PLENARY SESSION PRESENTATIONS

The Census of Marine Life: An update on activities

Cynthia Decker
Consortium for Oceanographic Research and Education, Suite 800, 1755 Massachusetts Ave. NW, Washington, DC, 20036 U.S.A. E-mail: cdecker@brook.edu

Introduction

The Census of Marine Life (CoML) is an emerging international research program to assess and explain the diversity, distribution, and abundance of marine organisms throughout the world's oceans. The planning and development stage for this decadal program is expected to require 1-2 more years. Pilot field projects should take place in 2002-2004. The main field projects should occur in 2005-2007. Analysis and integration of information should culminate in 2008-2010.

Scientific Steering Committee

Leadership and guidance for the Census of Marine Life are the responsibilities of the international Scientific Steering Committee (SSC), formed in June 1999. The SSC has met six times, and will meet during the rest of 2001 in Alaska and Argentina. The present focus of the SSC is the development of the scientific strategy for the CoML. The SSC has initially chosen to remain small in order to ease the scheduling of frequent meetings, but it expects that its membership will grow as the program takes shape and becomes more global. Subcommittees will be formed to lead particular aspects and projects of the CoML. Current SSC members are J. Frederick Grassle (Chairman), Rutgers University, U.S.A.; Vera Alexander, University of Alaska Fairbanks, U.S.A.; Patricio Bernal, Chile, and Intergovernmental Oceanographic Commission, France; Donald Boesch, University of Maryland, U.S.A.; David Farmer, Institute for Ocean Sciences, British Columbia, Canada, and University of Rhode Island, U.S.A.; Olav Rune Godoe, Institute of Marine Research, Bergen, Norway; Carlo Heip, Netherlands Institute of Ecology, The Netherlands; Poul Holm, Southern Denmark University, Denmark; Yoshihisa Shirayama, Kyoto University, Japan; and Andrew Solow, Woods Hole Oceanographic Institution, U.S.A.

Secretariat and Scientific Team

The Secretariat for the CoML program is located in Washington, DC, and is hosted by the Consortium for Oceanographic Research and Education (CORE). CORE is comprised of 62 oceanographic research institutions in the United States including universities, government laboratories, and non-profit aquaria. Dr. Cynthia Decker, a benthic ecologist, directs the activities of the Secretariat. Her associates include Pamela Baker-Masson, concerned with public outreach and education; David Hilmer, ocean science specialist; and Scott Sparks, program associate and webmaster.

Alasdair McIntyre, emeritus professor of fisheries and oceanography at the University of Aberdeen, Scotland, is serving as a senior consultant to the Census of Marine Life SSC and Secretariat, helping to develop European participation in the CoML. Dr. McIntyre earlier served as editor-in chief of Fisheries Research and as chairman of the United Nations Joint Group of Experts on Scientific Aspects of Marine Pollution (GESAMP).

The SSC and Secretarariat have hired Dr. Ronald O'Dor, Professor of Biology at Dalhousie Univeristy, Halifax, Canada, to be the Senior Scientist for the Census of Marine Life. Dr. O'Dor is an expert in cephalopod taxonomy, physiology and behavior, and has done research around the world on these organisms. Dr. O'Dor will start his duties with the CoML in late March, 2001, and will work with the SSC and the Secretariat to advance the Census of Marine Life program with international governmental, non-governmental organizations, and the general public.

Scientific strategy

The scientific strategy, laying out the overall goals and plans for the CoML, is scheduled for release early in 2001, for review and comment by the scientific and relevant stakeholder communities. The document will be posted on the CoML website (http://www.coml.org) as well as actively circulated. The plan is to revise the document for publication by September 2001.

The SSC has sought to balance the writing of planning documents with the timely launching of components of the CoML that the community has indicated are already well-defined and urgently needed. Two components of the CoML, its framework for data assimilation (OBIS), and its studies to document the history of marine animal populations (HMAP) are now underway. In addition, several pilot field projects are in planning stage.

Ocean Biogeographical Information System

The Ocean Biogeographical Information System (OBIS) is envisioned as a distributed network of repositories of marine biological and environmental data for use in examining changes in diversity, distribution, and abundance of organisms in time and space. In May 2000, the CoML announced the funding of eight projects to foster the design and development of OBIS. Under the auspices of the US National Oceanographic Partnership Program (NOPP), eight OBIS projects received funding totaling US $3,700,000 over two years (see http://core.cast.msstate.edu/censpr1.html). The projects will involve the participation of researchers at 63 institutions in 15 countries.

In September 2000, the CoML sponsored an international workshop at the University of Rhode Island Graduate School of Oceanography to further plan and organize the OBIS network. Co-chaired by Fred Grassle and Mel Briscoe (US Office of Naval Research), the workshop brought together the principal investigators of the eight funded projects, as well as several experienced leaders in the design and management of oceanographic and ecological databases. Topics discussed included interoperability of databases, taxonomic and regional data priorities, and the management of OBIS. A Workshop report has been posted on the CoML website.

The SSC will consider the workshop's recommendations for the governance of OBIS and will work with other stakeholders to develop effective mechanisms for its rapid, reliable fruition. The SSC will establish a steering committee for OBIS that will guide the development of the system, particularly in the context of other data system efforts that are emerging such as the US Virtual Ocean Data Hub and the Global Biodiversity Information Facility (GBIF).

History of Marine Animal Populations

Early in the planning for the CoML, participants recommended strongly that the program include a historical component to obtain, assemble, and make accessible information on marine animal populations since fishing became important. The History of Marine Animal Populations (HMAP) will combine classic historical archival research with marine biology to examine the distribution and abundance of species in the oceans over the past 500-1,000 years. The aim of HMAP is to improve our understanding of marine ecosystem dynamics through interdisciplinary studies, specifically with regard to the ecological impact of large-scale harvesting, long-term changes in stock abundance, and the role of marine resources in the development of human society. Integral to HMAP is the design and implementation of standard databases for marine species in collaboration with OBIS, the design and implementation of innovative biological sampling techniques to explore the marine environment, and the identification and use of historical data to aid in the development of predictive environmental models.

In December 2000, the SSC announced the formal launching of HMAP, with the establishment of Centers for the Study of the History of Marine Animal Populations at Southern Denmark

University, University of Hull (UK), and the University of New Hampshire (U.S.A.). The initial phase of HMAP, supported with more than US$1,200,000 in grants, will include case studies of marine populations in seven regions involving 31 institutions in 18 countries. The overall leader of HMAP is Steering Committee member Poul Holm of Southern Denmark University. A special issue of the International Journal of Maritime History dedicated to HMAP will be published in early 2001 (http://www.cmrh.dk/hmapindx.html).

Pilot projects

The Census of Marine Life will ultimately be the sum of a set of specially designed field projects observing populations in a variety of regions and ways, and integrated with ongoing (and enhanced) survey activities conducted by fisheries and environmental agencies. The SSC has been working with several segments of the research community to design pilot projects that can demonstrate the effectiveness in diverse settings of new approaches and technologies for the observation of marine life. While the SSC can influence resources sufficient to help completion of the planning phases for pilot projects, each project must ultimately secure the finances for research activities on its own. The goal is for the pilot projects to get the financial commitments to be "in the water" soon and to be completed in 2-3 years, so they can serve as examples for the main body of fieldwork conducted under the CoML. So far, groups of scientists have initiated planning for six promising pilot projects under the auspices of the CoML.

Census of Marine Life in the Gulf of Maine

Ken Foote, Woods Hole Oceanographic Institution, U.S.A. (http://www.whoi.edu/marinecensus/)

The Gulf of Maine and Georges Bank are much-studied regions commercially important for fisheries, and they thus offer an excellent chance to calibrate and demonstrate the superiority of new technologies to describe the diversity, distribution, and abundance of marine life. Targets include finfish, zooplankton communities, and the poorly-known benthic communities. A workshop held May 2-3, 2000, led to the establishment of a steering committee for the project and laid the basis for a regional consortium of institutions to carry out the project.

Ecosystems of the northern mid-Atlantic

Odd Aksel Bergstad, Institute of Marine Research, Norway

The biology of the waters overlying the Mid-Atlantic Ridge has been little studied and offers difficult challenges for new technologies to see deep and far. The tentative project goal is to identify and model the ecological processes that cause variability in the distribution, abundance, and trophic relationships among organisms inhabiting this pelagic zone. A planning workshop held February 12-13, 2001, in Bergen, Norway, has led to the establishment of a steering committee, which will further develop the project.

Pacific Ocean salmon tagging

David W. Welch, Pacific Biological Station, Nanaimo, British Columbia, Canada

Little is known about the distribution and behavior of salmon once they leave the rivers. This project proposes to use electronic tags and innovative acoustic arrays to track and monitor salmon populations on the continental shelf of Canada and the United States and in the open waters of the North Pacific. A planning workshop held December 8-9, 2000, in Vancouver, Canada, brought together leading experts on a variety of salmon populations to consider the design of this project and how it can serve as a template for study of salmon and other anadromous fish populations in the world.

Tagging of Pacific pelagics

Barbara Block, Stanford University, U.S.A.

A much better understanding of the distribution and behavior of large pelagic animals at the top of the food chain may allow strong inferences about the distribution and abundance of many other organisms that live in the oceans. A workshop held November 13-14, 2000, explored the design of an ambitious pilot project in the North Pacific to deploy advanced electronic data-storage tags to track and monitor large vertebrates, such as whales, sea turtles, and tuna. The workshop generated great interest among the public in the CoML as evidenced by coverage in the San Francisco Chronicle and on the news websites of ABC News and National Geographic (see http://www.abcnews.go.com/sections/science/DyeHard/dyehard001129.html).

Chemosynthetic ecosystems in the Arctic and northern Atlantic Oceans

Cindy Lee Van Dover, College of William and Mary, U.S.A.

Little is known about the basin-scale diversity, distribution, and abundance of marine life in deep sea chemosynthetic ecosystems such as hydrothermal vents and seeps in the northern Atlantic and Arctic oceans. In order to study these systems, new technologies for plume-tracking from autonomous underwater vehicles (AUVs) will need to be refined and used over large spatial scales. A planning workshop to develop this pilot project was held on 16-17 March 16-17, 2001.

Coastal survey of the western Pacific

Yoshihisa Shirayama, Seto Marine Biological Laboratory, Kyoto University, Japan

A major unanswered question is how marine biodiversity varies with the latitudinal gradient. A coastal study to be conducted under the auspices of the Diversitas International in the Western Pacific Area (DIWPA) program aims to quantitatively survey marine life and examine biodiversity in near-shore areas in the western Pacific in a continuum from the northern to southern boreal regions using traditional sampling methods (i.e., scuba gear). A workshop held in April 2001 refined the plans for this project.

Other activities

SCOR Working Group

The Scientific Committee on Oceanographic Research (SCOR) of the International Council of Scientific Unions has formed a Working Group on New Technologies for Observing Marine Life, which held its first meeting on November 9-11, 2000, in Sidney, British Columbia, Canada. The Working Group, chaired by David Farmer, is considering individual technologies, their integration, and transition to practice (http://core.cast.msstate.edu/censscor1.html).

Museums and marine laboratories

Natural history museums contain precious collections and expertise on marine biodiversity, as do marine laboratories, and the participation of these institutions is key to the success of the CoML. A workshop was held November 15-17, 2000, at the Institute of Marine Biology, Crete, Greece, that was organized by Annelies Pierrot-Bults (Zoological Museum of Amsterdam), Ross Simons (Smithsonian Institution, U.S.A.) and Carlo Heip (Netherlands Institute of Ecology, The Netherlands). This workshop explored ways for museums and marine laboratories to contribute to the CoML and their interests in it. Over 30 experts from 15 countries attended the workshop, which has sparked further interest in the CoML within these communities. A report on the Crete workshop will be published shortly.

Aquariums

Aquariums house displays of marine biodiversity and are a main way that the public learns about it. The CoML was featured in a plenary presentation in November 2000, at the International Aquarium Congress hosted by Monaco’s Musee Oceanographique, and was strongly endorsed as "an opportunity too good to pass up" in the concluding summary address by Jerry Schubel, director of the New England Aquarium. Follow-up activities will increase involvement of aquariums in the CoML. Jordi Sabate, director of the Barcelona Aquarium, will convene the directors of several of the world’s foremost public aquariums in the spring of 2001, to explore creation of a consortium of aquariums to work with the CoML. Meanwhile, another workshop in spring 2001, at the New England Aquarium, will bring together exhibit designers, film makers, and persons involved in outreach activities to advance the education and outreach dimensions of the CoML. Specifically, this workshop will identify the most effective vehicles for bringing the plans and discoveries of the CoML to the 150 million people who visit aquariums each year.

Southeast Asia Workshop

To strengthen CoML activities in the tropical areas of Southeast Asia and the western Pacific, the SSC is teaming with the Intergovernmental Oceanographic Commission's (IOC) SubCommission for the Western Pacific (IOC/WESTPAC). A workshop in mid-2001 at the IOC/WESTPAC headquarters in Bangkok, Thailand, will bring together numerous scientists from countries in the region involved in assessing the diversity, distribution, and abundance of species in Southeast Asia and the western Pacific.

POGO

About twenty of the world's leading oceanographic research institutions are now participating in a new Partnership for Observation of the Global Oceans (POGO), with a Secretariat at the Bedford Institute of Oceanography, Nova Scotia, Canada. The POGO institutions play major roles in the development and deployment of new monitoring systems, such as the Argo floats. The leaders of POGO are eager to assure that biological observations develop in conjunction with other environmental measures and have decided to make biological observations the focus of their 2001 meeting. The CoML provided a progress report at the November 2000 POGO meeting in Sao Paulo, Brazil (http://www.oceanpartners.org/).

US government initiatives

The US Congress passed the Oceans Act in 2000. This legislation directs that a Presidential Commission on the Oceans be established to review all US government ocean activities in the next two years and provide recommendations to the President and Congress. The Census of Marine Life expects to be invited to make a presentation to the Commission soon after it is established.

The US government is considering a major new initiative on ocean exploration, as recommended by the President's Panel on Ocean Exploration, whose report was released on December 4, 2000, in Washington DC. The report recognizes the Census of Marine Life and the Ocean Biogeographical Information System. Marcia McNutt, director of the Monterey Bay Aquarium Research Institute, chaired the panel, whose members included Frederick Grassle and Jesse Ausubel (http://oceanpanel.nos.noaa.gov/panelreport/ ocean_panel_report.html).

National Committees

Several nations are now in the process of bringing together the stakeholders in the CoML within that country to determine how best to organize the program at the national level for the Program. Following a pattern successful in other major global research programs, which require organization at both the international and national (and sometimes regional) level, the formation of National Committees for the Census of Marine Life should be one of the important developments during the next couple of years. The SSC and Secretariat are eager to work with the national interests for this purpose, and small amounts of funds will be available to help convene the appropriate national stakeholders.

Decadal climate variability in the Pacific Ocean, and theories as to its cause

Julian P. McCreary, Jr.
International Pacific Research Center, University of Hawaii, Honolulu, Hawaii, U.S.A. E-mail: jay@soest.hawaii.edu

Interest in decadal variability in the Pacific region increased considerably during the 1990s, both at mid-latitudes (PDV) and in the tropics (EDV). During the first half of the decade, the tropical

Pacific remained anomalously warm and this warming appeared to have limited ENSO predictability in coupled models (Ji *et al.* 1996). This EDV also had significant economic impacts, a prime example being the severe drought in Northeast Australia. At the same time, PDV has attracted much attention (Trenberth and Hurrell 1994; Mann and Park 1996; Nakamura *et al.* 1997). See Miller and Schneider (2001) for a recent review.

Observations

PDV is present in both atmospheric and oceanic variables. In contrast to ENSO, however, it does not have a sharp spectral peak, suggesting that it does not result from a single, well-defined process and even that it may be generated stochastically.

It is also not clear if there is just one type of PDV. Nakamura *et al.* (1997) and Nakamura and Yamagata (1999) reported two modes of North Pacific decadal variability based on sea surface temperature (SST) data, which they obtained using the empirical orthogonal function (EOF) statistical technique. Figure 1 shows the first two EOFs from their analysis. The EOFs were obtained in the rectangular box indicated in Figure 1, and the fields outside the box were then found by regressing the EOF time-series on SST anomalies in the full basin. Thus, implicit in their study is the idea that the box region is the key area for the generation of PDV. The first mode is confined to the North Pacific mid-latitudes, with most of its amplitude centered on the Subarctic Front. The second EOF extends over much of the basin. In northern mid-latitudes, it has a distinctive dipole-like structure, with anomalies of opposite sign on either side of the Subtropical Front, and anomalies with significant amplitude throughout the tropics in both hemispheres. It should be stated, however, that the EOF statistical technique seeks to find separate modes of variability. It may be, then, that there is really only one mode, that the EOFs in Figure 1 really represent two different phases of the same oscillation.

Figure 2 shows a time-series of SST anomalies in the NINO3 region (after Timmermann and Jin, 2001). To emphasize the decadal variability, the thick curve plots the 10-year running mean of the standard deviation of the time series.

There is a remarkable periodicity in the curve, with a time scale of 15-20 years. Thus, one aspect of EDV is that the amplitude of El Niño varies with surprising regularity on decadal time scales.

Hypotheses

At the present time, prominent aspects of PDV and EDV have already been successfully simulated in solutions to coupled ocean-atmosphere models, but neither the nature nor location of the primary generation mechanisms have yet been clearly identified. Indeed, the studies explore several different types of hypotheses, which can roughly be divided into three categories, namely, that PDV and EDV are generated by: i) midlatitude processes only; ii) both midlatitude and tropical

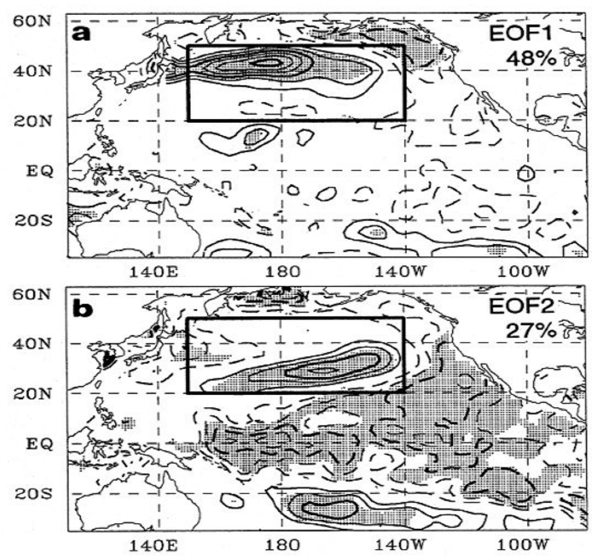

Fig. 1 First (top) and second (bottom) EOFs of decadal variability in North Pacific wintertime SST for 1968-92. The EOFs are determined within the indicated rectangular box, and linear regression coefficients are plotted between Pacific SST and the time-series (PCs) associated with the two modes. The contour interval is 0.1; it is thickened every 0.3, dashed for negative, and zero lines are omitted. Shaded areas are the regions in which correlation between SST and a given PC exceeds the 90% significance level assuming 3 degrees of freedom (after Nakamura *et al.* 1997).

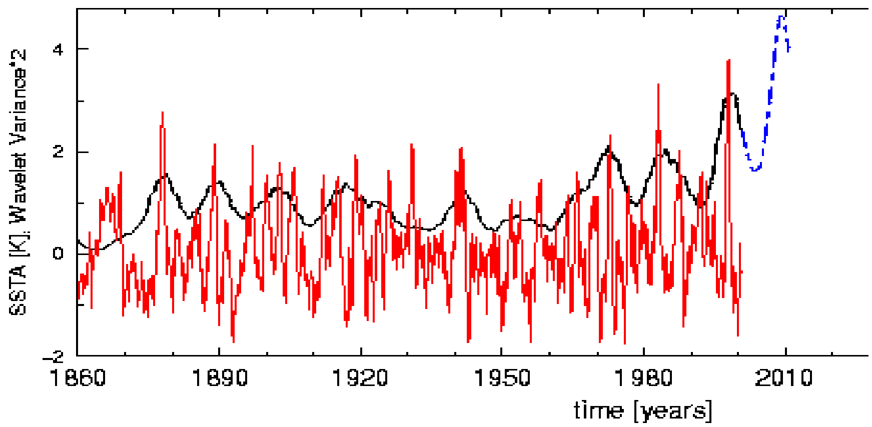

Fig. 2 Observed NINO3 SST anomaly time-series (highly variable curve), together with the 1-year running mean of its variance (smoother curve). The latter curve indicates that the amplitude of ENSO varies with a time-scale of 15-20 years (after Timmermann and Jin 2001).

processes; and iii) tropical processes only. I comment here on all these processes but focus on the first category, noting the role of the North Pacific Subtropical Cell (STC) in the generation of EDV.

Mid-latitude processes only

Latif and Barnett (1994, 1996) reported a mode of decadal oscillation in a solution to their global, coupled general circulation model (GCM). It was associated with SST anomaly patterns similar to both of the EOFs in Figure 1, with one pattern developing into the other. The oscillation existed even when tropical feedbacks were suppressed, indicating that its dynamics are distinctly different from those of ENSO. The authors concluded that positive feedbacks involving mid-latitude wind stress and heat flux anomalies were important for the mode's excitation, whereas subtropical gyre adjustment and advection (which both have decadal time scales) were likely responsible for determining its period. Other modelers, however, have not been able to produce as strong a midlatitude mode (e.g., Palmer and Sun 1985; Ferranti *et al.* 1994; Peng *et al.* 1995), likely because the other atmospheric models did not respond as effectively to mid-latitude SST anomalies as the one used by Latif and Barnett (1994, 1996).

Several pathways have been proposed to account for how mid-latitude PDV might influence the tropics. One involves atmospheric teleconnections from mid-latitudes to the tropics. Pearce *et al.* (2000) noted that in their coupled model the wind anomaly associated with PDV extended well into the tropics, and this anomaly generated the model's EDV. The other involves teleconnections from the subtropics to the tropics via the ocean's North and South Subtropical Cells (STCs).

The STCs are shallow (less than about 500 m) meridional circulation cells in which water flows out of the tropics within the surface layer, subducts in the subtropics, flows equatorward within the thermocline, and upwells in the eastern equatorial ocean (McCreary and Lu 1994; Liu *et al*. 1994; Rothstein *et al.* 1998; Lu *et al.* 1998). Figure 3 illustrates the STC pathways in the Rothstein *et al*. (1998) solution, showing streamlines at the surface (top panel) and in the thermocline layer (bottom panel).

The STC pathway has recently been proposed by Gu and Philander (1997) as a possible explanation for EDV. They hypothesized that SST anomalies in the North Pacific are subducted into the thermocline to join the North STC, and are subsequently advected to the equatorial Pacific with a time lag of the order of a decade, thereby providing a delayed negative feedback (labeled the vT′ hypothesis). This idea received observational support from Deser *et al.* (1996), who were able to follow the equatorward movement of a subsurface

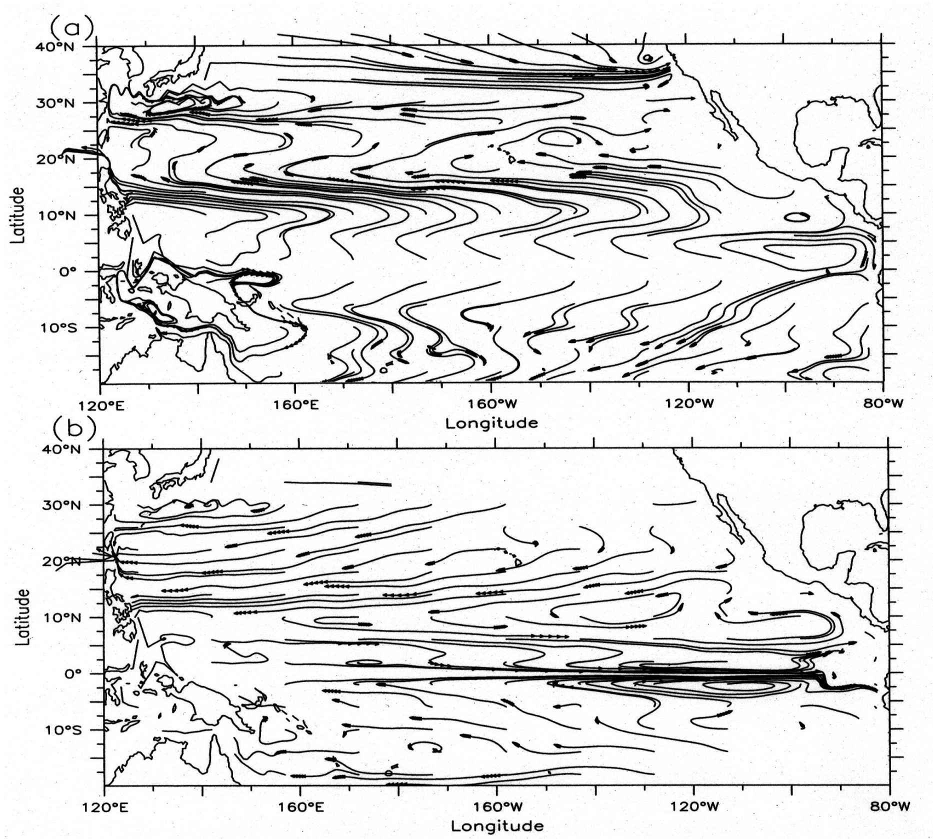

Fig. 3 Surface (top) and thermocline-level (bottom) currents from the Rothstein *et al.* (1998) solution. Areas of upwelling and subduction are labeled in the top and bottom panels, respectively. The panels illustrate the presence of closed, shallow, meridional overturning circulations, the model's North and South Subtropical Cells, which carry cool thermocline water into the tropics and return warm surface water to the subtropics.

anomaly for some distance. However, they did not follow the signal far enough to determine whether it moved into the equatorial region or simply recirculated within the Subtropical Gyre. Recent solutions to oceanic GCMs suggest that most of this signal does in fact recirculate, with little ever reaching the equator (Schneider *et al.* 1999; Nonaka *et al.* 2000). As proposed by Gu and Philander (1997), then, the STC pathway may not provide a sufficiently strong interaction to account for ENSO decadal variability.

An alternate hypothesis is that EDV is generated by variability in STC strength rather than its subsurface temperature (the v′T hypothesis). This idea has been explored by Kleeman *et al.* (1999) and Solomon *et al.* (2001) using intermediate coupled models. In the former study, solutions developed two oscillations, corresponding to PDV and to ENSO. Subtropical wind anomalies associated with the PDV mode altered the strength of the STC, thereby causing more or less cool thermocline water to flow to the equator, which led to a change in the size and strength of the equatorial cold tongue. This change in turn fed back to the atmospheric model to generate EDV. Solomon *et al.* (2001) extended and improved the Kleeman *et al.* (1999) model. They showed that the model PDV was generated by processes similar to those suggested by Latif and Barnett (1994, 1996), but that convection was important in northwest Pacific. In addition, they also reported solutions in a parameter range where the PDV mode is damped, requiring tropical air-sea interactions to maintain it. Thus, in this solution the generation of PDV is tightly linked to tropical air-sea interactions, similar to the solutions discussed next.

Tropical and mid-latitude processes

A number of studies have suggested that the generation mechanism of PDV (and EDV) may originate in the tropics, with PDV at mid-latitudes resulting from ENSO-like atmospheric tele-connections from the tropics (Yukimoto *et al.* 1996, 1998; Knutson and Manabe, 1998). In these solutions, subtropical Rossby waves provide the negative feedback that forces the solutions to shift from one extreme state to another (cold to warm state). The time scale of the decadal oscillation depends on the latitude band of the Rossby waves: the farther poleward the band is located, the longer is the period of the oscillation. The basic idea is thus analogous to the delayed-oscillator theory of ENSO, except that in the ENSO case the Rossby waves are equatorially trapped. A theoretical limitation of the idea is that there is no obvious dynamical reason why the system selects a particular latitude band for the Rossby waves, one that provides variability at decadal time scales rather than some other period. On the other hand, since observed PDV does not have an obvious preferred period, perhaps there is no preferential latitude band and this limitation is not so bad.

Tropical processes only

Finally, other studies using intermediate and simple coupled models suggest that EDV is generated entirely within the tropics by stochastic processes. This type of EDV is implicit in the solutions reported in Zebiak and Cane (1987). Recently, Timmermann and Jin (2001) have explored the nature of EDV in a simple (low number of degrees of freedom), tropical, coupled system, arguing that the decadal response results from tropical nonlinear interactions alone. They demonstrate that in their model the EDV has a character well known in applied mathematics, namely, that of "homoclinic chaos". In addition, in their solution the amplitude of ENSO varies decadally, rather like the observations in Figure 2. The authors also note similarities between their simple solutions and those to the Case and Zebiak (1987) model. Solutions of this sort have the advantage that they do not develop a sharp decadal peak, consistent with the observations.

Conclusion

In conclusion, the current suite of hypotheses for PDV and EDV is a confusing one, pointing toward the potential importance of several, apparently conflicting mechanisms. Part of the confusion may result from the fact that there is not one simple explanation for PDV and EDV, that in fact many (or all) of the aforementioned mechanisms are at work. In this regard, it is interesting that for a particular parameter range in the Solomon *et al.* (2001) model, PDV exists only when the model also allows for ENSO. In this solution, all the mechanisms noted above are at work except stochastic forcing. This solution therefore suggests that a simpler picture of the causes of PDV and EDV will soon emerge, one that unifies many or all of the existing hypotheses.

References

Deser, C., Alexander, M.A., and Timlin, M.S. 1996. Upper-ocean thermal variations in the North Pacific during 1970-1991. J. Clim. 9: 1840-1855.

Ferranti, L., Molteni, F., and Palmer, T.N. 1994. Impact of localized tropical and extratropical SST anomalies in ensembles of seasonal GCM integrations. Quart. J. Roy. Meteor. Soc. 120: 1613-1645.

Gu, D., and Philander, S.G.H. 1997. Interdecadal climate fluctuations that depend on exchanges between the tropics and the extratropics. Science 275: 805-807.

Ji, M., Leetmaa, A., and Kousky, V.E. 1996. Coupled Model Predictions of ENSO during the 1980s and the 1990s at the National Centers for Environmental Prediction. J. Clim. 9: 3105-3120.

Kleeman, R., McCreary, J.P., and Klinger, B.A. 1999. A mechanism for generating ENSO decadal variability. Geophys. Res. Lett. 26: 1743-1746.

Knutson, T.R., and Manabe, S. 1998. Model assessment of decadal variability and trends in the tropical Pacific Ocean. J. Clim. 11, 2273-2296.

Latif M., and Barnett, T.P. 1994. Causes of decadal climate variability over the North Pacific and North America. Science 266: 634-637.

Latif M., and Barnett, T.P. 1996. Decadal climate variability over the North Pacific and North America: Dynamics and predictability. J. Clim. 9: 2407-2423.

Liu, Z.Y., Philander, S.G.H., and Pacanowski, P.C. 1994. A GCM study of tropical-subtropical upper-ocean water exchange. J. Phys. Oceanogr. 24: 2606-2623.

Lu, P., McCreary, J.P., and Klinger, B.A. 1998. Meridional circulation cells and the source waters of the Pacific equatorial undercurrent. J. Phys. Oceanogr. 28: 62-84.

Mann, M.E., and Park, J. 1996. Joint spatio-temporal modes of surface temperature and sea level pressure variability in the Northern Hemisphere during the last century. J. Clim. 9: 2137-2162.

McCreary, J.P., and Lu, P. 1994. On the interaction between the subtropical and the equatorial oceans: The Subtropical Cell. J. Phys. Oceanogr. 24: 466-497.

Miller, A.J., and Schneider, N. 2000. Interdecadal climate regimes dynamics in the North Pacific Ocean: Theories, observations and ecosystem impacts. Prog. Oceanogr. 47: 355-379.

Nakamura, H., and Yamagata, T. 1999. Recent decadal SST variability in the Northwestern Pacific associated atmospheric anomalies. *In* Beyond El Niño: Decadal and interdecadal Climate. *Edited by* A. Variability, and Navarra. Springer, Berlin, pp. 49-72.

Nakamura, H., Lin, G., and Yamagata, T. 1997. Decadal climate variability in the North Pacific during the recent decades. Bull. Amer. Meteor. Soc. 78: 2215-2225.

Nonaka, M., Xie, S.-P., and Takeuchi, K. 2000. Equatorward spreading of a passive tracer with application to North Pacific interdecadal temperature variations. J. Oceanogr. 56: 173-183.

Palmer, T.N., and Sun, Z. 1985. A modeling and observational study of the relationship between sea surface temperature in the northwest Atlantic and atmospheric general circulation. Quart. J. Roy. Meteor. Soc. 111: 947-975.

Pearce, D.W., Barnett, T.P., and Latif, M. 2000. Connection between the Pacific Ocean tropics and midlatitudes on decadal time scales. J. Clim. 13: 1173-1194.

Peng S., Mysak, L.A., Ritchie, H., Derome, J., and Dugas, B. 1995. The differences between early and midwinter atmospheric response to sea surface temperature anomalies in the northwest Atlantic. J. Clim. 8: 137-157.

Rothstein, L.M., Zhang, R.-H., Busalacchi, A.J., and Chen, D. 1998. A numerical simulation of the mean water pathways in the subtropical and tropical Pacific Ocean. J. Phys. Oceanogr. 28: 322-344.

Timmermann, A., and Jin, F.-F. 2001. Homoclinic chaos: a paradigm for decadal ENSO amplitude modulations (Submitted.).

Trenberth, K.E., and Hurrell, J.W. 1994. Decadal atmosphere-ocean variations in the Pacific. Clim. Dyn. 9: 303-319.

Yukimoto, S., Endoh, M., Kitamura, Y., Kitoh, K., Motoi, T., Noda, A., and Tokioka, T. 1996. Interannual and interdecadal variabilities in the Pacific in the MRI coupled GCM. Clim.e Dyn. 12: 667-683.

Yukimoto, S., Endoh, M., Kitamura, Y., Kitoh, A., Motoi, T., and Noda, A. 2000. ENSO-like interdecadal variability in the Pacific Ocean as simluated in a coupled general circuylation model. J. Geophys. Res. 105, 13: 945-963.

Zebiak, S., and Cane, M. 1987. A model of El Niño-Southern Oscillation. Mon. Wea. Rev. 115: 2262-2278.

Comments on LMR-GOOS recommendations

Warren S. Wooster
School of Marine Affairs, University of Washington, 3707 Brooklyn Ave. NE, Seattle, WA 98105-6715 U.S.A. E-mail: wooster@u.washington.edu

The GOOS (Global Ocean Observing System) is being developed by IOC (UNESCO), with the cooperation of ICSU, WMO, and UNEP. FAO has joined in supporting consideration of living marine resources. The system intends to monitor changes in the condition of the ocean and its ecosystems, to process and analyze the resulting data, and to make them available to users. It is in effect an extension of the weather monitoring network to the ocean and arose from realization that the ocean and atmosphere were closely linked in the development of climate change.

Initially GOOS planning was dominated by physical scientists who were accustomed to networks of routine measurements and to having the observational data made available in near real time. Until last summer, there were four planning panels – climate, coastal, health of the ocean, and living marine resources (LMR). The last three have now all been merged into a so-called Coastal Ocean Observations Panel (COOP). Of these various elements, LMR had a late start and a brief life, from its first meeting in March 1998 to its last (fourth) in May 2000.

One reason for the late start was the controversy over what should be monitored – e.g., just plankton or also fish – and who were the potential users of the findings. There were two false starts from different ends of that controversy before a new panel was formed. The beauty of stopping at the plankton level is that the data are largely apolitical. Scarcely any humans are harvesting plankton, but by the same token, there is no constituency clamoring for such data. Attempting to transform plankton data into useful predictions of distribution, abundance, and availability of wanted fish and shellfish products is not a task for the faint of heart. But as soon as fish are included, political interests are aroused. One of the most serious consequences is that data become proprietary and real-time international exchange of such data becomes unlikely. Also, the task of assessing and predicting fish stocks is a tightly-held national prerogative, not one to be shared freely with other countries.

It is possible to identify many of the users of living marine resources and of information concerning their distribution and abundance. In the most obvious case, fisheries extract and sell such resources, and information on present and future status is useful to the fishers, industrial, subsistence, or recreational, and to those who manage their activities. Those who manage other human activities that affect marine ecosystems are also potential customers. Oceanographers, fishery biologists and investigators of climate change and its impacts can also use the outputs of a comprehensive ocean observing system.

Early on in its new life, the LMR Panel decided to take an ecosystem approach, to consider monitoring changes in the state of marine ecosystems along with the forcing functions of such changes. If assessments of such observations could be routinely produced, they would be of great utility at a range of time scale, from interdecadal and decadal to the seasonal assessments and predictions needed for fishery management. Essential ecosystem components to be monitored include the gamut of trophic levels, from plankton up to fish and top predators like marine mammals and seabirds. Plankton are important not just because of their trophic role, but as potential indicators of ecosystem changes. A complete ecosystem assessment cannot leave out certain significant components, for example salmon, because they "belong" to some country or international organization.

Obviously monitoring life in the sea is vastly more complex than that of the relatively simple abiotic components like temperature or atmospheric pressure. On large, ocean basin scales only satellite observations of surface ocean color, a measure of surface phytoplankton concentration, are routinely made. Zooplankton are only routinely sampled in a few regional programs (e.g., CalCOFI) and CPR surveys. Fish and shellfish of commercial interest are sampled largely by commercial and research fisheries for them on a local scale, and the only large scale information comes from compilations of catch statistics a few years after the fact. Unlike the situation with surface weather and ocean physical information, there is at present no obvious funding in prospect for large scale monitoring of living marine resources.

Sampling strategy is affected by the distribution of biota, especially those components of commercial or other human interest. The intensity of necessary sampling in time and space increases from the open ocean toward the coastal zone as does the availability of support for an observational program. While in the open ocean, regular sampling of biota is limited by the availability of platforms of opportunity, in waters less than a few hundred miles from the coast there are often research surveys funded by the coastal state.

Some ongoing programs have been identified as elements of the so-called Initial Operating System. In the North Pacific these are the Japanese and Korean LMR observing systems, the CalCOFI observations, and those of the Canadian Ocean Station P and Line P. Another category is that of LMR pilot projects which includes ongoing or planned programs intended to develop experience with routine biological observations. These include the northeast Pacific CPR surveys and the proposed project to study Biological Action Centers (BACs). Also, several retrospective studies were commissioned with a view to learning what sorts of observations permit identifying significant environmental changes such as regime shifts. In the PICES region, these were in the southern part of the California Current (CalCOFI and Mexico) and a joint Japan-Korea project in the East Sea/Japan Sea and the East China Sea.

The LMR Panel produced a catalog of desirable observations, physical, chemical and biological, and many of these may be appropriate for the open ocean. On the regional scale, however, there are significant differences between, for example, what is appropriate in the North Sea and what off the Peruvian coast. Thus our “strategic plan” included some examples of more specific suggestions relating to upwelling ecosystems, the Scotian Shelf ecosystem of Atlantic Canada, the Yellow Sea and East China Sea, and the Gulf of Guinea. Monitoring systems in these regions are in widely different stages of development, and it is hoped that they may be enhanced and brought together through the action of organizations such as ICES and PICES.

The generalized catalog of potential observations, physical and biological, is highly schematic. Think of it as listing all of the ingredients of some elaborate dish, say a bouillabaisse. Now we need a recipe, to select the proper quantities of each of the components and to determine how best to prepare them. The recipe for optimal monitoring schemes in the PICES region has been under consideration by the MONITOR Task Team and will likely be discussed at this meeting.

If one had a comprehensive set of monitoring observations, what could be done with them? In the first place, there are largely unsolved problems of compiling, storing, and making available for retrieval biological data and information that are far more heterogeneous than the more standard physical data. Then there are the problems of bringing them together with relevant physical and other data in a holistic analysis. This will undoubtedly involve the use of appropriate models such as those being developed in GLOBEC projects.

The Panel proposed that the assessments be prepared in regional analysis centers (RACs). In the PICES region, one can visualize perhaps three RACs, one for the open ocean, located perhaps in Hawaii, one for the eastern North Pacific and Bering Sea, located perhaps in British Columbia, and one for the waters off eastern Asia, perhaps under the sponsorship of NEAR-GOOS. Analysis teams should include scientists from different disciplines, and participation in such activities should attract the interest of graduate students as well as that of established scientists. In many parts of the world, RACs are expected to serve as centers for capacity building as well as for analysis.

The analyses will require a blending of the biotic and abiotic data from all sources, national and international, within a region. They should yield descriptive products on the current state of the ecosystem and its recent and longer-term changes, and analytic products in the form of forecasts of probable future conditions of the ecosystem and its components. Levels of information detail should extend from raw data to indices, alerts, and forecasts. The products would be regularly provided, perhaps on a quarterly basis, to participating countries and organizations and would be made widely available on the web. They could, among other things, contribute to improving the observational system. RACs might be based at national centers but would include participation from other countries contributing data and ideas.

Examples of descriptive efforts along these lines for several PICES regions are regularly produced by Freeland, Stabeno, and Sugimoto, and published in PICES Press. These are primarily summaries of physical conditions, reflecting the availability of data and the interests of the authors. There are also more comprehensive, but less frequent, syntheses such as the Canadian DFO Ocean Status Reports.

The desired structure and contents of such ecosystem status reports are topics for discussion at this workshop. The collective wisdom of this group should lead to a better understanding of what is desirable and what is feasible with current or anticipated technology and organizational structures and within conceivable budgets. The discussions should help to clarify how the monitoring system can best be strengthened to provide the necessary information and what arrangements would most facilitate regular preparation of the status reports.

RAC assessments can be described as follows:

Input data: atmospheric; physical, chemical, biological oceanographic; fisheries

Sources: national and international

Descriptive products: current state of ecosystem, recent and longer-term changes therein

Analytical products: forecasts of probable future conditions of ecosystem and components

Levels of information detail: (1) raw unformatted data; (2) indices; (3) alerts, status of stocks, maps; (4) forecasts

Background and objectives of POGO

Kees Zwanenburg
Marine Fish Division, Bedford Institute of Oceanography, 1 Challenger Drive, Dartmouth, NS, Canada. B2Y 4A2 E-mail: Zwanenburgk@mar.dfo-mpo.gc.ca

The Partnership for Observation of the Global Oceans (POGO) is a forum recently created by leaders of major oceanographic institutions (presently 14 countries) to promote global oceanography, particularly the implementation of international and integrated ocean observing systems.

The long-term goals of POGO are to participate in the creation and operation of an integrated global ocean observing strategy that addresses the information needs of decision-makers, researchers, service providers, and the general public by:

- Providing an informal forum for dialogue among leaders of key oceanographic institutions;
- Development of an advocacy plan for observing systems;
- Participating in the process to secure governmental commitments to funding ocean observing systems;
- Integrating the observational needs of different ocean disciplines (circulation, *biology,* climate);
- Reducing the barriers between research and operational research;
- Making the case for extensive and sustained observations, research, and modeling;
- Encouraging developing countries to participate fully in collecting and using environmental information; and
- Promoting training education and capacity building in oceanic observation.

POGO supports global oceanographic research and operational ventures but it is not a vehicle for launching new international programs. One of POGO's goals is to act as a catalyst and facilitator to develop and enhance existing programs, and to undertake and participate in collaborative training and capacity building. POGO can act as an effective voice for the oceans. POGO membership is open to individual institutions or consortia of institutions promoting regional collaboration and co-ordination.

POGO activities to date

Planning for POGO started in March 1999, and the first formal meeting was held in December 1999. At this meeting, an initial workplan was developed that included the following items:

- development of an advocacy plan for observing systems;
- participation in the process to secure governmental commitments to funding ocean observing systems;
- a data interchange pilot project; and
- establishment of a data clearing house for POGO members and the broader community.

The second meeting was held in December 2000, in Sao Paulo, Brazil. International organizations present were: IOC (Intergovernmental Oceanographic Comission), SCOR (Scientific Committee on Ocean Research), Argo, CLIVAR (CLImate VARiability and predictability), COOP (COastal Ocean Panel of GOOS), GODAE (Global Ocean Data Assimi-lation Experiment), OOPC (Ocean Observation Panel), and CoML (Census of Marine Life – Sloan Foundation).

The meeting focussed on issues pertinent to the southern ocean. Two-thirds of the world's oceans are in the Southern Hemisphere while most oceanographic institutions are in the Northern Hemisphere. The participants adopted a declaration to promote observations in the Southern Hemisphere, to identify the gaps in these observations, and means to fill them.

There was agreement to promote education by instituting a scholarship scheme in collaboration with SCOR and IOC, and to provide training to scientists and technicians from developing countries related to global ocean observations.

POGO agreed to co-sponsor SEREAD (Scientific Educational Resources and Experience Associated with the Deployment of Argo drifting floats in the South Pacific Ocean).

Structure of POGO

Executive Committee

Dr. Charles Kennel, Founding Chairman (Director, Scripps Institute of Oceanography, U.S.A.)

Dr. Robert Gagosian (Director, Woods Hole Oceanographic Institution, U.S.A.)

Dr. Howard Roe (Director, Southampton Oceanographic Centre, UK)

Dr. Michael Sinclair (Director, Bedford Institute of Oceanography, Canada)

Dr. Rolf Weber (Director, Instituto Oceanografico, Univeristy of Sao Paulo, Brazil)

Executive Director

Dr. Shubha Sathyendranath (Bedford Institute of Oceanography, Canada)

Future Activities

The next meeting of POGO is scheduled for fall, 2001, at the Bedford Institute of Oceanography. The major themes of the meeting will be:

1. Biological observations - observations are more complex, less automated, and vary depending on the objectives of the study. The needs of programs with climate/change carbon perspective and those that target biodiversity will be examined, so that POGO can requisite observations (note LMR GOOS has a lot to offer).
2. Time-series observations to complement the Argo program.

Plans for a CoML Workshop on Canadian Marine Biodiversity: Pacific, Arctic, and Atlantic

Kees Zwanenburg
Marine Fish Division, Bedford Institute of Oceanography, 1 Challenger Drive, Dartmouth, NS, Canada. B2Y 4A2 E-mail: Zwanenburgk@mar.dfo-mpo.gc.ca

Rationale and objectives of the workshop

The world demand for food from the oceans is expected to outstrip availability within the next few decades. Increased use of the oceans for extraction of non-renewable resources and the accelerating growth of coastal population centers will put additional pressures on these systems. In Canada this is reflected by increasing pressures on wild fish and invertebrate stocks, some to the point of fishery closure, increases in offshore oil and gas exploration, and increases in non-consumptive and other ocean use activities. At the same time there is increasing demand for conservation of marine habitats and biodiversity. The latter reflects a growing recognition that the welfare of mankind is inextricably linked to the welfare of these marine systems both as sources of food and as indicators of overall biosphere health. Rational management of future harvesting and other human marine activities requires a reliable information base and theoretical framework with which to make effective decisions. This workshop proposes to develop a national perspective on marine biodiversity in Canada's ocean territories, to develop recommendations for improved monitoring of this diversity in future and to provide guidance on what key factors may control biodiversity.

By signing the International Convention on Biodiversity, Canada has agreed to: make inventories of biodiversity, monitor changes in biodiversity, and make plans to conserve biodiversity. Although Canada ranks among the world leaders in marine research and has been carrying out biophysical monitoring since at least the 1950s, knowledge of its vast ocean territories is still rudimentary for many areas, especially for many groups of organisms inhabiting them. A pre-requisite to developing effective programs to protect habitats and biodiversity is to determine the extent to which information on biodiversity is available for Canada's Pacific, Arctic and Atlantic Ocean territories. Identifying the shortcomings in this information will allow us to amend existing biophysical monitoring activities to ensure that these information gaps can be filled. In addition, the theoretical framework within which these data are interpreted and from which generalities regarding biodiversity can be drawn are not well established for marine systems. Such a framework would allow us to make predictions about what major factors control biodiversity within marine systems and therefore what mitigative procedures would be effective for its maintenance. Most ecological theory and ecological generalizations about biodiversity were developed using terrestrial systems. The second pre-requisite therefore is to examine the applicability of terrestrial ecological theory to marine systems.

The Centre for Marine Biodiversity (CMB) will convene a national workshop to examine these biodiversity issues in Canadian marine waters. The CMB is proposing this workshop in recognition of the many projects relating to biodiversity that are being carried out in all of its ocean territories (Pacific, Arctic, and Atlantic) and the need to consolidate and review this knowledge at a national scale. Canada is well positioned for this workshop given the activity and caliber of its marine science community, the long tradition of monitoring of its marine systems, and the implementation of ecosystem level research in many of its marine institutions. Specifically the workshop will achieve the following objectives:

- A comprehensive description of information on biodiversity available for all of Canada's ocean territories (Pacific, Arctic, and Atlantic). This includes information collected as a result of government-funded biophysical monitoring surveys as well as the results of research carried out by universities, NGO's, fisheries organizations, and First Nations. The key elements of these data will be time and location of collection, the method of collection (sampling gear), and the number of specimens of each species observed.

- A gap analysis of these data to determine where information on marine biodiversity is lacking (both geographically and taxonomically).
- Recommendations for the improvement / augmentation of biophysical monitoring programs in each of the Pacific, Arctic, and Atlantic oceans based on the gap analysis of existing data, and focussed by model results if these indicate key taxonomic groups for which information is presently missing.
- An evaluation of the applicability of existing ecological theory and generalizations to marine biodiversity. Such an evaluation will focus on identifying key factors that maintain or modify the biodiversity of marine systems. This will be at three distinct but inter-dependent levels, ecosystem diversity, species diversity within ecosystems, and population diversity within species.
- Development of a National Plan for producing inventories of marine biodiversity, modifying or augmenting existing biophysical monitoring programs to ensure adequate monitoring of biodiversity, and providing guidance for the development of biodiversity conservation / augmentation plans.

Summary of proposed work

The CMB was recently established at the Bedford Institute of Oceanography to provide a focal point for the range of biodiversity related research presently being conducted in government institutes, universities, and NGO's in the Atlantic region. The proposed workshop will be attended by invited experts and others from the Pacific, Arctic and Atlantic regions of Canada and by international experts. They will develop a detailed overview of current knowledge and gaps in knowledge about organismal diversity in its three oceans. The workshop will also develop an overview of current models used to explore the trophic inter-relationships and organismal dynamics within Canadian marine ecosystems. The results of the gap analysis and model overviews will be used to focus recommendations for improving / augmenting existing biophysical monitoring programs. Finally, the workshop will examine and debate the underlying ecological theory applicable to the maintenance of biodiversity at the marine ecosystem, species, and populations levels with the specific objectives of identifying key factors controlling diversity at these levels of organization. The findings of the workshop will be used to develop a National Plan for cataloguing, monitoring, and providing the theoretical principles to govern the plans for conservation of biodiversity in Canadian marine territories. This plan will provide guidance for Canada to fulfill its obligations under the International Convention on Biodiversity.

Technical description of proposal

We propose a Canada-wide approach to ensure that the workshop reflects biodiversity issues from all three of Canada's oceans, and to encourage co-ordination and co-operation among researchers working in these areas. Such collaboration is essential to the successful development of a national view of marine biodiversity. Since development of a Canadian view of marine biodiversity could provide significant insights or lessons to a global scale project, DFO and the Census of Marine Life will partner funding of the project.

The motivations for the Census of Marine Life are that it provides opportunities to make exciting discoveries about our world, that it supports and operationalizes the International Convention on Biodiversity, and that this improved knowledge will lead to an improved ability to manage marine resources. Specifically the objectives of the Census are to describe: (i) what did live in the oceans, (ii) what does live in the oceans, and (iii) what will live in the oceans.

Between 1997 and the present, the Census of Marine Life sponsored a series of expert workshops examining the justification, scope, and feasibility of such a project (Ausubel 1999). These workshops have concluded that this is one of the grand challenges of marine science whose execution has the potential to unify all its disciplines (biology, chemistry, and physics). The global objectives of the Census are not only about classifying and counting the number of organisms in the sea; they are about understanding the complexities of biological-physical-chemical coupling in dynamic marine environments. An international steering committee has been established to integrate the most valuable and feasible ideas resulting from these and future workshops into a 10-year strategy document.

The historical component of the program will involve rescuing and putting into electronic formats historical information on biodiversity. For the Canadian workshop this will be accomplished, in part, by developing a meta-database of existing information on biodiversity. Once the data sources have been identified it may be feasible to consider development of an integrated biodiversity data set for Canada. Previous projects which developed integrated data sets of biophysical monitoring information (i.e. Mahon *et al.* 1998) resulted in many new insights into biogeography and (in this case) fish assemblages at previously unexplored geographic scales. The program is also developing an Ocean Biogeographical Information System (OBIS) which could be used to develop the integrated biodiversity data set. Work being carried out through Canada's Marine Environmental Data Service (MEDS) may also provide direction on how to merge these biological data with the accompanying physical data.

The "present" component of the program will involve a number of new field programs specifically aimed at assessing the efficacy of new technologies to make synoptic and synchronous measures [of biodiversity] over large areas of ocean. These will be in the form of pilot project in a number of key locations (Georges Bank / Gulf of Maine, Mid-Atlantic ridge and overlying deep-water, vent and seep communities, Pacific large pelagic fish populations, North Pacific salmon populations, and Western Pacific near-shore fauna). For the Canadian workshop we propose that the present component consist of an analysis of the available information to determine data gaps that will provide broad direction for the modification of existing biophysical monitoring programs to ensure effective future monitoring. We also propose that detailed direction for improved monitoring would be aided by results of modeling efforts to determine key structural or trophodynamic groups within systems.

Although integration and analysis of historical data, and identifying and filling in data gaps will lead to an improved description of Canada's marine system, the ultimate objective is to be able to predict what will happen to the diversity in these systems in the future. This objective requires the ability to model the systems with the objective of identifying major forcing variables, or at least to identify the major factors controlling the key species groups. This work is pre-requisite to developing or implementing management measures to protect or enhance the diversity of these systems. Such modeling will require a theoretical framework within which to interpret the existing data. These issues have been extensively deliberated for terrestrial systems but not for marine systems. Canada is presently embarking on a program to define and establish Marine Protected Areas. Although the objectives for these areas have not been explicitly articulated, they do imply some desire to protect biodiversity at least within the boundaries of the areas. The theoretical basis for determining the size, number, and location for such areas in order to maintain or enhance biodiversity has not been clearly articulated. Although it is not necessary to delay the implementation of MPA's while this theory is developed, deliberation and refinement of these concepts may lead to generalities that improve the efficacy of these areas. Specifically, knowledge of what controls diversity within marine systems will allow for more effective management.

An appraisal of current Pacific Ocean monitoring efforts existing within PICES countries

David W. Welch
Fisheries & Oceans Canada, Ocean Sciences & Productivity Division, Pacific Biological Station, Nanaimo, British Columbia, Canada. V9R 5K6 E-mail: welchd@pac.dfo-mpo.gc.ca

During the PICES Seventh Annual Meeting in Fairbanks (October 1998), it became clear that the PICES community does not have a good sense of how well the North Pacific is monitored. As a result, following the meeting we worked to collect information on current monitoring efforts within the PICES region. For purposes of this paper, we define monitoring as regular systematic ocean sampling. For simplicity, we restricted our survey to ocean monitoring that is still on-going. If we plot all of the ocean sampling that is currently occurring, the map of the North Pacific Ocean and adjacent seas looks fairly well-covered (Fig. 4). Reasonably extensive time-series of data exist at Station P (since 1949), Line P (since 1956), the GAK-1 line (since 1970) and the CalCOFI grid (since 1949).

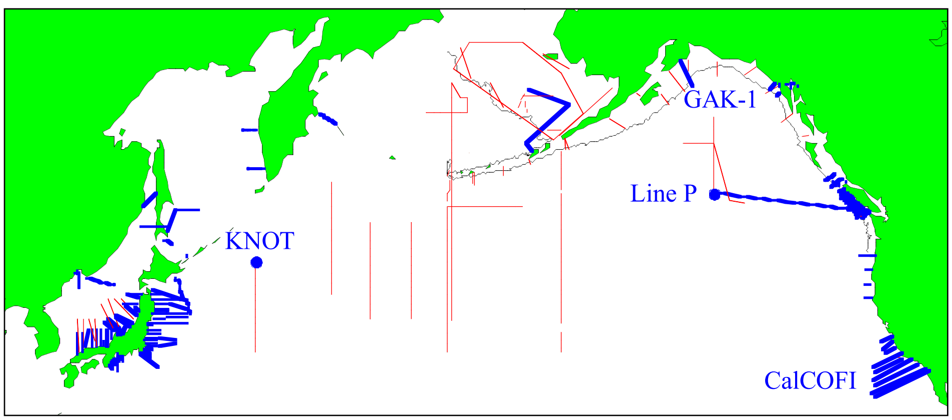

Fig. 4 Summary of on-going monitoring efforts in the PICES arena. The figure shows all locations sampled at least once per year.

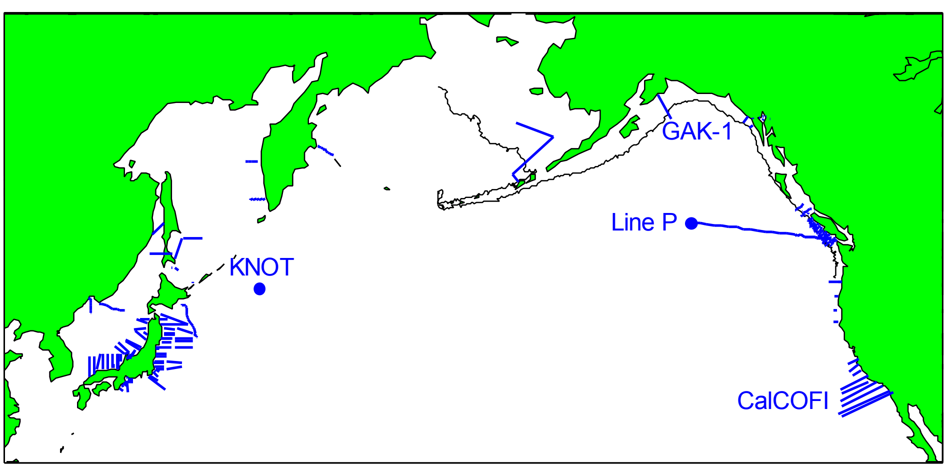

Fig. 5 The same chart as Figure 4, but restricting the definition of monitoring to sampling that occurs two or more times per year. Very little of the North Pacific is adequately monitored if seasonal variation occurs.

However, the time of peak abundance of the dominant copepod *Neocalanus plumchrus* has shifted by approximately two months in the eastern North Pacific (Mackas 1998), emphasizing the need for seasonal coverage in order to identify such changes. If we therefore restrict our definition of "monitoring" to sampling activities that re-sample the same locations two or more times per year, the picture changes dramatically (Fig. 5). The limited sampling is particularly noticeable in the open ocean, where apart from Line P and the new Japanese Station KNOT, no monitoring activities are taking place. As Steele (1998) has noted, coastal zooplankton populations appear to be forced by the offshore populations (at least in the Atlantic), so it is reasonable to expect that events happening offshore will have significant impacts in the shelf region as well. It is clear, however, that the role of offshore and shelf ecosystems under climate change will not be resolved with the existing monitoring effort.

Census of Marine Life – POST (Pacific Ocean Salmon Tagging) proposal

David W. Welch
Fisheries & Oceans Canada, Ocean Sciences & Productivity Division, Pacific Biological Station, Nanaimo, British Columbia, Canada. V9R 5K6 E-mail: welchd@pac.dfo-mpo.gc.ca

The goal of this project, which is currently under review by the CoML for funding a two-year planning phase, is to develop a project focussed (initially) on Pacific salmon. The purpose is to showcase the use of new electronic tagging technology that should allow marine scientists, for the first time, to really track and evaluate the movements of marine fish in the ocean environment. A companion program, "TOPP" (Tagging of Pacific Pelagics), may also go forwards which would focus on using Pacific bluefin tuna and elephant seals using different classes of electronic tags. This program is being co-ordinated by Barbara Block, Dan deCosta, and George Boehlert in California, U.S.A.

The biological objective of POST is to evaluate whether salmon do not merely return to their home address or spawning grounds, but also home to marine feeding grounds using population-specific migration routes. If this concept is correct, then salmon can be thought of as animals whose marine life history phase is every bit as complex and sophisticated as its freshwater phase. The main difference is that the ocean life history of salmon (and all other migratory fish) is hidden within the opaque medium of seawater.

The proposed CoML POST program has two components – an offshore component using archival tags to track the movements of Pacific salmon in the open ocean, and a nearshore component that would use an acoustic array to track the movements of salmon tagged with acoustic tags along the continental shelf (Fig. 6).

Only the second component is of direct relevance to the purpose of this meeting. Although acoustic tracking is normally considered to be of use over short distances and restricted time periods, it is likely that we can design and build an acoustic monitoring network that could stretch the length of the West Coast of North America at relatively low cost. This network is called "POTENT" (for ***P***acific ***O***cean ***T***racking ***A***nd ***E***valuation ***N***e***T***work), and would consist of about 600-700 low cost acoustic receivers that would be deployed in a series of acoustic listening lines, that would stretch across the shelf on the sea bottom from land to the shelf break.

As the continental shelf off the West Coast of North America is relatively narrow (20-30 km wide in most places), we believe that it will be possible to place a series of receivers at roughly 1-km spacings that should provide for virtually complete detection of all acoustically tagged animals that swim above it (Fig. 7). As each tag has a unique acoustic signature, and each receiver records the date and time that each tag is detected, it is possible to build up a detailed picture of the

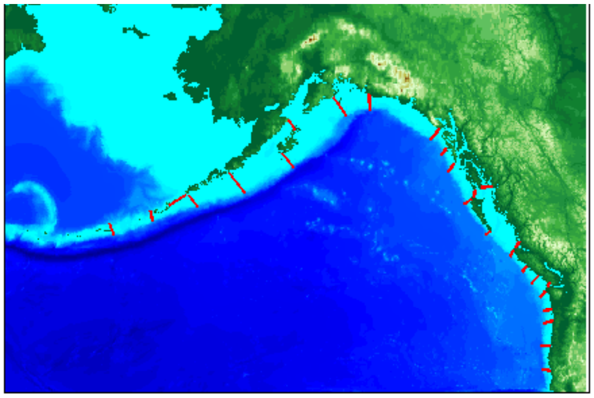

Fig. 6 Conceptual example of the monitoring network. Monitoring lines (in red) will be placed using islands and straits as bottlenecks to minimize the length of monitoring lines. For example, all tagged salmon migrating to or from the Fraser River or the East coast of Vancouver Island could be monitored with two short lines in Johnstone and Juan de Fuca Straits. Their detection north or south of the straits would demonstrate which direction specific stocks move and their rates of migration. Similar design criteria would apply to other major rivers such as the Columbia. Actual positions need to be determined as part of the planning process to minimize disruption to fisheries.

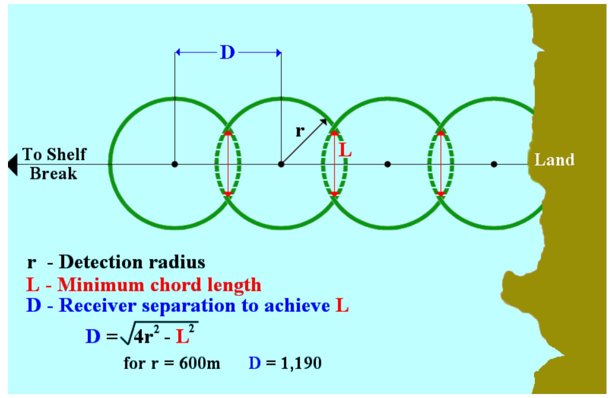

Fig. 7 Conceptual example of the cross-shelf monitoring array. The basic design goal is to determine the detection radius, r, at which an acoustically tagged animal can be identified under different oceanographic conditions. Knowing r, it is possible to determine the spatial separation, D, for the receivers to ensure that an animal crossing the array at right angles has a high probability of being detected. For a salmon smolt travelling at 20 cm/sec, assuming that the minimum chord length is L=100 m in the example given results in the animal travelling within the detection zone for a minimum of 8 minutes.

movements of individual animals during their migrations along the continental shelf over many months or years at sea. This approach should for the first time allow the study of large scale movements of shelf-resident marine fish, which are not otherwise amenable to study.

The POTENT array, if built, is thus of some interest for monitoring animals over wide regions along the continental shelf. However, a further aspect of the array is of relevance, which is its use as a framework within which a much wider range of sea-bed instruments (such as temperature or salinity probes) could sit. Assuming that the initial infrastructure can be developed, it should be possible to place a wide range of additional sensors on the seabed, and use the same infrastructure to retrieve long-term measurements of oceanographic properties as well. One could, for example, envisage such a seabed network recording the rate of movement of an El Niño at depth up the coast, since the greatest warming during the last two El Niños occurred at 200-400 m depth off British Columbia.