Global Ocean Ecosystem Dynamics (GLOBEC)

Ten years of research

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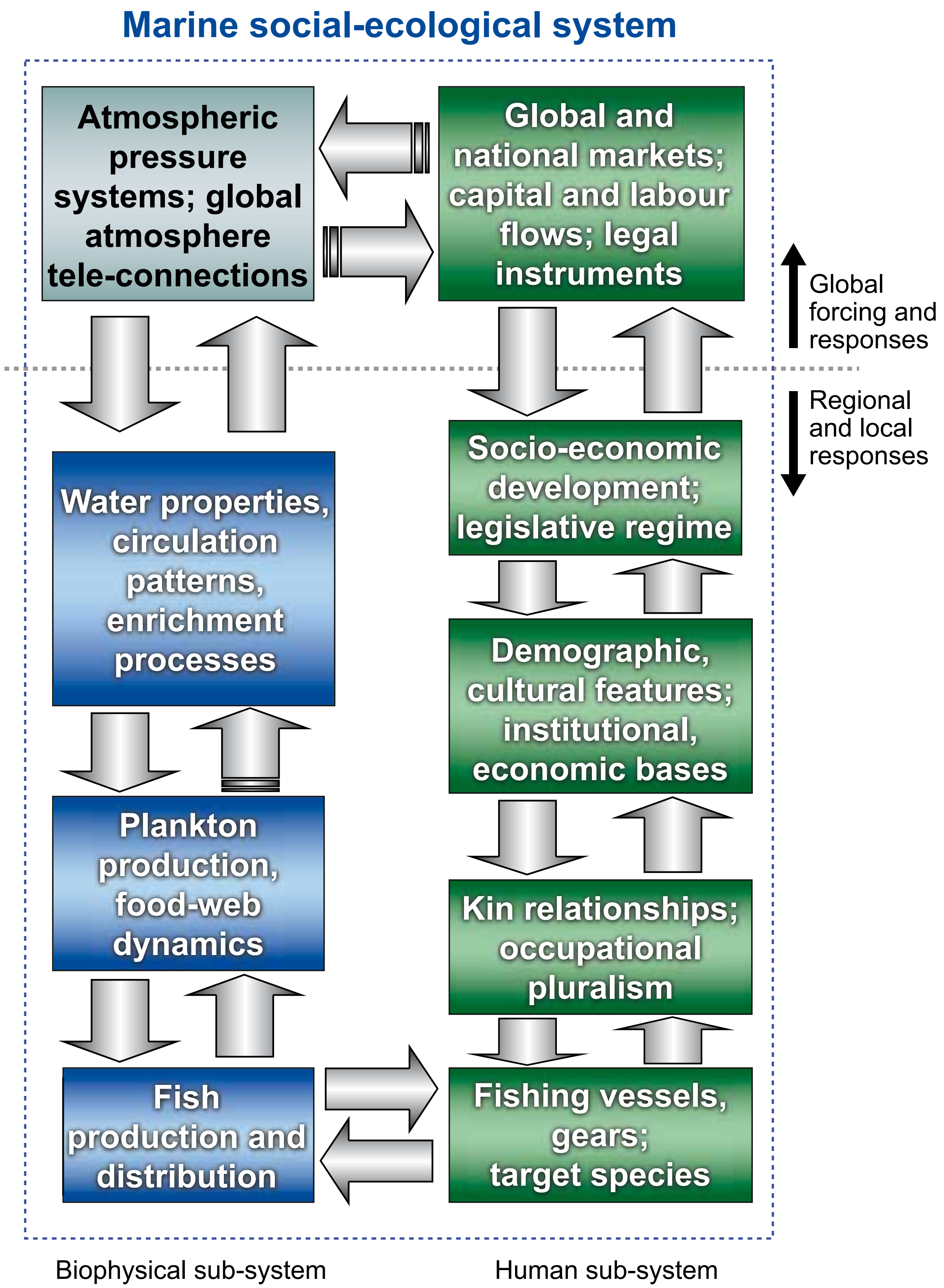
The international Global Ocean Ecosystem Dynamics (GLOBEC) project, a core project of IGBP, the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanic Commission (IOC), reaches the end of its more than ten years of intensive research at the end of 2009. This short article provides an overview of GLOBEC studies of marine biophysical systems, their associated human systems, and on the interactions between these systems and global changes. It also points towards some of the tools and policy options needed for humans to begin adapting to these changes.

Marine ecosystems and global change: towards policy options for human adaptations

The goal of GLOBEC has been to advance understanding of the structure and function of the global ocean ecosystem, its major subsystems, and its responses to physical forcing so as to develop a capability to forecast the responses of marine ecosystems to global change. GLOBEC accomplishments include advancing knowledge on marine ecosystems, physical and anthropogenic forcings, and improved understanding of physical, biological, and human interactions with changing marine environments. GLOBEC has also contributed to marine policy and management debates by providing conceptual understanding of how ecosystems respond to global changes, and by providing tools which incorporate uncertainties caused by climate-driven variability. Marine ecosystems (which can be called marine social-ecological systems when they include humans) are expected to be significantly affected by the interactive combination of climate change, over-exploitation of resources, and habitat disruption.

General impacts on marine systems as a result of large-scale changes related to temperature, winds, and acidification can be predicted, in some cases with a high degree of confidence [1]. At "rapid" time scales (a few years) there is high confidence that increasing temperatures will result in changes in distributions of marine species. Changes in the timing of life history events, such as the timing of reproduction, are also expected, with short life span species such as plankton, squid, and small pelagic fishes being the most quickly affected. At intermediate time scales (a few years to a decade), temperature-mediated physiological stresses and further changes to life history processes will impact the recruitment success and therefore the abundances of many marine populations. These impacts will be most acute at the extremes of species' ranges and for shorter-lived species. Changes in abundance will, in turn, alter the species composition of marine communities, which is likely to affect the structure and productivity of these ecosystems. At longer time scales (multi-decadal), the predicted impacts of climate changes depend upon changes to the net primary production in the oceans and its transfer to higher trophic levels. Current models show high variability in results and so all these predictions have low confidence. Overall, the responses of wind-driven upwelling ecosystems, which are the most productive per unit area, to global climate change are the most uncertain because the effects on their wind forcing lack predictability.

Marine social-ecological systems, however, are impacted by other changes occurring at global and local scales in addition to climate: these include intensive fishing and habitat disruption. A key conclusion [2] is that modern research and management of such marine systems must take account of the interactions between climate, fishing, and habitat disruptions rather than try to disentangle their effects and address each separately – hence the evolved emphasis on *global* change rather than climate change alone. In the biophysical (non-human) sub-system, climate conditions and circulation affect the physical characteristics of the regional and local ocean, which influence the productivity of the upper ocean and ultimately the production of fish. In the human sub-system, the impacts of global and national markets, capital and labour, and legal agreements flow through successively smaller



Characteristics and processes within the biophysical and human sub-systems of marine social-ecological systems, and their connections. Predominant connections between the biophysical (non-human) sub-system and the human sub-system occur at large scales (regional to global) and at the local scales (local to region) at which fish production and distributions interact with fishing. Solid arrows represent stronger interactions; dashed arrows represent weaker effects.

spatial and lower organisational scales from region, community, fishing fleet and household to individual vessels and fishers. It is the fishing vessels, fishing gear, the target species selected by fishers (in the human sub-system) and the production and distribution of fish (in the biophysical sub-system) that interact most directly [3] (see figure). More diffuse interactions between sub-systems do occur at other levels, ranging from local impacts of point-source contaminant releases to larger-scale impacts such as anoxic "dead zones". But, along with acidification, it is intensive fishing which has the global reach. Fishing reduces the life span, reduces the age at maturity, and reduces the "richness" (numbers) of distinct marine populations. These changes combine, in sometimes surprising ways, to alter marine populations, marine communities, and marine ecosystems and to bring them into states which track climate forcing more closely.

From the human side, how human communities respond to marine ecosystem variability can ameliorate or exacerbate these changes [3]. At shorter time scales, coping responses by both human and non-human marine systems have common elements, such as searching harder for prey, searching in new locations perhaps farther from home (and with greater exposure to predators or poor weather), diversifying to other sources of food, and migration. At longer time scales, however, many adaptive responses by human communities, such as networking, skills upgrading, political action, and closure of the community, have no analogues in non-human marine ecosystems. Such global changes can drive non-human systems to be more flexible and to adapt more quickly to variability, whereas these same changes may reduce the adaptive capacities of human systems. To achieve sustainability, marine resource managers must develop approaches which maintain the resilience of individuals, populations, communities and ecosystems to the combined and interacting effects of climate, fishing, and habitat disruptions. Overall, a less-heavily fished marine system, and one which shifts the focus from individual species to functional groups and fish communities, is likely to provide more sustainable goods and services when faced with climate variability and change than would a heavily fished system.

When faced with the interacting challenges of these global changes, a marine social-ecological systems approach to the management of marine resources is needed. Such an approach should involve all scales from local fishing sectors to regional and national governments in order to identify societal choices and to set objectives, which would include ecological, economic and social considerations [4]. Clear objectives need to be established recognising that the future may not be like the past. This will require identifying the appropriate scales (temporal, spatial, and organisational) and down- and up-scaling effects for both the problems and the solutions, identifying indicators and reference points for all the sectors expected to be impacted, close collaborations with multiple stakeholders, and monitoring for unanticipated surprises in other sectors and at other scales. Decision support tools and rules which evaluate their performance need to be established, which include explicit recognition of their uncertainties in such a world of change. Although the details of a future under climate change remain unknown, the outlines of appropriate adaptive responses for managing human interactions with marine ecosystems are becoming evident.

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