additionally, it was pointed out that in trying to achieve too many things, some of the objectives of FP V were contradictory.

Objections were also expressed about the *selection criteria*. In particular, about the *subjectivity* associated with assessing the question of *European added value*, the risk of underscoring or leaving out important regional problems and the fact that proposers from a given region have a better appreciation of regional problems than most evaluators. Assessment of the *concerns of the European citizen* was also deemed to be prone to subjectivity because concerns vary substantitally across the European Union and therefore, it is impossible to define "the standard European citizen". Finally, *sustainable development* was not believed to be a useful selection criterion for it is misused and void of concrete meaning. Lastly, the provocateur asked at which stage of the evaluation process and how these *non-scientific criteria*

would be taken into account. Inquired also by the audience, the Commission explained that the *two-stage evaluation* process installed during the second phase of MAST III would be maintained and that expert policy-makers and representatives of user groups and of industry would be called to participate in the non-scientific evaluation panels.

The provocateur then entered into the long-standing dispute of "*what is better, one large or a few small projects*". Fearing that the Commission would be promoting every day larger projects, the provocateur expressed the opinions that big is not necessarily better, that small projects are likely to obtain better results than large projects and, in sum, that project size must be related to the problem it addresses. In turn, the Commission praised some of the virtues of large projects such as the greatly improved opportunities for synergy and exchange of experience and knowledge, as well as for the integration of young scientists.

A general concern manifested by the provocateur and later voiced by the audience relates to the questions of dissemination and exploitation of results. With regard to *dissemination*, doubts arise so as "to whom" dissemination should be directed and "who" is most capable of disseminating project results. It was argued that professional people should do the dissemination of project results: costs for this activity could be budgeted in the proposal, said the Commission.

Concerning the *exploitation* of results, the provocateur, and later some members of the audience, questioned the viability of monitoring exploitation plans beyond the life of the project and expressed the view that without funding there would not be incentive or possibility to implement such plans. In response to this, the Commission declared that teams that do not have "intrinsic" interest for exploiting their results should not get funds for the project in first place. To ease the ambience, the Commission went on to say that the consortium could apply for funds to the Exploitation and Dissemination programme.

Finally, the provocateur raised a point of concern to many of the industry representatives attending the conference: how to raise the level of *participation of SMEs*. If involved as subcontractors — the simplest way — they are just service providers without property rights. If involved as partners, many small enterprises may not be able to afford the cost of allocating one person to a science and technology project full time. The Commission was pressed to find flexible solutions and should consider taking risks and building the possibility of failure in the process. In this context, the provocateur took up the suggestion made by one member of the audience to allow SMEs to participate on marginal costs: this would allow them to hire personal for the project. To this suggestion, the Commission clearly said that there were no plans to do so in FP V.

# Other comments and questions from the audience

The Commission was asked to facilitate information as to how consultation will be done to *prepare the work programmes*. The answer: a process of consultation through Expert Advisory Groups has been launched to advice the Commission on developing work-programmes. The members of these EAGs will be high-level

academia members, senior industrialists and high level representatives of user groups.

Although budget issues were not discussed in the session, there was general perception that the *budget* allocated to marine science and technology overall was lower than in FP IV. In this context, the view was expressed that there was a contradiction between a reducing budget and encouraging larger projects. The Commission clarified that possibly there was no need to move towards larger projects. The spread of size and the average size of MAST-III projects may be good guidance for typical project size.

In view of the dispersion of research areas throughout the programme, the possibility of establishing a system of *pre-screening* of proposals in FP V was first suggested for SMEs and later supported for all research proposals. To this the Commission responded that proposers should know what they want to do and to which area of the programme to submit their proposals. However, the Commission would help in the "grey areas" – such as biodiversity or GOOS in the current draft. In the view of the Commission, the information provided in the proposal summaries submitted for pre-screening is generally too sketchy to ensure their adequate and fair treatment.

Concerning the criteria of *innovation and European added value*, there was interest from the audience to know if improvement or adaptation of existing technologies would be considered to satisfy them. In this connection, it was suggested that the definition of innovation criteria should also read "improvement" and a debate was open about to which extent feasibility and innovation were contradictory criteria. The Commission pointed out that the modification of existing technology is more suitable for demonstration projects. Ideally, demonstration projects should be integrated in the RTD projects.

There was also interest to know what would be the relative weighting given to the various sets of *evaluation criteria*. The Commission explained that this information was not available yet but advanced that failure in any one of them would not be acceptable. In this context, one member of the audience raised the problem of the "lack of memory" of the evaluation system and pressed the Commission to make every effort to increase the robustness of the system.

One member of the audience requested clarification concerning the application of the selection criteria of respect for fundamental ethical principles. The example proposed was that of research which in its objectives or in its methods did not respect the precautionary principle. To this, the Commission replied that each case would be examined individually for compliance with the ethics criterion.

Finally, one member of the audience, voicing the concern of many others, inquired about the fate of the members of the MAST team in FP V: would the MAST secretariat be dismantled? The answer was not clear-cut, but the prospects for continuation of a MAST Secretariat or the like have been greatly improved by the existence of a Key Action on marine ecosystems.

# ROUND TABLE DISCUSSION ON MARINE SCIENCE AND TECHNOLOGY IN THE NEXT DECADE

# Marine Science and Technology in the next decade: a round table discussion

Chairperson: Pierre Papon, Paris

Keynote speaker: Ulf Lie, Bergen

Round table participants: Gian Mario Bozzo, Venezia
Pierre David, Paris
Ulf Lie, Bergen
Jacqueline McGlade, Coventry
Pierre Papon, Paris
Mario Ruivo, Lisbon
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# The role of science and technology in ocean governance

*Ulf Lie, University of Bergen*

1998, the Year of the Ocean is now celebrated with a number of important and interesting activities in many parts of the world, with EXPO 98 as the most spectacular event. The importance of the ocean for the welfare and indeed for the survival of life on earth is brought to the forefront and one might hope that the 1998 emphasis on the ocean will lead to more sustained attention to ocean related activities, in which ocean science and technology will have an important, and in my opinion a decisive role. In a complex, non-linear and dynamic world it is difficult to predict the direction of any development at all beyond a few years, and I certainly find it beyond my capacity to see the full scope of scientific and technological development during the next decade. It might be possible, however, on the basis of present scientific and socio-economic trends to identify potential driving forces for development of ocean affairs during the next decade, and thus also to predict which will be the issues requiring the attention of ocean science and technology. Most probably, the issues will be determined by players on the socio-economic and political stage, but the scientific community has also an opportunity to influence the development. This requires active participation of scientists in the decision-making processes at national and international levels and the establishment of institutions that integrate science and technology with socio-economic and cultural development.

During the recent decade the emphasis in marine science has centred on certain issues of global importance. The issues are fundamental and complex and their solutions are therefore not found within the time-frame of a regular 3-4 year research project. As an example, considering the development of the MAST programme from the second to the fourth framework programme we recognise certain enduring, basic issues, albeit with proper development from one framework programme to the next, and we have recently been informed that even the fifth framework programme to a certain extent will take up the same issues. This reflects on one hand the frustrating complexity of the situation, but it also reflects an encouraging dedication to attack the complexity.

On the basis of present trends the scientific emphasis during the next decade will probably continue to be centred on issues such as:

## i) The role of the ocean in the global life-support system

(e.g. climate change; biodiversity; coastal area degradation; harmful algal blooms; increased ultraviolet radiation).

ii) Sustainable economic utilisation of ocean resources

(e.g. scientific basis for improved management of living resources; sustainable utilisation of non-food biological substances; renewable ocean energy sources; application of the precautionary principle).

iii) Exploring the unknown

(e.g. understanding medium scale processes and large scale patterns in ocean circulation; new paradigms based on further studies of hydrothermal vents and the deep sub-seafloor biosphere; paleo-oceanography in understanding the quaternary history of earth).

iv) Science based technological innovation

(e.g. probes and integrated systems for ocean monitoring and forecasting; instrumentation for scientific studies of the deep-sea; technology for use of renewable ocean energy resources; technology for application in harsh environments).

Many or all of those issues have been discussed at length during the conference, and I see no point in returning to them now. Whether such issues will reach their solutions during the immediate future depends on the economic and political conditions for strengthening ocean research, but quite frankly the picture is rather bleak. In most countries there is a reduction in the funding of marine science and technology. Research vessels are taken out of commission, large and sophisticated equipment is hard to obtain and there is a reduction in permanent staff in marine research laboratories. It seems as if the message of scientists about the importance of the ocean resources and the need to protect the ocean environment does not reach the general public, and hence the political decision makers. Is there something wrong with the message, are we using the right, convincing arguments, and are the arguments packaged in a language and a format that can generate the required enthusiasm for the ocean?

In spite of the general gloom there are positive developments such as the growing attention to integrated coastal zone development, the acceptance of the precautionary principle in management of living resources, the tendency to take a more holistic view of the of the interaction between terrestrial, freshwater and marine systems, etc. Time does not permit a discussion of all those issues, but I will point to economic and political factors in two areas which I believe will enhance the attention to ocean affairs in the near future:

# a) Increased awareness of the value of the ocean

Exploitation of the resources of the ocean is as old as humanity itself, picking molluscs does not require more high-technology than picking roots and berries. Gradually, the exploitation of living resources has developed from subsistence of local communities to large scale economic enterprises in a global market economy. We have also witnessed the development of other major economic endeavours, and

the total gross domestic product of marine industries, which includes fisheries, maritime transport, marine tourism, oil and gas exploitation, etc., has recently been estimated at

1 trillion ($10^{12}$) US$. This sounds like a lot of money, but it amounts to only 4% of the global Gross Domestic Product and the interested citizen might therefore ask why scientists make all this fuss about the ocean.

The answer lies in the distinction between the marketable and the non-marketable value of the ocean resources. Ecological economists have made thorough studies of the value of the natural capital and the ecological services provided by global ecosystems (Costanza *et al* 1997). Clearly, all of those services are not provided by the marine ecosystems, an example being pollination, and for other services there is a lack of data. It is noticeable (Table 1) that the value of nutrient cycling in estuaries, sea grasses and algal beds was estimated at about US$20,000/ha/yr, while the highest value of any terrestrial ecosystem service, US$7,000/ha/yr, was waste treatment in coastal systems such as tidal marshes and mangroves.

Table 1. Estimates of the global value of annual ecosystem services in 1994 (based on Table 2 in Costanza et al (1997))

| Biome | Area (million ha) | Total value per ha ($US/ha/yr) | Total global flow value ($US billion/yr) |
|---|---|---|---|
| **Marine** | **36 302** | 577 | **20 949** |
| **Open ocean** | **33 200** | 252 | **8381** |
| **Coastal** | **3 102** | 4 052 | **12 568** |
| Estuaries | 180 | 22 832 | 4 110 |
| Seagrass/Algae belts | 200 | 19 004 | 3 801 |
| Coral Reefs | 62 | 6 075 | 375 |
| Shelf | 2 660 | 1 610 | 4 238 |
| **Terrestrial** | **15 323** | 804 | **12 319** |
| **Forest** | **4 855** | 969 | **4 706** |
| Tropical | 1 900 | 2 007 | 3 813 |
| Temperate/Boreal | 2 955 | 302 | 894 |
| **Grass/Rangelands** | **3 898** | 232 | **906** |
| **Wetlands** | **330** | 14 785 | **4 879** |
| Tidal Marsh/Mangroves | 165 | 9 990 | 1 648 |
| Swamps/Floodplains | 165 | 15 580 | 3 231 |
| **Lakes/Rivers** | **200** | 8 498 | **1 700** |
| **Desert** | **1925** | 92 | **128** |
| **Tundra** | **743** | | |
| **Ice/Rock** | **1 640** | | |
| **Cropland** | **1 400** | | |
| **Urban** | **332** | | |
| **Total** | **51 625** | | **33 268** |

Considering in addition the size of many marine biomes it is not surprising that the estimated total value of ocean and coastal ecosystem services is impressive

indeed: nearly 21 trillion US$, which is 63% of the value of the estimated total global ecosystem services or 21 times more than the ocean GDP.

Obviously, the uncertainty in such estimates is very high, but according to the ecological economists, improvements in data and methodology will probably result in even higher values of ecosystem services. And this is what the role of the ocean in the life support system of the globe is all about! Any major disruptions in the marine environment and its resources will have direct effects on the value of the ocean natural capital and ecological services, which can be demonstrated to economic and political decision-makers in units that they can appreciate. I may be over-optimistic and naïve, but I believe that increased awareness to this fundamental role of the ocean in the global life-support system will lead to a more rational ocean oriented behaviour, which will need the support of ocean science and technology.

## b) The role of ocean science and technology in global socio-economic development

It is an historic fact that only a small number of nations have had the economic and political strength to benefit fully from exploiting the wealth of the ocean. The majority of the population of the world are deprived of this opportunity, and even in our time the gap between the rich and the poor is widening. Between 1960 and 1991 the disparity between the richest 20 percent and the poorest 20 percent of the world population doubled (Anon 1997). This inequity is (or at least should be) a major item on the international political agenda, but it is also a significant barrier to further progress in marine sciences. I have throughout this presentation used the term "ocean" in singular rather than the plural "the oceans" in order to emphasise the contiguous nature of the ocean, which has major implications for marine science. Environmental protection of the free-flowing water masses and sustainable use of free-swimming living resources foster co-operation among neighbouring states, and in the case of long distance pollution and highly migratory living resources co-operation is required also among states that are not geographically close. But there is also another reason for strengthening international co-operation in marine sciences: as the physical and bio-geochemical processes are essentially the same everywhere in the ocean, only modulated by regional historic and climatic differences, scientific observations and results have a universal validity. Good experiments on double diffusion are equally interesting for a German scientist if the experiments were carried out in the Philippines or in France. This does not reduce the value of regional scientific co-operation, but one must take care that the regional emphasis does not lead to provincialism.

The value of scientific co-operation is dependent upon a reasonable equity in scientific competence among states, but in spite of spectacular progress in many developing countries, there is still a distinct scientific disparity. One possible parameter for measuring scientific capacity might be number of marine scientists. On the basis of the very useful directories of marine scientists published by FAO and IOC I tried to show how the number of marine scientists varied among groups of states (Lie 1990). The countries are grouped into the ten countries among the MDCs and LDCs with the highest number of marine scientists, and the number of marine scientists among the remaining countries of the two categories of developmental stage (Figure 1). As expected, the ten major MDCs had by far the highest number of

scientists, and the gap is widening in agreement with the fundamental law: nothing succeeds like success! Considering length of coast line, dependence on marine resources and population size in the LDCs, the inequity demonstrated in the graph is perhaps worse than indicated. On the other hand, it is interesting to note that the "remaining LDCs" had the highest growth rate in number of marine scientists. The graph is based on data up to 1983, but since then there has been significant development and economic growth in many LDCs, which probably also will show in the new directory of marine scientists of the world presently under preparation.

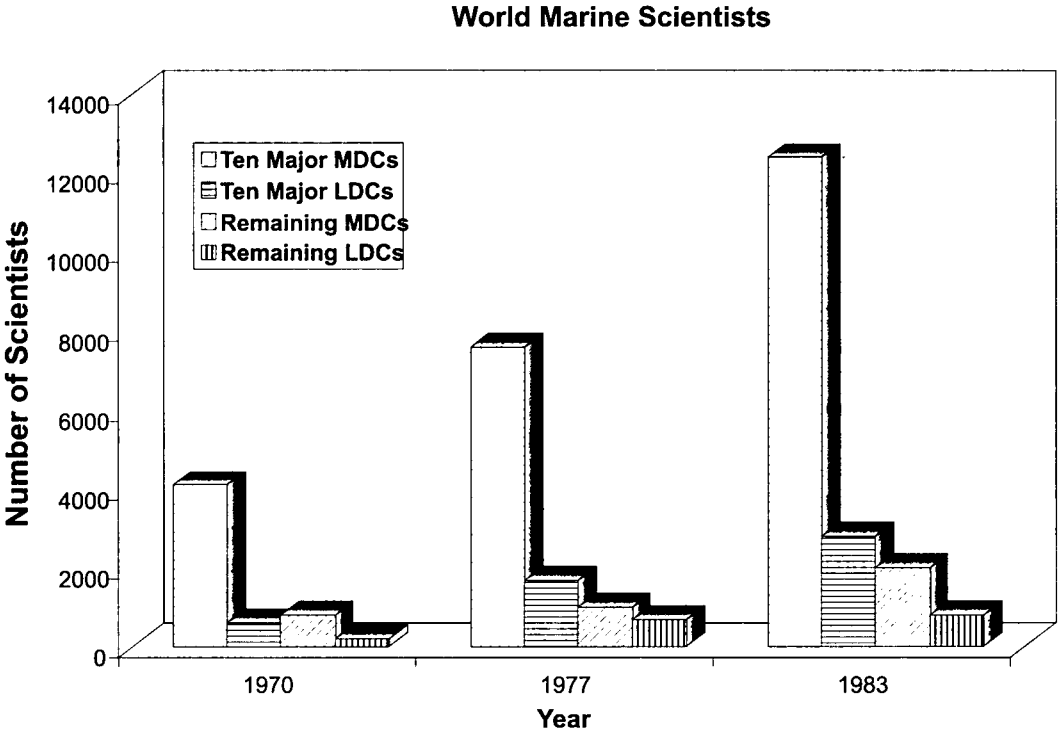



Figure 1. Number of marine scientists in More Developed Countries (MDCs) and Less Developed Countries (LDCs)

Considering the vast untapped intellectual resources in LDCs I therefore believe that we will see major contributions to marine science from developing countries in the near future. It is in the interest of science that this development be speeded up by technical assistance programmes and international scientific partnership.

In order to achieve a balanced, just and sustainable development of the ocean environment and its resources, the world community must develop mechanisms for ocean governance at national, regional and global levels of organisation by consideration of the following:

# a) Improved legal framework (UNCLOS)

The 1982 United Nations Law of the Sea Convention (UNCLOS) was a major step forward in the direction of a more equitable utilisation of the resources of the ocean. The 200 nautical miles Exclusive Economic Zones have placed the resources and the environment of about 25% of the surface area of the ocean under national jurisdiction. 90% of the fishery of the world takes place within the EEZs. In principle, this should improve the possibility for sustainable management of the resources, as coastal and island states have exclusive *rights* to the resources, but in the convention rights are linked to *responsibilities*. It remains to be seen if states are prepared to restrict their economic exploitation of national resources under the constraints of the concept of sustainability. Such rational behaviour must be underpinned by solid scientific information.

UNCLOS has also regulated the right to free scientific research in the EEZs under the so-called Consent Regime. At first the scientific community reacted rather negatively to the bureaucratic and time-consuming mechanisms to obtain research permits, and warned that the consent regime might hamper the development of marine sciences. Lately this complaint is less discernible, perhaps because the improved scientific competence of coastal and island states has given ground for joint ventures also in scientific research.

While UNCLOS is strong on protection of the non-living resources in the sea-bed of the high seas, it is very weak on living resources. While there has been encouraging initiatives during recent years, such as the 1995 Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks and FAO's Code of Conduct for Responsible Fisheries, regulatory mechanisms similar to those existing for the non-living resources have not been established. Clearly, in the case of fisheries this will be very difficult because of an existing large industry and long traditions, but there are reasons to call attention to other aspects of life in the high seas which might prove more readily exploitable than the non-living resources. Here I refer to the genetic resources of the ocean, in which there now appears to be considerable economic interests. The feasibility of establishing regulatory mechanisms for those resources differ from fisheries in that the exploitation is in its infancy and there are no historic rights to consider. Therefore, perhaps the genetic resources of the high seas could also be declared the common heritage of mankind in order to avoid that exploitation again will be dictated by the unholy alliance of know-how, capital and navies.

# b) Adequate national and international institutions

Very few nations have developed an integrated marine policy. As a rule a number of ministries have sectoral responsibilities, often with very little co-ordination. As a result, it is not uncommon to see governments take different stands on the same issues in international fora, depending on which ministry has composed the delegation. The ministries have their own advisory bodies, but very few countries have cross-sectoral advisory bodies in which all relevant stake holders engaged in ocean affairs are represented. Such national institutions, often under the name National Oceanographic Commissions, are excellent mechanisms for integrating

science and technology with commercial and political national actors, and they can contribute significantly to development of an integrated national policy.

The situation on the regional scenes is not much better. There are effective regional institutions for co-operation such as the International Council for Exploration of the Sea for the North Atlantic region and Comission Permanente del Pacifico Sur for the western coast of South-America, but such organisations have a limited mandate and are therefore particularly suited for sectoral advice on policy matters. The planned European Agency for the ocean will therefore represent a major step forward towards development of an integrated European marine policy.

The situation on the global arena is perhaps even more confusing and disintegrated. The UN system has a number of organisations with responsibilities for ocean affairs, such as FAO, UNESCO, WMO, IMO, and UNEP. However, the mechanism for co-ordination among the respective organisations, the Inter-Secretariat Committee for Scientific Programmes Related to the Ocean (ICSPRO), has not been an effective institution, and it remains to be seen if the on-going reshuffling of the UN system will improve the present situation.

## c) Public participation

It is not my view that governmental and inter-governmental institutions have an exclusive role in ocean governance. In fact the success of governmental initiatives are dependent upon the perception of the value of the ocean by the general public, and such awareness can only be generated through active participation of non-governmental organisations and various citizen groups at all levels in the decision making processes. I am convinced that the general image of science would also be strengthened by the participation of scientists with other citizen groups, because it cannot be taken for granted that the general public has very high regards for science and its servants. Surveys of public opinion in Europe and North America have shown that public attitudes towards science and scientists are now profoundly ambivalent (Grove-White *et al* 1992). While the central role of science and technology in creating the course of modern industrial society is recognized, science has also been implicated in such societies' negative features. In popular western culture the scientific expert is often perceived as ingenious and powerful, but socially naïve and hence dangerous. If we assume for the sake of the argument that such conceptions are wrong, scientists would do well to engage in efforts to enhance the public awareness of the value of the ocean and thus imrove the image of science and technology in the general public.

## d) Ocean oriented educational system

It is despairing that the concern for the welfare of the ocean is so low, even in countries that to very large extent are dependent upon the resources of the ocean. I have noticed that the general public is much more concerned about the sad state of the rainforests and the fate of elephants and large cats than about the ocean environment and its resources. Why is it that there is so little concern for the ocean? Simply because the case of the ocean is weakly or not at all presented to the general public in mass media and in our educational systems. Take a look at the

schoolbooks of your children and see how many examples of scientific principles are taken from the physics, chemistry, geology and biology of the ocean, not to mention the role of the ocean in global economics.

Ocean science is multidisciplinary, and most issues in which ocean science has a role to play require an interdisciplinary approach. However, universities are basically uni-disciplinary in their structure, and marine sciences are as a rule taught in different university departments. The result is that scientists who will have to work together to solve challenging ocean problems, are lacking the proper cross-discipline interface for truly interdisciplinary scientific research. There are some encouraging developments in the direction of integrated marine science education in a number of countries, but universities are as a rule rather conservative institutions which resist change from the existing structures.

I realise that my talk has not exactly been scientifically challenging, but I have tried to point to certain economic and political areas of ocean affairs that may have positive or negative consequences for the conduct of marine science. Ocean exploration and rational exploitation of its resources are, as for another major common, the outer space, totally dependent upon science and particularly technology. By taking a more active attitude towards developments in ocean economics, politics and law, the scientific community will ensure that decision makers have at their disposal the best scientific advice, which in turn will strengthen ocean science and technology.

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# Conclusions of the Panel discussion Final session

*Pierre Papon, Ecole de Physique et Chimie, Paris*

There is widespread agreement that we certainly need new and better tools to win greater wealth from the exploitation of the oceans in a sustainable manner and to achieve more satisfactory and rational governance of the ocean. Marine science and technology can certainly help us to go in this direction but increasing the scientific and technological effort is certainly not sufficient. In accordance with Ulf Lie's comprehensive and inspiring views we must convince our fellow marine scientists that the future of ocean science and technology (in terms of financial means and of acceptance by the public) depends mainly on two factors: a) the excellence of the research which is achieved in our laboratories: we have to address the most challenging issues in the exploration of the unknown and answer to social needs; b) the public awareness of the importance of ocean affairs for our future.

This being said, it appears that we have reached five main conclusions during our panel discussion:

- It is necessary to enlarge our scientific agenda so as to undertake more integrative and interdisciplinary approaches of ocean issues, which have to be dealt with in a more global perspective.
- Technology should have the importance it deserves, particularly in relationship with the efforts which are needed to enhance the competitiveness of European marine industry and to open new perspectives for the society (new marine services for example). It is of utmost importance to avoid gaps between scientific activities and technological competence.
- We must conceive new types of organisations and institutions to manage better our ocean resources, our coastal zones and, more broadly, to achieve an effective governance of the oceans. In this perspective we must innovate in the manners we conceive our relations with the policy-makers, the ocean users and the public opinion in a kind of renewed legal framework. These new institutions should rely on the network of existing competencies in Europe and render feasible participatory modes of ocean users.
- An ocean oriented education system is certainly a prerequisite to increase the public awareness of the importance of issues at stake in ocean affairs. Scientists should involve themselves more deeply in the definition of the objectives and the programmes of this system.
- European co-operation in marine science and technology is certainly of utmost importance to achieve these goals. Exchange of experiences and information, common programmes, use of oceanographic vessels and large infrastructures, etc. are means to progress in this direction.

Lastly we must recognise that it is timely to promote a true European maritime policy and that in this perspective marine science and technology is a powerful tool to give it the vision of the future which it needs and to implement it. This is a challenge calling for a greater European co-operation for which the EU Marine Science and Technology Programme has laid the proper foundation. This conference has proved once more that MAST has succeeded in creating a lively community in marine science and technology in Europe, which is an asset for the future.

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