1. Scale

- What are the scales at which marine ecosystems and coastal communities interact?
- How do different groups or users perceive and use "scale"?
- Mismatch of the scales of environmental change compared with scales on which humans have the ability to change and adapt.
- Up- and down-scaling, i.e. how to move between scales when the drivers may be global but the impacts local?

2. Knowledge

- "Open" and "closed" knowledge systems – e.g. publicly available, local knowledge, or group-based.
- How best to exchange information, in particular scientific information of marine ecosystems and its changes?
- How best to incorporate scientific and local knowledge networks into decision-making?

3. Values

- How is value assigned to various marine ecosystem states, e.g. is an ecosystem which supports Atlantic cod inherently better than one which supports northern shrimp?
- How to determine discount rates which incorporate future generations and different cultural values?

These are all questions and issues that Focus 4 is examining.

GLOBEC Focus 4 Membership, 2005–2007

The formal membership of the Focus 4 Working Group was constituted in 2004, with membership as indicated in the following table. The Working Group has two key goals for 2005, which will be discussed at its next meeting from 31 August–2 September 2005 in Victoria, Canada and which will contribute significantly to the Integration and Synthesis activities of the entire GLOBEC program. These are: 1) to develop an "appraisal" paper on inter-dependent changes in marine ecosystems and fishing-dependent human communities; and 2) to develop plans for a major symposium on coupled marine ecosystem-human community interactions in the face of global changes. The appraisal paper will take a case-study approach to compare and contrast situations in which there have been major marine ecosystem changes and the human coastal community responses (or lack of responses), i.e. to identify what makes for resilient (or vulnerable) coastal communities. The symposium will expand on the "appraisal" paper and include more global examples; it is tentatively planned for 2007.

Core Membership (* Co-Chairs):

Rosemary Ommer* (History)
Ian Perry* (Fisheries Oceanography)
Kenneth Broad (Anthropology)
Patrick Lehodey (Fisheries Oceanography)
Barbara Neis (Sociology)
Kevin Stephanus (Economics)
Ana Parma (Fisheries)
Renato Quiñones (Marine Ecology)
Svein Jentoft (Socio-economics)
Jiehua Lu (Demography)

Affiliated Members:

Rashid Sumaila (Economics)
Molly McCammon (Public Policy)
Ujjayant Chakravorty (Economics)
Nigel Haggan (Management)
Celia Marasse (Marine Ecology)

Impacts of climatic, anthropogenic and human forcing on long-term changes of the Black Sea ecosystem

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An important principle of environmental science is that changes introduced in single components of systems are likely to have consequences elsewhere in the same system. The Black Sea suffered from severe ecological changes during the last three decades due to a collection of concurrent perturbations. They were associated with strong impacts of the bottom-up (i.e. eutrophication) and top-down (i.e. overfishing and introduction of alien exotic species) controls as well as climate. The radical changes in the ecosystem have been triggered by an extraneous increase of nutrient and contaminant loads from rivers discharging into the northwestern continental shelf (Fig. 1a) as well as trophic cascades introduced by the overexploitation of fish resources during the early 1970s. Climatic effects have also contributed to the reorganisation of the Black Sea ecosystem since the 1980s and 1990s and have been characterised by dramatic variations in the regional climate (Daskalov, 2003; Oguz, in press). When combined with the physical constraints of long residence time of water masses in the surface layer due to very limited water exchange laterally through the Bosphorus Strait and vertically across the permanent pycnocline, the poorly-productive Black Sea prior to the late 1960s has become susceptible to notable structural transformations (Oguz, in press).

The most important feature of the eutrophic Black Sea was enhanced biological activity and diversion of the classical phytoplankton-zooplankton-fish food chain to an alternative pathway of phytoplankton-zooplankton-opportunistic species-gelatinous carnivores. The phytoplankton community structure has been modified substantially in terms of species succession, intensity, frequency and areal extension of blooms. The data based on all available measurements within the deep basin during summer–autumn months (Fig. 1c) suggest an order of magnitude increase in the biomass from 1 g m^{-2} during the 1960s to about 10 g m^{-2} in the 1970s and up to 20 g m^{-2} at the end of the 1980s (Mikaelyan, 1997). As also shown in Figure 1c, the same signature is noted from a sharp increase in the summer surface chlorophyll concentrations from 0.1 to 0.5 mg m^{-3} (Vedernikov and Demidov, 2002; Yunev *et al.*, 2002).

Trophic cascade by overfishing has started concurrently with eutrophication during the early 1970s as a result of depletion of medium and large pelagic fish catches (Fig. 1f). The smaller and lower valued planktivorous fishes (mainly anchovy and sprat) then acted as the main predators in the ecosystem, which led to doubling of their total catch at the end of the 1970s (Fig. 1f). A new and different type of top-down cascade process started operating on the lower levels of the food web with some decline in mesozooplankton biomass (Fig. 1d; Kovalev *et al.*, 1998) and a similar level of increase in phytoplankton biomass during the 1970s (Fig. 1c). The increase encountered in total phytoplankton biomass, therefore, was not a result of eutrophication alone, but a process that included overfishing effects as well. Moreover, the period of pronounced increase in phytoplankton biomass during the 1980s (Fig. 1c) is well correlated with the sharp drop in winter temperature values (Fig. 1b). The cold and severe winters apparently promoted a higher rate of nutrient supply from the chemocline zone, and thus led to higher rate of spring phytoplankton production. We note in Figure 1b the coldest and most severe winter conditions of the last century took place during 1980–1993 with the basin-averaged, winter (December–March) mean sea surface temperatures (SST) as low as ~7.2°C.

A more pronounced impact of overfishing was felt later when the small pelagic stocks were overfished during the 1980s. Once the small pelagics became the main target of industrial fishery, their catches started decreasing and were gradually shifted towards newly recruited, small sized fish groups. The catches finally exceeded a sustainable level in 1987/1988 (Daskalov, 2002; Gucu, 2002), and collapsed in 1989–1990 (Fig. 1f). As the small pelagic fish stocks were exploited, their niche was gradually replaced by gelatinous zooplankton (jellyfish *Aurelia aurita*, in particular) and other opportunistic species (e.g. *Noctiluca scintillans*). Their food competition and predation on eggs and larvae of small pelagics then led to the domination of gelatinous carnivores in the ecosystem at the expense of small pelagics. The total gelatinous biomass, dominated by the jellyfish *Aurelia aurita*, reached 1.5 kg m^{-2} during the mid-1980s, and finally attained the peak value of about 2.5 kg m^{-2} in 1989 when the population of ctenophore *Mnemiopsis leidyi* was exploded (Fig. 1e). Strong predation by *Mnemiopsis* on eggs and the early life stages of small pelagics, and their food competition for mesozooplankton against small pelagics have been suggested as possible causes for decline of the anchovy fishery (Kideys, 2002) as an alternative mechanism to the recruitment failure arising from

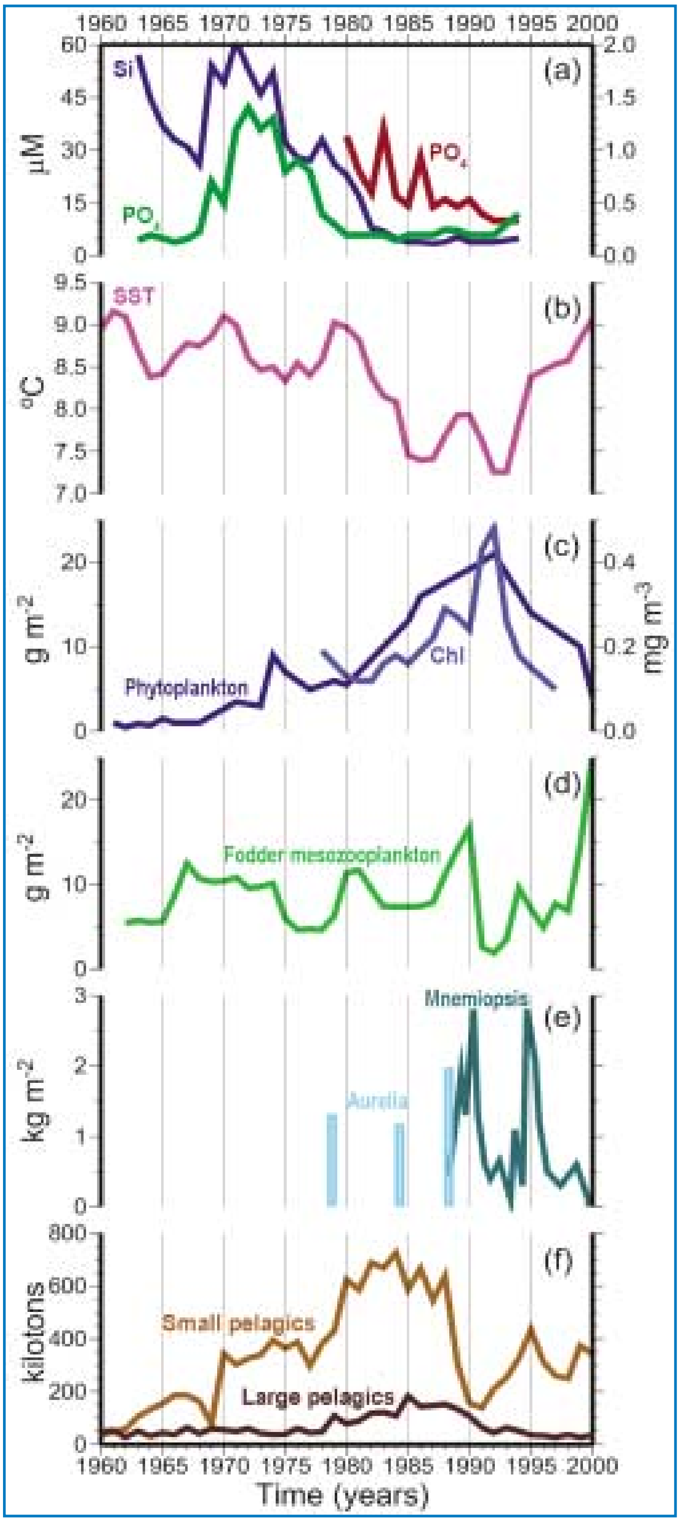

Figure 1. Temporal variations of the (a) annual-mean and water column averaged silicate, phosphate and nitrate concentrations measured at a station 20 nautical miles offshore of Constantza along the northwestern coast (note that the maximum scale is 30 μM for nitrate compared to that of 60 μm used for silicate on the left axis), (b) winter (December–March) mean sea surface temperature (°C), (c) water column integrated phytoplankton biomass (g m^{-2}),and surface chlorophyll concentration (mg m^{-3}); both of them are given as the averages of the summer–autumn periods, (d) annual-mean mesozooplankton biomass, (e) the gelatinous carnivores Aurelia biomass (vertical bars) and Mnemiopsis biomass (continuous line) as the averages of yearly measurements at all stations in the northeastern sector of the Black Sea, (f) the annual fish catches (in kilotons) of small pelagics and the sum of medium and large pelagics. Except otherwise indicated, all the data represent averages of the available measurements within the interior basin at depths greater than 1500 m.

overfishing during the 1980s (Gucu 2002; Bilio and Niermann, 2004). The available data seem to indicate that these two effects appear not to be alternatives, but they are complementary with strong feedback to each other.

The 1992–1993 period was a very special era for the Black Sea ecosystem. The *Mnemiopsis* biomass decreased sharply to around 0.5 kg m^{-2} immediately after their dramatic outbreak (Fig. 1e). The mesozooplankton biomass also exhibited a similar sharp drop from 17 g m^{-2} during 1990 to around 2-4 g m^{-2} during 1991–1993 (Fig. 1d). They were accompanied with the lowest level of fish stocks (Fig. 1f) and highest level of phytoplankton biomass (Fig. 1c) since the 1960s. These changes observed in biological structure seem to be closely related to the severity of winters and their response on the subsequent spring and summer months. Even though bottom-up conditions were quite favourable for mesozooplankton production, and there was no appreciable top-down grazing pressure from their predators (i.e., fish and gelatinous carnivores), the spring mesozooplankton production was affected unfavourably by very low temperatures of about 5–6°C in February–March. It also negatively affected overwintering and growth of *Mnemiopsis* populations for a few years.

As soon as the cold climate cycle ended in 1994–1995, a reverse trend was observed within the next two years characterised by increases in biomass of mesozooplankton and *Mnemiopsis*, as well as in fish catch, and decrease in phytoplankton biomass. *Mnemiopsis* biomass immediately attained its peak value observed at the end of the 1980s. These changes however do not necessarily represent a sign of improvement in ecological conditions in response to some protective measures imposed for controlling anthropogenic nutrient loading and overfishing (Kideys, 2002).

Starting by 1995, the Black Sea physical climate has entered into a warming cycle, prolonged up to 2002 at a rate of ~0.2°C per year for the sea surface temperature (Fig. 1b), as well as accompanying increases in the mean sea level and the net annual mean fresh water flux. From the fisheries perspective, the positive impacts of the climatic warming were to provide more suitable spawning and overwintering grounds for anchovy, and to promote more efficient growth of plankton communities by increasing their metabolic processes. Its negative impact, on the other hand, was weakening or disappearance of the major late winter–early spring peak of the classical annual phytoplankton biomass structure due to reduced upward nutrient supply from the chemocline under the conditions of less efficient vertical turbulent mixing and upwelling rate and stronger stratification (Oguz *et al.*, 2003). As a result, the total annual phytoplankton biomass was reduced by at least 50% after 1996 (Fig. 1c). Its effect was reflected at higher trophic levels in terms of reduced stocks of mesozooplankton and gelatinous carnivores (Fig. 1d), and pelagic fish (Fig. 1f) during the 1996–1998 periods. We note that, the total fish catch was still dominated by small pelagics (less than 30 cm) without any major contribution from other groups with high economical value.

Towards the end of the decade, the Black Sea ecosystem has been influenced by a new invader ctenophore Beroe ovata, a predator of *Mnemiopsis*. It has been introduced into the Black Sea with ballast waters in 1998, acclimated quickly and easily to the Black Sea conditions, and spread a year later over the northwestern, northeastern and southern Black Sea, and started depleting *Mnemiopsis* stocks (Fig. 1e). Following the settlement of Beroe, high values of *Mnemiopsis* biomass were only limited to 1–2 months during the late summer, as compared to 8–9 months from early spring to late autumn prior to the settlement of Beroe. Predation of *Mnemiopsis* was immediately reflected by 2–3 fold increase in the mesozooplankton biomass (Fig. 1d), and ichthyoplankton biomass and fish stocks (Shiganova *et al.*, 2003). The latter was also suggested by a gradual increase in the fish catch data after 1998 (Fig. 1f).

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