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The Role of IOC in Promoting Cooperative Research on Marine Ecosystems and Living Marine Resources

INTRODUCTION

This special issue of *Oceanography* is published in honor of the fiftieth anniversary of the Intergovernmental Oceanographic Commission (IOC). Established in 1960, IOC promotes international cooperation and coordinates programs in marine research, services, observation systems, hazard mitigation, and capacity development in order to learn more about and to better manage the nature and resources of ocean and coastal areas. Through the application of this knowledge, the Commission aims to improve the management practices and decision-making processes of its Member States (which now number more than 100), to foster sustainable development, and to protect the marine environment. *Oceanography* readers may remember that the first IOC Secretary was Warren Wooster, retired Professor of Oceanography at the University of Washington and one of the founding fathers of the North Pacific Marine Science Organization (PICES).

Since its inception, IOC has played a key role in coordinating and organizing several large programs. The earliest IOC program, established in 1961, was the International Oceanographic Data and Information Exchange (IODE), whose principal goal was to enhance marine research, exploitation, and development by facilitating the exchange of oceanographic data and information among participating Member States, and by meeting the needs of data and information product users. IOC contributed significantly to establishment of the Pacific Tsunami Warning System in 1965. After the Sumatra tsunami on December 26, 2004, IOC was mandated to help all UNESCO Indian Ocean rim Member States establish their own tsunami early warning systems. IOC continues to play key roles in coordinating the Global Climate Observing System (GOOS), the Joint World Meteorological Organization-IOC Technical Commission for Oceanography and Marine Meteorology, the World Climate Research Programme (WCRP), and the Argo drifter network. Each of these programs has worked to develop atmospheric and oceanographic observing networks, and, through great effort, has gotten commitments from many nations to support operational programs related to these important global observing systems. UN sponsorship and UNESCO assemblies assure that international cooperation is always the first priority of these global networks. IOC efforts help to improve operational oceanography as well as weather and climate forecasts, and to sustain the observing needs of the UN Framework Convention on Climate Change.

OCEAN SCIENCES SECTION ACTIVITIES

The chief purpose of this article is to review IOC's role in the development of marine ecosystem research programs as well as efforts to develop integrated assessments of the status of marine ecosystems. Such work falls under the purview of the Ocean Sciences Section (Figure 1). Because IOC was founded as a scientific organization, early on the Commission helped coordinate some familiar research programs that advanced understanding of the ocean (Holland, 2006). At that time (1960), IOC and its 50 member nations recognized that international cooperation was not an end in itself, but that, through cooperative research, the benefits of scientific, political, and economic endeavors would exceed their costs. In bringing together an international group of oceanographers, IOC focused attention on oceanographic problems that individual nations were unable to solve alone. A shining example of this approach was the International Indian Ocean Expedition (IIOE) during the 1960s. Similar efforts followed, including the International Cooperative Investigations of the Tropical Atlantic (1963–1964), the Cooperative Study of the Kuroshio and Adjacent Regions (1965–1977), and the Cooperative Investigation of the Caribbean and Adjacent Regions (1967–1976). In addition, IOC assisted in the development of global efforts to establish an International Decade of

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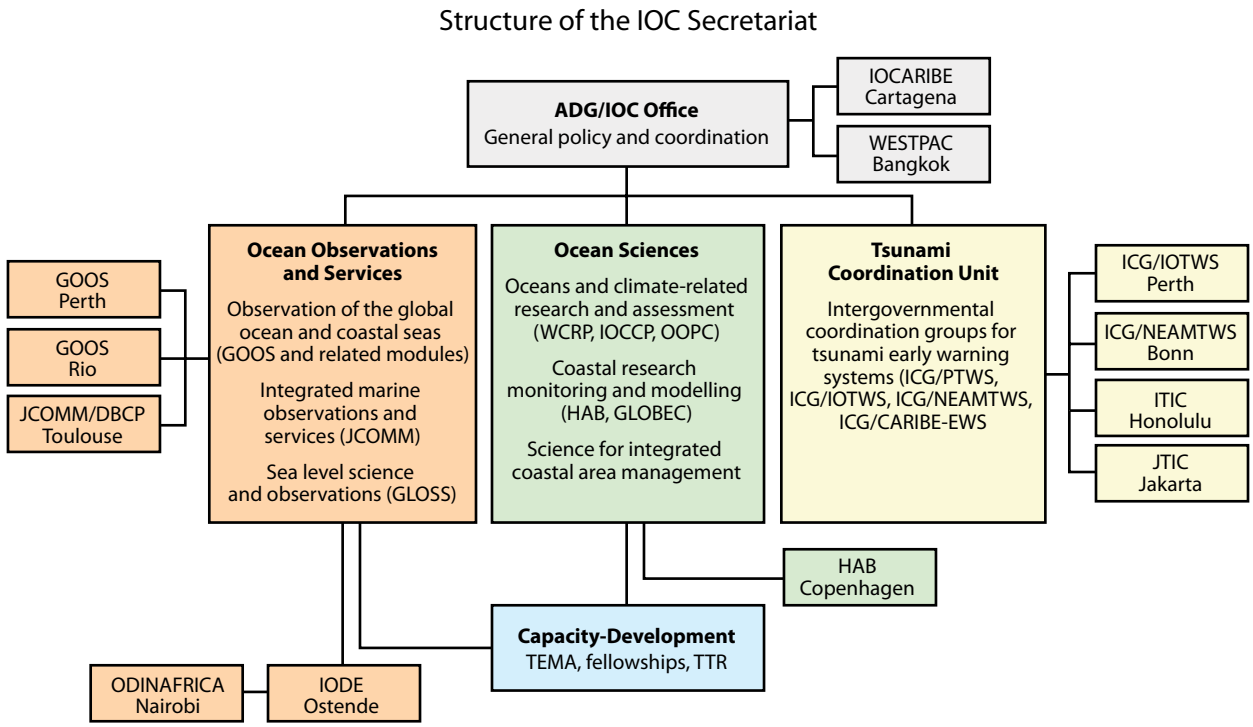

Figure 1. Structure of the IOC Secretariat. *From: http://www.ioc-unesco.org*

Ocean Exploration (IDOE, 1971–1980). Of this list, perhaps the Indian Ocean Expedition is the most familiar to biological oceanographers and the most relevant to this review paper.

THE INTERNATIONAL INDIAN OCEAN EXPEDITION OF THE 1960s

IIOE involved the efforts of 25 nations operating 44 research vessels from 1962 to 1965, and included work on Indian Ocean air/sea interactions, chemical oceanography, geology and geophysics, and investigations of marine life (Figure 2). An important anecdote is that Charles Keeling's carbon dioxide monitoring apparatus was employed for the first time aboard R/V *Argo* (Scripps) while transiting to the Indian Ocean as well as throughout the expedition itself.

As for biological work, one of IIOE's triumphs is that a Scientific Committee on Oceanic Research (SCOR) Working Group (beginning in 1957, then IOC beginning in 1960) not only developed the basic biological program but also made every effort to see that observations were made using standard methods, techniques, and equipment. This innovation ensured that the data and biological collections obtained would be intercomparable for all parts of the Indian Ocean surveyed, regardless of who did the work (Ryther, 1963). R/V *Anton Bruun* was designated as the main biological research vessel (ICO, 1964), based in Bombay (now Mumbai). Station work included hydrographic casts to 1000 m for temperature, salinity, dissolved oxygen, phosphate, nitrate, nitrite, silicate, and ammonia. The temperature and salinity work was done using Nansen bottles and reversing thermometers. Van Dorn bottles were used to gather water samples for nutrient and pigment analysis, and for 24-hour simulated in situ and 4-hour incubations with ^{14}C to estimate primary production. Zooplankton was sampled with vertical tows from 200 m with the standard IOE net (0.33-mm mesh) and from 200 m to the surface with a No. 25 mesh net (0.064 mm) for microplankton. Deep tows from 2000 m with a Bé open-closing sampler (0.33-mm mesh) were also taken. Some of the more well-known participants (at least, well known to the authors of this report) in these R/V *Anton Bruun* cruises included Edward Brinton (Cruise 1),

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Andrew Bakun (Cruise 2), Alan Bé and Arthur Ebling (Cruise 3), Dick Dugdale (Cruise 4), Mike Mullin (Cruise 5), George Grice (Cruise 6), and Bruce Collette (Cruise 8).

Many of the zooplankton samples collected during the *Anton Bruun* cruises were analyzed by cruise participants as well as by others, and results included monographs on the zoogeography of euphausiids (Brinton and Gopalakrishnan, 1973) and copepods (Fleminger and Hulsemann, 1973; Stephen et al., 1992).

Stanford University's R/V *Te Vega* was the second biological research vessel committed to work in the Indian Ocean. The ship's two years in the Indian Ocean were devoted to research concentrated on biological and physiological studies of island groups and other shallow-water areas. Though we, the authors, were unable to locate any summaries of the *Te Vega* efforts on the Web, a book is available in the locked stacks at the Stanford University library: *Te Vega Expeditions, Cruise Narratives*. Individual accounts can be found on the Web. For example, Malcolm Gordon (1993) describes his attempts in 1964 to capture a coelacanth during a three-month-long expedition by 15 scientists in the vicinity of northern Madagascar. Although none was captured, arrangements made during the *Te Vega* cruise resulted in a specimen being sent to Gordon in 1965. A well-known and highly regarded study of the ecology of *Conus* shells on coral reef platforms was initiated on R/V *Te Vega* (Kohn, 1967; Kohn and Nybakken, 1975). One notable participant was Dixie Lee Ray (then University of Washington associate professor, and later chair of the Atomic Energy Commission and the first woman elected governor of the state of Washington).

Figure 2. Harris B. Stewart, Chief Oceanographer of the Coast and Geodetic Survey, explaining the operation of the Nansen bottle to Ceylonese scientists visiting the C&GS Ship *Pioneer* during the International Indian Ocean Expedition. May 20, 1964. *Photo credit: Steve Nicklas, NOS, NGS*

According to Wooster (1984), IOC's involvement with IIOE was substantial. A major step in IOC participation came in mid 1962 when the Commission assumed responsibility for coordinating the expedition. Because IOC had been created "to promote scientific investigation…through the concerted action of its members," some felt IOC should immediately and automatically take over IIOE. However, IOC acted appropriately in supporting planning and coordination meetings, and communicating with its member nations to seek special treatment for expedition scientists and ships (including reduction of port and pilot fees, exemption from tax on fuel purchases, assistance in getting scientific equipment through customs, and simplification of clearance procedures). IOC organized training programs, arranged shipboard fellowships, and procured scientific equipment (e.g., bathythermographs were donated by the United States and tide gauges by Canada) and distributed it to the countries in the region. Another major IOC contribution was establishment of the Indian Ocean Biological Centre in Cochin, India. Further, data were exchanged through world data centers with IOC's encouragement and sponsorship.

Ryther (1963) summarized well the IIOE benefits: "The advantages of cooperation and collaboration, on a purely personal basis, are many. Our scientists [i.e., US scientists] working in new and unfamiliar waters, benefit immeasurably from the experience of those who know

the area and its flora and fauna. [Those experts], in turn, have the opportunity of meeting leading scientists from other parts of the world and of working aboard a major oceanographic vessel equipped with the best and most modern tools of the trade. The scientific exchanges and the international good will engendered by this type of cooperation must be considered as a major contribution of the program, ranking nearly equal in importance with the scientific results of the expedition." IOC's role in helping to organize this expedition cannot be overstated.

The authors of this essay suggest here that two major lessons were learned from the IIOE, both of which were (perhaps unknowingly or unwittingly) adopted by future international biological oceanographic programs such as the Joint Global Ocean Flux Study (JGOFS) and Global Ocean Ecosystem Dynamics (GLOBEC). First, early in the planning (done by a SCOR working group beginning in 1957), it was clear that there was a pressing need to agree upon standard methods, techniques, and equipment that would be used by all participants in these large programs. IOC largely implemented and facilitated this idea. Second, it was recognized that data needed to be made readily available to participants as soon as possible after collection. Toward this end, repositories were established at major data centers such as the National Oceanographic Data Center, now part of the US National Oceanic and Atmospheric Administration (NOAA). Results of analyses of algal, benthic invertebrate, zooplankton, nekton, and fish collections made during the Indian Ocean Expedition continued to be published well after the end of the IIOE program.

POST-IIOE ACTIVITIES RELATED TO MARINE ECOSYSTEMS

In 1979, the 11th IOC Assembly passed Resolution XI-17 to promote development of oceanographic studies of physical-ecological interactions of importance to fisheries (see Alheit and Bakun, 2009, for details and historical anecdotes). Toward that end, a "Group of Four" experts were asked to advise on program formulation (Bakun et al., 1982). IOC designated the UN's Food and Agriculture Organization (FAO) Advisory Committee on Marine Resources Research (ACMRR), together with SCOR, as bodies to help set up a new program called Ocean Sciences and Living Resources (OSLR; IOC, 1985). Subsequently, Working Group 67 for Oceanography, Marine Ecology and Living Resources was established (Barber et al., 1982).

The 12th IOC Assembly in 1982 adopted OSLR as a long-term program that would coordinate regional research projects aimed at elucidating the physical, chemical, and biological factors determining fish-population recruitment. It was the first attempt to link marine biology, fisheries science, and physical oceanography on a global scale, enabling an international approach to solving ecological problems. Early in the program, two key workshops were convened: Effects of Environmental Variation on Survival of Larval Pelagic Fishes, held in Lima in 1980 (IOC, 1981), and FAO Expert Consultation on Neritic Fish held in Costa Rica, in 1983 (FAO, 1983), both organized by IOC (Fernando Robles) and FAO (Gary Sharp) with strong support from Mario Ruivo, the IOC Secretary at that time. As a result of these efforts, developing country Member States of IOC soon viewed OSLR favorably because it addressed many living marine resource concerns (IOC, 1985).

One of OSLR's major activities was the International Recruitment Project (IREP), which aimed to investigate the relationship between environmental variability and fluctuations in marine resources (IOC, 1983). IREP subprojects included the Sardine/Anchovy Recruitment Project (SARP) and work on fish recruitment in tropical coastal demersal communities (IOC, 1990). Related work investigated the role that interspecific competition plays in fisheries recruitment in high-diversity ecosystems (IOC, 1985). OSLR also helped coordinate regional programs such as the Penaeid Recruitment Project in the Indo-West Pacific under the auspices of IOC's Regional Body for the Western Pacific. In 2001, The IOC Assembly restructured the Ocean Sciences Program and eliminated OSLR as a distinct IOC program element. However, the research initiated by OSLR and SARP continued and eventually morphed into the GLOBEC Small Pelagic Fish and Climate Change (SPACC) program discussed later in this paper.

Although attention to ecosystem and fisheries science has been a constant part of the IOC agenda, especially under OSLR, the scope has remained relatively limited, with attention being directed more toward programs such as the International Mussel Watch, Global Coral Reef Monitoring Network (GCRMN), Sir Alistair Hardy Foundation Continuous Plankton Recorder Survey, and Harmful Algal Blooms (HABs), and facilitation of

international cooperation in programs such as GLOBEC and JGOFS. The Ocean Sciences Section also helped establish and administer the Large Marine Ecosystem (LME) program, and the GOOS Living Marine Resources program (LMR-GOOS).

The LME program continues to flourish, with progress reported in annual meetings of the Consultative Committee on Large Marine Resources (e.g., IOC, 2009). Ongoing or recently ended LME projects include regions such as the Agulhas and Somali Current, Benguela Current, Gulf of Mexico, Yellow Sea, Bay of Bengal, the Baltic Sea, the Barents and Western Bering seas, and the Caribbean and Mediterranean seas.

The work envisioned as part of the LMR-GOOS concept was closely related to that planned by the SCOR/IOC/International Geosphere-Biosphere Programme (IGBP) Core Project on GLOBEC. The relationship with GLOBEC was deemed important to IOC because GLOBEC's mission was to advance understanding of the structure and functioning of marine ecosystems, and their responses to physical forcing, in order to develop the capability to forecast responses of marine ecosystems to global change—precisely those features of the marine ecosystem that LMR aimed to monitor and predict. In particular, it should be noted that the experience with logistics gained and the results and understanding obtained by GLOBEC would become important input to evolving LMR-GOOS plans.

Present-day activities of the Ocean Sciences Section (Figure 1) are under the leadership and guidance of Luis Valdés, who succeeded Ümit Ünluata in 2006 as section chief. Ünluata came to UNESCO-IOC in 1998, serving first for a year as Head of the Marine Pollution Unit, and then as head of the Ocean Sciences Section. Current IOC/Ocean Sciences programs that relate to aspects of biological oceanographic issues include:

- Ocean and climate-related research and assessments: WCRP, International Ocean Carbon Coordination Project, and Ocean Observations Panel for Climate
- Coastal research, monitoring, and modeling: HABs, GLOBEC, LMEs, and coral reef monitoring
- Science for integrated coastal area management

Of the more biological and resource-focused programs, the following are under the Ocean Sciences Section:

- Integrated Coastal Area Management (ICAM), established in 1998, is an interdisciplinary activity where natural and social scientists, coastal managers, and policymakers focus on long-term management of the diverse problems of coastal areas. See http://ioc3.unesco.org/icam for further information, and a detailed report on ICAM activities can also be found at: http://unesdoc.unesco.org/images/0014/001473/147313e.pdf.
- Global coral reef monitoring was a major theme when the International Coral Reef Initiative was launched at the United Nations Global Conference on Sustainable Development of Small Islands Developing States in Barbados in 1994. What followed was GCRMN, which seeks to improve management and conservation of coral reefs by providing manuals, equipment, databases, training, and problem solving, and helps to find funds for reef monitoring—all coordinated in a global network. From 1998–2002, IOC also administered, with support from the UK Department for International Development, the GCRMN South Asia Node, which coordinated coral reef monitoring in India, Sri Lanka, and the Maldives. In 2001, IOC and the World Bank initiated the IOC-administrated Coral Reef Targeted Research and Capacity Building for Management Program (http://www.gefcoral.org).
- The IOC HAB program was adopted by the IOC Assembly in 1993 and fosters the effective management of, and scientific research on, harmful algal blooms in order to understand their causes, predict their occurrences, and mitigate their effects. HAB work is reviewed in another article in this special issue (see Anderson et al., 2010).
- The marine spatial planning initiative involves helping countries implement ecosystem-based management with a focus on biodiversity conservation and sustainable economic development in marine environments. The program was the result of a workshop held November 8–10, 2006. It is a cooperative initiative between IOC and the Ecological and Earth Sciences Division of UNESCO's Man and the Biosphere Programme. A nice summary of the results of the workshop and the program are available at: http://ioc3.unesco.org/icam/images/stories//SEA CHANGE VISION .pdf
- In 1991, SCOR and IOC initiated a discussion of GLOBEC program sponsorship. GLOBEC was a logical program for IOC to adopt, and it was logical for GLOBEC to be closely

associated with IOC because many of the founding principles of the two were similar, including worldwide emphasis and approaches to ecosystem management. GLOBEC was also structured in much the same way as IOC in that it provided a framework for an international program that encouraged the fullest participation of national, multinational, and regional scientific efforts but did not impose a rigid template for how to do so. Though within-country national activities were coordinated by the individual countries' research communities, they were based on GLOBEC science and implementation plans.

IOC'S ROLE IN PLANNING AND IMPLEMENTING THE GLOBEC PROGRAM

Beginning in the early 1980s, during the OSLR program, the scientific community began to recognize that examining the relationship between biological and physical oceanography is crucial to the understanding and management of living marine resources. This combined approach to marine and environmental sciences initiated development of the "ecosystem approach" concept, and highlighted the need for greater attention to fisheries oceanography, a paradigm espoused by the international GLOBEC program. This approach recognized that living marine resources do not exist in isolation from the other components of the ecosystem, and that their dynamics are such that changes to a single element of the system may ripple through and impact the entire system. It was recognized that although the ocean's living marine resources are renewable, they are not inexhaustible, and as such they must be carefully managed for continued human consumption. An IOC goal was to advocate for protective, conservative, preventative, and precautionary local, national, and regional fisheries policies where gaps in knowledge and data exist. IOC also clearly understood that the complexity of ecosystem management requires collaboration among different scientific disciplines, and it endeavored to implement programs that employed the ecosystem-based approach to the scientific study and management of living marine resources.

The first preliminary discussion of an international GLOBEC program took place in Solomons, Maryland, from April 29–May 2, 1991 under the direction of Brian Rothschild; a more formal workshop followed in Ravello, Italy, from March 31–April 2, 1992. Work completed at the Ravello meeting provided building blocks for the foundation of the international GLOBEC program. At that time, involvement of international organizations, especially IOC, had only recently been confirmed by the IOC Executive Council at a meeting in March 1992. By that time, the International Council for the Exploration of the Sea (ICES) had initiated the ICES/GLOBEC/Cod and Climate Change program, which was soon followed by the PICES/GLOBEC Carrying Capacity and Climate Change program in the North Pacific, adopted in 1995.

In July 1994, IOC played a key role in the organization of International GLOBEC (known at that time as GLOBEC.INT) by organizing and hosting an international GLOBEC Strategic Planning Conference in Paris. The purpose of this meeting was to share and debate the draft GLOBEC Science Plan. The plan itself was first conceived during and following a January 1994 meeting of the GLOBEC Organizing Committee in Jekyll Island, Georgia. It is our view that the Paris meeting was perhaps the most critical meeting of the GLOBEC.INT program because it was there that after at least three years of "talk," a formal program was finally agreed upon.

Notable members of the first Organizing Committee of GLOBEC.INT included Patricio Bernal and Gunnar Kullenberg, both formally associated with IOC. For a listing of all members, visit the GLOBEC Web site (http://www.globec.org) and read some of the earlier GLOBEC newsletters, in particular volume 2, numbers 1 and 2.

GLOBEC had 18 fully fledged national programs. In addition, there were several regional and multinational efforts involving a total of 29 countries. The regional programs (GLOBEC 2001, GLOBEC 2004), although closely affiliated with GLOBEC, were not necessarily associated with IOC. More information on these programs can be found by consulting the GLOBEC Web page (http://www.globec.org) and clicking on "Structure" and "Regional Programs." The acronyms of these programs include CLIOTOP, ESSAS, ICES-GLOBEC CCC, PICES-GLOBEC CCCC, Southern Ocean GLOBEC, and SPACC. Multinational programs included two that focused on the Benguela: BENEFIT and ECO-UP, and a third, IDYLE, which focused on comparative analysis of fisheries oceanography of three upwelling areas, the Humboldt, Canary, and Benguela currents. Together, these efforts involved scientists from Namibia, Angola, and South Africa as well as

the co-sponsoring countries Germany, Norway, and France.

IOC's involvement in the international GLOBEC program was not purely as a sponsor. The Commission provided funds to GLOBEC, initially to help support the GLOBEC Scientific Steering Committee, but increasingly for specific activities. For example, one of GLOBEC's contributions was, at IOC's request, to develop a position paper on regime shifts and their management (deYoung et al., 2008). Additional funding was also provided occasionally to further the objectives of SPACC, a project of particular interest to IOC because of previous OSLR activities. For example, see GLOBEC Special Contributions 5 (Barange, 2001) and 6 (Barange, 2003), and the SPACC synthesis book (Checkley et al., 2009). IOC was a major funder for the synthesis workshop that resulted in the book, and the only funder of the two workshops that led to the GLOBEC Special Contribution reports referenced above.

MAJOR MARINE SCIENCE SYMPOSIA AND GLOBEC-RELATED MEETINGS

IOC also became a key sponsor of several well-attended international symposia in the 1970s and early 1980s. Given that it was unusual for anyone to convene international symposia during the decade of the 1970s, it could be argued that IOC's leadership contributed to a trend that continues today. Several of the symposia of which we are aware include:

- Joint Oceanographic Assembly, Tokyo, September 1970
- Joint Oceanographic Assembly (with SCOR), Edinburgh, September 1976
- Joint Oceanographic Assembly (with SCOR), Halifax, January 1982
- International Symposium on the Oceans in a High CO_2 World, Paris, May 2004
- First International Symposium on the Effects of Climate Change on the World's Oceans, Gijón, Spain, May 2008

IOC was also a key sponsor of several seminal GLOBEC meetings as well as other meetings on marine ecosystems and fisheries, for example:

- The second meeting of the GLOBEC/SPACC/IOC Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations, November 9–11, 1992, Paris, at UNESCO/IOC
- The first meeting of the international GLOBEC working group on sampling and observations, March 30–April 2, 1993, Paris, at UNESCO/IOC
- The formative meeting for GLOBEC.INT at which the science plan was adopted, July 18–22, 1994
- The first GLOBEC Open Science Meeting, March 17–20, 1998, Paris, at UNESCO/IOC
- International Workshop on the Ecosystem Effects of Fishing (with ICES and SCOR), Montpellier, March 15–19, 1999
- International Symposium on the Quantitative Ecosystem Indicators for Fisheries Management (with GLOBEC), March 31–April 4, 2004, Paris, at UNESCO
- The First International Symposium on the Effects of Climate Change on the World's Ocean, Gijón, Spain, May 19–23, 2008, co-sponsored by ICES, PICES, and IOC
- The third GLOBEC Open Science Meeting, Victoria, British Columbia, June 22–26, 2009
- The final meeting of GLOBEC International, A Summary for Decision Makers, March 8–10, 2010, Paris, at UNESCO/ IOC
- The Second International Symposium on Effects of Climate Change on the World's Ocean, planned for Korea in 2012

KEY ROLE OF CERTAIN INDIVIDUALS FROM NOAA AT THE IOC OCEAN SCIENCES PROGRAM

NOAA, through Mike Sissenwine, recognized that the IOC/Ocean Sciences office was understaffed (a continuing problem). By way of offering a helping hand, in the early 1990s NOAA initiated a program whereby senior fisheries scientists from the NOAA National Marine Fisheries Service (NMFS) would be encouraged to serve at the IOC office for two years. The first to be seconded was Geoffrey Laurence from the NOAA/NMFS/Northeast Fisheries Science Center, Narragansett Laboratory. While serving for two years as the Senior Assistant Secretary for Ocean Sciences in Relation to Living Resources, he helped to establish the GOOS Living Marine Resources (LMR) module.

In 1997, George Grice from the NOAA/NMFS Northeast Fisheries Science Center in Woods Hole accepted a similar appointment. Much of his effort involved development and oversight of the international coral reef monitoring programs and LMR-GOOS. At the time his death in 2001, Grice was Senior Science Advisor to the Executive Secretary of IOC, in charge of organizing and overseeing an independent

review of the IOC Science Program. He was the mind behind IOC support to several GLOBEC workshops, especially those leading to GLOBEC Special Contributions 5 (Barange, 2001) and 6 (Barange, 2003).

Many of the past IOC and GLOBEC-related activities set the stage for the implementation of an ecosystem approach to management that considers a wide range of relevant ecological, environmental, and human factors bearing on societal choices regarding resource use. Such assessments require a synthesis and quantitative analysis of information on relevant physical, chemical, ecological, and human processes in relation to specified ecosystem management objectives. Initially, an assessment should provide a big picture of an ecosystem, have a broad perspective and scale, and also a long-term perspective that includes human impacts. Toward this end, in the international arena, IOC provided leadership in the production of an "Assessment of Ecosystem Assessments," discussed next.

ECOSYSTEM ASSESSMENTS: ASSESSMENT OF ASSESSMENTS

In 2002, the World Summit on Sustainable Development in Johannesburg, South Africa, resolved the need to establish by 2004 a "Regular Process" under the United Nations for global reporting and assessment of the state of the marine environment, including socio-economic aspects. This need was endorsed by the United Nations General Assembly later in 2002 (Resolution 57/141). In 2005, the UN General Assembly launched the "Assessment of Assessments" (AoA) as a preparatory stage toward establishing the "Regular Process" (UNEP and IOC-UNESCO, 2009). It invited the United Nations Environment Programme (UNEP) and IOC to serve as lead agencies for the process to provide secretariat services and to coordinate the work. In 2006, the UN General Assembly, in the context of ecosystem approaches to ocean policy, resolved that "ecosystem approaches to ocean management should be focused on managing human activities in order to maintain and, where needed, restore ecosystem health to sustain goods and environmental services, provide social and economic benefits for food security, sustain livelihoods in support of international development goals, and conserve marine biodiversity" (Resolution 61/222).

The AoA committee identified the need for baselines and reference points. It was resolved that in all regions, more integrated, ecosystem-based approaches were needed in order to assess how to sustain ecosystem goods and services and their social and economic benefits and how to avoid the risks of change for human well-being. The UN recognized that it is essential to build on, guide, and strengthen existing marine assessments in order to advance a more coherent global system that clarifies and recognizes linkages within 16 ecosystems, including how climate change might affect the state of the marine environment.

The Group of Experts established by the lead agencies and approved by the Ad Hoc Steering Group began work in 2006. It agreed on a strategy for examining existing assessments to identify coverage and gaps in data and information, to examine the capacity to undertake marine assessments and the processes used, and to consider how existing assessments could contribute to the "Regular Process."

The Group of Experts identified 21 regions for the purpose of reviewing assessments at a regional level. They examined a range of individual assessments within each region and produced an overview of assessment practices and products in the region, together with regional summaries. Moreover, they developed an additional series of "supra-regional" summaries for larger-scale assessments focusing on a particular theme, sector, or assessment process. For example, supra-regional efforts included invasive species and marine biodiversity, the large marine ecosystem (LME) assessments of the Global Environment Facility's International Waters Programme, the Global International Waters Assessment, and the Millennium Ecosystem Assessment. To preserve the information collected and examined through the AoA process, the UNEP-World Conservation Monitoring Centre, known as the Global and Regional Assessments of the Marine Environment Database (http://www.unep-wcmc.org/GRAMED), created an online database. The complete AoA text can be found at http://www.unga-regular-process.org (UNEP and IOC-UNESCO, 2009).

In conclusion, the 50-year evolution of IOC is characterized by many success stories. It is the view of the authors of this article that an important IOC legacy began with the Indian Ocean Expedition—that is, IOC's insistence on the need to (1) establish data centers where all data and reports would be archived, and (2) establish the ways and means of involving multinational approaches to joint oceanographic studies, through use of agreed-upon sampling protocols. The IOC mission

statement—"To promote international cooperation and to coordinate programmes in research, services and capacity building, in order to learn more about the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement [of] management, sustainable development and protection of the marine environment and the decision making process of its Member States"—without question continues to be applicable today.

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REFERENCES

Alheit, J., and A. Bakun. 2009. History of international co-operation in research. Pp. 1–5 in *Climate Change and Small Pelagic Fish*. D.M. Checkley, J. Alheit, Y. Oozeki, and C. Roy, eds, Cambridge University Press.

Anderson, D.M., B. Reguera, G.C. Pitcher, and H.O. Enevoldsen. 2010. The IOC International Harmful Algal Bloom Program: History and science impacts. *Oceanography* 23(3):72–85.

Barber, R.T., T. Csirke, J. Jones, R. Lasker, R. Parrish, and M. Tomczak. 1982. *Report of SCOR/ACMRR Working Group 67, Oceanography, Marine Ecology and Living Resources*. SCOR/WG-67, 21 pp.

Bakun, A., J. Beyer, D. Pauly, J.G. Pope and G.D. Sharp. 1982. Ocean sciences in relation to living resources. *Canadian Journal of Fisheries and Aquatic Sciences* 39:1,059–1,070.

Barange, M., ed. 2001. *Report of the 1st Meeting of the SPACC/IOC Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations*. Cape Town, South Africa, September 3–5, 2001. GLOBEC Special Contribution No. 5, 122 pp. Available online at: http://web.pml.ac.uk/globec/products/reports/spec_cont.htm (accessed June 25, 2010).

Barange, M., ed. 2003. *Report of the 2nd Meeting of the SPACC/IOC Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations*. Paris, France, December 9–11, 2002. GLOBEC Special Contribution No. 6, 156 pp. Available online at: http://web.pml.ac.uk/globec/products/reports/spec_cont.htm (accessed June 25, 2010).

Brinton, E., and K. Gopalakrishnan. 1973. The distribution of Indian Ocean euphausiids. Pp. 357–382 in *The Biology of the Indian Ocean*. B. Zeitzschel and S.A. Gerlach, eds, Springer-Verlag, Berlin.

Checkley, D., J. Alheit, Y. Oozeki, and C. Roy, eds. 2009. *Climate Change and Small Pelagic Fish*. Cambridge University Press, 392 pp.

deYoung, B., M. Barange, G. Beaugrand, R. Harris, R.I. Perry, M. Scheffer, and F. Werner. 2008. Regime shifts in marine ecosystems: Detection, prediction and management. *Trends in Ecology and Evolution* 23:402–409.

FAO. 1983. *Proceedings of the Expert Consultation to Examine Changes in Abundances and Species Composition of Neritic Fish Resources*. San Jose, Costa Rica, April 18–29, 1983. FAO Fisheries Report No. 291, ftp://ftp.fao.org/docrep/fao/005/x6850b/x6850b00.pdf.

Fleminger, A., and K. Hulsemann. 1973. Relationship of Indian Ocean epiplanktonic calanoids to the world oceans. Pp. 339–347 in *The Biology of the Indian Ocean*. B. Zeitzschel and S.A. Gerlach, eds, Springer-Verlag, Berlin.

Gordon, M.S. 1993. The international program of research on *Latimeria* in the 1960s. *Environmental Biology of Fishes* 36:407–414.

Holland, G. 2006. Observing and understanding planet ocean: A history of the Intergovernmental Oceanographic Commission (IOC). Pp. 332–353 in *Sixty Years of Science at UNESCO 1945–2005*. UNESCO Publishing, Paris.

ICO (Interagency Committee on Oceanography). 1964. *United States Participation in the International Indian Ocean Expedition and the International Cooperative Investigations of the Tropical Atlantic*. ICO Report #6IP-64, June 64. Obtained from the Woods Hole Oceanographic Institution Data Library and Archives.

IOC (Intergovernmental Oceanographic Commission). 1981. *Workshop on the Effects of Environmental Variation on Survival of Larval Pelagic Fishes*. Lima, Peru, April 20–May 5, 1980. G.D. Sharp, ed., Intergovernmental Oceanographic Commission, UNESCO, Paris, Workshop Report 28, 323 pp.

IOC. 1983. *Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR)*. Intergovernmental Oceanographic Commission, UNESCO, Paris, Workshop Report 33, 17 pp.

IOC. 1985. *IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in Relation to Living Marine Resources: First session*. Paris, France, July 16–20, 1984, UNESCO/IOC, Paris, 20 pp.

IOC. 1990. *IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in Relation to Living Marine Resources: Third session*. Paris, France, February 5–9, 1990, UNESCO/IOC, Paris, France, 25 pp.

IOC. 2009. *IOC-IUCN-NOAA Consultative Committee Meeting on Large Marine Ecosystems (LMEs): Eleventh Session*. Paris, France, July 9–10, 2009, IOC-UNESCO, Paris, 34 pp. Available online at: http://www.lme.noaa.gov/LMEWeb/Publications/Consultative_2009.pdf (accessed June 25, 2010).

Kohn, A. 1967. Environmental complexity and species diversity in the gastropod genus Conus on Indo-West Pacific reef platforms. *The American Naturalist* 101(919):251–259.

Kohn, A.J., and J. Nybakken. 1975. Ecology of Conus on eastern Indian Ocean fringing reefs: Diversity of species and resource utilization. *Marine Biology* 29:211–239.

Ryther, J. 1963. International Indian Ocean Expedition. *AIBS Bulletin* 13(5):48–51.

Stephen, R., K.S. Devi, P.P. Meenakshikunjamma, T.C. Gopalakrishnan, and M. Saraswathy. 1992. Calanoid copepods of the International Indian Ocean Expedition. Pp. 143–156 in *Oceanography of the Indian Ocean*. B.N. Desai, ed., Oxford and IBH, New Delhi.

UNEP (United National Environmental Programme) and IOC-UNESCO. 2009. An Assessment of Assessments, Findings of the Group of Experts: Start-up Phase of a Regular Process for Global Reporting and Assessment of the State of the Marine Environment Including Socio-economic Aspects. ISBN 978-92-807-2976-4. Available online at: http://www.unep.org/DEWA/products/publications/2009/AoA.asp (accessed June 25, 2010).

Wooster, W.W. 1984. International studies of the Indian Ocean, 1959–1965. *Deep-Sea Research* 31(6–8):589–597, doi:10.1016/0198-0149(84)90029-3.