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GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN
COMMISSION GÉNÉRALE DES PÊCHES POUR LA MÉDITERRANÉE

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GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN

SCIENTIFIC ADVISORY COMMITTEE (SAC)

Thirteen Session

Marseille, France, 7-11 February 2011

Report of the workshop on Algal and Jellyfish Blooms in the Mediterranean and the Black Sea

Istanbul, Turkey 6-8 October 2010

OPENING, ARRANGEMENT OF THE MEETING AND ADOPTION OF THE AGENDA

1) The SAC-SCMEE Workshop on Algal and Jellyfish Blooms in the Mediterranean and the Black Sea was held in Istanbul, Turkey, from 6th to 8th October, 2010. It was attended by 62 participants from Turkey, Italy, Israel, Tunisia, Lebanon, The Netherlands and Morocco, as well representatives of FAO and the GFCM Secretariat (see List of participants in Appendix A).

2) Mr. V. Kürüm, Head of Fisheries Department of the Turkish Ministry of Agriculture and Rural Affairs, welcomed the participants and thanked them for attending this meeting. He stressed the relevance of the GFCM as the appropriate regional body to present and discuss important issues related to the fisheries management in the Mediterranean and the Black Sea.

3) Mr. A. Srour, Deputy Executive Secretary of the GFCM, welcomed the participants and thanked the Turkish authorities for their kindness in hosting and arranging the

meeting. He introduced the GFCM and its functioning and recalled the frame of the meeting.

4) Mr. Boero underlined that the ecosystem-based approach is the driver of GFCM approach to tackling fisheries problems, and this led GFCM to recognize the importance of both algal and jellyfish blooms in determining deviations from the "normal" ecosystem functions that sustain fisheries. GFCM, thus, promoted the organization of a workshop considering algal and jellyfish blooms as the two faces of the same medal, asking the scientific community to join efforts towards a better understanding of these phenomena within the framework of the ecosystem approach applied to fisheries and other relevant human activities. It is felt, in fact, that the separate approaches that, so far, addressed the problem of algal and jellyfish blooms might impair their full understanding. Furthermore, the management of these phenomena from a single point of view, due to the overlap of many of their features, will lead to spare resources.

5) Ms. Penna underlines that HAB phenomena have incrased during these recent decades and that main causes can be resumed into the more explotation of coastal areas by human activities (eutrophication, sediment removing or resuspension, infrastructures, mariculture) with higher frequency of shipping; but, also the scientific awareness contributed a lot to develop new HAB typologies. She also stressed the importance of the role of the Marine Strategy Framework Directive in the control and management of HAB events.

6) The Agenda was introduced and adopted by the Workshop (see adopted agenda in Appendix B). The Workshop has been characterized by a series of Power Point Presentations and Posters, followed by discussions and by work of groups of attendees to develop specific recommendations. Mr. F. Boero and Ms A. Penna acted as rapporteurs.

7) Mr. Srour informed the participants about the scheduled GFCM-SACs meetings in Malta during November/December 2010 and encouraged them to attend.

SESSION ON JELLYFISH BLOOMS

8) Mr. Boero made a brief introduction to underline the urgency of facing the jellyfish bloom phenomena that affect nearly all of the world's marine waters. Mr. Boero stressed the importance of the ecosystem approach to investigate in deep the environmental causes that lead to algal and jellyfish frequent outbreaks.

9) A total of 9 presentations were exposed by experts on the **jellyfish bloomings in the Mediterranean and Black Sea**, **human health-related problems caused or associated with the jellyfish bloomings**, **effects of jellyfish bloomings on fisheries**, **methodologies and data collection programs related to jellyfish blooming**. The abstracts as submitted by their respective authors are listed below (following the Agenda order).

- **Jellyfish blooms in the Mediterranean and Black Sea: a brief review (by Nastasi A.)**
  Blooms of autotrophic algae and some heterotrophic protists are increasingly frequent in coastal waters around the world. Algal blooms are natural events that occur seasonally due to the renewed availability of nutrients in the ocean waters; nevertheless, it has been demonstrated that these events are occurring more frequently where human activities are highly concentrated. Phenomena such as pollution and human-related nutrient enrichment can favour the expansion of algal bloom events. The Mediterranean and Black Sea basins have been experiencing several algal blooms events during the last 50 years mostly in areas such as bays, lagoons, ports beaches and estuaries. Algal blooms, frequently grouped as harmful algal blooms (HABs), not only lead to a deterioration in water quality but they also cause fish kills and high risks to human health due to specific toxins that may enter the food chain. Thus, national and regional water quality assessment efforts and routine coastal monitoring programmes to detect species, toxins, and toxicities are increasing worldwide.

- **Jellyfish bloom in the Lebanese seawaters: is it a sequence of the "Tropicalization" of the Levantine Basin? (by Lakkis S. and Zeidane R.)**
  Among six species of Scyphomedusae present in the Lebanese coastal waters, *Rhizostoma pulmo* and *Rhopilema nomadica* are the most important. This latter is a recent migrant from the Red Sea into the Levantine basin where it appeared in the plankton community during the seventies and overcame later *R. pulmo* in importance and abundance. The stinging and venomous *R. nomadica* became invader in early nineties, showing pronounced multi-annual fluctuations and clear seasonal variations. The released "ephyrules" larvae became young individuals starting to appear by mid-June when seawater temperature rise suddenly to 24-25˚C, reaching a bloom in early July, coinciding with a high phytoplankton standing crop followed with heavy zooplankton abundance community. Heavy populations with high density (1-5/m-2) generate fearing to the tourist swimmers and creating damage in the nets of fishermen; lasting during July and August to disappear completely afterwards. During a long-term survey (1970-2008) on Scyphomedusae, we conclude that the bloom of *R. nomadica* occurring between mid-June and mid-August is not regular every year with regard to the density of the aggregations. It is related to hydrological factors, especially the rise of temperature during early spring and summer and ecological and trophic factors such as the phytoplankton bloom and the abundance of zooplankton. It was clear that the changes in the hydrology of the Levantine Basin due to the increase of seawater temperature and salinity (ΔT= 0.40˚C, S~0.35‰) following the functioning of Aswan High Dam, has induced ecological changes in the whole ecosystem, enhancing biological invasion of Indo-Pacific species. On the other hand, certain "Tropicalization" of the Levantine Basin due to Global warming and Climate change, may also enhance the migration process from the Red sea into the Mediterranean and the occurring of the jellyfish bloom.

- **The price of change: jellyfish outbreaks along the Mediterranean coast of Israel (by Galil B.)**
  Some recent changes in biodiversity patterns in the Mediterranean littoral may be linked to direct drivers such as climate change and invasive species. The invasive alien jellyfish along the Mediterranean coast of Israel are reviewed and their impact the already teetering fisheries, coastal installations, and tourism discussed. The Erythrean invasion swept ashore the scyphozoan jellyfish, *Rhopilema nomadica* Galil, 1990. Each summer since the mid 1980s huge swarms of the Erythrean jellyfish have appeared along the Levantine coast. These planktotrophic swarms, some stretching 100 km long, must play havoc with the limited resources of this oligotrophic sea, and when the shoals draw nearer shore, they adversely affect tourism, fisheries and coastal installations. As early

as the summer of 1987 severe jellyfish envenomations requiring hospitalization had been reported in the medical literature. The annual swarming brings each year reports of envenomation victims suffering burning sensation, eurythema, papulovesicular and urticaria-like eruptions that may last weeks and even months after the event. Local municipalities report a decrease in holiday makers frequenting the beaches because of the public's concern over the painful stings inflicted by the jellyfish. The local newspapers and TV news report during the summer months the presence of jellyfish along the beaches. Coastal trawling and purse-seine fishing are disrupted for the duration of the swarming due to net clogging and inability to sort yield -it is not uncommon that fishermen, especially purse seines, discard entire hauls due to the overwhelming presence of poisonous medusae in their nets. Jellyfish-blocked water intake pipes pose a threat to cooling systems of port-bound vessels, coastal power plants and desalination plants.

- **Jellyfish outbreaks: do we know enough? (by Piraino S.)**
  The understanding of complex ecological phenomena, such as the recurrent occurrence of jellyfish outbreaks, require large-scale integrative approaches to couple ecophysiological optima of key outbreaking-forming species (OFS) with their environmental envelopes. Mechanisms boosting jellyfish proliferations can be overlooked without a comprehensive knowledge of their biology and ecology. This is the case not only for rare or alien species, but also for most popular taxa, like *Aurelia* spp. or *Pelagia noctiluca*. The developmental plasticity of cnidarian jellyfish if proverbial and the ecological potential of their diverse life cycle adaptations grants their ecological success and persistence in worldwide ecosystems. Resting stages, high regeneration potential, reverse development are all shared features within Medusozoa, leading to rapid jellyfish population growth in narrow time windows. A combination of traditional methodologies, innovative technologies and multisciplinary approaches (from natural history observation to video-acoustic behavioural records from biochemical investigations of trophic relationships to molecular taxonomy and phylogeography) will be required to a) understand the roles of jellyfish in the health of our seas, b) analyse causes and consequences of outbreaks, c) foresee environmental envelopes and hot spots of jellyfish occurrences, and d) eventually developing mitigation countermeasures against OFS negative impacts. Besides the common negative perception of outbreak events, jellyfish can be a resource for humans, as they have a number of properties that may be of benefit to society as a source of healthy molecules in cosmetics (e.g. collagen), pharmacology (e.g. free radicals scavengers and antioxidant proteins, anti-cancer drugs), nutraceutics (food for humans, feed for animal farming and aquaculture). In my talk, I briefly summarized some of the potential outcomes that might be achieved by a recently established network of 15 Mediterranean laboratories from 10 different countries dedicated to the study of jellyfish biology (the JELLYMED consortium).

- **The effect of jellyfish on the small scale fishery in the Black Sea (by Özdemır S., Erdem E. and Bırıncı Özdemır Z.)**
  By-catch in fisheries has been considered a serious problem. Horse mackerel is a most of the economic fish in the Turkey small scale pelagic trawl fishery. Jellyfish are important by-catch pelagic trawl fisheries in the Black Sea coast of Turkey such as inedible, damage to target species, decreasing catch amount and mean length of fish. The experiments were carried out Black Sea coast (Sinop-Samsun) in October 2008; total 11 night and 11 daytime pelagic trawls were towed. Horse mackerel (*Trachurus mediterraneus*) and moon jellyfish (*Aurelia aurita*) were caught by pelagic trawl in the study 19540 kg and 8220 kg respectively. In the present study the effect of moon jellyfish (*Aurelia aurita*) on the catch efficiency and length composition of horse mackerel caught by the midwater trawl were established. The results showed that moon

jellyfish catch amount increased, horse mackerel catch amount decreased in pelagic trawl fishery in the fishing region at night on the other hand jelly fish ineffective on horse mackerel catch and size composition at daytime. Differences between mean length of horse mackerel in the hauls are significant ($p<0.05$).

- **Decreasing methods of jellyfish bycatch on the trawl fishery (by Özdemır S.)**
Fishery by-catch and discards are old issues in fishing history but have become one of the most significant problems currently encountered by many fisheries. Large quantities of jellyfish are discarded in the anchovy, horse mackerel, bluefish and bonito fisheries in Turkish waters. The devices varied depending on the need of the particular fisherman. Some fishermen developed grids to exclude turtles, rays, sponges, and jellyfish, because these animals were caught frequently or because the value of their target catch could be increased markedly. Several fishermen took an interest in developing devices to reduce fishery by-catch in Black Sea. Grids are used to expel sea turtles and jellyfish. Grid practice could be preventing to catch of these species, on trawl fisheries in Black Sea. Additional, it is possible more quality of target species and selectivity by grid systems in trawl net.

- **Natural and anthropogenic impact on North Sea gelatinous zooplankton population dynamics: implications for ecosystem structure and functioning (by Langenberg V. T., van Walraven L. and van der Veer H. W.)**
Gelatinous zooplankton taxa are a diverse group of ctenophores, cnidarians and pelagic tunicates. Most of these animals exhibit brisk population dynamics and opportunistic lifestyles. Sudden outbreaks of gelatinous zooplankters occur regularly in most coastal, estuarine and open-ocean ecosystems worldwide. There is mounting evidence that in recent decades the impact of these outbreaks has been increasing causing serious plagues, invasions, and episodes of various socioeconomic setbacks to fisheries, aquaculture, coastal industries and tourism. Chronic eutrophication, climate change and overfishing are hypothesised to have created a situation in which soft-bodied zooplankton species may proliferate better or even conquer a dominant role in the ecosystem by significantly outcompeting other species and organisms. The dramatic increase in numbers of certain gelatinous zooplankters may prove to be a good indicator of the quality of our seas. The more of them we find, the stronger the signal that something in our seas is changing. According to leading scientists, gelatinous zooplankton abundance and composition in the Northern seas will most likely alter. Seeing the recent development in adjacent seas (North-East Atlantic, Baltic, Mediterranean, and Black Sea) an impact on ecosystem functioning, its goods and services, and related socioeconomics may consequently be probable in the North Sea as well. Currently, a lack of critical knowledge on the success and activity of important North Sea Zooplankters hinders the full integral assessment of the North Sea production structures and functioning. Therefore, with gelatinous zooplankton increasingly competing with fish, either for food or acting as predator, a more comprehensive understanding of their role and place within the North Sea foodweb is urgently needed for reassessing its overall trophic structure and functioning now and in the future, both prerequisites in assessing the production potential at higher trophic levels including shellfish, fish, birds and mammals. This study aims to advance our understanding of the role of gelatinous zooplankton in steering and determining the structure and functioning of the North Sea ecosystem. The new insights will modernise monitoring and risk assessment instruments as well as identify measures needed to protect the North Sea environment and its valued ecosystem services. The presently proposed study will be carried out by a research group formed by experts from the *Royal Netherlands Institute for Sea Research (Royal NIOZ)* and *the University of Groningen (RUG)* in close cooperation with *DELTARES*.

- **Two years of CIESM Jellywatch Project in Italian waters (by Boero F., Gravili C., Prontera E., Piraino S.)**
  The CIESM Jelly Watch Program was set up to gather for the first time baseline data on the frequency and extent of jellyfish outbreaks across the Mediterranean Sea. In summer 2009, we initiated JellyWatch by launching a pilot, citizen-based study in Italian waters. A poster was broadly diffused to draw the attention of coastal users (fishermen, divers, tourists) but also ferry passengers, asking for their report of sightings of jellyfish swarms. The poster presents true-to-life drawings that illustrate the most common species of jellyfish found in the Mediterranean, along with a list of basic questions (formulated for the non-specialist observer) on the location, type and extension of the observed swarms. The poster was successfully tested: records were sent by email to key scientists who acted as focal points in different regions. The media were heavily involved in the campaign, from televisions, newspapers, magazines, to internet websites. The massive presence of jellyfish during 2009 - when Israel was added to the pilot phase with equal success (lead: Dr Bella Galil) - enhanced the value of the initiative, and hundreds of records, documented by photographs, have been received. The campaign continued in 2010 with the aid of the science magazine *Focus* that published the poster and opened a web page where medusa occurrence was shown on a daily basis. Medusa blooms have been documented as never before. Now the Jellywatch project is currently implemented in coastal sectors in France, Greece, Israel, Italy, Monaco and Turkey and will be further expanded to northeast Adriatic, Egyptian, Maltese, Syrian waters.

- **Basin-Wide Black Sea Mnemiopsis Leidyi Database (MLDB) (by Myroshnychenko V. and Kideys A. E.)**
  The database was created in 2008 in framework of the FP6 Black Sea SCENE project and further supported by the Permanent Secretariat of the Black Sea Commission. A team of scientists studying the *M. leidyi* in the Black Sea organized a consortium on a voluntary basis with purpose to maintain the database and provide their data and metadata on jellyfish in the Black Sea to common use. At the moment database contains ML metadata and data covering all the Black Sea for period 1989-2009.

SESSION ON ALGAL BLOOMS

10) Miss Penna made a brief introduction to Harmful Algal Blooms in the Mediterranena Sea with an overview of last decades of HAB events. She also stressed the importance of the role of the EU's Marine Strategy Framework Directive in the control and management of HAB events.

11) Mr. Türkoğlu implemented a brief introduction to Harmful Algal Blooms with a general survey of last two decades of HABs in the Mediterranean Sea, especially Turkish Straits System and the Black Sea ecosystems. He underlined that mainly due to progressive eutrophication from various pollution sources, harmful algal blooms by various species were recurred almost each year. He also stressed that total phytoplanktonic biomass increased from oligotrophic toward the eutrophic zones of the not only bays, but also all of the seas such as Turkish Strait System and the Black Sea.

12) Miss Bizsel underlined the importance of the best (=optimal) sampling resolution in time and space for future data collection efforts. As the "good ecological state" has

been recommended by the EU's Water Framework Directives, the phytoplankton data should comprise total abundance, abundance of major groups and prorportion of dominant species to monitore discoloration.

13) A total of 11 presentations were exposed by experts on the algal bloomings in the Mediterranean Sea and Black Sea, human health-related problems caused or associated with the algal blooming, and methodologies and data collection programs related to algal blooming. The abstracts as submitted by their respective authors are listed below (following the Agenda order).

- **Natural eutrophication inducing phytoplankton bloom along Lebanese coastal water (Levantine Basin) (by Lakkis S., Novel-Lakkis V. and Zeidane R.)**
  The Levantine Basin, including the Lebanese seawater are highly oligotrophic water body, showing the highest seawater temperature and salinity in the entire Mediterranean. Algal bloom is regularly observed during spring along the coast of Lebanon. Uncontrolled eutrophication of coastal water can lead to undesirable consequences such as algal blooms, appearance of toxic algae, overgrowth, hypoxia, anoxia, fish killing, transformation of sediments, disappearance of macrophytes etc. Enriched nutrients of river, water runoff and liquid urban wastes are the main factors of eutrophication inducing algal bloom. This phenomenon is observed usually in April-May coinciding with maximum freshwater input, corresponding to increased surface temperature and stratification of water layers. Reduced water transparency is noticed during algal bloom, accompainied with discolored coastal seawater leading to phytoplankton bloom and sometimes to the « red tide ». Few species dominate the whole community such as: *Skeletonema costatum*, *Pseudo-nitzschia pungens*, *P. fraudulenta*, *P. delicatissima*, *Leptocylindrus danicus* and *Chaetoceros* spp. Few dinoflagellates contribute also to the bloom namely *Prorocentrum micans*, *P. schilleri*, *Ceratium furca* and *Dinophysis* spp. Potentially toxic microalgae are noticed in phytoplankton especially during algal bloom. Among those we mention**:** *Pseudo-nitzschia pungens*, *P. closterium*, *P. fraudulenta*, *P. delicatissima* producing ASP « Amnesic Shellfish Poisoning » ; while toxic Dinophyceae secrete diarrhoetic toxic substances (DSP). Other toxic microalgae like *Gonyaulax polyedra*, *Gymnodinium* sp., *Gyrodinium contortum* and *Alexandrium minutum* produce hemolytic hydrosoluble toxines such as Paralytic Shellfish Poisoning (PSP group). However no cases of intoxication were reported during the period of survey 1990-2008, since the density of toxic species in the sea is very low. Furthermore, consumption of wild mussels, and other bivalves oysters is not very common within local population, and no conchyloculture parks are practiced in Lebanon.

- **Phytoplankton blooming in Gabes Gulf (Tunisia): twenty years of monitoring (by Hamza A., Feki W. and Bel Hassen M.)**
  During the past two decades, the phenomena of coloured water generated by phytoplankton are growing both in frequency and by their intensity in some coasts of Gabes Gulf (Tunisia). In this work, following a retrospective study of the database collected during twenty years of observations, we investigated the phenomena of blooms likely to emerge from temporal and spatial patterns in the pairing of these episodes and correlate these appearances with the variability of abiotic conditions, mainly represented by temperature, salinity and pH. The results show that the summer is a specific period of blooms of cyanobacteria *Trichodesmium erytreum*. The period from August to January, with peaks in September and January, seems to be favourable to dinoflagellates blooming that are responsible of 89% records. The species *Karenia selliformis* representing 64% of the occurrences. *K. selliformis* fluctuates independently of years and months, but it shows a specific requirement for salinity (higher than 42 g/l). This

parameter can be used as a marker to predict the appearance of *K. selliformis* in the Gulf of Gabes. The others phytoplankton species do not have any specific requirements for the studied abiotic variables.

- **Recurrent blooms of a common heterotrophic dinoflagellat *Noctiluca scintillans* in the Dardanelles (Turkish Straits System) (by Türkoğlu M.)**
  The study focuses on the short time (weekly) variations in the density and bio-volume of dinoflgellate *Noctiluca scintillans* between March 2001 and January 2004 in surface waters of the Dardanelles. An analysis of temporal distribution of *N. scintillans* population size with respect to various ecological parameters was discussed. It was also discussed vertical distribution of this species in very excessive bloom time periods during the sampling period. While cell density of *N. scintillans* variated between 0.00E+00 and 2.20E+05 cells L^{-1} (1.59E+04 ±3.01E+04 cells L^{-1}), cell volume variated between 0.00E+00 and 1.31E+12 μm^3 L^{-1} (9.81E+10 ±1.84E+11 μm^3 L^{-1}). March-June and October-December periods were very excessive bloom periods during the year. Late spring periods during the three years were more important than late autumn and early winter periods both in view of cell density and cell volume. However, the bloom in early winter period (December 2001) occasionally revealed to be higher (7.33E+04 cell L^{-}1) than late spring periods. Contribution of *N. scintillans* to total Dinophyceae and phytoplankton cell density was lower (0-33.3 and 0-3.70% respectively) than contribution to total Dinophyceae and phytoplankton cell volume (0-99.5 and 0-99.0%, respectively). This situation was supported by correlation data. As a result, high production capacity of *N. scintillans* during the year and it's high contribution to total phytoplankton has revealed that the Dardanelles and thereby the Sea of Marmara are hypereutrophic ecosystems due to the Black Sea surface waters and waste waters of some megacities such as Istanbul and Izmit around the Sea of Marmara.

- **Excessive growth of *Cladophora* sp. in the Southwestern Istanbul Coast (Marmara Sea) (by Balkıs N., Sıvrı N., Fraim L. N., Balcı M., Durmuş T.)**
  Over population, pollution, deforestation and natural disasters are among the major problems faced by the world today. Istanbul, which is Turkey's largest metropolitan city with a population of over 12 million, tries to solve its encountered environmental problems such as severe coastal erosion, shoreline recession and over pollution which it has been exposed to primarily in the last 20 years as a result of the coastal response to human activities. The global increase in temperature negatively affects the life in water systems day by day. In recent years, the temperature has been above normal seasonal levels and has started to show its effects in sea water systems too. In July 2010, the excessive growth of *Cladophora* sp. in the southwestern shoreline of Istanbul, which carries great importance for tourism, has drawn major attention. The aim of this study was to investigate the excessive growth of *Cladophora* sp. and ecological parameters of surface waters in the southwestern coast of Istanbul in July 2010. The genus *Cladophora* is cosmopolitan in temperature and tropical in regions like freshwater, brackish and marine habitats. Its metabolism and morphology are related to hydrodynamic conditions. During the period this species multiplied, a mucilage like environment was formed. Due to the lack of available evidence prior to the sampling, it is possible that the excessive mucilage formation may have been trigged by *Cladophora* sp. *Cladophora* samples were collected on different sampling dates in July 2010. On these sampling days, the temperature, salinity and dissolved oxygen levels of the seawater ranged between 26.6-28°C, 14-33 ppt, and 8.2-9.7 mg L^{-1}, respectively. Nitrate+nitrite-N (0.21-0.26 µg-at L^{-1}), ammonium-N (0.43-0.94 µg-at L^{-1}), Phosphate-P (0.53-3.50 µg-at L^{-1}) and Silicate-Si (9.6-15.3 µg-at L^{-1}) concentrations were measured.

- **Mucilage events in the Sea of Marmara and the associated processes: Field and laboratory findings (by Polat Beken Ç. Tüfekçi V., Sözer B., Yıldız E., Telli - Karakoç F., Mantıkçı M. and Ediger D.)**
  Four major mucilage event were recorded in the İzmit Bay (Marmara Sea); October 2007, January 2008, September-October 2008 and December 2009 where all were connected to similar occurances in the Sea of Marmara. A research project (TUBITAK-108Y083), based on laboratory experiments and field studies, was initiated in 2008 to investigate the conditions that may activate these events. Laboratory batch culture studies under controlled light and temperature were established with different N/P ratios using four target phytoplankton species: *S. costatum, C. closterium, P. micans* and *G. fragilis*. Field studies were organized in two ways; monitoring at a fixed station in front of the Marmara Research Center (outer İzmit Bay) every 1-3 weeks, supported with monthly monitoring activities in the whole İzmit Bay (supported by Greater Municipality of Kocaeli) and patchily visiting other sites (e.g. Erdek Bay) during the events periods. Field investigations were designed basically to monitor the phytoplankton distribution and standard oceanographic and meteorological features to understand better the occurring conditions of the mucilage events. In almost all the recorded events, dinoflagellates either were more abundant or at comparable numbers with diatoms (all target species were recorded comparatively in higher numbers). Among them *Gonyaulax fragilis* or *Gonyaulax* sp. was distinctive. However, the assemblage could rarely be blooming by any of the species whereas the numbers of *Gonyaulax fragilis* getting increased before the aggregate formations. Temperature, light and nutrient controlled laboratory experiments were designed for 3-7 weeks to monitor DOC and carbohydrate accumulation and observe aggregate formations in the design medium. A considerable accumulation of DOC and total dissolved-CH at *P. micans* cultures was observed at maximum cell numbers and during the death phase. CH-C increased about 20-fold towards the end of the experiments. DOC and CH increase in batch cultures of target diatoms was less pronounced, however, decrease in exposure concentrations of nutrients without changing the N/P ratios caused marked CH accumulation. FTIR spectra of field mucilage aggregates and laboratory formations obtained in phytoplankton cultures have had similar features. These were supported with FTIR spectra reported for other mucilage aggregates in the literature that are related to phytoplankton. These results indicate that the mucilage formations are closely linked with CH-rich exudates of phytoplankton in the Marmara Sea.

- **First observation of the mucilage formation in the Sea of Marmara in October 2007 (by Yuksek A. and Sur H. I.)**
  Mucilage formation was first observed in the Sea of Marmara in October 2007 as dozens of square kilometers of the sea surface was covered by mucilage. It has caused not only visual pollution but also economical damage on fisheries by continuing for months and blocking fishing nets. Within this study, meteorological and hydrographical conditions as well as chemical and biological changes were examined to determine the causes of mucilage phenomenon observed in the Sea of Marmara in October 2007. As a part of monthly water quality monitoring project conducted by the Institute of Marine Sciences and Management, sea water samples were taken before and after the aggregate formation from the stations located in the northern part of the Sea of Marmara. Results from August to September have been compared with the previous years' data for a better understanding of the aggregate formation. Replies of fisherman to questionnaires, which were designated to find out information on the mucilage formation in the Sea of Marmara, showed that no obvious change was occurred on the sea surface in autumn 2006. These replies also show that the aggregate formation was first encountered by fishermen through smeared fishing nets which became heavier due to the mucilage aggregation. Purse seiners also reported that they realized thick gelatinous formation

while setting around the fish although this formation was not detected by equipped echo sounders. Questionnaires results showed that fishermen associated this phenomenon with the invasive species *Mnemiopsis leidyi* which caused a very significant damage and sharp decline on fisheries in the Sea of Marmara in 1994. In August 2007, abnormal conditions were gradually observed by fishermen as fishing nets became extremely heavier. Aggregate formation took place in whole Sea of Marmara in late October 2007 and fishermen had serious problems. Some previous work on aggregate formation focus on the role of phytoplankton and therefore qualitative and quantitative phytoplankton analysis were also carried out on monthly basis. Results showed that there was a decreasing pattern in phytoplankton abundance from August till October in 2007, thus pointing to the presence of a planktivorous species in high amounts. Zooplankton of the Sea of Marmara also displayed significant differences in 2007 when compared to the previous periods. With the dense aggregate formation zooplankton abundance decreased sharply. During the aggregate formation the most important change has been witnessed in macro gelatinous zooplankton distribution. During the basin wide research conducted in the Sea of Marmara in 2005, dense distribution of *Liriope tetraphylla* has been detected particularly at the northern parts. The dominance of the species over other macro gelatinous species was 63%. The species outnumbered the most common and dominant species *Aurelia aurita,* and also *Mnemiopsis leidyi* which caused a drastic collapse in Turkish fisheries in 1990's. On the other hand the frequency of occurrence of the species was 85% in the Sea of Marmara and this can be taken as a proof that the aggregate formation event occurring at regions having different ecological conditions and species compositions, such as Izmit, Erdek, Bandırma and Gemlik bays, should be originated by the same species. When underlying factors beneath the rapid increase of the species has been investigated, it is seen that neither chlorophyll a, nor phytoplankton abundance has increased. This strengthens the idea that a significant shifts in the pelagic food web has occurred. With the decrease in planktivorous fish abundance and hence lack of competition, this new medusa has increased exponentially. Nitrogen/phosphate ratio increased prior to the aggregations and phytoplankton abundance decreased significantly, together with a drastic reduction in zooplankton abundance. Invasive *Liriope tetraphylla* abundance increased exponentially in August and died in masses as a result of starvation and oceanographic conditions. The region witnessed dense mucilage formation during the period characterized with low phytoplankton abundance and high *L. tetraphylla* biomass in 2007. In October, following the mucilage matter production another new species for the region *Gonyaulax fragilis* was observed through the basin. The species was a frequent member of phytoplankton in December 2009, however its abundance was relatively lower. In conclusion, our works in 2007 links mucilage production and breakdown of food chain. Overfishing in the Sea of Marmara provided a ground for invasive and/or opportunistic species and an increase in abundance of planktivorous species. As a result, *Liriope tetraphylla* became more dominant in the disturbed environment of the Sea of Marmara. Nutrient concentrations are high in the Sea of Marmara as a result of the surface inputs, and mucilage phenomenon therefore occurs as a result of not exactly known processes in the highly productive system. Therefore, biological and chemical treatment of domestic and industrial wastewater input to the Sea of Marmara may be important steps in preventing these kinds of outcomes of pollution. To understand and prevent mucilage formation; a nation-wide monitoring network should be established, and also radical measures to protect planktivorous small pelagic species stocks (such as anchovy, mackerel, sardine and sprat) should be implemented immediately. As an example, fishing may be banned 10 miles around the entrance and exists of Çanakkale and İstanbul straits.

- **Effects of mucilage bloom on the fisheries of the Sea of Marmara through the 2007/2008 fishing period (by Zengın M., Güngör H., Demırkol C., Yüksek A.)**
In this study, the effects of a kind of musilage that has been firstly appeared in the second half of 2000s (2006) and densely bloomed in 2007 and 2008; on commercial fish stocks and activities. The study was realized on fishery localities those are differently characterized but representing the overall fisheries in the Sea of Marmara by means of a stratified sampling procedure regarding the vessel size and the method of fishing. In this study, a comparison was made between the usual fishing period (2006/2007) and the period within musiage bloomed and caused a great loss in fisheries production (2007/2008). According to obtained data, the loss in amount of the landings and its corresponding cost was nearly three times of the one in usual period. The rate of loss was the highest in small pelagic fishes (purse seine fishery). This was followed by the fisheries of shrimp and benthopelagic fishes (beam trawl and bottom trawl fishery). The last one was the coastal/artisanal fishery (bottom/surface gill nets, long lines and hooks). The jellyfish or algal blooms may be resulted in gelatinous masses affected the fishery areas of all the different levels which are inshore, offshore, surface, pelagic and benthic in the Sea of Marmara and a significant depletion occurred in fishery economics. It is certain that the following proposals are worth to consider, in order for reducing the effects of gelatinous organisms on fish stocks and fisheries. Firstly, it is required to decrease the fishing effort in the Sea of Marmara. On the other hand, the uncontrolled and unconscious fishery should be taken under control. The depletion in fish stocks creates a negative feeding competition between small pelagic fishes and gelatinous organisms that shares the same trophic food chain in the ecosystem. In order to come over this case, it is necessary to develop a long-term fishing strategy for small pelagic stocks and firstly; (1) the fishery of small pelagic stocks should be completely banned for a certain period, a quota system which designs a reduction in the negative effect of over-exploitation should be applied after the stocks renewed and reached a significant biomass.

- **MAREM (Marmara Environmental Monitoring) Project (by Artüz O. B. and Artüz M. L.)**
The project "Changing Oceanographic Conditions of the Sea Of Marmara" MAREM (Marmara Environmental Monitoring) is the longest monitoring project that ever been done for any of the seas. Since 1954 till now, at the Sea of Marmara and the Turkish straits, horizontally at 50 stations, there were about 25 parameters have been observed at the convenient depth cutaways (0.5m.-1200m.). Firstly in 1980, taking the Sea of Marmara into consideration, all the studies about the sea were wished to be put together to have a data base by İlham Artüz. O. Bülent Artüz has developed his applications on system programming and project management software for years also has developed an environment which can be tested and used for this project and he also has developed a project management environment for this kind of researches and also has given an opportunity to use this management and reporting system over internet, for the ones who can freely sign up and use. Researchers can use this database to display their own data through internet, using this system, graphically and positioning on maps. Explorers, can easily enter and seize their data to system and share with other researchers with maximum security, and also distribute their work through internet on this systems web page, if they want and after the latest updates, the system is not only prepared for storing physical data but also for the classification of living matters and measurement results, to store their photos and mass measurements in a new database. So they can use, to watch and calculate the evolution of the environment in years, for the main purpose of this process.

- **Retrospectives of two decades of the Harmful Algae Bloom monitoring in Morocco (by Taleb H.)**
  Extending over 3500 km with two façades, Atlantic and Mediterranean, the Moroccan coasts contain the valuable resources for fish and shellfish. However, these products are subject to recurrent threats caused by Harmful Algae Bloom (HAB). Given this fact, National Fisheries Research Institute was established a monitoring network of coastal safety, which include eight regional stations located to cover the national level and conduct regular monitoring of the coast safety and the appearance of HAB. After two decades of intensive monitoring, a substantial body of information on the occurrence of HAB and negative impact that generate were obtained. The obtained outcomes allowed localising the favourite sites of HAB occurrence and the identification of responsible algae species. In this communication we will talk about various episodes of HAB recorded on Mediterranean and Atlantic shores of Morocco, which appear to be different in nature and problem they pose.

- **Harmful benthic algal species in the Mediterranean Sea: genetic diversity and ecological aspects (by Penna A.)**
  Recently, toxic benthic dinoflagellates have been responsible of higher frequency of harmful events in the temperate coastal areas of the Mediterranean Sea. In particular, the epiphytic genus *Ostreopsis* high-biomass proliferations have been related to harmful episodes of human intoxication by toxic aerosol and skin irritation, and water quality deterioration causing the benthic invertebrate and fish mortalities. *Ostreopsis* produces palytoxin-like compounds that can be transferred through the food web of benthic herbivore invertebrates or filter bivalves potentially causing death or highly sufferance in these benthic communities. In general, the *Ostreopsis* occurrences developed in late spring to early autumn with maximum epiphytic concentrations above 10^6 cells g^{-1} fw on seaweeds during the summer period. In the last decade, *Ostreopsis* blooms became more intense, frequent and widely distributed or in expansion in many Mediterranean areas (www.bentoxnet.it). The dynamic and consequences of the *Ostreopsis* outbreaks occurred in the Mediterranean Sea pose serious concern for the public health, environment quality and also for the economic activities in those coastal regions, which are mostly dependent on tourism, fishing and aquaculture services. Further, *Ostreopsis* is associated with other potentially toxic benthic dinoflagellate as *Coolia monotis*, *Prorocentrum lima* and *Amphidinium* cf. *carterae* that co-occur in lower abundances. Up to date, in the Mediterranean Sea, molecular phylogenetic and morphological investigations based on the sequence analyses of concatenated ribosomal genes, showed that all *Ostreopsis* spp. isolates grouped into two distinct species, *Ostreopsis* cf. *ovata* and *O.* cf. *siamensis*. Few identified genetic species, as *O.* cf. *ovata*, *O.* cf. *siamensis*, *O. lenticularis* and *O. labens*, were analyzed based on the phylogeny and nucleotide diversity at inter- and intra- species level especially at the Mediterranean area. In the *O.* cf. *ovata* different genetic lineages correlated with macrogeographical distribution are present; they are represented by the Mediterranean/Atlantic and Indo-Pacific clades. *O.* cf. *ovata* is found to be widely dispersed, while the other species turn out restricted to just one of the two main warm-water oceanic basins. *O.* cf. *siamensis* was found only in the Mediterranean Sea and eastern coast of Atlantic, and strains identified as *O. lenticularis* and *O. labens* were found only in the Indo-Pacific region. In the Mediterranean Sea, genotype of *Coolia monotis* was identified and phylogenetic position was clarified in comparison with other *Coolia* spp. ribosomal sequences worldwide. The most widespread and toxic abundant species of *Prorocentrum* is *P. lima* reaching abundance up to 10^5 cells g^{-1} fw of macrophytes. It is always found in association with *Ostreopsis* blooms along the Mediterranean coasts and its records have also increased. Finally, genus *Gambierdiscus* was detected along Greek coasts. This genus includes toxic species producing ciguatoxins that are the causative agent of CFP disease in the

tropical areas. The presence of *Gambierdiscus* sp. also in the Mediterranean Sea may imply the onset of ciguatera disease in this area. This fact posed new and serious hazard for human health and sea-related activities. In this context, morphological, genetic and toxicological analyses are underway to clarify the origin and the toxicity of this taxon in the Mediterranean Sea.

- **HABs incidents and monitoring efforts in Izmir Bay, Turkey (by Bizsel N., Bizsel K. C. and Inanan B. E.)**
  The first red-tide and mass fish mortalities had been reported in 1950's by Numann (1955) in a harbour region, which is the innermost part of Izmir Bay (Aegean Coast). However, the first record on toxic phytoplankton species was *Alexandrium minutum*, which had been reported in 1983 by Koray (1983) during a red-tide (8 millions celles/l). In 1990's, the pace of research efforts on phytoplankton, and hence, on red-tides, have gradually increased. The ministry of Agriculture and Rural Affairs (MARA) through its responsible authorities, i.e., General Directorate of Conservation and Control, has started an action plan on monitoring HABs. But, the monitoring was restricted with the shellfish production grounds. This includes both collecting and rearing grounds, which comprise the coasts of Northern Aegean Sea, Turkish Straits systems (Dardanelles, the Sea of Marmara and Bosphorus) and the Western Black Sea. This figures out that the considerable incompleteness of the inventory is very likely. A concrete example displaying this incompleteness is the results obtained in one of our research project carried out in Izmir Bay where the phytoplankton is most extensively studied in comparison with the other coastal areas of Turkey. In the research project, the samples could be collected with relatively finer time resolution, i.e., weeks or days. The result was astonishing, because, we could identify almost 40 new records of phytoplankton species in relatively well studied area, Izmir Bay. Such a high number of new records is a reliable evident that the number of species can significantly increase as the sampling efforts are refined in time and space scales. During the period of the research project, the occurrence of some toxic species coincided with a massive fish mortality event after the spring bloom (Bizsel and Bizsel, 2002). When the event of fish mass mortality was observed on April 21,1998, the abundance of *Alexandrium minutum* was high with a maximum value of $4x10^5$ cells/l. If we look slightly in more detail, there were also some discrete cases. For example, some findings from an aquaculture site and another site affected by a chicken farm showed the occurrences of toxic Dinophysis species and the toxic *Prorocentrum lima*, respectively. The latter could not be found and identified throughout the bay during our studies. When we review the literature on causative organisms of red-tide in Izmir Bay in 1983, 1994 and 1998; *Noctiluca scintillans, Prorocentrum micans, Scrippsiella trochoidea,* Thalassiosira, Protoperidinium, Ceratium species were observed generally in each three years, *Alexandrium minutum and Eutreptiella gymnastica* species in 1983 and 1998, *Dinophysis rotundata*, Cryptophyceae, *Ebria tripartita*, *Gymnodinium, Katodinium, Heterocapsa, Heterosigma*, *Nitzschia longisima* species only once in 1998, *Eutreptiella gymnastica* in May 1999, *Prorocentrum micans* in May 2001, *Scrippsiella spinifera, Gonyaulax* sp., *Prorocentrum* sp. in the brown tide in August 2006 and finally reddish tide has been observed through the coast line of Izmir bay in August-September 2010 caused by Cyanophycea, *Cylindrotheca closterium, Prorocentrum micans* and *Eutreptiella* sp. The reasons, that make sampling efforts uncoordinated, discontinuous, limited and scattered in space and time, are the chronical insufficiencies in infrastructures and shortages in finance and human resources. There are significant on-going and completed progresses in solving these insufficiencies and shortages. The infrastructure requirements have been updated and upgraded. There are challenges to improve coordination of efforts county wise.However, the drawbacks such as limited experience in data collection, storage and processing, restricted international communications (particularly in institutional basis),

have been slowered down the above mentioned progresses and their efficiency. The network a firm and efficient base for the targeted objectives focusing on public health, economics, and social problems that have been faced in Mediterranean coasts. And, its achievements dictate us to improve it in terms of comprehensiveness and promptness so that it will be an efficient tool enabling us to control HABs events and to mitigate the relevant adverse consequences.

OUTCOMES OF DISCUSSIONS ON EXPERTS PRESENTATIONS

The ecosystem-based approach

14) The Rio Convention on Biological Diversity advised the adoption of the ecosystem approach to tackle the problems related to the management, protection, and conservation of the living world, recognizing its importance for our well being. In the past, and also at present, the solutions to biodiversity issues are often searched for by considering just the specific objects of the problem, extracting them from the rest of the system, for ease of analysis. Fisheries biologists study just the fish, plankton ecologists study just the plankton, benthic ecologists study just the benthos, as if all these systems where not part of the same ecosystem. The adoption of the ecosystem approach, thus, should eliminate the conceptual barriers that hinder our understanding of the inter-connections among the various components of the ecosystems, allowing for better understanding leading, then, to improved management.

The ecosystem-based approach to ecosystems

15) Ecosystem functions are measured by considering some important variables, such as decomposition rates or primary production. These performances give a hint about ecosystem functioning, especially in terms of production, but do not help detecting structural changes that, eventually, might lead to changes in their functioning. The changes in species abundances (rare species becoming common, common species becoming rare) and also in species composition (arrival of Non Indigenous Species – NIS – or local extinction of common species) might be sudden, so to lead to regime shifts like the global transition from a fish to a jellyfish ocean. The tipping points of these shifts, however, are reached after periods of appearance of the novel species (or disappearance of the common ones), to their numerical increase (or decrease season after season) and then to their sudden prevalence in ecosystems that, due to their presence, are in a much different state than before their appearance. The ecosystem approach, thus, must consider the intricacies of ecosystem functioning, accounting for their widespread non-linearity.

Microalgal and jellyfish blooms, an ecosystem-based approach

16) Due to their impacts on many human activities, blooms of microalgae (HABs: Harmful Algal Blooms), mucilages, and jellyfish blooms (both of Cnidaria and of Ctenophora, but also of Thaliacea) are considered as important ecological events. Their impacts, hence, have been and are being the object of focused studies. When inserted into an ecosystem perspective, these bloom phenomena, especially in the Mediterranean and Black Sea regions, are deviations from "normal" plankton dynamics. The functioning of the ocean, in fact, is based on a succession of pulses, first of primary producers (phytoplankton) and then of secondary producers (crustacean zooplankton) that sustain the rest of the trophic network up to the fish

that we eat or the cetaceans that we love. Plankton community dynamics are regulated by the life cycle patterns of the individual species, often with resting stages in the benthic realm for even long periods, and by the physical processes occurring in the water column. Phytoplankton dynamics are mostly regulated by seasonal conditions linked with nutrient loads, irradiance, temperature (bottom-up effects), by the recruitment of excisted resting stages from sediment bottom, and by the grazing of zooplankton (top-down effects). The heterotrophic groups are driven by both seasonal variations in the chemico-physical features of the water column (e.g., temperature, salinity, irradiance) and by the features of the trophic web, with bottom-up effects linked to prey availability and top-down effects linked to predatory pressures from higher levels of the food webs. Under long temporal scales, some observed harmful algal blooms were atypical both for species-specific causative agents and were also shifted in respect to “normal” temporal occurrences. According to some interpretation of bloom phenomena, the norm of a phytoplankton bloom, followed by a zooplankton bloom can be disrupted when, in the place of the “traditional” taxa (usually diatoms for phytoplankton, and crustacea for zooplankton), alternative taxa are taking advantage of seasonal resource availability. If the alternative taxa to “normal” ones are phytoplanktonic, then HAB or mucilages occur, whereas, if they are zooplanktonic, jellyfish blooms occur. In both cases, the components of the main production pulses change, and this, in its turn, changes ecosystem functioning in a dramatic way. Both microalgal and jellyfish blooms, thus, must be considered as alternative pathways in ecosystem functioning, deriving from the disruption of the seasonal sequence of pulses that we tend to consider as “normal”. In these “short circuits”, the living matter is channelled into opportunistic species (the blooming microalgae or jellyfish) that take advantage of an opportunity for growth and that monopolize the environment for some time, causing its malfunction, at least in terms of conditions that are favourable to our aims. Fish are the main good that we receive from marine systems.

Fisheries and the ecosystem-based approach

17) Fisheries science usually considers just fish populations and the impact of fisheries on them. Usually, furthermore, each species is considered in isolation from the rest of the ecosystem that allows for its existence. For many fish species, even the life cycles and life histories are poorly known and our knowledge is limited to where and when they can be caught more efficiently, and to the periods of sexual reproduction. The life cycles of even popular species, such as the halibut, were unknown since not long ago and, for many fish species, they are still unknown or poorly known. Larval and juvenile mortality are black holes in the knowledge of the biology of most fish species, even though the success of recruitment is a prerequisite to have exploitable fish populations. When the Non Indigenous ctenophore species *Mnemiopsis leidyi* invaded the Black Sea, the local fisheries suddenly collapsed. This showed to fisheries ecologists and biologists that gelatinous predators can impair the recruitment processes of fish species, leading to the collapse of their populations. It might be argued that, in the case of *Mnemiopsis*, the importance of the species in determining the viability of fish populations was near to 100% since the presence of the ctenophore was very strongly related to the absence of fish. Normally, the importance of gelatinous zooplankton in fisheries

studies is considered as 0%, whereas it is arguable that it might have intermediate values between the 100% attributed to *Mnemiopsis* and the 0% attributed to gelatinous zooplankton in general (at least in fisheries models). The adoption of the ecosystem approach to fisheries, thus, should take into account the occurrence of episodic events such as microalgal or jellyfish blooms that change the functioning of the ecosystems and that presumably affect the viability of fish populations.

GENERAL CONCLUSIONS OF THE WORKSHOP

18) Stemming from the presentations and the discussions, the workshop agreed that fisheries science must incorporate the rest of the ecosystem, and that microalgal and gelatinous plankton blooms are important drivers of ecosystem functioning, that their occurrence has become more and more frequent in the last decades, and that this needs proper measures in terms of performed research and of management practices. Besides improving our understanding of ecosystem functioning in general, the incorporation of these phenomena in fisheries science will improve also the management and the sustainable use of fish stocks. The main conclusion of the workshop, thus, is that GFCM rightly addressed the issue of algal and jellyfish blooms as a fisheries-related problem. With these principles in mind, the workshop agreed upon the following recommendations.

RECCOMENDATIONS

19) Stemming from the general conclusions, the workshop agreed to recommend the following issues (listed in order of priority within each category):

On RESEARCH

20) Carry out medium-term integrated research programmes in the GFCM area covering the following aspects:

Biology of blooming species (microalgae and gelatinous plankton)

- Improve the knowledge on morphological and molecular taxonomy. Assemble all available data reported in the literature to produce guides for the identification of the main species forming blooms, and of those that might possibly form them. New species able to form blooms are continuously identified and it might be possible to single out a series of features that allow to identify potential bloomers.

- Improve the knowledge about the ecology of blooming species. This will allow detecting possible triggering clues, optimal environmental conditions for blooms (these might be different, according to the species). E.g. are rising temperatures conducive to more frequent blooms?

- Improve the knowledge of jellyfish and algal species life cycles. Many blooming species are usually at low concentrations or even absent from the environment, to appear then in huge abundances during blooms. These species usually have resting stages (cysts or spores for algae and heterotrophic protists, or polyps for jellyfish). The “seeds” that will lead to blooms in the plankton, thus, are often in the benthos and, without appreciation of this aspect, our understanding of blooms remains poor. Are there particular places where resting stages are accumulated (coastal areas, coastal defences, harbours, canyons, sediments below gyres, etc.)? Answering these questions might allow for some management.

- Improve the knowledge of the eco-physiology, both of the resting stages and of the active ones. What are the clues that trigger the hatching of the resting stages, or the production of medusae by polyps? What are the conditions that sustain a bloom in terms of physiological requirements? What are the possible controlling factors (nutrient availability, predation, etc.)?

- Improve the biochemical characterization of target species and the knowledge about toxins composition.

- Investigate on the potential uses of microalgal and jellyfish biomasses and/or bioactive molecules as a resource for biotechnological applications, from biofuels to pharmacology, from cosmetics to nutraceutical health products, from food for humans to feed for livestock or aquaculture farms.

Ecology and biogeography of blooming species (algae and jellyfish)

- Fill the gap of information on the temporal and spatial abundance trends together with environmental data (climatic, oceanographic, topographic).

- Perform population studies to acquire knowledge on the genetic structure, geographic distribution, and dispersal mechanisms.

- Develop and apply innovative methods (remote sensing from satellites and airplanes, buoys, video-acustics tools, molecular tools) for real time acquisition (when and where possible), or long-term series of appropriate frequency, of integrated data on occurrence, distribution, identification, and quantification of blooms.

- Identify correlations with environmental descriptors and drivers (with special attention to oceanographic regimes), distinguishing critical thresholds of change and identifying early warning signals.

- Identify hot spots for bloom initiation.

- Develop empirical and analytical models to estimate probabilities and behavioural aspects of bloom events under given sets of circumstances, and define spatio-temporal maps of habitat suitability for blooms.

- List *Non Indigenous Species* (*NIS*) and collect historical data about their occurrence, identify human and naturally mediated ways of introduction and dispersal, analyse resting stages, polyps and adult forms in possible vectors and recipient environments.

- Improve knowledge on direct and indirect, trophic/non trophic relationships between target species and other taxa in the community.

Socio-economy of blooming species (algae and jellyfish)

- Assess the impact on ecosystem goods and services, impacts on sea-based human activities (fisheries, aquaculture, tourism, hydraulic engeneering, industry, transport) and human health.

- Evaluate the socio-economical impacts of blooms in terms of economic losses of any kind and, also, of possible economic gains (e.g. biotechnological applications).

On MANAGEMENT

21) The proposed actions on Management are formulated in harmony with the EU's Marine Strategy Framework Directive. The EC Member States are already coherent with the application of MSFD principles. It is relevant to apply an ecosystem-based approach to the management of human activities, and at the same time it is essential to enforce a sustainable use of marine goods and services; priority should be given to achieve or maintain a good environmental status in the marine environment, to continue its protection and preservation, and to prevent subsequent deterioration.

Management for research and data acquisition

- Enforce the ecosystem approach to microalgal and jellyfish blooms issue. *They cannot be tackled in isolation but as parts of a single system.*

- The Workshop identified key and priority species that are in need of urgent management (See Jellyfish fact sheets in Appenidx C and Algal fact sheets in Appendix D).
- Set up regional networks in GFCM area with the aim of producing and exchanging knowledge and data: start monitoring, observation and follow up systems about microalgal and jellyfish blooms (including mucilages and benthic microalgae), working under a single rationale, taking advantage of already existing networks and initiatives (e.g. fisheries monitoring programmes, first aid on beaches, national environmental monitoring programmes, IOC-HAB program, the citizen science experience of the CIESM Jellywatch in Italy and Israel, FAO networks in general, etc.). *This will lead to early warning systems when the phenomena will be properly understood (link cause with effect).*

- Strengthen collaboration and synergy among different regional organizations and initiatives. *Initiatives must not be designed and carried out independently, but must stem from an agreed upon rationale.*

- Enhance international exchange of knowledge *with leading orgasnisations and inititatives studying similar bloom species and their socioeconomical impacts*.

- Establish task forces that will act fast (collect specimens, study the bloom dynamics, evaluate potential impacts, etc.) whenever blooms are recorded. *It is tenuous to try to understand these phenomena after they have occurred.*

- Develop a regional meta-database of these phenomena and national or sub-regional databases of the newly available data (with mirror databases to ensure safe storage of data), using a single platform. Improve data quality by setting precise standards. *Data must be available for comparisons and to identify possible causative effects.*

- Improve access to oceanographic and meteorological data and strengthen collaboration with oceanographers and meteorologists (e.g. evaluate changes in stratification of the water column, extended periods of calm sea and high temperature, rain patterns, Saharan dust). *The synergy among different disciplines is crucial to understand such complex phenomena.*

- Devise and standardize preservation methods of specimens allowing for both morphological and genetic analysis. *Genetic and morphological analyses can be carried out only if specimens are preserved in specific ways.*

- Enhance institutional buildings to tackle issues related to microalgal and jellyfish blooms. *E.g. store reference collections of organisms and tissues for further studies, implement facilities for the rearing of the species under controlled conditions, etc.*

- Enhance capacity building in local scientific communities; develop integrated approaches. *HAB and jellyfish scientists must work together and must learn from each other.*

- Set up early warning systems. *When microalgal and jellyfish blooms will be properly linked to causative scenarios, it will be possible to predict their possible occurrence.*

Management measures for fisheries

- Devising and testing selective fishing gear and methods (including employed materials for gear).

- Consider ways of disposal of bycatch jellyfish and mucilages (usually they are thrown at sea again, possibly exacerbating the phenomena).

- Adoption of detailed log books for by-catch and for any other “anomaly” observed at sea.

- Identify and manage fish species that predate on jellyfish or graze on phytoplankton or trigger trophic cascades that enhance blooms.

- Management of critical areas where the bloom phenomena are possibly triggered and eventually controlled by some resident species (feeding on the bloomers) that, then, should not be fished.

- Prevent transport of resting stages and polyps among different regions through nets and equipment that are operated over large areas (e.g. from Mediterranean to Black Sea and viceversa).

Management measures for aquaculture

- Mitigate the overload of nutrients and other chemicals (e.g. antibiotics and hormones) stemming from aquaculture activities since they might enhance blooms.

- Adopt a risk-based spatial planning of aquaculture firms according to the probability of bloom events (bays, offshore, vicinity with nutrient outputs, etc.).

- Design aquaculture farms so to react to these events (e.g. displacement of cages).

Management measures relevant to tourism

- Enhance tourist awareness about these problems.

- Set up first aid in beaches with standard protocols of treatment.

- Evaluate the efficacy of exclusion nets.

- Inform the public about harmless species of jellyfish that might become an attraction.

Management measures for coastal installations

- Reduce nutrient and other chemicals overloads by proper treatment, avoiding unbalances in the abundances of nutrients.

- Design coastal defences and harbours while considering that they might enhance blooms (e.g., reservoirs for resting stages, settling sites for polyps).

- Test for the presence of resting stages before any dredging activity. Dispose sediments in a safe way if resting stages are present, since dredging of harbours and sand extraction might trigger HABs.

- Early warning networks to avoid gelatinous masses of any kind in cooling systems and desalination plants.

- Redesign intake and outflow pipes of industries and desalination plants so to avoid gelatinous masses.

Management measures against introduction of Non-Indigenous Species (NIS)

- Control ballast waters and design proper eradication protocols (encysted forms can be very resistant to any treatment).

- Control fouling on ship hulls and its disposal when hulls are cleaned.

- Control and regulate aquarium trade (avoid free trade of NIS, e.g. *Phyllorhiza*).

- Control imported or translocated live seafood (shells might allow cyst or polyp transport).

- Eliminate or treat plastic debris that can host attached cysts or polyps.

Management measures for public awareness

- Increase public awareness (starting from schools) about blooms and their consequences leading to stakeholder participation.
- Open a web site for dissemination of information.

- Produce information packages for managers.

- Introduce simplifying indicators and offer visualisation tools.

- Produce material allowing for the identification of the main species, with distinction between stinging and non-stinging forms.

- Enhance citizen science, so to cover every macrodescriptor of change (including HABs and mucilages).

- Ensure media coverage through efficient press offices, preventing unjustified alarms that might hurt local economies.

- Promote public behaviours that will prevent harm to humans in case of bloom events and of any contact with blooming organisms *(e.g. do not put jellyfish in your diving mask for observation: the tentacle remains will sting your face when you will put your mask on again).*

FUTURE WORK

22) The Worhshop proposes to organize new working meetings dealing with several scientific/management aspects. To achieve and implements the aims of the Reccomendations there might be multidisciplinary working groups on:

(1) Technical guidelines to implement the recommendations of this report (e.g.: database structure, monitoring scheme, intercalibration, etc.). Scientists must work in direct contact with Information and Technology specialists, so to adopt user-friendly platforms.

(2) Protocol for task-force action during a bloom event and the subsequent follow up. Rationale: the recommendations advise to use task forces that will spring into action whenever a bloom is recorded by the observatory network. These task forces should act according to a standard protocol that, so far, does not exist. This should lead, then, to training courses so to prepare the personnel to face these situations.

(3) Environmental conditions leading to bloom events. Rationale: Identification of monitoring stations, putative hot spots, target sites, in collaboration with physical oceanographers. Identification of possible sites of resting stage accumulation (e.g. coastal sites, gyres, canyons, eddies), triggering mechanisms (e.g. trawling, bioturbation, dredging, endogenous cycles).

(4) Economic valuation of bloom impacts.

(5) Biogeography and dispersal of blooming species.

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Appendix A

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Appendix B

Adopted Agenda

1 **Opening, arrangement of the meeting and adoption of the agenda**

2 **Session on Jellyfish Blooms**
(Moderator: Mr. Ferdinando Boero)
2.1 General Introduction (by Boero F.)
2.2 Jellyfish bloomings in the Mediterranean and Black Sea
2.3 Human health-related problems caused or associated with the jellyfish blooming
2.4 Effects of jellyfish bloomings on fisheries
2.5 Methodologies and data collection programs related to jellyfish blooming
2.6 Scientific framework to advice on management options to eliminate and/or mitigate jellyfish blooms
2.7 General discussions

3 **Session on Algal Blooms**
(Moderators: Ms. Antonella Penna and Mr. Muhammet Türkoğlu)
3.1 General Introduction (by Penna A. and Türkoğlu M.)
3.2 Algal bloomings in the Mediterranean and Black Sea
3.3 Human health-related problems caused or associated with the algal blooming
3.4 Effects of algal bloomings on fisheries
3.5 Methodologies and data collection programs related to algal bloomings
3.6 Scientific framework to advice on management options to eliminate and/or mitigate algal blooms
3.7 General discussions

4 **Any other matter**

5 **General conclusions and recommendations on algal and jellyfish blooms in the Mediterranean and Black Sea**

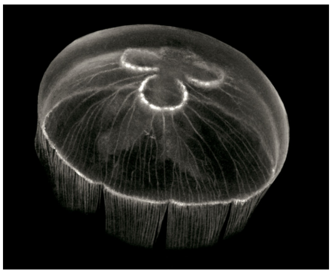
6 **Adoption of the final report/conclusions and recommendations**

Appendix C

Jellyfish Fact Sheets

(Illustrations by A. Gennari, 2010)

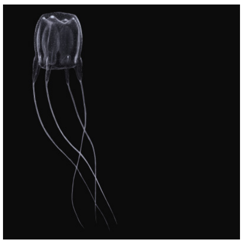
Aurelia aurita (Linnaeus, 1758)



- **Indigenous or non indigenous or cryptogenic**: indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** has a typical bipartite scyphozoan life history in which benthic scyphopolyps asexually strobilate ephyrae that grow into sexual medusae, the females of which brood larvae that settle into the shallow coastal benthos within a few days of being released (Dawson and Jacob, 2001). Large development plasticity (e.g. podocysts, pseudoplanulae, reverse development) (Piraino *et al.*, 2004)
- **Presence (regular – occasional – seasonal patterns):** the main period of strobilation, resulting in release of ephyrae, starts in the late winter/early spring. The ephyrae released develop into medusae by early spring, which enduretill summer or early autumn. Prolonged or even semi-continuous periods of strobilation have been reported in some areas, resulting in the presence of ephyrae in the water column for much of the year (Lucas, 2001). Occasional medusae in midwinter (Galil *et al.,* 1990).
- **Behaviour (vertical migrations):** very common in the mixed layer down to the subthermocline in the Black Sea. Small individuals are mostly found above the thermocline, while larger individuals (up to 40 cm umbrella diameter) below (Bat *et al.*, 2009). Exhibits a consistent pattern of diel vertical migration (Malej *et al.*, 2007).
- **Ecophysiology:** poorly known.
- **Genetic characterization**: molecular studies revealed cryptic species (Dawson and Jacob, 2001)
- **Association with other species:** unknown.
- **What it lives upon (food – nutrients):** small copepods, copepodites, larvae of Gastropoda, Bivalvia, Cirripedia, nauplii, Appendicularia, fish eggs and larvae (Malej *et al.,* 2007).
- **Fed upon by:** probably fish, not well documented.

- **Documented blooms (one, several, many):** many, both in the Mediterranean and the Black Sea.
- **Geographic distribution in the Mediterranean and Black Sea:** common inhabitant of nearshore waters circumglobally between about 50 °N and 55 °S (Turk *et al.,* 2008; Dawson and Jacob, 2001). Common in the Adriatic Sea, also in closed basins (Mliet Island, Lake of Varano). Occasionally abundant in the Black Sea and in the Western and Central Mediterranean.
- **Documented impacts:** Aggregations may clog cooling water intakes of coastal power plants and block fishing nets (Dong *et al*., 2010).
- **Putative impacts:** impoverishment of plankton communities.
- **Gaps in knowledge (e.g. triggering of blooms):** distribution of polyps.
- **Management measures:** reduce polyp growth.

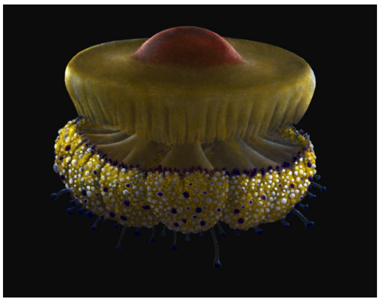
Carybdea marsupialis (Linnaeus, 1758)



- **Indigenous or non indigenous or cryptogenic**: indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** reproduces sexually through planulae (larvae) that after a short planktonic period turn into a primary polyp which then turns into jellyfish. The cubopolyp of the box jelly *Carybdea marsupialis* reproduces asexually by lateral budding, and by almost total transformation of the polyp into a cubomedusa (Fischer and Hoffmann, 2004). Two types of metamorphosis occur in the life cycle of *Carybdea marsupialis*. In addition to the metamorphosis, during which the entire polyp transforms into one medusa, there is a second type of metamorphosis which leaves a regenerative remnant. This mode of medusa formation seems to be derived from the strobilation known from Scyphozoa (Pohl and Jarms, 2005).
- **Presence (regular – occasional – seasonal patterns):** First recorded from the Adriatic Sea in 1986 (Boero and Minelli, 1986). In 2009 and 2010 very common in the Adriatic Sea and in the Western Mediterranean.
- **Behaviour (vertical migrations):** attracted by city lights during the night, approaching the coast. It can enter harbors. Very active swimmer.
- **Ecophysiology:** poorly known.
- **Genetic characterization:** unknown.
- **Association with other species:** unknown.
- **What it lives upon (food – nutrients):** polychaetes, crustaceans and fish (Larson, 1976).
- **Fed upon by:** unknown.
- **Documented blooms (one, several, many):** many, in the last years, in the Adriatic Sea and the Western Mediterranean.
- **Geographic distribution in the Mediterranean and Black Sea:** Adriatic Sea and Western Mediterranean.

- **Documented impacts:** causes cutaneous reactions characterized by erythematous linear weals, accompanied by intense burning sensations and pain, which are irritant rather than allergic (Peca *et al*., 1997).
- **Putative impacts**: might affect fisheries yields.
- **Gaps in knowledge (e.g. triggering of blooms):** ecological role in food webs.
- **Management measures:** avoid settling space for polyps. The presence of coastal defences seems to be linked to the presence of this species, probably due to provision of proper substrates for polyps.

Cotylorhiza tuberculata (Macri, 1778)



- **Indigenous or non indigenous or cryptogenic:** indigenous
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** Occurrence, growth, maturation, and aging of medusae indicated an annual life cycle of this rhizostomous jellyfish. Ephyrae are released during strobilation peaks in spring and summer; exceptionally high growth rates lead to medusa diameters of up to 40 cm after six months. Due to symbiotic zooxanthellae the medusae are potentially autotrophic; P : R values ranged from 0.36 to 1.17. The gonochoristic medusae mature during summer; a sexual dimorphism is evident by brood-carrying filaments in females. The life span of the medusae is about half a year, while scyphistomae are potentially perennial. The observed annual metagenetic cycle is interpreted as a life history adaptation to a highly seasonal environment (Kikinger, 2008).
- **Presence (regular – occasional – seasonal patterns):** June to September (Ruzafa *et al.*, 2002). Occasionally in winter (Galil *et al.,* 1990).
- **Behaviour (vertical migrations):** poorly known.
- **Ecophysiology**: poorly known.
- **Genetic characterization**: poorly known.
- **Association with other species:** juvenile fish are often associated with it, and it might enhance recruitment success in some species.
- **What it lives upon (food – nutrients):** microphagous.
- **Fed upon by:** *Caretta caretta* (Revelles *et al.*, 2007).
- **Documented blooms (one, several, many):** formed blooms in the past, although they were not documented very frequently (Kogovsek *et al.*, 2010).
- **Geographic distribution in the Mediterranean and Black Sea:** throughout the Mediterranean Sea (Galil, 1990).
- **Documented impacts:** none.
- **Putative impacts**: it might have a positive effect on fish recruitment by providing shelter to juveniles.

- **Gaps in knowledge (e.g. triggering of blooms):** impact on food chains.
- **Management measures:** limit substrates conducive for polyp settlement, such as dead mollusc shells.

Mnemiopsis leidyi (Agassiz, 1865)

- **Indigenous or non indigenous or cryptogenic:** non indigenous; originating from the Western Atlantic (Purcell *et al*. 2001), in coastal waters over a wide latitudinal range (40°N–46°S), it invaded the Black Sea in the 1980s, followed by subsequent invasions of the other large water bodies in the Mediterranean basin (Shiganova *et al*. 2001, Galil *et al*. 2009).
- **If non indigenous, ways of introduction:** ballast water (Shiganova, 1998).
- **Life cycle:** the life cycle of *M. leidyi* encompasses size changes from ~0.5 mm to more than 50 mm in length and development from the cydippid larval stage to adult lobate morphology (Rapoza *et al.,* 2005).
- **Presence (regular – occasional – seasonal patterns):** population sizes in temperate locations small during cold winter temperatures, and increase with reproduction in the spring (Kremer, 1994).
- **Behaviour (vertical migrations):** usually at a depth shallower than 20 m during all months. The ctenophore was found in the deepest layer, at 50 - 100 m, only in summer months (Roohi *et al.,* 2010).
- **Ecophysiology**: metabolism and growth of *M. leidyi* are clearly influenced by temperature (Kremer, 1977). *Mnemiopsis* is found in an extremely wide range of environmental conditions (winter low and summer high temperatures of 2 °C and 32 °C, respectively, and salinities of < 2 - 38‰) (Purcell *et al.,* 2001).
- **Genetic characterization:** two of the sequenced ctenophores (SAL-1 and HAF-1) contained an ITS composite genotype that was previously found in invasive *M. leidyi* from the Black Sea (south western Black Sea and Gelendzhik Bay, Russia) and the Sea of Azov (various locations), as well as in native ctenophores from the United States, possibly indicating common recent ancestry (Fuentes *et al.,* 2009).
- **Association with other species:** unknown.
- **What it lives upon (food – nutrients):** feeds on a variety of prey (Larson, 1988); Cladocera, copepods, bivalve larvae, crab larvae, diatoms, dinoflagellates, fish eggs and fish larvae (Purcell *et al.,* 2001).

- **Fed upon by:** *Beroe ovata, Chrysaora quinquecirrha, Cyanea capillata, Peprilus alepidotus* and butterfish *P. triacanthus* (Fuentes *et al.,* 2009).
- **Documented blooms (one, several, many):** blooms of the invasive ctenophore, *Mnemiopsis leidyi*, occurred in 2009 along the Mediterranean Sea coasts of Spain and Israel (Galil *et al.,* 2009; Fuentes *et al.,* 2009). In the framework of the CIESM Jellywatch campaign in the summer of 2009, *M. leidyi* was recorded from the Ligurian, Tyrrhenian, and Ionian Seas, including swarming episodes that, together with those reported from Spain in the same period, suggest a great success of the species in the Western Mediterranean (Boero *et al.,* 2009).
- **Geographic distribution in the Mediterranean and Black Sea:** present since more than two decades in the Black Sea, became abundant in the whole Mediterranean since 2009.
- **Documented impacts**: invasion of regions outside its historical distributions have resulted in dramaticplanktonic community alterations and destruction of fisheries in regions such as the Black Sea (Shiganova *et al.,* 2003). Interfered with operation of desalination plants in Israel (Galil *et al.,* 2009).
- **Putative impacts:** unknown.
- **Gaps in knowledge (e.g. triggering of blooms):** establish how many colonization events did occur, was there an adaptation to Mediterranean conditions?
- **Management measures:** discharge ballast waters in the mid-Atlantic and fill ballast tanks in regions where putative aliens are less frequent.

Pelagia noctiluca (Forskål, 1775)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** holoplanktonic.
- **Presence (regular – occasional – seasonal patterns):** regular, mostly in summer, first sightings in February, present until October. Possibly, it spends the winter in deep water, or as resting stages. Ocassionally winter swarms (Galil *et al.,* 1990).
- **Behaviour (vertical migrations):** forms enormous swarms, carried by currents, known to move vertically in the water column, especially in winter.
- **Ecophysiology:** poorly known.
- **Genetic characterization:** mixed populations throughout the Mediterranean.
- **Association with other species:** unknown.
- **What it lives upon (food – nutrients):** zooplankton, including ichtyoplankton.
- **Fed upon by:** several fish species (undocumented quantitatively).
- **Documented blooms (one, several, many):** many.
- **Geographic distribution in the Mediterranean and Black Sea:** abundant especially in the Western Mediterranean, occasionally in the Eastern Basin.
- **Documented impacts:** human health, tourism, fisheries, aquaculture, power plants.
- **Putative impacts:** not applicable (all the negative impacts of jellyfish are directly applicable to this species, so no putative ones remain)
- **Gaps in knowledge (e.g. triggering of blooms):** where are they when they are not present? Are there areas from where the blooms spread?
- **Management measures:** reduce overfishing, especially of medusivorous species. Instruct first aid stations on beaches how to alleviate stings. Increase public awareness.

Phyllorhiza punctata (von Lendenfeld, 1884)

- **Indigenous or non indigenous or cryptogenic:** non indigenous.
- **If non indigenous, ways of introduction:** unknown. The records from the Levantine Basin suggest entry from the Red Sea through the Suez Canal (Jarms 2003), whether by drift or transported by vessels (ephyrae with ballast water, scyphistomae attached to hulls) (Navandi and Reinhard, 2007; Galil *et al.,* 2009).
- **Life cycle**: poorly known.
- **Presence (regular – occasional – seasonal patterns):** Off the Israeli coast it was found in January, July and October (Galil *et al.,* 2009). In Brazil, the presence in late winter and spring of all size classes suggested a prior period of continuous ephyrae release synchronized to seasonal high water temperatures and extended photoperiod (Haddad and Nogueira, 2006).
- **Behaviour (vertical migrations):** unknown.
- **Ecophysiology:** poorly known.
- **Genetic characterization**: poorly known.
- **Association with other species:** algal endosymbionts (zooxanthellae) (Garcia, 1990; Galil *et al.,* 2009) and thus autotrophy may be important for this species.
- **What it lives upon (food – nutrients):** zooplankton.
- **Fed upon by:** unknown.
- **Documented blooms (one, several, many):** several (e.g. Gulf of Mexico), but not in the Mediterranean Sea.
- **Geographic distribution in the Mediterranean and Black Sea:** both in the Eastern and the Western basins, so far only occasional.
- **Documented mpacts**: none in the Mediterranean Sea. In the Gulf of Mexico it clogged fishing nets.
- **Putative impacts**: may harm fisheries by predating on fish eggs and larvae and their prey, zooplankton (Boero *et al.,* 2009).

- **Gaps in knowledge (e.g. triggering of blooms):** very little is known about this species in the Mediterranean Sea.
- **Management measures**: common in marine aquaria displays. Control aquarium trade.

Physalia physalis (Linnaeus, 1758)

- **Indigenous or non indigenous or cryptogenic**: non indigenous, native of tropical and subtropical areas (Wilson, 1947).
- **If non indigenous, ways of introduction:** enters the Mediterranean occasionally, through the Strait of Gibraltar (suggested by distribution patterns).
- **Life cycle:** an "individual" is actually a colony of unisexual organisms. Every individual has specific gonozooids (sex organs or reproductive parts of the animals, either male or female). Each gonozooid is comprised of gonophores, which are little more than sacs containing either ovaries or testes. *Physalia* are dioecious. Their larvae probably develop very rapidly to small floating forms. Fertilization of *Physalia* is assumed to occur in the open water, because gametes from the gonozooids are shed into the water. This may happen as gonozooids themselves are broken off and released from the colony. The release of gonozooids may be a chemical response occurring when groups of individuals are present in one locality. Critical density is probably required for successful fertilization. Fertilization may take place close to the surface. Most reproduction takes place in the fall, producing the great abundance of young seen during the winter and spring.
- **Presence (regular – occasional – seasonal patterns):** occasional in the Mediterranean Sea, more abundant in recent years.
- **Behaviour (vertical migrations):** transported by wind, it floats on the surface.
- **Ecophysiology**: powerful venom, occasionally lethal.
- **Genetic characterization**: poorly known.
- **Association with other species:** *Lepas fascicularis* and *L. pectinata, Caretta caretta, Nomeus gronovii* (Wilson, 1947).
- **What it lives upon (food – nutrients):** larval fish comprised 70 to 90% of the prey types found in stomach contents of *Physalja physalis. P. physalis* feeds also on chaetognaths and small squids (Purcell, 1984).

- **Fed upon by:** *Glaucus atlanticus, Janthina janthina, Caretta caretta.*
- **Documented blooms (one, several, many):** several, especially in the Atlantic, but also in the Mediterranean Sea.
- **Geographic distribution in the Mediterranean and Black Sea:** mostly in the Western basin, but may pass Sicily Channel and reach Malta.
- **Documented impacts:** lethal (Stein *et al*., 1989), one case reported in the Mediterranean (Sardinia, summer 2010).
- **Putative impacts**: potential impact on commercial fishing in the area. A popular food choice for the Man o' War is larval fish: if too many fish are consumed in their larval stage, there won't be many adult fish for humans to harvest.
- **Gaps in knowledge (e.g. triggering of blooms):** dependance of Mediterranean populations on Atlantic propagules, impact on food chains.
- **Management measures:** close bathing facilities when the species is present. Collection and disposal on land.

Rhizostoma pulmo (Macri, 1778)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** Fertilization external, planulae appear after 2 days, settle polyps reproduced asexually mainly by podocysts. Strobilation is induced by temperature cue. During transformation from newly released ephyra to young medusa, velar lappets appear and increase in number (Paspaleff, 1938). Reverse transformation of ephyrae into scyphopolyps has been observed (Paspaleff, 1938).
- **Presence (regular – occasional – seasonal patterns): s**easonal, occurring usually in late spring when the temperature increase to 25.5 °C (Galil *et al.,* 1990; Mariottini and Pane, 2010).
- **Behaviour (vertical migrations):** poorly known.
- **Ecophysiology:** swarms seemed to correlate with high temperature and nutritional factors connected to the abundance of zooplankton, which is the food for this microphagous jellyfish (Mariottini and Pane, 2010).
- **Genetic characterization**: unknown.
- **Association with other species:** the crab *Liocarcinus vernalis* is often transported by this jellyfish.
- **What it lives upon (food – nutrients):** diatoms (Lilley *et al.*, 2008).
- **Fed upon by:** unknown, probably many fish species.
- **Documented blooms (one, several, many):** annual blooms (Kogovsek *et al.,* 2010). During the years of the bloom in the Mediterranean Sea, *Rhizostoma pulmo* occurred in large numbers in the Northern Adriatic Sea, in open sea and along the coastline, as well as in the Southern Adriatic Sea and the Northern Ionian Sea, mainly in winter. *Rhizostoma pulmo* was indicated to be the largest and most abundant jellyfish in Lebanese coastal waters, occurring usually in late spring when the temperature increase up to 25.5 °C, staying in Lebanese waters up until mid-August and disappearing later on (Mariottini and Pane, 2010).

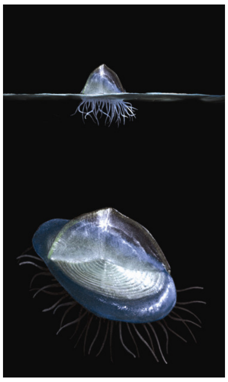
- **Geographic distribution in the Mediterranean and Black Sea:** mainly Adriatic Sea, Ionian Sea, Ligurian Sea, Eastern Mediterranean, Tunisian waters, Western Mediterranean and Black Sea (Mariottini and Pane, 2010). During the last decade, in some Eastern Mediterranean waters *Rhizostoma pulmo* has been replaced by *Rhopilema nomadic*a (Herut & Galil, 2000)
- **Documented impacts**: many economic problems and also health implications (Mariottini and Pane, 2010). After a contact cutaneous pain, erythematous with subsequent small vesicles (Kokelj and Plozzer, 2002). The stings are much milder than those of *Pelagia noctiluca*.
- **Putative impacts:** unknown.
- **Gaps in knowledge (e.g. triggering of blooms):** triggering of blooms.
- **Management measures:** reduce eutrophication, utilization as a food.

Rhopilema nomadica (Galil, 1990)

- **Indigenous or non indigenous or cryptogenic:** East African species. It was first recorded along the coastlines of Israel in 1977 (Galil *et al.,* 1990). At present is found along the Levantine Basin with a single record off the Peloponnesus, Greece (Galil *et al.,* 1990; Siokou-Frangou *et al.,* 2006).
- **If non indigenous, ways of introduction:** invasion through the Suez Canal.
- **Life cycle:** life cycle from planula to ephyra to young medusa described. Strobilation considered dependent on temperature, with rapid strobilation between 18 - 20 °C and declining at 24 - 26 °C. The rise of water temperature supports the strobilation in spring, while inhibited in winter and in summer (Lotan *et al.,* 1992).
- **Presence (regular – occasional – seasonal patterns):** huge swarms are formed each summer since the mid 1980s along the SE Levantine coast (Galil *et al.*, 1990, 2010).
- **Behaviour (vertical migrations):** poorly known.
- **Ecophysiology:** laboratory studies support the possibility that synchronization and annual occurrence are controlled by seasonal changes in water temperature regimes, leading to rapid strobilation and release of ephyrae during springtime. The sensitivity of the polyps to low temperatures might explain why its dispersal is limited to the eastern Mediterranean (Lotan *et al.*, 1994), but this sole reason is probably too simplistic.
- **Genetic characterization**: unknown.
- **Association with other species:** juveniles of *Alepes djedaba* (Forskal, 1775), a carangid fish that entered through the Suez Canal , are commonly found in association with *R. nomadica*, taking shelter under its umbrella and among the filamentous mouth arms (Galil *et al.*, 1990).
- **What it lives upon (food – nutrients):** unknown
- **Fed upon by:** unknown.
- **Documented blooms (one, several, many):** many, in the Levant Basin.
- **Geographic distribution in the Mediterranean and Black Sea:** South-Eastern Mediterranean.

- **Documented impacts**: the swarms adversely affect tourism, fisheries and coastal installations. The summer swarming results each year in envenomation victims suffering burning sensation, eurythema, papulovesicular and urticaria-like eruptions that may last weeks and even months after the event. Coastal trawling and purse-seine fishing are disrupted for the duration of the swarming due to net clogging and inability to sort yield. Jellyfish-blocked water intake pipes pose a threat to desalination plants, cooling systems of port-bound vessels and coastal power plants. (Galil *et al.*, 1990; Galil, 2007; Mariottini and Pane, 2010).
- **Putative impacts:** impoverishment of plankton communities.
- **Gaps in knowledge (e.g. triggering of blooms):** distribution of polyps triggering of blooms, competing species and predators, etc.
- **Management measures:** reduce suitable substrates for polyps, reduce overfishing.

Velella velella (Linnaeus, 1758)



- **Indigenous or non indigenous or cryptogenic:** indigenous, circumglobal in warm and temperate waters.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** the floating stage is a polyp colony. It produces medusae that reproduce sexually, the larvae sink in deep water, and then migrate towards the surface while the colony is formed, going through several growth stages.
- **Presence (regular – occasional – seasonal patterns):** prsent in spring, early summer.
- **Behaviour (vertical migrations):** wind-transported.
- **Ecophysiology**: poorly known.
- **Genetic characterization**: poorly known.
- **Association with other species**: *Scrippsiella velellae* (*PERIDINIALES*) (Banaszak *et al.,* 2006).
- **What it lives upon (food – nutrients):** iponeuston, including fish eggs and larvae.
- **Fed upon by:** *Caretta caretta* (Parker *et al*., 2005); *Puffinus carneipes* (Gould *et al*., 1997); *Ianthina janthina* (Bayer, 1963).
- **Documented blooms (one, several, many):** many, also in the Mediterranean Sea.
- **Geographic distribution in the Mediterranean and Black Sea:** Eastern and Western Mediterranean (Bouillon *et al.,* 2004).
- **Documented impacts:** stranded swarms form masses of putrescent material.
- **Putative impacts**: might impair the recruitment of some fish species, if the blooms match the period of presence of fish eggs and larvae.
- **Gaps in knowledge (e.g. triggering of blooms):** the studies on the life cycle are very old. Little has been done in recent years.
- **Management measures**: none. This species is affected by oil pollution.

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Appendix D

Algal Fact Sheets

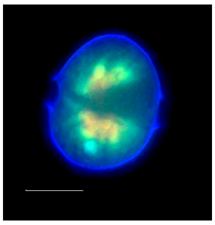
Alexandrium catenella (Whedon and Kofoid, 1936) Balech, 1985

(Photo by M. G. Giacobbe)

- **Indigenous or non indigenous or cryptogenic:** non indigenous (?).
- **If non indigenous, ways of introduction:** anthropogenic pathways, ship ballast waters or aquaculture activities.
- **Life cycle:** heterothallic.
- **Harmful effect:** producer of paralytic shellfish poisoning toxins (CTX c1-c4 toxins, GTX, STX) possible toxins accumulation in marine food webs, high-biomass blooms.
- **Presence: (regular – occasional – seasonal patterns):** regular, mostly in spring and summer.
- **Habitat:** planktonic, distributed in temperate coastal waters; it has been frequently reported in the western Mediterranean (Vila *et al.,* 2001a).
- **Ecology:** related to high salinities and high concentrations of NO_3 and NH_4 (Collos *et al.,* 2004; Jouzein *et al.,* 2008).
- **Ecophysiology:** known.
- **Genetic characterization:** homogeneous species belonging to the Temperate Clade (based on ribosomal genes) (Penna *et al.,* 2005a); Mediterranean population based on microsatellites (Masseret *et al.,* 2009).
- **Association with other organisms:** unknown.
- **Documented blooms (one, several, many):** many; blooms are associated with eutrophic, warm water surface temperatures, in semi-confined areas and lagoons, with local accumulation of cysts in the western Mediterranean Sea (Bravo *et al.,* 2008).
- **Geographic distribution in the Mediterranean Sea and Black Sea:** Western Mediterranean Sea.
- **Documented impacts:** on environment, on human health, aquaculture contamination.
- **Gaps in knowledge:** introduced or indigenous species?

- **Management measures:** monitoring of coastal waters programs; reducing nutrient content of riverine inputs (urban waste water, agricultural and industrial discharge); treatment of sediments, plastic debris; control of ballast waters.

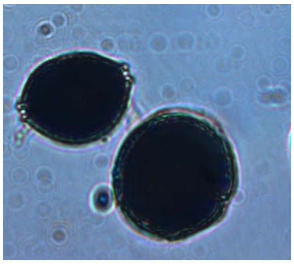
Alexandrium minutum (Halim, 1960) Balech, 1989



(Photo by M. G. Giacobbe)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** heterothallic.
- **Harmful effect:** producer of paralytic shellfish poisoning toxins (GTX, STX, neoSTX), possible toxins accumulation in marine food webs, high-biomass blooms, water discolouration events.
- **Presence: (regular – occasional – seasonal patterns):** regular, mostly in spring and autumn.
- **Habitat:** planktonic in warm, temperate, coastal and estuarine waters. In particular, found in coastal enriched sites, harbours, estuaries or lagoons (Vila *et al.,* 2005).
- **Ecology:** related to low salinities and nutrient-rich freshwater inputs; euryhaline and eurytherm.
- **Ecophysiology:** known.
- **Genetic characterization:** homogeneous species belonging to Global Clade (ribosomal genes) (Lily *et al.,* 2005; Penna *et al.,* 2008).
- **Association with other organisms:** observed to be infected by sporocysts of the parasite *Parvilucifera* (Apicomplexan) (Figueroa *et al.,* 2010).
- **Documented blooms (one, several, many):** many; many blooms are associated with local accumulation of cysts in confined water areas (Anglés *et al.,* 2010; Estrada *et al.,* 2010).
- **Geographic distribution in the Mediterranean Sea and Black Sea:** broadly distributed.
- **Documented impacts:** on human health, zooplankton, fisheries, aquaculture, tourism.
- **Gaps in knowledge:** known.
- **Management measures:** monitoring of coastal waters programs; reducing nutrient content of riverine inputs (urban waste water, industrial and agricultural discharges); treatment of sediments, plastic debris; control of ballast waters.

Alexandrium taylorii (Balech, 1994)



(Photo by A. Penna)

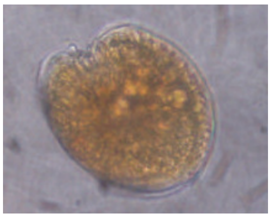
- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable. Cell dispersion can also be favoured by anthropogenic means, as plastics or movement of recreational boats in summer.
- **Life cycle:** homotallic.
- **Harmful effect:** high-biomass blooms, water discolouration events.
- **Presence: (regular – occasional – seasonal patterns):** regular, mostly in summer
- **Habitat:** planktonic, distributed in temperate coastal waters.
- **Ecology:** related to high concentrations of inorganic nitrogen, phosphorus and high water temperature, calm sea and weak tide (Giacobbet *et al.,* 2007).
- **Ecophysiology:** known.
- **Genetic characterization:** unique and homogeneous Mediterranean genotype (based on ribosomal genes) (Penna *et al.,* 2008).
- **Documented blooms (one, several, many):** recurrent blooms; the high production of temporary cysts play a significant role in the bloom dynamics (Basterretxea *et al.,* 2005).
- **Geographic distribution in the Mediterranean Sea and Black Sea:** presence in the western and eastern areas of the Mediterranean.
- **Documented impacts:** on tourism with high economic losses.
- **Gaps in knowledge:** resting stages in the sediments.
- **Management measures:** monitoring of coastal waters programs; reducing nutrient content of riverine inputs (urban waste water and agricultural discharges); plastic debris.

Dinophysis sacculus (Stein, 1883)

(Photo by A. Zingone and I. Percopo)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** heterothallic.
- **Harmful effect:** producer of diarrhetic shellfish poisoning toxins (OA, DTX-1).
- **Presence: (regular – occasional – seasonal patterns):**
- **Habitat:** planktonic, distributed in cold and temperate coastal waters; frequently reported in semi-enclosed basins, estuaries and lagoons.
- **Ecology:** it was characterized as a typical late spring-early summer species (France and Mozetic, 2006) and stratified waters favour high abundances and accumulation of cells. Freshwater inputs influence the growth of this species. It was found to be negatively correlated to salinity in the Adriatic (Caroppo 2001) and off the Catalan coast (Vila *et al.*, 2001b).
- **Ecophysiology:** known.
- **Genetic characterization:** grouped into Cluster I with other *Dinophysis* species (based on ribosomal genes) (Papaefthimiou *et al.*, 2010)
- **Documented blooms (one, several, many):** several occurrences have been reported in the Mediterranean Sea.
- **Geographic distribution in the Mediterranean Sea and Black Sea:** distributed in the Western Mediterranean.
- **Documented impacts:** on human health and aquaculture with high economic losses.
- **Gaps in knowledge:** time of delayed toxicity in relation to the occurrence of toxic species in the water column.
- **Management measures:** monitoring of coastal waters and intensive analyses of mussel toxicity at shellfish farms.

Gambierdiscus sp. (Adachi and Fukuyo, 1979)



(Photo by K. Aligizaki)

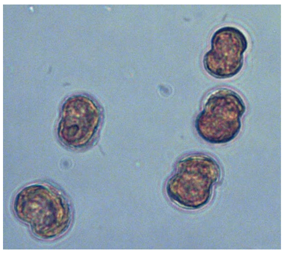
- **Indigenous or non indigenous or cryptogenic:** cryptogenic or indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** unknown.
- **Harmful effect:** under study, potential producing toxins of Ciguatoxin family (Caillaud *et al.,* 2010)
- **Presence: (regular – occasional – seasonal patterns):** not clear; detected in winter, summer and autumn months along Greek coasts (Aligizaki and Nikolaidis, 2008)
- **Habitat:** benthic and epiphytic, usually found on macrophytes.
- **Ecology:** generally warm waters.
- **Ecophysiology:** unknown.
- **Genetic characterization:** species different from other *Gambierdiscus* species (ribosomal genes) (Aligizaki and Fraga *unpubl.*).
- **Association with other organisms:** assemblages with other benthic microalgal species of the genera *Amphidinium, Coolia, Ostreopsis, Prorocentrum* and *Sinophysis*.
- **Documented blooms (one, several, many):** not documented blooms.
- **Geographic distribution in the Mediterranean Sea and Black Sea:** South and South East Aegean Sea.
- **Documented impacts:** unknown.
- **Gaps in knowledge:** toxin content, genetic, distribution, life cycle.
- **Management measures:** monitoring of benthic substrates and seawaters along the Mediterranean coasts, toxin content determination of strains.

Gonyaulax spinifera (Claparède and Lachmann, 1859) Diesing, 1866

(Photo by A. Godhe)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** not well known, producing resting cysts, affinities with other *Gonyalux* species (Ellegard *et al.,* 2002)
- **Harmful effect:** YTX producer, shellfish farm contamination.
- **Presence: (regular – occasional – seasonal patterns):** regular, mostly in late spring and autumn.
- **Habitat:** planktonic, found in estuarine waters.
- **Ecology:** poorly known.
- **Ecophysiology:** poorly known.
- **Genetic characterization:** species identified based on ribosomal genes (Riccardi *et al.,* 2009).
- **Documented blooms (one, several, many):** it is a recurrent species in the northern Adriatic Sea forming also blooms.
- **Geographic distribution in the Mediterranean Sea and Black Sea:** widely distributed in the Mediterranean Sea.
- **Documented impacts:** shellfish farm contamination and related economic losses.
- **Gaps in knowledge:** life cycle, ecology, ecophysiology.
- **Management measures:** monitoring of coastal waters and intensive analyses of mussel toxicity at shellfish farms.

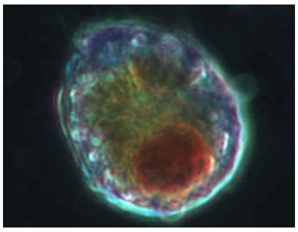
Karlodinium veneficum (Ballantine, 1956) Larsen, 2000



(Photo by E. Garcés)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** heterothallic.
- **Harmful effect:** toxic to a range of marine invertebrates and fish. Produces so-called karlotoxins that exhibit a broad-spectrum lytic effect on cellular membranes.
- **Presence: (regular – occasional – seasonal patterns):** regular.
- **Habitat:** planktonic in temperate estuaries.
- **Ecology:** related to freshwater inputs with high nutrient concentrations and reduced nutrient dispersal (Hall *et al.,* 2008).
- **Ecophysiology:** known.
- **Genetic characterization:** genetically distinct species based on ribosomal gene sequence analyses (Garcés *et al.,* 2006).
- **Association with other organisms:** infected by the parasitic dinoflagellate *Amoebophrya* sp. (Bachvaroff *et al.,* 2009).
- **Documented blooms (one, several, many):** recurrent winter blooms (Garcés *et al.,* 2006).
- **Geographic distribution in the Mediterranean Sea and Black Sea:** Western Mediterranean.
- **Documented impacts:** responsible for massive fish kills.
- **Gaps in knowledge:** testing the toxicity of the species at different food web levels.
- **Management measures:** monitoring of coastal waters programs; reducing nutrient content of riverine inputs (urban waste water, industrial and agricultural discharges).

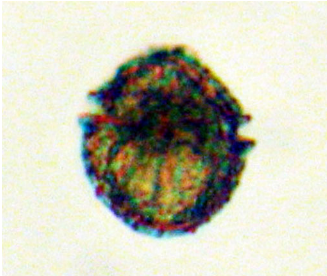
Ostreopsis cf. *ovata* (Fukuyo, 1981)



(Photo by M. G. Giacobbe)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** unknown.
- **Harmful effect:** producer of palytoxin and palytoxin-like compounds related to toxic aerosol for humans, accumulation through the food web; high-biomass blooms affecting benthic communities and recreational activities (Aligizaki *et al.,* 2008; Ciminiello *et al.,* 2008; 2010; Riobò *et al.,* 2008).
- **Presence: (regular – occasional – seasonal patterns):** regular, summer and early autumn periods.
- **Habitat:** epiphytic on soft and hard substrata, sediments and seawater.
- **Ecology:** massive, frequent and widely distributed benthic blooms in sheltered areas.
- **Ecophysiology:** poorly known. It seems that *O.* cf. *ovata* strains from different areas may exhibit different ecophysiological characteristics (Guerrini *et al.,* 2010)
- **Genetic characterization:** existence of the Atlantic/Mediterranean panmictic *O.* cf. *ovata* population (based on ribosomal genes) (Penna *et al.,* 2005b; 2010)
- **Association with other organisms:** epiphytic on macrophytes, rocks, invertebrates and soft sediments (Mangialajo *et al.,* 2008; Totti *et al.,* 2010).
- **Documented blooms (one, several, many):** many; frequent, intense and widely distributed in many Mediterranean areas.
- **Geographic distribution in the Mediterranean Sea and Black Sea:** widely distributed in the Mediterranean coastal areas.
- **Documented impacts:** on human health, benthic communities, aquaculture, tourism with high economic losses.
- **Gaps in knowledge:** toxin profile, environmental conditions and factors promoting blooms; presence of toxins or *O.* cf. *ovata* cells in the aerosol; life cycle.
- **Management measures:** monitoring of benthic substrates and seawaters along the Mediterranean coasts, toxin content determination in different substrates (macrophytes, aerosol, seawaters, aquaculture farms).

Protoceratium reticulatum (Claparède et Lachmann, 1859) Bütschli, 1885



(Photo by S. Capellacci)

- **Indigenous or non indigenous or cryptogenic:** indigenous.
- **If non indigenous, ways of introduction:** not applicable.
- **Life cycle:** not well known, producing resting cysts.
- **Harmful effect:** YTXs producer, shellfish farm contamination (Ciminiello *et al.,* 2003; Paz *et al.,* 2004).
- **Presence: (regular – occasional – seasonal patterns):** regular, mostly in late spring and autumn.
- **Habitat:** planktonic, found in estuarine waters.
- **Ecology:** poorly known.
- **Ecophysiology:** effect of CO_2, salinity, nutrient, temperature on the growth rate, phtosynthetic and respiratory rates, and toxin production (Paz *et al.,* 2006; Guerrini *et al.,* 2007; Montechiaro and Giordano, 2010).
- **Genetic characterization:** phylogenetic characterization based on ribosomal and mitochondrial genes (Zhang *et al.,* 2007)
- **Documented blooms (one, several, many):** it is a recurrent species in the northern Adriatic Sea forming also blooms.
- **Geographic distribution in the Mediterranean Sea and Black Sea:** widely distributed in the Mediterranean Sea.
- **Documented impacts:** shellfish farm contamination and related economic losses.
- **Gaps in knowledge:** life cycle, ecology.
- **Management measures:** monitoring of coastal waters and intensive analyses of mussel toxicity at shellfish farms.

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