# Recommendations to Census of Marine Life Project from the SCOR Panel on New Technologies for Observing Marine Life

Meeting #1
Goa, India
14-16 February 2005

The Panel on New Technologies for Observing Marine Life of the Scientific Committee on Oceanic Research (SCOR) met for the first time in Goa, India on 14-16 February 2005. The first term of reference of the panel is to "review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects." A significant amount of time was spent at the first meeting discussing the CoML Research Plan and the panel makes the following recommendations to CoML and its projects:

- Many of the projects are using the same technology (see attached inventory of technologies used) and could benefit from sharing information about the observation technologies and work together to improve the use of the shared technologies. For example, the experience of MAR-ECO scientists in using existing and new technology at sea can be documented and shared with other CoML projects.
- CoML should provide a database of CoML-related cruises on its Web site.

From the information about technologies being used, as well as knowledge about the kinds of observations and sampling the projects will pursue, the Panel offers the following advice:

- All projects that will actually sample organisms, particularly fragile specimens, should (1) collect the samples in a way that is compatible with molecular barcoding techniques, (2) preserve voucher specimens, and (3) where voucher specimens cannot be maintained, collect three-dimensional images. CeDAMar, the margins project, and CenSeam particularly fall into this category, because of the expense of collecting the samples and the difficulty of re-sampling.
- CMarZ and ICOMM should consider employing sampling from volunteer observing ships.
- Projects should take advantage of opportunities to make observations from new observatory systems being planned. Ocean observatories might be especially useful for CeDAMar, ChEss, and MAR-ECO. Observatories in high-latitude areas, greatly under-observed, would benefit ArcOD and CAML.
- Projects should involve oceanographers and make oceanographic measurements to the extent that the project is attempting to understand what controls the distribution of marine organisms. For example, seamounts are significantly influenced by the hydrodynamics of current flows that surround them, and hence physical processes do affect the biology of seamounts. Therefore, it would be useful to involve and obtain inputs from physical oceanographers in the project.

Some projects could benefit from the passive detection of sound from marine organisms, including both data collection and "voice recognition." Projects that could benefit from knowing about sounds from marine organisms should involve experts on animal acoustics. The TOPP project already does this.

SCOR Panel on New Technologies for Observing Marine Life

Meeting Summary

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The Panel on New Technologies for Observing Marine Life of the Scientific Committee on Oceanic Research (SCOR) met for the first time in Goa, India on 14-16 February 2005. Participants included the panel members Elga de Sa (chair), Yogi Agrawal, David Farmer, Gaby Gorsky, Alex Rogers, Heidi Sosik, Song Sun, and Bob Ward. Panel members Geoff Arnold, John Gunn, and Antonio Pascoal were unable to attend. Other participants included Edward Vanden Berghe (Chair of the IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices), D. Chandramohan (member of CoML Scientific Steering Committee), P.A. Lokabharathi (Indian Ocean CoML Secretariat), and Ed Urban (SCOR Executive Director).

Elgar de Sa made some opening remarks about the Panel. It has been founded on the excellent work that was initiated by SCOR Working Group 118 with the same name (www.coml.org/scor/scor.html/). The Panel will evaluate and recommend new and emerging technologies for CoML. The Panel will have its own Web site on new and existing key technologies. The Panel will operate initially for a period of three years. The tasks for this meeting include

- Examine the CoML Research Plan and identify technologies that are being used by the projects. Can the technologies identified in this meeting be used in the CoML Program and, if so, which projects? The Panel should be seen as a body that can provide reliable technological advice to requests from CoML projects. The Panel Web site should project this image.
- Assign Panel members to different technology areas in the CoML research plan, for example, DNA techniques, optics, acoustics, platforms, imaging systems, etc.
- Discuss structure of the beta version of the panel Web site (www.scoml.org), and make suggestions on how it can benefit CoML projects, and also act as a forward-looking source of information about emerging technologies of oceanographic sciences. Panel members will be responsible for updating and providing content for their technology area on the Panel Web site.
- Make recommendations that will be disseminated to CoML projects and will be posted on the panel Web site.

Elgar de Sa finished by stating that the Panel needs to interact with manufacturers who understand the reality of building reliable instruments. Regular annual updates of emerging technologies by the panel should feature in *Sea Technology* magazine.

Ed Urban, the SCOR Executive Director, added some additional thoughts about what the Panel can contribute:

- Help CoML leave a technology legacy
- Help CoML contribute to the biological portion of GOOS
- Transfer successful technologies among projects
- Serve as a major source of ocean technology information by bringing together information from many different sources
- Help CoML enlarge the "knowable" about ocean organisms and ecosystems

David Farmer presented an overview of the status of all CoML projects. He reiterated the expectations of the SCOR panel from CoML, namely to summarize technologies, to identify the greatest needs and to look for the most promising opportunities for CoML projects. Panel members presented their areas of research that are relevant to the Census of Marine Life and began implementation of all of their terms of reference:

1. **"To review the Census of Marine Life (CoML) Research Plan and make recommendations about technologies that could be applied to CoML projects."**

A significant amount of time was spent at the meeting discussing the CoML Research Plan and the panel developed recommendations to CoML and its projects (see Recommendations section at end of document). The Panel spent most of its time and discussion on the newer projects.

In general, some of the best equipment for the projects is available "off the shelf," because it is well tested and potentially less expensive. The size of the organism to be observed will determine which technology is appropriate. Advances might be achieved by coupling technologies, such as acoustical and optical techniques, or barcoding and optics.

Meeting participants noted that many CoML projects are using, or could use, the same technologies. They should develop a mechanism to cooperate in the technologies they use. For the new projects, optical imaging should be useful for CMarZ and the Continental Margin Ecosystems on a Worldwide Scale project. Molecular barcoding and voucher specimens should be employed by CeDAMar; barcoding is already being used by ChESS. CenSeam should use AUVs and ROVs. ChEss needs devices to use in combination with hyperbaric samplers, to keep animals alive for observation and experimentation after reaching the sea surface.

**Census of Seamounts (CenSeam)—**Alex Rogers reviewed the CenSeam project. He noted that there are probably 100,000 seamounts worldwide. Seamounts tend to be high exposure, with swift currents, so that they have little sediment cover. Seamounts are oases in the open ocean because they promote upwelling, have hard substrates, are at shallower depths, and attract breeding aggregations of some species. Seamounts create significant complexity in currents and mixing and can exert an influence on the ocean up to 50-100 km away. Upwelling caused by seamounts can cause polynyas in ice-covered seas. Biological exploration of seamounts has resulted in the discovery of many new species and indicates that seamounts tend to have high diversity and high endemism. For example, a survey of the Tasman Seamounts found 850 species of animals, 29-34% of which are new to science and are potential endemics. There is a low overlap of species among the Tasman Seamounts. The Norfolk Ridge Seamounts off New Caledonia feature more than 2000 species so far, more than half of which are previously undescribed. On the Nasca and Sala y Gomez Seamounts, 52% of the invertebrates and 44% of the species are endemic to this chain. Some seamounts feature cold water coral formations that are 8,000-10,000 years old.

Unfortunately, these biological resources are endangered by deep-sea fishing on seamounts on the breeding aggregations of some fish species, such as orange roughy and oreos. In every seamount range where bottom trawling and deep-sea coral ecosystems coincide, severe damage has been observed. One of the most fundamental scientific questions in relation to seamounts is how species disperse among seamounts, including the role of physical oceanography in dispersal and larval trapping.

Technologies currently used to study seamounts include trawls and dredges, but these destructive methods create a bad impression of scientists studying seamounts. ROVs and submersibles have also been used, as well as multibeam acoustics. It would be much better to switch to more observations by ROVs and AUVs, such as the Autonomous Benthic Explorer (ABE: http://dsg.whoi.edu:90/ships/auvs/abe_description.htm) and Autosub (http://www.soc.soton.ac.uk/PR/Autosub.html). CenSeam should focus on good video transects, as well as selected sampling for barcoding, microsatellite DNA studies, and taxonomic work. It is important to add Doppler current profiling (including towed Doppler) and acoustic imaging of the biological layers in the vicinity of seamounts. CenSeam should work cooperatively with CeDAMar, MAR-ECO, CoMarE, and TOPP.

**Biogeography of Chemosynthetic Ecosystems (ChEss) —**Alex Rogers gave an overview of the ChEss project. It is a study of chemosythetic habitats, which include areas of venting or diffusion of hydrogen sulfide, hydrocarbons (methane), and ammonia-rich hypersaline fluids, and diffusion of lipids from dead whales. Many organisms in these areas live by harboring chemosymbionts: bacteria that break down hydrogen sulphide or methane for energy. Vent and seep areas are rare habitats in the deep sea. Like seamounts, chemosynthetic habitats feature a high level of endemism although, unlike seamounts, the species diversity is usually low. The sampling technology is well developed for chemosynthetic ecosystems for most purposes, including for mapping, chemistry, and studies of megafauna. Molecular biology is well incorporated into studies of evolution and taxonomy. The microbial communities of chemosynthetic ecosystems are understudied, including metagenomic studies, particularly the Chile Margin and the Southern Ocean. The technology is available for such studies, but it is not currently funded. Additional technologies that could be beneficial to use in chemosynthetic habitats include ADCP (towed), echosounders, and high-frequency acoustic methods.

**Arctic Ocean Diversity (ArcOD)—**ArcOD already is working, through compilation of existing data in OBIS and a research cruise in the Chuckchi Sea in 2004. Plans are developing for activities during the International Polar Year, to be coordinated with the Census of Antarctic Marine Life. In the future, ArcOD will continue to compile existing data, process unprocessed samples, and conduct new collections to fill gaps. Since much untapped information and samples exist in Russia, this project has an emphasis on Russian partners and activities.

**Census of Antarctic Marine Life (CAML)—**Bob Ward presented the new CAML project. It will focus on inventories of species (Antarctic fauna of slopes and abyssal plains, benthic fauna under disintegrating ice shelves, and plankton, nekton and sea-ice biota), and defining critical habitats for top predators. CAML's main technologies include net sampling for pelagic animals; underwater video recording; CTD/Niskin bottle water sampling; benthic trawls, grabs, and sleds; and barcode of life sampling with high throughput DNA sampling; archiving of voucher specimens will also be important. CAML obviously overlaps with some other CoML projects with Southern Ocean activities, and with other projects, such as EBA (Evolution and Biodiversity in Antarctica) project. Data from CAML will need to be interoperable with databases from other projects, for example, for EurOBIS. In the future, CAML will proceed with entry of data into the MarBIN database of Antarctic data and will coordinate cruise activity. MarBIN data holdings will be used to identify data gaps. CAML will take advantage of SCAR-led physical benthic mapping to be combined with biological data. At the end of CoML in 2010, CAML will integrate MarBIN with OBIS to produce an Antarctic Biodiversity Atlas.

**Patterns and Processes of Ecosystems in the Northern Mid-Atlantic (MAR-ECO)—**David Farmer made a presentation about the status of MAR-ECO. This project focuses on mid-water and near-bottom macrofauna, including fish, cephalopods (squids, octopods), gelatinous plankton, and crustaceans. The project uses mid-water trawls (3 types, 2 with multisampler), vertical nets, optical profiling, acoustics (organisms, current), and temperature and salinity profiles. The project also does near-bottom sampling with bottom mapping, ROV dives, bottom trawls, benthic landers, longlines, and traps. They employ bait traps and acoustic landers at medium to long term. Project scientists adjust net sampling to sample acoustically located layers of biological activity. The project has collected 50 species of cephalopod, some of which were not named previously. Regarding fish, 179 mid-water species have been recovered, but the number probably will increase to beyond 200 after final analysis. 87 near-bottom fish species have been recorded. Many of these species have been recorded for the first time in the North Atlantic Ocean, and many still are not identified with certainty. MAR-ECO should be requested to document the technology lessons it has learned, so that these can be shared with other projects.

**Pacific Ocean Shelf Tracking (POST)—**POST technology is described at http://www.postcoml.org/project/technology.php. David Farmer provided information relevant to the POST project. POST uses high-frequency sound, multiple receivers, and short ranges. Each tag has a distinctive coded signal. Propagation is restricted by absorption, and boundary and internal scattering. POST is implanting the tags in salmon and sturgeon. Another method that could be useful for POST-type studies would be a RAFOS approach, in which the tags are passive (and thus low power), with the few fixed sources being powered, rather than the other way around. This is the concept behind the Fish Chip. This approach allows the use of very small tags, low frequencies for long-range detection, and continuous measurement far from choke points. POST tags are commercially available. Alternatively, in the next generation of such observations, they should evolve to having the receiving systems occasionally transmit a trigger signal, so that the tags only need to transmit when they are near a receiver. Farmer described the Fish Chip, which is a passive receiver implanted in fish that can record where the fish travels. The tag includes a thermistor, hydrophone, and memory.

**Census of Marine Zooplankton (CMarZ)—**Song Sun described the CMarZ project. CMarZ is a taxonomically comprehensive, global-scale census of marine zooplankton, to produce accurate and complete information on zooplankton species diversity, biomass, biogeographical distribution, genetic diversity, and community structure by 2010. CMarZ will analyze the about 6,800 described species (and will likely discover at least this many new species) of marine metazoan and protozoan holozooplankton (animals that drift with ocean currents throughout their lives). It will include gelatinous zooplankton, but not the larvae of non-drifting forms. CMarZ has some relevance to CenSeam. CMarZ will use standardized sampling methods, based on GLOBEC methods, so that samples can be compared from different locations. It will use a nested sampling approach, with net sampling and barcording of organisms collected. CMarZ will be based on standardized sampling gear, including the Multiple Opening-Closing Net and Environmental Sensing System (MOCNESS) and the Continuous Plankton Recorder (CPR). Sampling of gelatinous zooplankton requires nets with large cod-ends and manual sampling. Zooplankton sampling approaches will be designed to obtain specimens and data from a variety of taxa using protocols that will yield specimens suitable for morphological and molecular analysis, as well as samples that are suitable for quantitative analysis. Traditional morphological analysis of zooplankton samples will remain a central component in the processing of new and existing collections of zooplankton. Such analysis continues to provide an ecological context for most groups. CMarZ will ensure that additional efforts will be applied to sample analysis to improve the quality of data, especial rare species, which are typically under-represented in zooplankton studies.

The project could benefit from adding acoustic observations. It is also important that they use noiseless nets, which can be tested by deploying on-net cameras and/or acoustic sensors to determine whether any organisms are regularly able to avoid the nets. Lights can be used to attract some species. One difficulty in the project is getting research groups to modify or give up their traditional methods. There is a great potential for re-analysis of samples collected earlier.

**Ocean Biogeographical Information System (OBIS)—**OBIS should integrate barcoding data in some way with barcoding databases, to make sure that molecular data are accessible with other data about species, and to avoid duplication.

**Questionnaire Results—**The panel received questionnaire responses from a high percentage (57%) of the CoML field projects. The purpose of the questionnaire was two-fold: (1) to determine what technologies are being used by the projects and (2) to determine what kind of information (and with what frequency) the projects would like information on the Panel Web site. The questionnaire results also provided information about the other ways that projects obtain technology information. These results were used to form recommendations to the projects, help direct the future work of the Panel, and design the Panel Web site.

**2. "To communicate with CoML project leaders on a regular basis to discuss project technology needs."**

The panel began its communication with CoML projects and their leaders through a questionnaire that was developed to obtain information about the technologies currently being used by the projects and their need for information on available technologies. Future communication will be both direct and through the panel Web site.

The panel concluded that it could provide the greatest benefit to CoML projects that are in their development phase, that is, CenSeam, CMarZ, CAML, ArcOD, CeDAMar, ICoMM, and the reefs and margins projects, if approved. Two panel members will attend the CenSeam planning meeting in the Azores and other panel members will be identified to attend other meetings of the other projects. The role of panel members at these meetings will be to learn about the projects and to convey in person any advice from the panel.

### 3. "To identify and bring to the attention of the international community of fisheries scientists, marine biologists and others, the potential benefits of emerging technologies in the detection of marine life."

**Barcoding—**Alex Rogers and Bob Ward made presentations about how new molecular techniques are being used to study marine biodiversity. "Barcoding" involves using specific regions of genes to assess the genetic and taxonomic diversity of organisms, comparing observed sequences against each other. The selected gene regions depend somewhat on the organism studied, although an attempt is being made to use gene regions that can be used widely with different taxa. For higher organisms, the recommended barcoding gene is the mitochondrial DNA cytochrome oxidase I gene (COI, see barcoding.si.edu or www.barcodinglife.org).

Rogers has worked on nematodes collected with box corers and multicorers in the equatorial Pacific Ocean at the Clarion-Clipperton Fracture Zone as part of the CeDAMar project, using 18S ribosomal genes. The results of these studies indicate that there are many rare species. Using a BLAST search against known 18S sequences, no sequences were found showing 100% identical matches to any known nematode species. Barcoding detects more species, especially single specimens of a species. Some larvae can be identified to species level by molecular analysis, but others only to the family level. In general, however, barcoding allows better discrimination among species than do morphological methods, particularly for larvae.

New studies are being conducted on Antarctic zooplankton, to assess how genetic expression is controlled by environmental effects and lead to ecosystem effects. Zooplankton were compared using COI, 18S, and 28S regions, using a variety of primers. For example, temperature can affect the expression of genes in Antarctic organisms (e.g., for production of as many as 5 different anti-freeze proteins in fish), leading to changes in physiology and behavior that can ripple up through food webs. The results of such analyses could help predict the effects of climate change on Antarctic systems. The BIOFLAME (Biodiversity: function, limits and adaptations from molecules to ecosystems diversity) project is studying how genetic expression affects ecosystems. The BIOFLAME approach involves (1) experiments using different temperatures, (2) identification of genes that respond, (3) detailed studies of gene expression in animals from populations at different latitudes, and (4) sequencing of affected genes.

Shotgun sequencing of genetic material found in seawater samples from the Sargasso Sea has demonstrated that

- 1800 species of bacteria, Archaea, and viruses were present, including 148 new bacterial phylotypes.
- 1.2 million previously unknown genes were discovered.
- Organisms previously considered characteristic of eutrophic or terrestrial environments were found in the this oligotrophic open ocean area.
- Widespread genes for rhodopsin-like photoreceptors were found.

as reported by Venter et al. (2004) in *Science*.[1]

Bob Ward has worked on barcoding of fish species, particularly in Australian waters. Fish are the largest vertebrate group, are morphologically and genetically diverse, and feature an interesting evolution. The value of global fisheries is about US$200 billion annually and employ 35 million people. The COI enzyme is contained in ribosomes and is a conserved region that can be used in barcoding of shark fins, fish eggs, and fish larvae.

Ward discussed ongoing international barcoding activities, including the Consortium for the Barcode of Life (CBOL: http://barcoding.si.edu/index.htm) and the Barcode of Life Database (BOLD: http://www.barcodinglife.org/). BOLD can be used to search for genetic sequences that closely match newly identified sequences. Most species included in BOLD are represented by voucher specimens. CBOL is presently supporting major projects on birds, fish, and plants, and will soon add zooplankton (ZooGene).

It would be useful to be able to barcode museum specimens, but it is difficult to use specimens that have been preserved in formalin. Barcoding studies can identify which groups of organisms need attention from taxonomists.

Applications of fish barcoding include

- Identification of fish, fillets, fins, and fragments to detect substitutions, and conduct quota and bycatch management.
- Identification of processed product (e.g., canned fish, dried fish, mixtures) to detect species substitutions.
- Identification of threatened, endangered and protected species for conservation purposes, from parts of the animals, such as shark fins.
- Identification of fish eggs and fish larvae for ecosystem research and fisheries management.
- Identification of prey items in stomach contents to study food webs and trophic interactions.
- Identification of historical, archived and museum material for taxonomic purposes.
- Identification of new species and possible fusions, insights into phylogenetic relationships (fish biology, evolution).

To date, COI barcoding of Australian fish has yielded 901 sequences from 264 taxa (209

[1] Venter, J.C. et al. 2004. Environmental genome shotgun sequencing of the Sargasso Sea. *Science* 304:66-74.

"good" + 55 "undescribed/to be identified" species).  This work will continue to barcode Australia's marine fish (about 4,000 described species, maybe 30% endemic, and about 500 undescribed) and freshwater fish (about 195 described species and about 20 undescribed).  This database will be made available to the general public and will be compared with similar databases now being developed for North American and South African fish.  A Global Fish Barcode Network is being established, which will aim to barcode all the marine fish species of the planet.  About 15,500 species are currently recognised, expected to increase to 20,000 species as a result of CoML and other activities.  There will be an international workshop in June 2005 in Guelph, supported by the Alfred P. Sloan Foundation, including geneticists, taxonomists, database managers, and delegates from fisheries organizations.  The Global Fish Barcode of Life could be completed (except for rare species) within about 5 years subject to funding.

**Protein electrophoresis—**Methods to study the protein products of genes are less sensitive than molecular techniques, but also less expensive, and thus could be good for monitoring gene expression at lower cost. Gel electrophoresis of proteins resolves most species, but has limited use in detecting community change and closely related species.  The equipment for electrophoresis is relatively inexpensive and potentially could be miniaturized.

In the Australian fish retailing (and probably elsewhere), species are not always correctly identified.  An Australian handbook of gel electrophoresis patterns has been created with 380 domestic commercial species and another handbook includes 175 imported commercial species.  Unfortunately, protein "fingerprints" won't always separate closely related species, so barcoding of Australian fish has started using COI-based techniques.

**Autonomous Surface Vehicles**—Elgar de Sa described a small autonomous surface vehicle (ASV) being developed in his laboratory.  ASVs are robot platforms that navigate along programmed transects on the sea surface using GPS satellite and line-of-sight guidance.  They can be used to map surface chlorophyll distributions for sea-truthing of satellite ocean color images, monitor surface pollution hotspots in coastal areas, follow shallow water bathymetry if modified with path-following guidance, and detect and map surface blooms of harmful algae, such as *Trichodesmium*.  Examples of ASVs include Delfim from Portugal, Autocat from the United States, and ROSS from the National Institute of Oceanography in India.  ROSS is made from inexpensive, off-the-shelf components, as much as is possible so that they can be constructed for about US$15,000 each.  (The greatest cost is for the motors.)  The vehicle is heading-controlled and has an endurance of 7 hours.  It currently carries a fluorometer and has been used in transects in coastal areas.  In the future, it could be possible to implement sensor-based navigation, so that the ASV could map and follow tracer fields.

**Drifters—**A near-bottom drifter with cameras could be particularly useful for several of the projects, such as CeDAMar and the margins project.

**Particle Size and Number Sensors—**Yogi Agrawal made a presentation about his instruments that are used to determine particle size distributions using laser detection (see http://www.sequoiasci.com).  The instruments developed by his company can discriminate 32 size classes, from 1.25 to 1500 microns in different models.  These types of instruments are important for studying sediment transport in bottom boundary layers, settling rates of different sized particles, and other applications. The shape of the detector in the instrument can be modified for different purposes. The company is studying the effects of shape on measurements. Agrawal stated that detectors for particles of less than one micron in size would be difficult to design and market.

**Acoustic Methods—**David Farmer discussed a variety of acoustic approaches to the detection of marine life, including (1) propagation, as in use of tags for fish tracking (active or passive tags), (2) scattering, as in fish and zooplankton sonars (scattering inversion and acoustic imaging), and (3) passive detection, as in use of vocalizations from marine mammals and fish.

Active acoustic tags are being used by the CoML Pacific Ocean Shelf Tracking (POST) project (see above).

Passive receiver tags have been shrunk to about 2-3 centimeters diameter. They have a range of about 100 km and can measure temperature and salinity. It could be possible to add sensors that would allow the monitoring of the tagged organism's eating activities, heart rate, and other physiological parameters.

Scattering of sonar signals can be used to study aggregations of fish and plankton. Scattering models are developed by measuring the signals of known concentrations of organisms in tanks. Multi-frequency sonar can be used to determine the size distribution of plankton, as is being done by Van Holiday. Thin layers of concentrated organisms have been discovered this way. Acoustical techniques can also be used to detect organisms up to 8 km way (at 12 kHz and typical fish sonar power). "Acoustic cameras" can be used to provide high-resolution images of fish, even in turbid waters. Optics can be added to improve acoustic images.

Passive acoustic detection can be used to help understand distributions of marine organisms that make distinctive vocalizations, such as fish, marine mammals, snapping shrimp, etc., potentially of use to some CoML projects. Passive acoustics could provide new information in coral reef environments, in terms of grazing and other activities in reef areas. Adding optical observations would be necessary to identify the organisms making the observed noises.

**Optics—**Gaby Gorsky noted that it is a long way from an original idea to the prototype of an instrument. It takes a long time to get the prototype operating and to demonstrate its usefulness. It is even a longer struggle to make the instrument commercially available to the scientific community. Gorsky described optical tools available for observing marine life. The laser-optical particle counter (LOPC: http://www.brooke-ocean.com/lopc.html) can be towed at a speed of 12-14 knots, to 6000 meters. The Video Plankton Recorder (VPR: http://www.whoi.edu/instruments/viewInstrument.do?id=1007) II can be used in undulating mode, as well as put on Remote Environmental Monitoring Units (REMUS: http://www.whoi.edu/science/AOPE/dept/OSL/remus.html) or observatories. With VPR, there is a strong emphasis on image analysis. The FlowCAM (see http://www.bigelow.org/flowcam/) has a depth maximum of 300 meters. Particles are photographed and lasers used to determine the pigments in the particles. ZOOSCAN is a commercialized particle scanner. It can be used to analyze samples collected in the past and archived. ZOOSCAN can be used to detect changes in zooplankton populations over time. The ZOOVIS system (http://www.whoi.edu/institutes/oli/activities/participants/mb.html) is a high-resolution zooplankton imaging system. IFREMER also has developed a High-Definition Video System (HDVS) for ocean observations and an autonomous vertically profiling plankton observatory. These instruments are all designed for operation in the water column. Other instruments have been developed for near-bottom observations. The Autonomous Vertically Profiling Plankton Observatory (AVPPO: http://4dgeo.whoi.edu/vpr/vpr_overview.html) takes repeated vertical profiles (over days to months), including VPR observations, from the surface to the bottom in up to 100 m depth. In the future will be the Exocet/D Video Acquisition and Storage unit, a compact, low-power camera system that can be deployed on a variety of platforms. Further in the future will be "virtual holotypes", three-dimensional images of organisms that can be used as standard images against which to compare samples.

Heidi Sosik described the FlowCytobot (see http://www.whoi.edu/science/B/Olsonlab/insitu2001.htm) that she helped develop. The FlowCytobot has been deployed since 2001 at the Martha's Vineyard Coastal Observatory and is open to new users. This instrument is a flow cytometer that is anchored at the seafloor and water is pumped down to it. It is similar to lab-based flow cytometers. It counts phytoplankton and samples continuously and thus can be used to track phytoplankton abundance and growth over hourly to seasonal scales and to help understand variability in nano/picoplankton communities over time. FlowCytobot can also determine phytoplankton growth rates over time. For each particle, the instrument measures forward scattering, side scattering, red fluorescence, and orange fluorescence. Base-line data are available in real time and as archived data. The Imaging FlowCytobot is optimized for large cells. Measurements can be triggered on fluorescence or light scattering. Data analysis is a problem, so they are trying to automate and increase the speed of the process. So far, they have been able to achieve 85-96% correct classifications, at a rate of 1200 images analyzed per minute.

**Zooplankton Sampling—**Sun Song described the various methods available for sample zooplankton, including net sampling, optical particle counters (OPCs), the CPR, acoustical techniques, VPRs, molecular techniques, and sampling pumps. The methods can be implemented singly or together on various platforms, such as moorings, ROVs, and AUVs. Acoustical techniques are quick and are particularly useful for ecological studies. The BIo-Optical Multi-frequency Acoustical and Physical Environmental Recorder (BIOMAPER) is a new-generation towed vehicle (see http://www.ccpo.odu.edu/Research/globec/3sciinvest/wiebe1.htm) that can be used to map zooplankton distributions. Intercalibration among the different methods is important, to make their results comparable.

**Remote Sensing—**Remote sensing is not suitable for studying biodiversity, per se, but can be helpful for understanding the distributions of marine organisms, by providing the environmental context (e.g., temperature, currents, chlorophyll) for the observed distributions, particularly for surface ocean dwellers.

**Volunteer Observing Ships—**Some projects might use instruments towed behind, or otherwise deployed from, volunteer observing ships (VOSs). Parameters such as temperature, salinity, and chlorophyll can be observed from engine intake water on ships. Commercial ships follow regular routes, so can provide time-series measurements. Volunteer observing ships have been used for many years with the CPR and deploying XBTs. VOSs provide a lower–cost way to deploy instruments and make measurements than research vessels for some measurements, because the ship time is free. The ships also operate around the clock and in all seasons. It may be possible to modify the CPR package to include other sensors, such as for temperature and chlorophyll. The CPR has been successful because it is simple and robust, and can be towed at the high speed of commercial ships. Other measurements might be made with XBT-like expendable instruments. Other potential commercial "platforms of opportunity" include drilling rigs and pipelines.

**Ocean Observatories—**Several ocean observatories have been developed in the past decade, with many new ones under development (see http://www.oceansites.org/OceanSITES/). CoML projects that are making observations in sites where observatories will be deployed should take advantage of opportunities to add CoML-relevant equipment. Particularly important could be observatories in high-latitude areas and, potentially, sonar added to the global ocean bottom seismometer (OBS: http://obslab.whoi.edu/nobsip.html) network.

**Data Management—**Edward Vanden Berghe presented information about the MarBEF activity (see http://www.marbef.org/), which is an EU Network of Excellence designed to integrate data management and communication activities. Linked to MarBEF is EurOBIS, the European node of the CoML OBIS. EurOBIS is a metadatabase that can be examined for gaps in species information. It is a distributed system, using the Darwin protocol. The European Register of Marine Species is also connected to MarBEF. Eventually, the goal is to capture the distributed data in an archive/depository, through the International Ocean Data and Information Exchange's Group of Experts on Biological and Chemical Data Management and Exchange Practices (IODE/GE-BICH). The objectives of GE-BICH are to

- document the systems and taxonomic databases currently in use in various data centers;
- document the advantages and disadvantages of different methods and practices of compiling, managing and archiving biological and chemical data;
- develop standards and recommended practices for the management and exchange of biological and chemical data, including practices for operational biological data;
- encourage data centers to compile inventories of past and present biological and chemical data holdings; and
- encourage data holders to contribute data to data centers for the creation of regional and global integrated oceanographic profile and plankton databases.

GE-BICH's pilot projects include a distributed system for metadata, a distributed system for nomenclature, and a catalogue of systems in use to store/archive biodiversity data. GE-BICH has held two conferences so far, on "The Colour of Ocean Data" and "Ocean Biodiversity Informatics."

The IODE Ocean Teacher system (http://www.oceanteacher.org/) provides a tool box of methods to deal with biodiversity data sets.

**4. "To explore the relative merits of different technologies and identify those that deserve further research based on their potential for making significant contributions to the detection of marine life."**

The panel discussed a variety of different technologies that could be used for the detection of marine life, as described above. The Panel believes that several technologies deserve to be explored in workshop settings (see list in Recommendations section of potential workshops on technologies that could be useful to CoML projects and more broadly). Funding for such workshops would need to be obtained from other sources, as the funding for the panel from the Sloan Foundation is not adequate to fund workshops. Panel members and SCOR staff will seek other funding sources.

**5. "To summarize the Panel's discussions on its Web site and in published articles, so as to make it as widely available as possible."**

The panel reviewed the input from CoML projects in relation to the Web site content and received a presentation from the Web site developers.

The Panel will produce a variety of written products, including

- Article about formation of the panel, in *Sea Technology* and/or *EOS*
- End-of-the-year summary to be published in *Sea Technology*
- Minutes/summaries of discussions from Panel meetings, to be posted on the Panel Web site.
- Annual letter to CoML projects, with recommendations from the Panel
- Concept article

Other topics were discussed during the meeting:

**Indian Ocean CoML**—D. Chandramohan described efforts to develop and strengthen activities related to CoML in the Indian Ocean (see http://www.coreocean.org/Dev2Go.web?id=248310&rnd=30946). Planners must overcome several limitations found in the region: (1) rigid hierarchy that exists among organizations and between organizations and the national governments, (2) slow process of securing bureaucratic approvals, (3) restrictions on exchange of information on biodiversity, especially related to intellectual property rights and biopiracy, and (4) the frequent requirement of national or in-house funds to complement the contribution of international agencies.

Several programs funded by India fit with CoML objectives. An Indian Ocean CoML (IO-CoML) committee has been formed and a secretariat set up. This followed a 2003 workshop on Coastal and Marine Biodiversity of the Indian Ocean. IO-CoML hosts a listserver to encourage information exchange in the region and also hosts a database on Indian Ocean taxonomy (see http://www.ncbi.org.in). The Natural Geography in Shore Areas (NaGISA) project will be implemented as part of IO-CoML in the near future. Indian scientists have conducted a lot of deep-sea benthic sampling in relation to deep-ocean mining plans, which could contribute data and samples to CoML projects.  IO-CoML is also interested in the CenSeam project.  IO-CoML is expected to contribute to marine ecosystem-based management, science education and communications, and ocean observing systems in the region.

**Interactions of the Panel with Industry—**Yogi Agrawal briefed the Panel about how it might interact with industry.  He reminded the Panel that industry's driving motivation is profitability.  Industry will not commercialize instruments identified by CoML projects or the Panel unless there is a sufficient market for the instruments.  They will not produce one-of-a-kind instruments to be used by a small number of scientists.  Many companies do not protect their instruments with patents because of the disclosure required and because they cannot afford to defend against patent infringement.  Scientists tend to underestimate the knowledge that industry representatives have regarding what is going on in science relevant to their area of instrumentation.  It could be useful for Panel members to attend instrument trade shows to learn about new instruments that have been developed.

**Meetings—**The Panel should be represented at CoML project planning meetings, for the new projects, as well as at other related meetings.  Specifically, the meetings of CenSeam, ArcOD, CAML, CMarZ, CeDAMar, and ICoMM should include Panel members to help these projects incorporate appropriate technologies.  Other meetings that Panel members should attend to help achieve the Panel's terms of reference include the 2006 Deep-Sea Biology meeting at Southampton Oceanographic Centre and the 2006 ASLO/AGU/TOS Ocean Sciences Meeting in Hawaii (20-24 February).

There was a specific request from Mark Costello to endorse a workshop on marine acoustics on 17-21 October 2005 in New Zealand.  There was no request for funds.  The Panel believes that representatives from POST and TOPP should be invited to attend.  David Farmer will contact Costello for more information about how many people are expected at the workshop, as well as other details.

The Panel should find funding for and convene some specific meetings that would advance CoML projects and, more generally, observations of ocean organisms beyond the life of CoML:

- State of the art and research needed to make progress on barcoding ocean organisms.  Also needed is a methods manual.  Particularly important is to take samples for barcoding before a sample is destroyed for some other measurement.  A protocol for ship-board sampling would be useful and the panel will draft a protocol to post on the Web site, in consultation with the Barcode of Life project.  This meeting should focus on how the technology is best implemented.  It should include forensic scientists and discuss software for handling barcodes and databases for barcode data.  Such a meeting would be a chance to get together CoML projects to discuss the use of barcoding in each project and to bring bar-coders together with taxonomists.
- Use of nanotechnology for small sensors on fish tags, Argo floats, towed vehicles, and other platforms.  Such a meeting could also explore how to miniaturize existing technologies, such as protein electrophoresis and con-focal microscopy.  What new sensors could be deployed on next-generation Argo floats and/or gliders?

- New uses of platforms of opportunity.  What new instrument packages could be towed behind, or otherwise deployed by, ships of opportunity?
- Image recovery/enhancement techniques
- Passive acoustics for automatically identifying fish
- Microfluidics
- Transferring techniques from medical sciences to oceanography
- Advances in instrumentation
    - Combinations of existing technologies
    - Better batteries
    - Instruments to observe fast-swimming mid-water organisms
    - Combination of remote sensing imaging from satellite sea surface height/gravity sensors and ocean color/sea surface temperature sensors to determine the impacts of seamounts on ocean productivity
    - Smart instruments that make decisions when interesting events occur.

**Panel Web site—**The developers of the Panel's Web site (the beta version is available at www.scoml.org) made a presentation to the Panel, explaining the features of the Web site, and receiving feedback from the Panel on desired changes.  The Web site contains an open section that is accessible to the public, as well as a password-protected area for discussions among Panel members.  The projects were enthusiastic about a Panel Web site that would provide the following information:

- Links to forums for different kinds of CoML-relevant instrumentation
- Relevant technology conferences
- Reviews of equipment: summaries, not evaluations
- A vendor list, input by interested companies
- Cruise schedules
- Resource-sharing possibilities: ships, equipment, samples
- Success stories

Changes need to the Web site include

- Redesign banner to simplify.  The colors look washed out.  Use the same color for all the words in the left navigation bar.
- Put links to CoML project Web sites in the top bar areas
- Make it possible to navigate events calendar better
- Keep the older articles in an archive
- Put meeting announcements in events and subsections
- Allow comments to be submitted by anyone, unmoderated for now
- Change "Electronic Tags" to "Tags"
- Change "New Sensors" to "Biosensors"
- Change "DNA Techniques to "Molecular Techniques"
- Change "Imaging Systems" to "Image Processing"
- Search engine to search all articles
- For "Library Resources", make a pull-down menu

- Give Panel a periodic update of discussion threads
- Never have a page without a graphic
- Try to make the site live by the time of the April 26-29 IODE meeting and 26-27 April CoML Scientific Steering Committee meeting

**Assignments for Providing Technical Information for the Panel Web site**

Molecular Techniques: Alex Rogers and Bob Ward
Acoustics: David Farmer
Optics: Gaby Gorky, Heidi Sosik, and Yogi Agrawal
Tags: Geoff Arnold and John Gunn
Platforms: Elgar de Sa

ArCOD: Bob Ward
CAML: Bob Ward
ChEss: ??
CeDAMar: Alex Rogers
CenSeam: Alex Rogers
CmarZ: Sun Song
GOMA: ??
ICoMM: Heidi Sosik
MAR-ECO: Gaby Gorsky
NaGISA: ??
POST: David Farmer
TOPP: David Farmer

<u>Acronyms</u>

| | |
|---|---|
| ABE | Autonomous Benthic Explorer |
| ADCP | Acoustic Doppler Current Profiler |
| ArcOD | Arctic Ocean Diversity |
| ASV | autonomous surface vehicle |
| AUV | automated underwater vehicle |
| AVPPO | Autonomous Vertically Profiling Plankton Observatory |
| BIOMAPER | BIo-Optical Multi-frequency Acoustical and Physical Environmental Recorder |
| BOLD | Barcode of Life Database |
| CAML | Census of Antarctic Marine Life |
| CBOL | Consortium for the Barcode of Life |
| CenSeam | Census of Seamounts |
| ChESS | Biogeography of Chemosynthetic Ecosystems |
| CMarZ | Census of Marine Zooplankton |
| COI | cytochrome oxidase I |
| CoMarE | CoML continental margins project |
| CoML | Census of Marine Life |
| CPR | Continuous Plankton Recorder |
| CTD | conductivity-temperature-depth sensor |

| | |
|---|---|
| DNA | deoxyribonucleic acid |
| EBA | Evolution and Biodiversity in Antarctica project |
| EU | European Union |
| GE-BICH | Group of Experts on Biological and Chemical Data Management and Exchange Practices |
| GLOBEC | Global Ocean Ecosystem Dynamics project |
| GOMA | Gulf of Maine Area project |
| GOOS | Global Ocean Observing System |
| GPS | Global Positioning System |
| HDVS | High-Definition Video System |
| ICoMM | International Census of Marine Microbes |
| IFREMER | Institut Francais de Recherche Pour l'Exploitation de la Mer |
| IO-CoML | Indian Ocean Census of Marine Life |
| IODE | International Ocean Data and Information Exchange |
| LOPC | laser-optical particle counter |
| MarBEF | Marine Biodiversity and Ecosystem Functioning EU Network of Excellence |
| MarBIN | Marine Biodiversity Information Network |
| MAR-ECO | Patterns and Processes of Ecosystems in the Northern Mid-Atlantic project |
| MOCNESS | Multiple Opening-Closing Net and Environmental Sensing System |
| NaGISA | Natural Geography in Shore Areas project |
| OBIS | Ocean Biogeographical Information System |
| OBS | ocean bottom seismometer |
| OPC | optical particle counter |
| POST | Pacific Ocean Shelf Tracking project |
| RAFOS | SOFAR spelled backwards. SOFAR signifies Sound Fixing and Ranging float |
| REMUS | Remote Environmental Monitoring Units |
| ROV | remotely operated vehicle |
| SCAR | Scientific Committee on Antarctic Research |
| SCOR | Scientific Committee on Oceanic Research |
| TOPP | Tagging of Pacific Pelagics project |
| UVP | Underwater Video Profiler |
| VOS | volunteer observing ship |
| VPR | video plankton recorder |
| XBT | expendable bathythermograph |
| ZooGene | A DNA sequence database for calanoid copepods and euphausiids |