Vol. 4 No.3 30 September 2010

INTECOL e-Bulletin

International Association for Ecology

Global Forum

1

A Tribute to the Census of Marine Life (2000-2010)

Meeting Report

13

URBIO2010

Meetings & Congresses

14

1. The First International Conference on Pollution, Environmental Health and Sustainable Development

2. The 6th World Congress on Allelopathy

3. The 8th IALE World Congress

4. XI International Congress of Ecology

Global Forum

A Tribute to the Census of Marine Life (2000-2010)

Michael SINCLAIR[a], Serge M. GARCIA[b], and Meryl J. WILLIAMS[c]

[a] Bedford Institute of Oceanography, P.O. Box 1006
Dartmouth, N.S., B2Y 4A2, Canada
E-mail: Michael.Sinclair@dfo-mpo.gc.ca
[b] Former FAO, Via Perdasdefogu 14, 00050 Aranova (Rome) Italy
E-mail: garcia.sergemichel@gmail.com
[c] 17 Agnew Street, Aspley, Qld. Australia 4034
E-mail: meryljwilliams@gmail.com

INTRODUCTION: FROM LONE SCIENTIFIC HEROES TO A COMMUNITY

During the 19th century there was a grand tradition of global expeditions to discover the diversity of life, terrestrial but also marine. The voyage of the HMS *Beagle* from 1831 to 1835 is today the best-known example, as in 2009 there were extensive worldwide celebrations of the bicentenary of Charles Darwin's birth and the 150th anniversary of his publication of *"On the Origin of Species"*. Other British examples, involving close friends of Darwin, are the Antarctic explorations in 1836 on the HMS *Erebus* (Joseph Hooker), the survey of the Great Barrier Reef on the HMS *Rattlesnake* (Thomas Huxley), and the expeditions to Brazil and the Malay Archipelago by Alfred Russel Wallace from, respectively, 1848 to 1852 and 1854 to 1862. In this era of exploration, the accomplished naturalists on extended voyages became heroes of their generation; and the general public followed the adventures with anticipation and excitement. Publications on taxonomic discoveries and on the personal adventures were best sellers.

In the mid to late 20th century the focus shifted away from expeditions on global biodiversity; and, with perhaps the exception of expeditions such as those by the R.V. *Dr Fridtjof Nansen* and other vessels surveying potential fisheries resources, more emphasis was directed to the study of ecological processes. However, thanks to the vision, leadership, and generosity of the Alfred P. Sloan Foundation and the efforts of the various institutions it mobilized worldwide, after 10 years of marine expeditions and associated work on biodiversity a truly global 21st Century "Census of Marine Life" (CoML) (www.coml.org) comes to fruition. In contrast to the initiatives of the 19th and 20th centuries, this Census has been undertaken by a large community of about 2,000 international scientists working together in a common endeavour, with none of the scientists being household names. That said, just as was the case in the mid-19th century and thanks to the very effective communication strategy of the projects, the general public has been fascinated by the stories, discoveries, and stunning images produced and "instantly" diffused by the research activities of CoML through the modern and traditional media of websites, "YouTube" and newspapers - in addition to the conventional journals and books. The intellectual tradition of enduring devotion to science that characterized expeditions and follow-up work of Darwin and his colleagues during the "age of heroes" is being maintained by the modern "Census community".

Despite the bygone centuries, CoML shares many other striking similarities with the earlier endeavours. The diverse expeditions have generated exciting new discoveries on the beauty and complexity of life in the oceans, as well as innovative ideas to interpret the observed patterns. There is, however, a major difference in the implications of the 19th and the 21st century observations. The biodiversity of Earth, including the oceans, is experiencing what has been called the "sixth major extinction event" since life itself evolved. We have entered into what has been defined as the "anthropocene", in which human influence is significantly impacting all ecosystems (Crutzen and Stoermer 2000). Because of the dramatic and disturbing impact of our collective societal activities on global biodiversity there is an urgency to manage them properly. Therefore, in addition to the joy of discovery that the Census community still shares with Darwin, Hooker, Huxley and Wallace, the results of the 2010 Census are critically important to society because of their potential application to management. In this essay, we explore how the Census results are being, or could be, used in marine policy and management, with a focus on fisheries.

CHANGING NEEDS: FROM A UTILITARIAN TO AN ECOSYSTEM APPROACH

Even though one of the major objectives of marine research at the turn of the 20th century was to facilitate and guide the expansion of fisheries and to understand the fluctuations of fish stocks - a focus still of interest today - it was very early on suspected and then recognized that overfishing was a serious threat to the sector's prosperity (Rozwadowski 2002). For example, in 1902 when the International Council for the Exploration of the Sea (ICES) was created, a major focus was on overfishing of flatfish in the Southern North Sea. An Overfishing Committee was established to direct research of the member countries, under the leadership of Walter Garstang, an Englishman, and then Frederick Heincke, a German - two very distinguished ecologists. From these early studies in European waters, coupled with initiatives predominantly on the west coast of the USA and Canada (e.g. by William Thompson [an American] and Bill Ricker [a Canadian]), the agenda for marine research in support of fisheries was well established by the mid 1950s. The focus was mainly on the species targeted by the diverse fisheries, with the management goal of maximizing the harvest in a sustainable manner. The tools for management, to a large degree, involved regulations of gear (e.g. mesh size) and restrictions on the number of boats (e.g. number of licences), and the location and time of fishing (e.g., spawning closures). Later on, restrictions on annual catches by management area were also established. The scientific needs of fisheries management were, in relative terms, ecologically narrow, focussing on fish populations rather than ecosystem dynamics. The research undertaken, to a large degree, appeared to meet the demand, especially as fishing pressure had not yet reached its most damaging intensity.

In the latter half of the 20th century, a series of global happenings and observations challenged the narrow focus of fisheries science. Some fisheries collapsed, creating a long trail of negative social and economic consequences; marine ecosystems shifted in their species compositions; climate variability and change affected fish distributions; different fisheries seemed to interact with each other; and some species were feared to be in danger of extinction. For several decades, these observations and considerations sent early warnings that changes in the scope of management were warranted and that broader multidisciplinary research programs were required for their support. One well-documented early warning and response was the decline of the Californian sardine fishery from its peak in the 1930s. Alarm over the decline led to an early forerunner of the broader approach. The California Cooperative Oceanic Fisheries Investigation

(CalCOFI) programme was established in 1949 under the leadership of Harald Sverdrup, and has just celebrated its 60th anniversary (http://www.calcofi.org/index.php). Finally, a new (or extended) fisheries science and management paradigm began to emerge (McLeod and Leslie 2009).

The changes involve two nested concepts: Integrated Management (IM) and an Ecosystem Approach to Management (EAM). The first promotes cross-sectoral integration, while the second specifies the objectives and constraints under which IM should be implemented for broader environmental and societal benefits. Competing uses of ocean space have increasingly led to conflicts within and amongst industry sectors (fishing, aquaculture, recreation, tourism, waste disposal, oil/gas extraction, transportation, and seafloor cables). As a consequence, a pressing need for IM of ocean-related industries emerged, first in the coastal zone. The 1992 United Nations Conference on Environment and Development (UNCED) called for clearer allocation of space and resources to optimize overall economic performance and reduce conflict and externalities, a parallel concept with such initiatives as city and land use planning. IM governance in the oceans, although very challenging given the historical lack (and functional difficulties) of cross-sectoral institutions and the complexity of property rights for mobile resources under multiple systems of jurisdiction, is under development. Early IM governance, such as that by the Great Barrier Reef Marine Park Authority established in 1975 in Australia, are now being joined by, for example, marine spatial planning movements in Europe.

The second concept underpinning this new paradigm is the articulation and implementation of comprehensive ecosystem conservation objectives for the aggregate ocean-use activities within an IM regime. Piecemeal management of the respective sectors in relation to their narrow objectives has led to environmental degradation threatening sustainability [see the Global Environment Outlook of UNEP (2007) and the Millennium Ecosystem Assessment (2005)]. This calls for managing sectoral human activities with respect to their intrinsic socio-economic objectives and the wellbeing of the ecosystem and society as a whole. This concept has been defined as "EAM". When the objectives are restricted to the fisheries sector only, the acronym becomes "EAFM". For simplicity the acronym EAM will be used in this essay to cover both activities.

The legal frameworks for both IM and EAM have evolved during the past two decades, both nationally and internationally. In fisheries, at the international level, important developments include the 1992 Agenda 21 of UNCED, the 1992 Convention for Biological Diversity (CBD) , the 1995 Food and Agriculture Organization (FAO) Code of Conduct for Sustainable Fisheries, the 2001 Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem, and the 2002 World Summit for Sustainable Development (WSSD). Regional and national examples are the 2009 European Union Marine Strategy Framework Directive, the 1997 *Oceans Act* in Canada, and the 1998 *Oceans Policy* in Australia. Each of these legal instruments addresses in varying degrees the obligations of maritime nations to conserve biodiversity, as well as additional ecosystem features in the face of human exploitation and use. Furthermore, retailers and consumers of seafood are a new and potentially strong driver of change in fishing industry practices through responsible sourcing policies and eco-labelling. The Marine Stewardship Council (http://www.msc.org), for example, includes conservation of ecosystem features as one of three pillars in the process of industry accreditation.

The recent paradigm shift in marine management includes a new focus on the protection of biodiversity, and thus a need for involving a broader range of biodiversity and ecological science in support of policy. The implementation of the legal obligations involving EAM is a hot issue at the national level within both the scientific and management communities. Indeed, both the marine scientific and management elements of EAM call for greater knowledge than that currently available. The Alfred P. Sloan Foundation's identification (in the late 1990s) of marine biodiversity as a field of research requiring fresh attention was indeed prescient. The 2010 Census is important to the implementation of diverse ecological aspects of EAM.

EAM AND THE "CENSUS"

The EAM requires regulating human activities in order to maintain a productive and healthy ecosystem in the future. In practice, however, the task is difficult, the approach is perceived differently by different people, and the intervention choices are often compounded by large knowledge gaps. Our understanding of the structure and function of marine ecosystems is fragmentary; the explanations of observed major changes are often both controversial and limited; and governments can be unwilling to act with caution when there is considerable uncertainty. As a result, some ecologists and parts of the interested lay public have a healthy scepticism toward

EAM, that they see as a "pipedream" that is not achievable given the present limits to knowledge and the difficulties of scientific observation, resource allocation, and fisheries control in the ocean. Sceptics argue that as the narrow conservation objectives of extant regimes, such as single-species fisheries management, have been less than successful in many cases, how can one realistically anticipate that a more complex set of conservation objectives can be met? Others point out, however, that addressing effectively the narrow traditional goals of fisheries management would go a long way to meeting the goals of EAM. Despite the differences in perspective, essentially all of the participants in the ongoing dialogue agree that conserving marine ecosystem structure and function is not only laudable but vital, and that the present conservation outcomes of fisheries management are not being met. As defined by FAO (FAO 1995) EAM evolves from existing practices and includes a broadening of the conservation objectives to cover both human and ecosystem wellbeing. The changes in management under EAM indeed are complex but all agree that greater knowledge is required to achieve progress. With this in mind, we illustrate how the Census results can contribute under two interconnected themes: 1) the broadening of conventional conservation objectives of sectoral management plans such as those for fisheries, and 2) the enhancement of scientific support for emerging oceans policy issues.

Presently, most fisheries management regimes include conservation of the target species of the respective fisheries. Under EAM the conservation objectives are broadened to include productivity of non-target species and trophic levels, impacts on biodiversity at the three hierarchical levels defined by CBD (the population/genetic level, the species level, and the community/seascape level), and critical habitat features within the area of fishing activity (e.g. O'Boyle and Worcester 2009).

The biodiversity overarching conceptual objective could be stated as: In order to preserve the structure and natural resilience of the ecosystem, do not cause unacceptable reduction in biodiversity. The problem is in defining what is "acceptable". In addition, interpreting that objective with respect to the three hierarchical levels of biodiversity mentioned above requires agreement on, and practical definitions of, operational objectives and strategies. Then for each strategy there is a need for one or more indicators that can be tracked efficiently, as well as a reference point (or direction of change) that triggers management actions. The results of the 2010 Census are important for both the definition of indicators of biodiversity trends and associated reference points.

Closer looks at strategies that are associated with the conservation of biodiversity illustrate the nature of the management actions, and the links to ecosystem attributes being conserved (e.g. Gavaris 2009). The Gulf of Maine is one of the more productive fishing areas of the global oceans, and this area has been the focus of a CoML project (Incze et al. 2010). A key goal of the project has been to provide the science needed to deal with future management issues. Examples of tentative strategies developed for Georges Bank in the Gulf of Maine and that address the three hierarchical levels of biodiversity defined by the CBD (see above) are (Gavaris 2009):

- manage the area of disturbed bottom habitat (seascape diversity),
- control incidental mortality of all non-harvested species (species diversity), and
- distribute mortality of population components in relation to their relative biomass (population diversity).

Examples of the application of CoML results to each strategy illustrate the expanding information needs of EAM compared to the extant traditional approach. The first of the above-noted strategies addresses the community (or seascape) level of diversity. To manage the area of bottom habitat disturbed, one needs a map of the spatial pattern of seascapes. This is tricky given the challenge of sampling the sea floor in sufficient detail to define realistically the spatial patterns. The Gulf of Maine Area (GoMA) project, in collaboration with researchers working on the Great Barrier Reef in Australia, has developed an innovative approach to habitat mapping using physical surrogates which can be measured or modelled at a sufficiently high spatial resolution (Pitcher et al. 2007). Given that fishing can be spatially identified with seascape type, annual disturbance by fishing gear by seascape can be used as an indicator for this management strategy. The definition of a limit reference points (i.e. the level beyond which the fishing or other ocean-use disturbance within a seascape is considered to be excessive) is a challenge. Different seascapes are more or less resilient to diverse disturbances. A simple reference point, in the absence of an understanding of the function of critical habitat, could be a maximum allowable aerial percentage of each seascape type to be disturbed. Fragile three-dimensional living features, such as deep-sea corals, may be able to sustain little or no fishing gear disturbance whereas tidally energetic sand waves could allow a high percentage of the area to be disturbed. The definition of these caps, or reference points, is a societal decision; but the results of CoML projects addressing the benthos provide required technical information on the geographic extent of seascapes and necessary clues to their resilience (Baker et al. 2010, Consalvey et al. 2010, Ebbe et al. 2010, Menot et al. 2010)

The second of the above-noted strategies addresses the species level of diversity. In the Gulf of Maine, a number of vulnerable species are of particular concern because their numbers are now very low (e.g. right whale, porbeagle shark, barndoor skate, cusk). Several of these species are formally listed as being at some level of species survival risk. The indicator for the EAM strategy of controlling "incidental mortality of all non-harvested species" is the number caught (size and sex) by geographic area. The reference points for management actions are based on the recovery strategies and associated "allowable harm" limits. The data management system at the heart of the Census, the Ocean Biogeographic Information System (OBIS) (Vanden Berghe et al. 2010), provides ready access to global data sets on vulnerable species of this type and the information required to define evidence-based reference points (e.g. Ricard et al. 2010). The history project of CoML (Holm et al. 2010) is also particularly valuable in this respect. The project has reconstructed the likely historical abundance levels of key resources, based on interpretation of data sets on early periods of marine fisheries, providing an improved objective base for establishing targets for species recovery (e.g. Alexander et al. 2009; Rosenberg et al. 2005).

The third strategy addresses the conservation of population/genetic diversity. The fisheries management approach in this case is to distribute fishing mortality across population components of the target (and non-target) species in a relatively even manner. In the Gulf of Maine area there had been a reasonable understanding of the population richness for many of the commercially important species (e.g. cod, haddock, herring, and scallops) prior to the initiation of CoML. That said, the tools developed during the past decade, such as low-frequency acoustics for estimating the large-scale distribution and abundance of pelagic species (Makris et al. 2006; Makris et al. 2009) and tagging technologies (Payne et al. 2010, Block et al. 2010), have enhanced the capacity to track the abundance of population components of commercial species and thus will provide improved indicators for this strategy in the coming decade.

The pragmatic approach to EAM illustrated above has legitimately been criticized. In a piecemeal fashion, the strategies address diverse components of ecosystems (of which only some biodiversity features were outlined above). The critics lament that the framework is not sufficiently holistic and it does not include the emerging concept of "ecosystem services" beyond the services rendered to fisheries, i.e., food production. The critics ask: where is the "ecosystem" in this minimalist EAM framework? The relatively simplistic inclusion of indicators and reference points that constrain fishing activities with respect to certain ecological features does not address a wide range of additional challenges to the fishing industry and society at large (e.g. invasive species, climate change impacts, contamination, other habitats degradations). Also, a new set of technical challenges arises as we transition from sectoral management to IM. Perhaps the most challenging of which is the thorny issue of how one addresses cumulative effects of diverse impacts on a specific ecosystem feature.

In summary, the incremental or pragmatic approach at the sectoral scale gets one started on the implementation of EAM, at the working level of fisheries management planning, with no formal action on other, non-fishery-related, impacts on "ecosystem services". The approach generates attention to a number of ecological issues (e.g. reference points for disturbance of diverse benthic seascapes; definition of population richness of species in new fisheries for which there is limited knowledge) and offers an opportunity to deal with complex governance challenges within the fisheries sector and between it and other sectors. It is recognized as an evolutionary stage and a partial but valuable sectoral response within the more cross-sectoral management change required to meet the national obligations of recent legal instruments. The expectation is that we will learn both locally and globally by acting locally and that the fisheries example will lead to more cross-sectoral management frames.

In addition to the implementation of EAM, the Census results are being very useful in a wide range of marine policy issues. A few such issues are considered next.

THE CENSUS CONTRIBUTION TO OCEANS POLICY

The Census results are relevant to a wide range of economic and social sectors and the conservation needs of particular ocean realms. The comprehensive nature of the Census work, across all realms, oceans and from pole to pole, delivers strong synoptic power to policy and decision makers wishing to understand global, regional and national contexts for ocean marine life conservation and use, as the following examples illustrate.

Global Trade of Marine Species

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments aimed at ensuring that international trade in specimens of wild animals and plants does not threaten their survival. With the recognition of the high pressure exerted by fisheries on ocean resources, and of the growing risk of extinction of the more vulnerable species, CITES has started stepping into the fishery management arena. Their involvement adds to the conventional arsenal of measures to control removals and fishing pressure. A control on international trade can be implemented in cases when the depleted species is recognized as threatened.

Considering that approximately 50% of the total fishery production is traded internationally, and that approximately 25% of the fish stocks are severely depleted (according to FAO), the potential role of CITES is significant. The number of marine species presently listed by CITES includes most marine mammals, a few sea birds, a number of marine reptiles (mainly turtles), some sharks (basking, whale, and great white sharks), a sawfish (*Pristic microdon*), some sturgeons (*Acipenser* spp.), the coelacanth (*Latimeria* spp.), the eel (*Anguila anguila*), the sea horse (*Hippocampus* spp.), the date mussel (*Lithophaga*), and one sea cucumber (*Isostichopus fuscus*). None of the major finfish species has been listed yet. However, the intense negotiation and lobbying undertaken in 2009-2010 to list the bluefin tuna (*Thunnus thynuus*), even though unsuccessful in this attempt, may be the first of a long series to add CITES trade controls to conventional management action for depleted species.

CITES controls involve a complex procedure of listing species with reference to three appendices, according to the degree of protection they need. "Appendix I" includes species clearly threatened with extinction, the trade of which is banned or permitted only in exceptional circumstances. "Appendix II" includes species which may not necessarily be threatened with extinction, but could be so if their trade is not controlled to avoid a level of utilization incompatible with their survival. Their trade is possible only with certification and permits. "Appendix III" contains species that are protected in at least one country, which has asked other CITES parties for assistance in controlling the trade. The big issue is generally whether a species should be listed or not and, if yes, whether it should be listed in Appendix I or II. Considering the important immediate social and economic consequences of a listing by CITES, particularly under Appendix I, the listing process (which originates in a proposal by one or many CITES members) is a difficult one in which the scientific evidence, advocacy groups, and political games play an important role.

Underpinning this process is also a global and heated debate on the respective mandates and objectives of fishery management institutions (ensuring sustainable use) and CITES (preventing extinction). The roles are obviously convergent and complementary, but the debate relates to the level of risk at which CITES intervention in the management process becomes legitimate and the likely technical efficacy of trade restrictions, as well about the real capacity of CITES to enforce trade controls in the ocean in the case of highly valuable fishing activities. The conventional fisheries management reference values (e.g. for minimum biomass limits) are much more stringent than CITES values. The fact remains, nonetheless, that fisheries management is ineffective in many areas and that the low level of some key stocks raises genuine concern regarding their risk of extinction. In addition, where there is no management organisation or where international trade derived from illegal fishing is a threat, CITES trade measures could be useful.

The CITES listing criteria refer essentially to population (size, structure, variability, life history), geographical distribution (range, degree of fragmentation, and variability), habitat (quality and quantity), and to the degree of decline in these criteria, whether observed, inferred, or projected. In addition, the "look alike" provision allows CITES to also control the trade of species that resemble a formally listed species (in the case that it cannot be distinguished, or when a species is a member of a taxon of which most species are already listed). The CITES criteria, developed for terrestrial animals, are however not totally adequate for abundant marine species. As such they could trigger CITES action too early or too late depending on the species concerned, and its exploitation context. Debates are indeed ongoing to adapt CITES criteria to the reality of ocean populations. It is in that perspective that the work of the Census is very useful.

A fundamental aspect of the CITES process is the correct identification and naming of the species proposed for listing. In this respect, OBIS (Vanden Berghe et al. 2010) provides support to the taxonomists of the world (federating, validating, organizing, providing access and mapping the information they produce on species names). Having the back-up of an authoritative source like OBIS is of value in any listing proposal. Furthermore, in the case of species for which confusion in identification is possible, the genetic techniques developed in the marine barcode of life project, affiliated to the CoML

(.http://www.marinebarcoding.org) are an important tool (see Radulovici et al. 2010 for example).

Geographical distribution of the species, and the distribution of its various populations (or stocks), are also fundamental. Both in conventional fishery management and in conservation, understanding the fish distributional range, the structure of that distribution (nurseries, feeding areas, etc.), and the movements within the range (migration highways) is vital. Conventional fishery data and scientific surveys have been providing such information for several decades. However, the recent progress in electronic tagging of marine animals of a wide range of sizes [made in the Census projects on Tagging of Pacific Predators (TOPP) (Block et al. 2010) and the affiliated Ocean Tracking Network (OTN) project [http://oceantrackingnetwork.org/] have enhanced our capacity to describe fish distributions. These tags are able to register both the external environment of the animal (geographic position, pressure, light, temperature), as well as its internal condition (e.g. body temperature). The information can be transmitted either when the tag itself is recovered (in the case of archival tags recovered on fish after capture), or when the automatically released tag comes to the surface to radio its information to satellites (in the case of pop-up tags). The information can also be recovered (e.g. in the OTN project) when the tagged fish passes by a listening device (moored, carried by a ship, or by an autonomous underwater vehicle). Future developments address the capacity for data to be passed from one tagged fish to another as they meet (the so-called exchanging of “business cards” at sea) facilitating future data recovery. These new technologies have generated very useful information about the sources of mortality in Pacific salmon (Payne et al. 2010) and the movements of large predators in the Pacific (Block et al. 2010). The methods have confirmed the suspected separation of the Atlantic bluefin tuna into two distinct populations (with different reproduction areas, yet largely overlapping feeding areas), and have inferred the homing behaviour of this species (Rooker et al. 2008). This type of information has played a key role in the debates on the listing of the Atlantic bluefin tuna by CITES.

The decline criteria are central to the listing of a species. There is considerable debate about the degree of decline, and the size of the residual population at which listing can be considered. A key issue is the reference value used to measure the decline. A common practical reference point has been the highest abundance observed (or estimated from available fishery data). However, in many instances, exploitation had started decades or centuries before the development of fishery science and databases, and thus the risk of choosing a low baseline is significant. The use, within the Census, of innovative and unconventional methods to rebuild the past history of marine populations extends our vision into the past and provides more realistic estimates of historical baselines (Holm et al. 2010).

In addition, the decline criteria require a projection into the future in order to estimate the risk of extinction (that would be reduced by listing the species under Appendix II). The methods and approaches used in the Census project on the Future of Marine Populations (FMAP) are an asset in trying to see beyond the present horizon, anticipating on emerging risks (Worm et al. 2010).

The "look alike" issue is a tricky one in the ocean, as it could lead to unnecessarily barring very similar species or different populations of the same species from trade. The socio-economic consequences of this would most likely lead to serious opposition of the industry and governments, possibly weakening the action on the endangered population. Therefore, having a tool such as barcoding device (http://www.fishbol.org/; Ward et al. 2009) to distinguish effectively between very similar species and, possibly, between populations (e.g. between Atlantic and Pacific bluefin tuna) will be of help in difficult cases.

The effectiveness of CITES rests to a large extent on its capacity to regulate and control trade, and to detect illegal trade. The work of the BoL project of the Census has illustrated the fact that the name of fish species sold in restaurants can be incorrect (usually putting lower-valued products under higher-valued species names). This practice is thought to be widespread, and that the manipulation occurs at the restaurant level. It could, however, happen also during the trade process. Indeed, correct fish species identification is a key concern for wholesale fish buyers because of the important differences in price among similar-looking species. In the absence of an official norm for species names, taxonomic information systems like OBIS or FishBase become *de facto* the source of authoritative information. The temptation for fraud may be high, however, particularly when the price differential is high or when a species has been listed by CITES. The future application of the barcode technology coupled with databases of barcodes, e.g., FISHBOL, promoted by the Census will offer convenient instruments of control both to buyers and customs officers.

To the degree that fisheries management fails to sustain viable populations of exploited species, there will be a growing temptation to involve CITES and other listing processes such as the IUCN Red List to strengthen the mechanisms for sustainable use and the conservation of biodiversity. The potential to increase the listing of marine species is high, particularly for species in a vulnerable position because of: 1) their life history; 2) their economic value; or 3) the jurisdictional difficulty affecting their control. More large predators (tunas, sharks) and deep-sea fish (such as orange roughy) may be considered in the coming decades. Regarding fish species in deep-sea ecosystems, the work of the Census on coastal margins (Menot et al. 2010), the Mid-Atlantic ridge ecosystem (Vecchione et al. 2010), and seamounts (Consalvey et al. 2010) are laying the foundations for the future monitoring and protection of particularly vulnerable species that may be harvested from these relatively remote ecosystems in coming decades.

World Summit for Sustainable Development (WSSD): target of reduction of biodiversity loss

The 2002 Johannesburg Plan of Implementation of the World Summit on Sustainable Development established a number of ambitious conservation targets, and called for the investment of new resources to significantly reduce, by 2010, the rate of loss of biological diversity. Complementary targets for reducing overfishing, rebuilding stocks, and establishing Marine Protected Areas (MPAs) were also adopted. While very few if any species targeted by fisheries have become globally extinct, many local populations have reached the level of economic extinction, and some populations have been eliminated during the developmental phases of fisheries.

To track progress towards the 2010 Johannesburg biodiversity target, a set of indicators have been developed through the Convention on Biological Diversity (CBD) processes. Few of these indicators substantively cover marine biodiversity, and even fewer are specific to the "fishery biodiversity". The latter category includes all the species targeted, or potentially targeted in the future, by fisheries together with their associated and dependent species, as provided by the 1982 UN Law of the Sea. The implication is that the "fishery biodiversity" includes the species involved in the food chain that are directly or indirectly affected by fishing. The indicators are now under review, but marine biodiversity continues to receive little attention (and as such has the potential to be left out of global management concerns and action).

The synthesis of Census results will effectively "rewrite the book" on marine biodiversity across ocean realms, across time, from top predators to microbes and in the interstices of apparently well-studied ecosystems such as coral reefs. This "new book" will contain the seeds of future concepts underpinning new indicators that are needed to track the status of biodiversity in the oceans. It will facilitate answering a wide range of questions on how best to track marine biodiversity trends. In the interests of monitoring fishery biodiversity trends, indicators that are directly policy relevant are the priority. Indicators based on fishery data are a major focus at present, but indicators independent from fishing will provide additional perspective and identify potential biases in fisheries data. The policy focus on indicator systems is a very positive development, but a less utilitarian approach is needed. A broader range of indicators that track marine ecosystem integrity, especially in the face of a changing climate, is required. This is illustrated by considering three fisheries questions that could be asked in the face of climate change:

1. How should fisheries management and fishers prepare for and respond to large-scale natural and human-induced structural changes in ecosystems and their biodiversity?
2. What are the implications to fisheries management and fishers of large-scale natural or climate change-related modifications in the composition and distributions of commercially important species?
3. Can the impacts of climate change on the distribution and productivity of exploited species and their habitats be predicted? At what scale? With what precision? With how much lead time? What contingency plans might be needed?

The responses to these three questions imply knowledge on the complete life cycle of the species concerned with its external drivers, on the resilience and adaptation capacity of the industrial and artisanal fisheries sub-sectors and it also implies a capacity to predict changes in the resource and marine biodiversity base. The Census synthesis will partially address the challenge of tracking changes in marine resources and biodiversity by providing a new biogeography of the oceans and an enhanced understanding of processes underlying the patterns. For example, the FMAP project of the Census has developed methodologies to predict the distributions of both commercial species and those of "special concern" (such as whales) based on temperature and habitat algorithms (Worm et al. 2010). Based on future climate change scenarios, the future species distribution maps can be modelled by such tools as OBIS and Aquamaps (a collaborative initiative with the Census) (www.aquamaps.org; Kaschner and Watson 2006, Kashner et al. 2007).

CBD: 2012 target for marine protected areas

CBD has set a 2012 target for the establishment of a comprehensive network of MPAs for the global oceans. As part of the process for implementation a biogeographic classification system has been prepared, as well as the definition of criterion for Ecologically or Biologically Significant Areas (EBSAs) that require protection. The seven criteria are:

- uniqueness or rarity
- special importance for life-history strategies of species
- importance for threatened, endangered or declining species and/or habitats
- vulnerability, fragility, sensitivity, or slow recovery
- biological productivity
- biological diversity
- naturalness

The criteria have been applied in a number of coastal and shelf seas areas. The Census has been particularly important in the process of identifying EBSAs in the 64% of the oceans beyond national jurisdiction. During a CBD workshop held in the autumn of 2009 the combination of mapping tools, new observations from the continental slopes to deep sea ecosystems, and OBIS data were applied (in an exploratory manner) to each of the seven criteria mentioned above. These illustrations provided a range of approaches to identifying sensitive species, habitats, and important oceanographic features. The illustrations used the results of Census field surveys extracted from OBIS, as well as data from a variety of sources (e.g. satellite tracking of tagged fish, remote sensing products on location of fronts and productive areas, and modelling approaches to predict ecological features). OBIS has been particularly instrumental at identifying best estimates of key high biodiversity areas, applying biodiversity indices to over 22 million geo-referenced species records and adjusting the comparative displays for data point intensity (Ardron et al. 2009).

The comprehensive Census approach, from surveys to model predictions, is proving to be essential to meeting the ambitious targets set by the Convention. Furthermore the easy access of information on biogeographical and oceanographic features on Google Ocean has been facilitated by the Census. The visual images of EBSAs, as they become defined by the international scientific community, as well as future MPAs in the deep oceans, will be experienced in a virtual sense by all.

Global Ocean Observing System (GOOS): the biodiversity component

GOOS has developed a comprehensive global monitoring strategy during the past two decades. They have been particularly successful with the oceanographic components, from the coastal fringe to the deep sea. The oceanographers and meteorologists have had a rich tradition of monitoring of climatic and oceanographic conditions (mainly physical and chemical variables) at the full range of scales from meso-scale features to ocean basins, as these are the appropriate dimensions for developing functional models and making predictions. A recent addition has been the incorporation of the ARGO float program to enhance observations from deep sea poorly sampled parts of the ocean.

Marine ecologists and fisheries scientists have, in contrast, mostly focussed on coastal and shelf seas conditions, as these have been the priority areas for addressing pressing management issues, and explaining the phenomena of interest. Particularly noteworthy in this respect has been the long series of shelf seas trawl surveys conducted in many regional seas for decades to identify fishery resources and monitor their evolution under fishing pressure. Thus, with the exception of a few components (ocean colour estimates of primary productivity, the Continuous Plankton Recorder lines, and the multi-species shelf seas trawl surveys), the ecological components of GOOS have been short-changed. Given the importance of climate variability, and the changing needs of oceans management, there is some urgency to enhance the biodiversity components of GOOS to the scale of the global oceans.

CoML has added considerable capacity to global oceans monitoring through the development of tools (Payne et al. 2010). The concept of electronic listening curtains across shelf seas has been elegantly developed for salmon (as a proof of concept) for the Eastern Pacific Ocean and subsequently expanded to the world oceans through OTN. The network of sea-floor listening beacons is generating the capacity to track movements of tagged individuals through narrow straits and along shelf seas. The tool allows monitoring of fish and marine mammal distributional properties and swimming behaviour (feeding, diving, and reproducing) in a way and at a cost that have not previously been possible.

The application of pop-up satellite tags, as used in the

Tagging of Pacific Predators (TOPP) project to define migration patterns and "hotspots" for such species as leatherback turtles and bluefin tuna (Block et al. 2010), are a second category of tools of great potential for global ocean monitoring. As well as allowing observations on fish migrations, the "biologging" allowed by these smart tags are collecting data on the physical properties of the water masses through which the tagged animals move (depth, light, temperature) and sometimes even on the body temperature. The information is relayed by satellites to oceanographic institutes by radio signals, in a cost-effective manner, and allows more accurate understanding of animal behaviour and of the surrounding ocean conditions. Surprisingly, more data on the physical properties of the oceans is now being collected by biologging with fish and mammals than by vessels and instrumented arrays at fixed stations. CoML has made timely contributions to these tagging tools at a time when the international community is defining a global monitoring program.

A major challenge in fisheries monitoring has been to estimate trends in abundance of schooling species such as herring, sardines, mackerel, and capelin. In contrast to groundfish, for which trawl surveys give a reasonable estimate of distributional changes in space and time, the monitoring strategies for these schooling species have relied on acoustics. Given the highly aggregated distributions, and the relatively rapid movement of the schools, there tends to be wide error bars on the estimates. CoML research has developed an innovative application of low-frequency acoustics that allows synoptic estimates to be made at very large spatial dimensions (of the order of 100 km). The methodology has been applied to herring on Georges Bank (Makris et al. 2006) and on the Norwegian Shelf (Makris et al. 2009). The method fills a major gap in monitoring strategies; but its cost has proven to be somewhat of a constraint to date.

Routine identification of species and accessible information summarising scientific knowledge are key challenges for oceans monitoring, given the sheer volume and diversity of the samples involved and the lack of expertise. The BoL addresses this challenge to some degree. This emerging technology allows routine identification of marine species using a genetic "barcode" which can be identified from a small sample of tissue. The codes are in the process of being verified by expert taxonomists. There are, as well, cryptic species that are very difficult to distinguish. A surprising recent example has been the discovery that the "at risk" skate in the Irish Sea is in fact two species (Dulvey and Reynolds 2009). Thus even in well-studied areas, such as European waters, the "barcoding" tool will be a great asset to future monitoring programs.

In addition to the creation of OBIS, the Census has also had a catalytic role in enriching the "e-biosphere", the growing set of Internet-based taxonomic resources that make available the knowledge from libraries, museum specimen collections and research institutes. For example, the Census helped create the Encyclopaedia of Life (www.eol.org), which aims to create species pages for each species of life and is working to ensure that a large share of named marine species will each have their page by the time the first phase of the Census is complete. The Census, through OBIS, also promoted the World Register of Marine Species (WoRMS, www.marinespecies.org), a taxonomic exercise to sort out and remove redundancies and queries among the estimated 230,000 named marine species.

CoML has generated added value to existing trawl surveys through OBIS, which aggregates the taxonomic data across space and time, allowing the elaboration of maps and time series and the extraction of data for diverse purposes beyond those of interest when the fish surveys were designed (e.g. Fisher et al. 2008). The impact of long-term climatic oscillations and change on biogeographic patterns can now be analysed using the OBIS data and interactive mapping tools. The explanatory power of OBIS applications will increase as further data is stored and becomes available for meta-analyses. The recent "adoption" of the OBIS programme within the International Oceanographic Data and Information Exchange (IODE) program of the Intergovernmental Oceanographic Commission is a very important step toward a better integration of the oceanographic and biodiversity data (increasing the heuristic power of both).

In summary, the improvement of tagging technologies, the support for the marine component of the BoL and other components of the e-biosphere, the development of low-frequency acoustical methodology for pelagic fish species, and the establishment of OBIS, is several tools that CoML has supported in a developmental phase, that are becoming key components of emerging monitoring activities. As such, the modern ecologists are now capable of complementing the visionary path of global ocean monitoring initiated by the oceanographers in the 20th century. The "adoption" of OBIS by the IOC and the recognition of CoML by the United Nations Assessment of Assessment (AOA) initiative (http://www.un.org/Depts/los/global_reporting/global_reporting.htm), are major moves toward improvement of biodiversity monitoring of the global oceans.

"A FULLER PICTURE", WITH EXPLANATORY POWER

In the final chapter of his book *The Voyage of the Beagle*, Charles Darwin states: *"The map of the world ceases to be a blank; it becomes a picture full of the most varied and animated figures"*. For the oceans, his conclusion of 1839 is even truer today, following the decade of discoveries of CoML. Furthermore, the images in our new "map of the marine world" are significantly changing our understanding of the oceans. Seeking understanding of natural phenomena has a rich history. Endersby (2009), in a delightful recent review article, addresses the interest by Joseph Hooker in being considered a "natural philosopher" rather than a "natural historian". The latter activity was considered in the 19th Century to be merely descriptive (involving cataloguing and naming, without necessarily explaining observed phenomena). In contrast, natural philosophy *"was the forerunner of the elite sciences, especially physics, which provided the model of those naturalists who wished to raise their discipline to comparable status"*. In this sense Hooker was seeking general laws to interpret global biogeographical patterns of plants, just as Darwin interpreted the patterns of classification of species by evolutionary theory.

The Census scientists, with this same spirit of the "natural philosophers" of the 19th Century, are seeking explanatory power on such issues as the role of diversity on ecosystem functioning and the physical basis of observed global biogeographical patterns. For several decades there has been theoretical and experimental focus on the role of diversity on productivity and stability of ecosystems. These relationships are perhaps the "holy grail" of modern ecology. However, evidence from the overall ecological literature is contradictory with respect to these general laws. The Census work by FMAP provides new promise. Through an innovative mix of meta-analysis of global data sets and modelling, it is concluded that reduction of diversity has led to lower productivity and less resilience for a wide range of marine ecosystems (Worm et al. 2010). Time will tell whether these emerging interpretations are robust. From understanding will come the predictions that are essential for the complex marine policy and management decisions at this critical period in the anthropogenic era of our "blue planet".

The findings of the 2010 Census are arriving just in time to further raise the awareness on the issue of conservation and sustainable use of marine biodiversity under EAM, in general in the oceans, and more specifically in fisheries. Through its support for the Census of Marine Life, the Alfred P. Sloan Foundation has reinvigorated the previously languishing field of marine biogeography and systematics, such that the known is richer and the knowable unknowns circumscribed and targeted (Snelgrove 2010).

REFERENCES

Alexander K.E., W.B. Leavenworth, J. Cournane et al. (2009) Gulf of Maine cod in 1861: historical analysis of fishery logbooks, with ecosystem implications. Fish and Fisheries 10:428-449.

Ardron J. et al. (2009) *Defining Ecologically or Biologically Significant Areas in the Open Oceans and Deep Seas: Analysis, Tools, Resources and Illustrations.* https://www.cbd.int/doc/meetings/mar/ewbcsima-01/other/ewbcsima-01-multiorgs-en.pdf

Baker M.C., E. Ramirez-Llodra, P.A. Tyler et al. (2010) Biogeography, Ecology and Vulnerability of Chemosynthetic ecosystems in the Deep Sea. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Block B.A., D.P. Costa, S.J. Bograd (2010) A view of the Oceans from Pacific predators. In McIntyre, A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Consalvey M., M.R. Clark, A.A. Rowden, K.I. Stocks (2010) Life on Seamounts. In McIntyre, A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Crutzen P.J., E.F. Stoermer (2000) The Anthropocene. Global Change Newsletter 41, 17-18. May 2000

Dulvey K.D., J.D. Reynolds (2009) Skates on Thin Ice. Nature 462:417.

Ebbe B., D. Billett, A. Brandt et al. (2010) Diversity of Abyssal marine Life. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Endersby J. (2009) Lumpers and Splitters: Darwin, Hooker, and the Search for Order. Science 326:1496-1499.

FAO (1995) Code of conduct for responsible fisheries. FAO. Rome (Italy): 41 p.

Fisher J.A.D., K.T. Frank, B. Petrie et al. (2008) Temporal dynamics within a contempory latitudinal diversity gradient. Ecology Letters 11:1-15.

Gavaris S. (2009) Fisheries management planning and support for strategic and tactical decisions in an ecosystem approach context. Fisheries Research 100:6-14.

Holm P., A.H. Marboe, B. Poulsen, B.R. MacKenzie (2010) Marine Animal Populations: A New Look Back in Time. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Incze L.S., P Lawton, S.L. Ellis, N.H. Wolff (2010) Biodiversity Knowledge and its Application in the Gulf of Maine. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Kaschner K., J. Ready, E. Agbayani, P. Eastwood, T. Rees, K. Reyes, J. Rius, R. Froese (2007) About AquaMaps: Creating standardized range maps of marine species. See http://fishbase.sinica.edu.tw/tools/AquaMaps/AboutAquaMaps.doc

Kaschner K., R. Watson et al. (2006) Mapping worldwide distributions of marine mammals using a Relative Environmental Suitability (RES) model. Marine Ecology Progress Series. 316: 285-310.

Makris N.C., P. Ratilal et al. (2009) Critical population density triggers rapid formation of vast oceanic fish shoals. Science 323:1734-1737.

Makris N.C., P. Ratilal, D.T. Symonds et al. (2006) Fish population and behavior revealed by instantaneous continental shelf-scale imaging. Science 311:660-663.

McLeod K.L., H. Leslie (2009) Ecosystem-based Management for the Oceans. Washington, D.C; Island Press, 368pp.

Menot L., M. Sibuet, R.S. Carney et al. (2010) New Perceptions of Continental Margin Biodiversity. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, D.C.

O'Boyle R., Worcester T. (2009) Eastern Scotian Shelf, Canada. In: McLeod K.L., Leslie H., editors. Ecosystem-based management for the oceans. Washington, DC: Island Press, p. 253–67.

Payne J., K. Andrews, C. Chittenden et al. (2010) Tracking the Movements and Survival on the Northeast Pacific Shelf. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Pitcher C.R., P. Doherty, P. Arnold et al. (2007) Seabed Biodiversity on Continental Shelf of the Great Barrier Reef World Heritage Area. AIMS/CSIRO/QM/QOPI Final Report to CRC Reef Research. 320pp.

Radulovici A. E., Archambault P., Dufresne F. (2010) DNA Barcodes for Marine Biodiversity: Moving Fast Forward? *Diversity* 2(4) 450-472.]

Ricard D., R.M. Branton, D.W. Clark, P. Hurley (2010) Extracting ground fish survey indices from the Ocean Biogeographic Information System (OBIS): an example from Fisheries and Oceans Canada. ICES Journal of Marine Science, 67:638-645

Rooker J.R., D.H. Secor, G. DeMetrio, A.J. Kaufman, A.B. Ríos, V. Tic˘ina (2008) Evidence of trans-Atlantic movement and natal homing of bluefin tuna from stable isotopes in otoliths. Marine Ecology Progress Series. 368: 231–239.

Rosenberg A.A., W. H. Bolster, K.E. Alexander et al. (2005) The history of ocean resources: modeling cod biomass using historical records. Frontiers in Ecology and the Environment. 3:84-90.

Rozwadowski H. (2002) The Sea Knows No Boundaries: A Century of Science under ICES. University of Washington Press, Seattle. 448pp.

Snelgrove P.V.R. (2010) Discoveries of the Census of Marine Life: Making Ocean Life Count. Cambridge University Press.

UNEP (2007) Global Environment Outlook GEO4. Environment for development. UNEP (Nairobi). http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf. :540 p.

Vanden Berghe E., K. Stocks, J.F. Grassle (2010) Data Integration: The Ocean Biogeographic Information System. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Vecchione M., O.A. Bergstad, I. Byrkjedal et al. (2010) Biodiversity Patterns and Processes on the Mid-Atlantic Ridge. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.

Ward R.D., Hanner R., Hebert P.D.N. (2009) REVIEW PAPER: The campaign to DNA barcode all fishes, FISH-BOL. Journal of Fish Biology (2009) 74, 329-356

Worm B., H.K. Lotze, I. Jonsen, C. Muir (2010) The Future of marine Animal Populations. In McIntyre A.D. (Ed.) Life in the world's oceans: diversity, distribution and abundance. Wiley-Blackwell (Oxford): in Press.