SCOR WG 118

RECORD OF MEETING AT EL PUEBLO HOTEL, LIMA, PERU, 28-30 OCTOBER 2002

1. OPENING COMMENTS

(a) Welcome & local arrangements

David Farmer welcomed the group to Lima, introduced his co-chair Van Holliday and defined the group's purpose. He reminded us that WG 118 was primarily a discussion group and outlined the agenda. He then introduced Mariano Gutiérrez Torero, who welcomed the group to Peru on behalf of IMARPE and dealt with logistical arrangements for the meeting.

(b) Objectives and agenda

Van Holliday presented the group's Terms of Reference for the benefit of new members and as a reminder of the tasks that remained to be done before the group reported in 2003. The full Terms of Reference (http://www.jhu.edu/scor/wg118front.htm) are:

- 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.
- 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.
- To prepare a summary of the results of the Working Group's discussion so as to make it as widely available as possible.

(c) CoML and WG 118

Jesse Ausubel (Alfred P Sloan Foundation) gave a comprehensive presentation about the origins and aims of CoML (http://www.coml.org), which were to assess and explain the diversity, distribution and abundance of marine life and to make clear statements about what was known, unknown and unknowable. He outlined some of the main drivers for the initiative, which included the need for marine protected areas and sustainable fisheries and concerns about habitat loss, pollution and global climate change. Limited knowledge of the biology of the oceans, which was based mainly on catch statistics for about 200 commercially exploited species living on the continental shelves, provided the incentive for undertaking the task now. Ninety-five per cent of the oceans remained unexplored biologically, there had been few surveys of the 'whole water column', and no comprehensive ecosystem surveys. CoML's aim was to complete a suite of major oceanic research projects by 2010, concentrating on species diversity and habitat, and complementing, rather than competing with, existing initiatives such as IGBP, with its primary focus on biomass, carbon flux and global change. Technology had a vital role to play in realising CoML's goals. It was also the rationale for WG 118, whose role was to identify the potential benefits of emerging technologies and bring them to the attention of the international community of fisheries scientists, marine biologists and others concerned with the biological welfare of the oceans.

The Grand Challenge questions for CoML were:

- what did live in the oceans;
- what does live in the oceans;
- what will live in the oceans; and
- how to access and visualise data on living marine resources?

The programmes dealing with these four questions were History of Marine Animal Populations (HMAP), New Field Projects, Future of Marine Animal Populations (FMAP) and Ocean Biogeographic Information Systems (OBIS -), details of which can be found on CoML's web site http://www.coreocean.org/Dev2Go.web. There were currently seven field projects (NaGISA, GoM, MAR-ECO, ChEss, POST, TOPP and CeDAMar) in the second programme, but the ultimate aim was 25-30 projects with worldwide coverage.

After summarising progress with the four programmes, Jesse Ausubel explained CoML's institutional structure and arrangements for developing partnerships with existing governmental (e.g. ICES, IOC, FAO) and non-governmental organisations (e.g. ICSU, IPPECA, OGPA). He also stressed the importance of education and outreach to all age groups throughout the life of CoML programme. Apart from intrinsic merit, education would generate public clamour and bring pressure to bear on governments, which would inevitably continue to be the primary source of funding for marine research for the foreseeable future.

The presentation was followed by an extensive discussion during which Jesse Ausubel answered a variety of questions about the CoML programme, many of which focused on OBIS (http://www.iorbis.org). At the general level there was concern about the possible misuse of data and the potential conflict between premature or unwise use of marine resources on the one hand and the introduction of unnecessary regulations on the other. On balance, it was agreed that benefits probably outweighed risks and that data should be equally available to those wishing to exploit ocean resources and those wishing to conserve them. Detailed questions about OBIS concerned: incentives to provide data; compatibility with other marine databases; the need to structure the database to anticipate future questions; the need to recognise the particular needs of taxonomists; problems of data entry; the need for dialogue between designers and users; IP issues; and sources of funding.

2. REPORTS AND ACTIVITIES

(a) Mar del Plata

Geoff Arnold summarised the presentations given at the previous meeting of the WG in Mar del Plata, Argentina in October 2001. He highlighted the technical problems identified by the leaders of the first six CoML Pilot Projects and David Farmer commented on potential solutions and needs for further research and development. The full report of the Mar del Plata meeting can be found at http://pulson.seos.uvic.ca/meeting/scor2001/list2.html.

(b) AGU/ASLO Ocean Sciences

Emmanuel Boss gave a presentation entitled 'Taxonomic recognition of plankton using optics' (http://www.marine.maine.edu/~eboss/presentations/Boss_SCOR_2002.pdf), which dealt with the detection of micro-plankton species. In general, cells <20µm in diameter look very similar and it is difficult to differentiate species by morphology. Cells can, however, be differentiated by functionality, presence of specific organelles and pigments, or by genetic information. Optical properties of cells can be used either for single particle or bulk particle analysis. Single particle techniques include flow cytometry (forward scattering, side scattering & fluorescence), imaging cytometry (fluorescence & microscopy), imaging in flow (microscopy) and multi-angle light scattering. Bulk particle analysis can employ spectral absorption and fluorescence of specific pigments, multi-angle light scattering of specific morphology and internal structure and remotely sensed reflectance. Both approaches have an important role because analysis of complex plankton communities with limited resources requires a compromise between getting accurate population counts and cell measurements and accurate species identification. The corollary of this Sieracki 'uncertainty principle' is that it is very difficult to get high-resolution measurements and taxonomic identification from an ecologically significant number of samples.

Imaging cytometry using digital analysis of epifluorescence microscope images is ideal for analysing prokaryotes and heterotrophic protists from natural marine samples. Such imaging systems provide rapid determination of cell abundance and sizes for calculating size spectra and biomass. Flow cytometry is ideal for detecting and quantifying prokaryotes and pico- and nano-phytoplankton from natural samples. 'Allometric analysis' uses plots of side scatter and forward scatter; 'taxonomic analysis' uses plots of fluorescence and forward scatter. The FlowCAM instrument, which can be installed on a floating dock or in the flow system of a ship underway, images cells in flow using a chlorophyll fluorescence trigger. Cell sizes are measured directly from the images and the instrument is ideal for analysis of microplankton (>20µm), including phytoplankton and ciliates. New methods of deployment allow *in-situ* cytometry to be undertaken from a boat, a mooring or a submarine (e.g. AUTOSUB). SIPPER (Shadowed Image Particle Profiling & Evaluation Recorder), which produces shadow profiles of larger organisms (e.g. chaetognaths, copepods, euphausiids, pteropods, salps, siphonophores, fish larvae and many other organisms) can be deployed in an AUV or in a towed package for high-resolution *in-situ* measurements. A variety of SIPPER images can be found at http://cot.marine.usf.edu/multimedia.sap.

Size fractionated *in-situ* absorption spectroscopy can be used to produce spectral distribution curves from different size fractions (e.g. <5µm, 5-20µm, >20µm) of a bulk sample. Dominant species in each size fraction can be identified microscopically and species composition confirmed by the spectral characteristics of the relevant cell pigments. Fourth order derivative spectra and similarity indices can be used to differentiate between mixed assemblages of phytoplankton.

Taxonomic data can be derived by remote sensing of spectral reflectance, which can be expressed as a function of the backscattering to absorption ratio. These two properties are in turn parameterised by linear combinations of optically active components, which include water, particles, phytoplankton, coloured particulate and dissolved organic materials. Assuming spectral shapes for each component (eigenfunctions), magnitude (eigen values) can be estimated by non-linear regression.

Observed spectral reflectance curves can be compared either with a single phytoplankton eigenfunction (standard model) or with a species-dependent reflectance inversion model based on six phytoplankton absorption eigenfunctions, whose spectral differences are due primarily to pigment composition and secondarily to relative pigment concentrations. The more advanced model can be used to derive the species compositions, which can be validated by direct sampling and identification.

Bench-top methods based on the optical properties of both single cells (e.g. flow-cytometry) and bulk cells (e.g. absorption spectroscopy) are now being packaged for *in-situ* analysis on moorings, hydrocasts and AUVs. In future, molecular techniques will be combined with single cell optical methods to provide genetic taxonomic data. Optical properties of bulk cells will be utilised by routine use of inversions of hyper-spectral remote sensing. One in situ flow cytometer is in commercial production, although not yet fully debugged. A silhouette flow camera and several remote-sensing instruments are also available

(c) POGO + IOC/CoML Worksop (Thailand)

Elgar Desa reported first on the POGO (Partnership for Observation of the Global Ocean) Workshop held in Dartington (UK) in June 2001 and entitled 'Biological observations of the global ocean: requirements and how to meet them'.

Topics discussed at this workshop were: biodiversity & conservation; sustainable management of living resources ('responsible fisheries'); oceanic biota & global change; bio-invasion; ocean fertilisation; and threatened habitats (corals & seagrass). For each of the three related scientific issues (global change & the carbon cycle; constraints on primary production & remineralisation; biodiversity & ecological function) key variables and measurements were identified. For biodiversity & ecosystem function, highest priority was afforded to ocean colour, CPR and CTD. DNA probes were also accorded high importance and recommended for development to the operational level, together with functional groups (DNA), image analysis, molecular data banks, and microscopy. Appropriate sensors and platforms were: time series stations & oceanic observations; small AUVs; volunteer observing ships (VOS); Argo type autonomous floats (with a variety of sensors for fluorometry, oxygen, CTD, photosynthetic yield, nutricline); bioprobes (telemetry tags on mobile marine mammals); and research vessels. The workshop discussed OBIS and drew lessons about data management and the distribution of biological observations from GOOS, IOC, PICES and CoML. It also recommended various ways of building research capacity, which included links with graduate education in marine science and contact with local scientists and research cruises. In relation to bio-diversity, it was concluded that there was a need to embed biological observations in a physical context (CTD), to develop a number of emerging technologies to an operational level, and to conduct low cost surveys at large scales. In this context, the key emerging technologies were DNA probes, flow cytometers on buoys (automated); holographic cameras and small AUVs of the hovering type.

Elgar Desa's second report concerned the IOC/CoML workshop on marine biodiversity held at the Marine Biological Centre in Phuket in October 2001. The purpose of this workshop was to introduce and expand CoML activities in SE Asia and to introduce SCOR WG 118 to scientists in the WESTPAC region. Regional participation was from Singapore, Philippines, Thailand, Indonesia, Malaysia, China, Vietnam, Cambodia and Australia. The workshop addressed two questions: to what extent is advanced sampling/identification technology known and being used in SE

Asia; and what are the major needs for new technology in the region? Discussion revealed that most researchers are aware of and use the following technologies: video cameras and microscopes; DNA probes (in the Philippines); electronic keys for taxonomy; data buoys; ROVs (limited use in Malaysia because of cable problems); GIS; satellite ocean colour; acoustics (mainly for fisheries investigations). Reactions to emerging technologies were varied. Some scientists felt there was no pressing need, others welcomed it but expressed the need for training, and others felt it was too costly; there were also reservations about ocean colour imagery because of cloud cover. Most regional participants agreed that their needs were: training to organise, clean up, catalogue and expand available databases; references on 'species'; computer aided taxonomists; image processing techniques; and appropriate technologies for shallow water ecosystems, including high-resolution digital cameras and expertise in DNA probe technology for species identification because of genetic diversity in the region. The output of the workshop is available as eight reports on CD (Country Reports, IOC Workshop on the Census of Marine Life in South East Asia, Phuket, Thailand, 10-12 October 2001) . It was concluded that, whilst there is considerable local awareness of the rich biodiversity in the region, there is a need to organise available information and to introduce low cost surveys to rapidly monitor and identify biodiversity over large scales.

(d) ICES Annual Science Conference 2002

Olav Rune Godø reported on the CoML session ('Where new technology might be used') at the ICES Annual Science Conference in Copenhagen in October 2002. Although the session was well attended and the programme included 30 papers, most presented data, only a few indicated needs and even fewer dealt with technology. Despite this, the key technical challenges appeared to be how to: quantify visual observations or transects; apply standard methodologies in deep water; collect information from available sources; understand temporal variability when during surveys; and understand differences in catch results.

One interesting French presentation (L18) had compared results of close-up studies with ROVs and Landers equipped with video cameras and bait with data from fishing gears. Because of behavioural reactions of fish to noise and artificial lights, fish that were often caught in trawls were rarely seen on video. The need therefore was for cheaper, faster and less noisy platforms that provided a larger sampling volume and did not affect the behaviour of the organisms under investigation. For deep water observations, such as were needed for CoML's MAR-ECO project, it would be necessary to apply standard acoustic techniques in deep water using towed vehicles and AUVs, together with complementary sampling techniques involving fishing and video observations. Stomach sampling was also needed for diet analysis and here the challenge was to catch fish at depth to avoid regurgitation, a problem to which the Icelandic automatic tagging and fish-collecting machine might provide a solution http://www.star-oddi.com/. Temporal resolution during snapshot surveys might be studied with instrument rigs that recorded acoustic measurements and environmental factors (as described in paper L10) and ships of opportunity. Because of sampling bias, catch results could not be taken at face value and interpretation required visual validation and an understanding of the processes between the application of the technology and the received results.

In discussion, it transpired that, although ICES was addressing ecosystem problems, it still had a fisheries bias and had not fully integrated the CoML approach. ROV technology was very noisy and, although it was improving, did not yet allow quantitative sampling. Quieter vehicles with laser cameras and acoustic imaging or visualisation would be very useful, particularly if the technique allowed species recognition.

(e) SCOR Working Groups 119 and 115

Van Holliday reported that he was keeping a watching brief on SCOR WG 119 (Quantitative ecosystem indicators for fisheries management) in order to see if it identified any needs for new technology. He had also attended the first meeting of WG 115 (Standards for Survey and Analysis of Plankton) as an invited observer. This group had been identified as a likely source of information on technologies needed by biological oceanographers for surveying and sampling plankton. The terms of reference for WG 115 and 119 can be found at http://www.jhu.edu/~scor/.

The WG 115 meeting included a series of short presentations designed to define the breadth of the scientific questions, challenges and 'hot topics' that need to be addressed by biological oceanographers globally. These talks provided graphic illustrations of some of the issues relevant to future discussions of WG115 and WG 118. They identified a number of basic needs, which included: ensuring that monitoring surveys in different oceans produce comparable data; providing basic technology, research vessels and trained staff in countries with limited resources; preserving, curating and archiving samples for long periods; sampling over the correct scales of space and time to identify the unaliased and unbiased patterns required to understand cause and effect; developing techniques for rapid synoptic surveys over wide areas at reasonable cost to allow ecosystem management.

Whilst its Terms of Reference strongly encourage it consider the addition of unconventional technologies to existing plankton survey and sampling methods, WG 115's first meeting was largely concerned with the Continuous Plankton Recorder and its unique place in plankton monitoring. As a result, consideration of new technologies was limited to a discussion of optical and acoustic methods of plankton sampling and assessment at a generic level. Following presentations on these two subjects, WG 115 divided into four discussion-groups, one of which considered a standard package of additional measurements that should be made in conjunction with routine plankton surveys. The initial list of ancillary measurements identified and prioritised by this group was: latitude, longitude and time associated with each sample; sample depth(s); temperature; salinity; irradiance or PAR (photosynthetically active radiation); wind speed and direction; fluorescence; and flow. The group also suggested the collection (where possible) of data from multi-frequency acoustics, a variety of optical instruments (e.g. transmissometers & scatteromemeters), bioluminescence sensors and the Optical Plankton Camera (especially the new imaging version when commercially available).

With respect to future deliberations of WG 118, Van Holliday drew a number of conclusions about the use of new technology in plankton sampling, which can be summarised as follows. Current CPR programmes address only a small fraction of the issues that biological oceanographers must consider, if they are understand the processes that determine the distribution of plankton in space and time at all scales from that of individual organisms to ocean basins. Although monitoring programmes such as the CPR can reveal shifts in species distribution, monitoring programmes cannot provide all of the information needed to develop predictive capability and provide sound management advice. For this it is necessary to conduct process studies with much greater spatio-temporal resolution than can be provided by conventional methods. Advanced technologies exist to overcome these problems and the challenge is how to get them into the hands of trained users. New and improved sensors are, however, still needed to examine the small-scale distributions that are now known to be ecologically critical. For example, whilst modern optics and acoustics have shown that some sub-meter scale vertical structures may contain 80-90% of the plankton biomass in the water column, no techniques exist to collect zooplankton from within them. Techniques for sampling phytoplankton in these structures are also limited. Some of these structures are known to harbour seed organisms for harmful algal blooms and current sampling methods are unlikely to detect these "seeds" before they bloom and become a health issue.

Avoidance, extrusion and sampling at critical scales (i.e. Shannon or Nyquist rate sampling) in 4-D space in a heterogeneous environment from a moving, heaving platform are all real and demanding problems. As a community, biological oceanographers need to detect and localise biological and physical structure in the water column with high-tech sensors in order to direct their limited sampling effort efficiently. Because of limited budgets, they also need to develop sensors that can be deployed on cruises and moorings whose primary purpose is oceanography or meteorology.

Training is a critical issue in some disciplines, where the disappearance of specialist skills (e.g. plankton taxonomy) may result in failure to progress. We need more scientists and engineers trained to collect, maintain, calibrate and interpret data from high-technology sensors and also more people to develop new technology. In developing countries there are well-trained scientists with invaluable knowledge of understudied areas of the world's oceans who could make a major contribution to biological oceanography, if they could be given access to medium- or high-tech instruments. One way to achieve this might be to persuade international funding agencies (e.g. the World Bank) to contribute to the acquisition of these instruments, thereby widening the scope of international programmes. Another approach would be to simplify the funding of multi-national efforts to attack specific research objectives. Finally, it would be valuable to find ways of funding the development medium-tech, low-cost, low-maintenance sensors that could be used by all nations to expand the ocean areas from which data can be currently obtained. If successful, such an initiative could well triple or quadruple the number of biological oceanographers worldwide.

(f) SAFAE

Van Holliday also reported on the Symposium on Acoustics in Fisheries and Aquatic Ecosystems, which took place in Montpellier, France in June 2002. Subjects had included some unsophisticated papers on seabed classification, as well as a range of fisheries topics and the usual contributions on target strength and reflectivity. Two hundred and eight papers had been presented and 84 of these would be published in the ICES Journal of Marine Science and Aquatic Living Resources after peer review.

(g) PICES

Gaby Gorsky reported on the technical theme session he had attended during the PICES meeting in Quingdao, China in October 2002. He also gave a resume of the talk he had given entitled 'Can optical methods quantify, identify and measure zooplankton effectively? Full details can be found at http://www.sciviews.org.

Topics discussed during the PICES technical theme session included systems of managing and merging complex data (difficult to implement with biological data), data collection using large arrays of optical instruments at locations with large concentrations of zooplankton, and global sensing using passive floats with satellite data retrieval. Instruments included a prototype system for collecting discrete samples in thin layers, which was being developed in Japan and consisted of a set of small packed tubes in a towed body, and an optical plankton camera, which had been developed in Russia. The camera, which produced silhouettes of plankton using a narrow sheet of light, had been abandoned because results showed major disagreements with net catches.

Gaby Gorsky began his talk by reminding the PICES meeting of the close connections between top predators and plankton and the increases in the abundance (e.g. Black Sea) of phytoplankton and gelatinous zooplankton that could follow overfishing. He also reminded them of the avoidance problem and the difficulties of obtaining representative samples with a conventional plankton sampler. He then reviewed the relative merits and capabilities of modern optical plankton sampling instruments, which included towed instruments (e.g. optical plankton camera, video plankton recorder), vertical profilers (UVP, ZOOVIS, LAPIS) and towed platforms, such as SIPPER, FLOWCAM and ZOOSCAN, as well as various holographic cameras. ZOOSCAN, for example, could sample up to 6000 organisms per day and produce a master data table with measured parameters and an image for each individual. Identification, which was largely automatic, was based on a training set (look-up table) of images and a neural network. A new look-up table was needed for each region with the images in the same proportion (e.g. 80% copepods) as the local organisms.

Despite substantial progress with optical instruments in recent years, there were still a number of major problems to be solved, mainly related to resolution, field of view, identification and the probability of non-detection. Fields of view, for example, were generally very small except for LAPIS, which had a field of view of 2 x 4 m^2. Rapid advances in image processing and computing indicated, however, that significant further advances were possible in the near future, particularly if optical instruments were used in combination with acoustics to increase the sampling volume and laser illumination.

(h) Fisheries Acoustics, Japan

Kouichi Sawada gave a presentation on new acoustic technologies that were being developed in Japan to quantify and identify fish during fisheries surveys (http://cse.fra.affrc.go.jp/ksawada/NacoustTecJ.htm). These developments included target strength analysis software (TSAN) to analyse echo traces for swimming vectors, TS and tilt angles and a quantitative echo-sounder for fish identification, which was based on frequencies characteristics of sound scattered by different groups of species. This sounder was a dual-frequency instrument (38 & 120 kHz) which was being developed by the KAIJO Corporation under contract with Marine Fisheries System Association of Japan (MFSAJ). It could display fish length distributions, as well as single targets and fish school information. The Furuno Corporation was developing a quantitative scanning sonar based on the Furuno FSV-24 omni-directional sonar also under contract with MFSAJ. The new sonar would provide near-surface sampling, scan a large volume of water using a cylindrical array, and produce quantitative data using three-dimensional TS data and information on the direction of movement of the fish. Another instrument under development was J-Quest, which consisted of a 70 kHz echo sounder (148 elements, beam width 8.4 or 11.8°) combined with a stereo camera, to be deployed in a towed body. In the longer term, Japan had plans to increase acoustic survey capacity by using fishing vessels as well as research vessels, together with AUVs for more detailed surveys. It was planned to make observations of whole ecosystems in important coastal waters with multidisciplinary methods including tomography. Other plans include a detailed study to investigate the effect of swimbladder shape and tilt angle on TS.

3. BRIEFS ON TECHNICAL AREAS NOT COVERED PREVIOUSLY

(a) Marine mammals

Dave Mellinger gave a presentation (*web site address*) about some of the new technologies used to study marine mammals, starting with a description of the satellite tags used by Bruce Mate of Oregon State University to track whales. Currently, these tags, which have a life of weeks to months, are attached sub-dermally to the largest whales and can thus not have a depth sensor. The position of the whale is determined with an accuracy (according to Argos) of 0.15 to 11 km. Earlier work with smaller odontocetes, using external tags with a depth sensor, also provided information about depth and dive duration, albeit with rather coarse resolution. In future it is hoped to miniaturise the tags, extend their use and add sensors to measure depth, heart rate and body temperature.

Dave Mellinger's own work involved the use of passive acoustics to record whale sounds, identify them to species, and count individuals by tracking position over time with fixed or mobile hydrophones and digital recording tags. Fixed listening stations had been used with both military and civilian sites in the USA, the central Atlantic and Australia. Autonomous hydrophones with beam forming characteristics were positioned in the Deep Sound Channel, singly or in groups of three for target location, and used to record time series of acoustic pressure measurements (5 Hz to 5 kHz) for periods of 3 months to 2 years. These frequencies encompassed the sounds emitted by mysticetes, lower-frequency odontocetes and many pinnipeds. Records were scanned for marine mammal sounds (using automated techniques to recognise calls) and for trends in abundance of calls with season. The method had shown the presence of sperm whales in the Gulf of Alaska and had provided information on seasonal abundance and geographical variation in abundance. Movements had been deduced by comparing occurrence of calls at different listening stations. Future technical needs included satellite data transmission, higher capacity recorders and an extension of the frequency to encompass the full vocal range of whales from 10 Hz to 100 kHz. Also required were better call recognition algorithms, better estimates of the range at which calls could be detected, and improved models (and data) for estimating the number of individuals present at a listening station. Threshold and data compression systems, which were lacking at present, would also be desirable.

Mobile systems included towed hydrophones (100 Hz - 24 kHz) and drifting directional hydrophones or sonobuoys (10Hz - 22.5 kHz). The lower frequency limit for towed hydrophones, which had a range of 5-40 km, was set by towing noise (2 knots and up), which made the technique poor for the larger whales with call frequencies at the lower end of the spectrum. Sonobuoys, which could radio data to a research vessel, had a range of 20 km but could be used in pairs to estimate the location of the whale. Future technical needs included better integration of acoustic and visual surveys, better field tools, better call recognition methods and better statistical methods. A workshop was to be held in November 2002 to discuss these issues.

Digital acoustic recording tags were placed on the outside of the whale with a pole - a difficult technique - and attached with suction cups. The tags, which had a life of only 8 hours, recorded sound (to 8 kHz), depth, pitch and roll and acceleration integrated over several minutes. They had been used to record dive profiles (750-800 m) and the distribution of different calls (regular clicks, creaks, rubbing sounds etc.) during different parts of the profile. Future technical requirements included a tag life ≥1 day, a quieter pressure-operated vacuum pump to improve the performance of the suction cups, a 3-D velocity meter and a sensor for body heat.

(b) Molecular tools for analysing marine bio diversity and abundance

Pat Gaffney began his review (*www.?????*) by contrasting patterns of variability in the marine (35 phyla) and terrestrial (28 phyla) environments and noting that high phyletic variability in the oceans was accompanied by very low species diversity. There were, for example, only 1500 species of copepods and 4000 species of phytoplankton in the sea, compared to 1-8 million species of beetles and 250,000 species of plants on land. Similarly, there were only about 1200 species of bacteria in the entire ocean. Marine organisms were poorly known because of difficulties of observation, collection and culture and a shortage of taxonomists; there was also disagreement over phylogenetic relationships. Basic questions were therefore what organisms were present in the oceans and in what abundance?

The traditional approach to species identification, which was based on morphology, behaviour and ecology, was of limited value for various reasons including lack of expertise and shortage of time. These could be overcome by molecular techniques based on the polymerase chain reaction (PCR) and DNA sequencing. The PCR, which selectively amplifies a target DNA region to 10^6-10^9 above background, works with small samples and old, poorly preserved material. The amplification is equivalent to selecting a single sentence or paragraph from a book with 350,000 pages and making several million copies. Synthetic oligonucleide 'primers', 15-30 nucleotides long, anneal precisely to target complementary sequences in template DNA. The primer is extended by DNA polymerase and heating through n cycles to produce 2^n copies. Different types of primer provide different levels of identification. Universal primers identify homologous targets in wide array of species, such as all bivalves; specific primers work only with a selected taxon. The technique, which has revealed a vast, previously unknown, species richness among microbes, is biased against organisms with sequence differences in the primer site and doesn't work with viruses, for which electrophoretic methods provide an alternative.
DNA sequences can be determined directly by automated sequencing, which identifies the entire sequence of the target gene, or indirectly by a number of methods, such as restriction fragment length polymorphism (RFLP), hybridisation probes, DNA arrays, single nucleotide polymorphisms (SNP), and denaturing gradient gel electrophoresis (DGGE). In RFLP the restriction enzyme cuts the DNA at or near the target sequence; an electrophoretic gel is then used to separate cut and uncut DNA. With hybrid probes a synthesised oligomer nests against the matching chromosome sequence and is labelled with fluorescene. FISH (fluorescent in situ hybridisation),

for example, detects whole individuals of target microbial taxa. DNA arrays, which consist of small spots of DNA probes on glass, offer the most powerful tool. They can rapidly and simultaneously search large numbers (thousands to hundreds of thousands) of targets and provide some measure of quantity, as well as presence or absence. Cross-hybridisation of probes is currently a problem, as is cost, although competition in the biomedical field is rapidly driving costs down. SNPs are ubiquitous and thousands to millions of samples can be handled in a day when this technique is used in conjunction with temperature gradient capillary electrophoresis (TGCE). These indirect techniques offer the prospect of rapid, standardised identification and classification with no need for taxonomic expertise, although it is probably necessary initially to define how many base pair changes are typical of the differences between species in each taxon. Within a species there is typically 2% variation in a target gene, although there are slight variations between populations in different geographical areas. Automation of the whole process is possible and MBARI is designing a remote environmental sampler, although this may possibly be an unduly complicated approach. SNPs can be used for field studies of larval dispersal, survival and recruitment. They have been used, for example, to discriminate between different populations of oysters and DGGE has also been used for the same purpose. Pyrosequencing can identify small numbers of oyster spat with specific haplotypes from large numbers of samples taken over a wide area.

Some of these molecular techniques can be used for estimating abundance and biodiversity, as well as for identification. Hybridisation probes can be used in conjunction with cell count and fluorescence to measure abundance; quantitative PCR (e.g. Real-time PCR) can be used to determine how many target species are present in a toxic algal bloom, such as a red tide. Biodiversity has been investigated in Limulus populations on the Atlantic coast of the USA and in Patagonian tooth fish in the South Atlantic.

In discussion it transpired that molecular techniques could readily differentiate between vertebrates and invertebrates in fish stomach contents and, with appropriate probes, also identify individual species of prey. The quantitative measurements required to estimate digestion rates would, however, be more difficult. Scales and otoliths presented no problems and samples as old as 100,000 years would be acceptable. The techniques clearly had great potential in the context of the CoML initiative, although there some caveats in relation to taxonomy.

(c) Phytoplankton

Acknowledging that phytoplankton and technology were both very big topics, Jan Rines (http://thalassa.gso.uri.edu/rines/scor) set out to explain the instrumentation that could assist the CoML programme. She also considered the broader interests of SCOR and showed movies of a variety of typical plankton organisms, which were usually small and often fragile. The big challenge was to describe the spatial and temporal scales of variation of the species-specific distribution of plankton and determine their relationship to the physical structure of the ocean. The technical challenges were to locate the plankton, which were small and ephemeral, collect them without damage, photograph and describe living cells, isolate cultures for molecular characterisation, preserve material for electron microscopy and match physical and bio-geographic data. The primary need was for directed sampling with optical, physical and acoustic instruments to obtain fine scale profiles that could be linked with physical and other environmental data collected at the relevant spatial and temporal scales. Technology was also needed to map the information over large scales. Fine scale profiles could be obtained with a number of instruments, which could be deployed from a ship or a mooring (e.g. ORCAS), or incorporates in an ROV (e.g. Ventana).

The technology also had important practical applications, because there was a need to identify and measure the abundance of the species of phytoplankton responsible for producing harmful algal blooms, such as paralytic shellfish poisoning (PSP), amnesiac shellfish poisoning (ASP), diarrhetic shellfish poisoning (DSP) and Ciguatera fish poisoning. The issues were the safety of seafood for human consumption and the protection of aquaculture stock. Although it involved bioassays with laboratory mice, monitoring for toxins was a much more rapid process than monitoring for the causative species, for which available techniques were slow (microscopy), inaccurate (clonal and physiological variability in toxicity) or had unknown specificity (antibody & nucleotide probes). New techniques, which avoided the inherent variability associated with the 'standard mouse', involved binding toxins to specific targets and were currently increasing the advantages of toxin testing over species identification. Some of these tests were available commercially (see e.g. MIST Alert™ at http://www.jellettbiotek.ca/).

(d) Zooplankton acoustics

Van Holliday (http://www.aard.tracor.com/AARDDefault.html) or (http://206.251.232.34) outlined some of the advances made in zooplankton acoustics as a result of the large increases in spatial and temporal resolution achieved over the last decade. State-of-the-art instruments now achieve vertical, horizontal and temporal resolutions of approximately 12.5 cm, 1 m and 1 minute, compared with equivalent values of ~2 m, 500 m and 1 hour in the early 1990s. At the same time, increased transducer bandwidths (spatial resolution) and higher data acquisiton and processing speeds have been accompanied by reduced power needs. As a result, it is now possible to obtain fine scale depth profiles from multi-frequency acoustic instruments used in conjunction with CTDs, neutrally buoyant floats or autonomous moorings. Moored instruments can be used to monitor the water column continuously for periods of up to six months and data can be telemetered over line-of-sight distances of 20-30 km. In addition to calculating the density and length distribution of the various types of scatterers and revealing the distribution and vertical movements of both neuston (e.g. *Pseudocalanus* and other crustaceans) and protists (e.g. *Noctiluca scintillans*), these instruments can detect micro-bubbles trapped on marine aggregates (snow) or living phytoplankton. They have also revealed the existence of decimeter scale thin layers, which have been found in most sites so far inspected, and which can vertically advected by internal waves with amplitudes of meters (e.g. 2-10 m) and periods of tens of minutes, or less. This makes conventional sampling extremely challenging, if indeed it can be done at all. Acoustics have shown zooplankton to concentrate on these thin layers during some nights, possibly to feed, and that they migrate into the water column but avoid the layers on other nights. Nearby direct sampling of phytoplankton during periods when the zooplankton are avoiding the layers has revealed the presence of toxic algal species in the layers.

The phytoplankton component of these thin layers has been sampled and characterised optically with an autonomous profiler such as ORCAS (Percy Donaghay - Graduate School of Oceanography, University of Rhode Island), which has a vertical resolution of 1 cm. Thin layers affect the structure and dynamics of marine ecosystems and appear to be of very great significance. However, a full understanding of critical scale structures, including function and structure, will only come from an examination of the sea at high spatial and temporal resolution over long periods. This will require the development and application of even better instruments designed to obtain information in all three dimensions and record time changes in the scattered signals. Their value will be enhanced if they are used in conjunction with a variety of high-tech optical instruments.

Further information is available from the following web sites:
http://es.ucsc.edu/coestl/
http://zooplankton.lsu.edu/scattering_models/MultifreqInverseMethods.html, http ://www.gso.uri.edu/criticalscales/

(e) Lofoten monitoring

Olav Rune Godø pointed out that some geographical areas are more important than others. Significant events for the whole ecosystem may happen in a limited area over a very limited time scale, and at these *hubs* there are more dynamics and interactions - both biological (inter and intra-specific) and with the environment – than elsewhere. Hubs present an opportunity to adopt a different strategy for monitoring marine resources. At present, surveys are usually made when dynamics are minimal and the snapshot that is obtained is compared with earlier snapshots made under similar circumstances. In contrast, because they are focused on highly dynamic locations, hubs provide an opportunity to gather information that helps understand dynamics and is important for ecosystem modelling.

In special cases, the whole of a stock, or a defined part of it (e.g. the spawning stock) passes a narrow section and, by using stationary sensors with online data availability, can monitored more effectively than elsewhere in their distribution. This situation occurs, for example, with Norwegian spring spawning herring, which spend the winter in very large shoals in the narrow fjords near Lofoten, before spawning along much of the western coast of Norway, and subsequently feeding in the Norwegian Sea. The proportion of the spawning stock that overwinters in Ofotenfjord can now be monitored when it passes through an acoustic fence, erected as a demonstration project across the mouth of the fjord. Currently the fence consists of upward-looking echosounders (38 kHz with a 32º x 8º manipulated beam) and a 200 kHz acoustic Doppler current profiler, combined with a 40-element, 12 kHz sonar directed horizontally from one side of the fjord to the other. The ADCP records the currents and bioflux at the mouth of the fjord, as well as behaviour of organisms (but not zooplankton) in relation to the tidal current. Flux data can be compared with targets tracked through the split-beam of the echosounders. A 32-bit broad band connection is planned to connect the project to the Institute of Marine Research in Bergen and also the Internet. In general, depending on the nature of the task, any kind of sensor (biological, physical or chemical) could be added or substituted, and the fence could also be patrolled by an ROV to provide additional coverage.

Future plans include building a similar fence from northern Norway to Bear Island to monitor the influx of water and biological material into the Barents Sea, whose productivity depends entirely on these inflows for heat and recruitment. The distance is 300 nautical miles and the task is feasible logistically because a gas field (Snøhvit) is to be built in a key area. A number of key research establishments and commercial companies with different technical interests (e.g. acoustics, AUV, ADCP, cabled sensors) are already involved and others may be interested.

(f) State of technologies in developing countries: progress report

Mariano Gutiérrez Torero (IMARPE) outlined the use of technology for observing marine life in developing countries and summarised their future needs. At present, almost all work is directed to the support of fisheries and, with the exception of acoustics, which are primarily used to map the abundance of exploited species, few technologies are available. Despite scientific and economic support from developed countries, most developing countries cannot afford the high costs of marine research and lack the trained staff it requires. The level of government support for fisheries investigations also varies from country to country, depending on the state of the economy and the importance of their fisheries. In some countries, a small amount of marine research is carried out by private universities, often with the help of international sponsorship (e.g. EU, JICA, NORAD, and FAO). Problems of coastal pollution and poor fisheries practices (e.g. discarding and by-catch) are, however, rife and shared problems hard to solve. Progress has been impeded by the political problems of coastal states and these have also impeded the study of four of the most important marine ecosystems in the world - the Peru, Canary, Benguela, and Somalia Currents - which are adjoin developing countries.

In general, developing countries need to increase their technical capabilities and expend more effort on identifying and monitoring key populations and communities in the main ecosystems. To do this, they need to acquire LIDAR, optics, broad band acoustics and other new technologies and, just as importantly, train scientific staff to use them. Developing countries also need to develop co-operative programmes with developed countries, seek funds from international agencies and set up international, multidisciplinary research units, which can use the new instruments and test them in the field in real conditions.

Following its previous meeting in Argentina in 2001, WG118 had initiated a sub-group to assist this process. The aims of the group, which consisted of F. Gerlotto (France), I. Hampton (South Africa), D MacLennan (UK), A. Madirolas (Argentina) and M. Gutiérrez (Peru), were to make an inventory of research programmes, scientific expertise, technology, research vessels and related infrastructure currently available in developing countries. The sub-group had begun by identifying developing countries with marine interests, and grouping them into 11 regions. On the basis of replies to an extensive questionnaire, the group had then produced a series of maps of available resources, which included research vessels, detection technologies, portable oceanographic instruments, scientific expertise, remote-sensing programmes and international agreements for joint research. Historically, a paper by Venema (Successes and failures of fisheries acoustics in developing countries, Fisheries Research, 14, 143-58, 1992) provided a benchmark against which to assess progress. Whilst the use of acoustics had increased significantly in some developing countries over the last decade, it was still primarily used to assess fish distribution and abundance and it was proving difficult for scientists in developing countries to publish their results. In South America, all countries now used acoustics compared with only half in 1992, although in the Caribbean use was still irregular. In Africa, in contrast, whereas there had been acoustic teams in most countries in 1992 and extensive support from Europe, there were now few practitioners left. Similarly, in Asia, active acoustics teams were confined to Thailand and Indonesia, when previously there had been European support in several countries. Chile, South Africa, Argentina and Peru now had TS programmes, when previously there had been none. In 1992, foreign experts managed most acoustics programmes with the support of a few local staff; in 2002, following training by European nations, there were several national teams in developing countries. Similarly, whilst no developing countries were represented in international acoustic communities, such as the Fisheries Acoustics Science & Technology (FAST) working group at ICES in 1992, participation was now significant, if limited.

Although the group had made good progress with its initial enquiries, much still remained to be discovered and a formal approach was needed to obtain information from several countries.

(g) 'Black box' technologies in Peru

Mariano Gutiérrez Torero (IMARPE) reported on the Eureka programme, which has been running in Peru since 1966, and spoke about proposals for the future use of acoustic 'black boxes'. The Eureka programme consists of a series of quick, cheap synoptic surveys to map fish distribution, measure relative abundance, establish demographic structure and determine oceanographic conditions. About half of the surveys are undertaken to establish if the spawning season is finished and fishing can start again. Another 20% are used to investigate the possibility of providing new quota when the existing catch quota has expired and a further 20% are used to locate fishing grounds, especially during winter when fish populations are more widely dispersed. The remaining 10% are undertaken when new oceanographic conditions menace the stability of fishing operations. Each survey, which is financed by the fishing companies, takes 2 days and involves 25-50 purse-seiners, each of which carries 2-3 observers. Their job is to record the abundance and spatial distribution of fish by observing the echosounder and completing an acoustic logbook. Oceanographic data are obtained on key transects with CTDs, Hensen nets and phytoplankton nets. Logbooks are sent to by FAX to IMARPE, which completes a report within 3 days of the end of the survey showing, for example, changes in the centre of gravity of the anchovy population. Despite their utility, survey results are biased by the varying skill of the large numbers of observes and the difficulty of paying close attention to the echosounder screen throughout the survey. Most sounders lack a printer and there is also a lot of variation in performance between different instruments.

High costs and the need for trained observers have led to proposals to automate the surveys by installing acoustic black boxes on fishing vessels to record the digital signals from commercial echosounders. With calibrated sounders, observers would not be needed at sea and trained staff could concentrate on data processing. Under the ACTIVE proposal, each tamper-proof black box would record continuously and data would be removed periodically, using hard discs. The 25 fishing vessels used in the Eureka surveys sail no less than 900 000 nautical miles each year (equivalent to 130 surveys) and the data collection capacity could therefore be significantly increased. The main problem is that commercial echosounders usually produce a stepped acoustic pulse, rather than the square wave signal emitted by scientific sounders on research vessels. There will also be challenges with data processing and data security, as well as those entailed in securing and maintaining close and sustained collaboration between the scientists and the commercial fishing companies.

The ensuing discussion raised a number of pertinent points. These included the possibility of using a cheap, calibrated single-beam echosounder instead of the black box, the need to quantify (possibly with a multi-beam sonar) the relationship between avoidance and the noise levels of individual fishing vessels and the need to avoid using different frequencies of different vessels.

(h) Activities in Mexico

Carlos Robinson (Universidad Nacional Autónoma de México - UNAM) gave an account of research on pelagic fish carried out on the Pacific coast of Baja California since 1992. Single- and split-beam echosounders (200 kHz) had been used to investigate the behaviour and abundance of schools of sardines and anchovies in relation to both seasonal and inter-annual changes in local oceanographic conditions.

Low salinity and temperature prevailed between March and June under the influence of the California Current. In winter an influx of tropical water produced high salinity and temperature and there was also coastal upwelling at various times. The abundance of sardines and anchovies had fallen to zero after the 1997 El Nino, adversely affecting the fishery, whose main centre was the northern port of Ensenada. Since 1997, there had also been a conflict between catches and acoustic estimates of abundance of sardines, possibly because of detection problems.

Research on the fish behaviour was being undertaken in Bahia Magdalena, where small pelagic fish were abundant and where catches of sardine, anchovies and mackerel exceeded 30 000 tonnes per year, mostly caught within the bay itself. The aim was to track the migrations of Pacific sardine (*Sardinops caerulus*) and the red crab (*Pleuroncodes planipes*), which had apparently filled the ecological niche previously occupied by anchovy. Bahia Magdalena had semi-diurnal tides, whose range was 2 m. Chlorophyll concentrations occurred at the mouth of the bay with tidal upwelling on a rising tide.

(i) Activities in Colombia

Argiro Ramirez reported that acoustic surveys had been conducted in the Pacific since 1970 with assistance from FAO, NORAD and the EU. Surveys for medium size pelagic fish had been undertaken since 1995, using both fishing vessels and research vessels. In the Caribbean there were similar surveys for small pelagic fish, using EK 500 echosounders. Future needs included multi-beam sonar, techniques for detecting near-bottom fish and ‘fences’ to detect migration.

(j) Activities in Venezuela

Alina Achury gave an account of the research being carried out in her institute, the Estación de Investigaciones Marinas de Margarita (EDIMAR), which was responsible for fisheries biology, marine biology, oceanography and aquaculture, as well as some special projects. Research, which is focused on five areas in the Caribbean, comprises optical observation of phytoplankton, optical observation of marine communities, acoustic surveys of sardine stocks, and the evolution of fish populations in the Orinoco delta.

Phytoplankton studies include comparison of *in situ* optical and chlorophyll measurements with USF data from SeaWiFs images, in order to correct algorithms used with the SeaWiFs optical sensor. As part of the community study, results of a visual census of *Strombus gigas*, an endangered species, are being compared with satellite images from Landsat 7 and an important relationship has been found between density, age and the soil substrate. Acoustics have been used since the 1970s to monitor the distribution and abundance of small pelagic stocks, mainly sardines on the northeast coast. Sardines comprise 25% of the catch in Venezuela and about 150 000 tonnes are caught each year. Acoustics are also now being used to survey the fish populations in the Orinoco Delta, a remote region with great fishing potential. Distribution, density and species composition along the estuary all change seasonally.

In future, EDIMAR wants to study the effects of upwelling on the distribution of sardines but this entails working in shallow water (0-20 m), where a research vessel is unable to follow. This is a general problem in tropical waters and EDIMAR is considering the use of LIDAR or imaging sonar. Operating range might be limited with horizontal sonar, however, and during the subsequent discussion a number of other techniques for deploying an echosounder were suggested. These included an

AUV, which could be fast and quiet, an unmanned catamaran, and a small manned boat.

(k) Activities in Chile

Jorge Castillo (IFOP) summarised the purpose of work to detect marine life in Chile. Aims were to describe the spatial distribution of exploited fish populations, measure their abundance and demography (including historical data), determine the effect of the environment on the resource and study the behaviour of fish schools. Investigations were financed by a tax on fishing companies through a Fund for Fisheries Research (FIP), which selected projects through open competition. New technologies under development included a sonar to detect loss of food in salmon farms and a pump for collecting the eggs of anchovies and other pelagic fish. These were being developed in conjunction with Biosonics and CUFES, respectively.

Fisheries investigations used echo integration to estimate the abundance of demersal species, such as hake, southern hake and hoki and (since 1998) for pelagic species, such as Spanish sardine, jack mackerel and anchovetta. Government to provide fishing forecasts used results. Two research vessels were available for acoustic surveys and some fishing vessels had EK60 sounders; some also had sockets into which scientists could plug an EK500 sounder. The acoustics team consisted of six scientists who conducted acoustic surveys and combined the results with data from oceanographic and ichthyoplankton surveys to produce an integrated analysis. The output was charts of the spatial distribution and abundance of anchovy and sardine, school size and location, and distribution in relation to bathymetry, temperature and salinity. In some instances distribution was influenced by freshwater run-off from rivers. Three-dimensional images of fish schools had revealed that the density of fish in the central hot spot of the school was often twice that of the average density in the school. (Gerlotto, F. & Paramo, J. (The three dimensional morphology and internal structure of Clupeid schools as observed using vertical scanning multibeam sonar, Aquatic Living Resources, Proceedings of the 6th Symposium on Acoustics in Fisheries and Aquatic Ecosystems, (in press)).

Future needs included the ability to investigate deeper resources, such as dory and orange roughy, and the inclusion of sonar in acoustic surveys to study school structure. It was suggested in discussion, on the basis of experience in Australia and New Zealand, that orange roughy might be identified and differentiated from other species by sonar reflections. Ray bending might, however, present problems with the use of sonar at great depths.

4. REPORTING AND OUTREACH PLANS

Van Holliday chaired a session to decide whether WG 118 should produce a one-off hardback report in 2003, as originally intended, or should change tack and record its findings on a dedicated web site. As David Farmer pointed out, the advantages of a web site were that CoML was supporting Outreach for all projects and was launching its own site next year, in which WG118 would be included. This site would be well run, fully supported and properly financed. During the meeting, Jesse Ausubel had also specifically suggested that WG 118 should adopt a wider brief and remain in existence until the end of the CoML programme in 2010. A web site would be ideal for promulgating the group's deliberations and involving others, particularly the leaders of the CoML research projects. A site would also offer scope to publish technical methods, along the lines of the new electronic journal to be published by the American Society of Limnology & Oceanography; it could also be a good place in which to publish the results of research programmes in developing countries. A discussion page could be used to disseminate problems and discuss solutions and, with good management, would provide a new focus and bring in more people. Provided the WG was still active, funding would probably be forthcoming to allow a web site to evolve over the duration of the CoML programme.

After a short discussion, during which Olav Rune Godø pointed out that a final report from WG 118 later in 2003 would be too late for most of the CoML Pilot Projects, it was agreed that the group should opt for a web site. At David Farmer's suggestion, it was agreed that this should be based in the Graduate School of Oceanography (GSO) at the University of Rhode Island. At David Farmer's request, it was also agreed that participants at the Lima meeting should send Geoff Arnold the addresses of web sites on which the power point demonstrations they had given during the meeting would be available. These links would be included in the part of the site devoted to the Lima meeting. GSO would be able to help anyone who had problems in accessing a web site.

5. OVERVIEW OF TECHNOLOGIES DISCUSSED

After reminding the group of its Terms of Reference, David Farmer chaired a discussion about the technological needs of the CoML Pilot Projects. This was followed by a discussion of possible synergies between the various technologies.

(a) Technical needs of CoML Pilot Projects

(i) ChEss: The concept of this project (Biogeography of Chemosynthetic Ecosystems) was to explore the fauna and flora of hydrothermal vents in the North Atlantic using chemical sensors fitted to an autonomous underwater vehicle. This was cutting edge technology and there was some discussion about the availability, reliability and operational capability of both sensors and vehicles. Although AUVs were being used in survey work and costs had been calculated, application to oceanography was lagging and quite a lot more work was required before they became standard tools. Autosub was operational, but most other AUVs were not and the autonomous capability needed further development; steering and endurance were both issues. The operating costs of REMUS, which carried a sensor for bioluminescence, were reasonable, but it required support from a research vessel. Because they were designed for minimal weight and long life, gliding AUVs carried few sensors and there would be problems in trying to add more. A hovering AUV was desirable but was not available. The recent development by Al Hanson at the Graduate School of Oceanography, URI (akhanson@gso.uri.edu; http://www.subchem.com) of a sensor that could detect very low concentrations in real time and follow a chemical gradient was, however, close to satisfying the needs of a 'sniffing' AUV. In general, however, sensor development was lagging.

(ii) NaGISA: This project (Natural Geography in Shore Areas) was described as the Coastal Survey of the Western Pacific (part of DIWPA) at the previous meeting of WG 118 in Mar del Plata in 2001. Nagisa is now funded (by the Sloan Foundation and Japan) and is already underway, although further participants are sought, for example in South America. The plan involves developing both skills and infrastructure. A system for taking bottom samples and recording videos is in place, but the identification of meiobenthos still presents a major challenge. Several possible solutions were identified. One option would be for roaming molecular biology laboratories to visit archives of samples and undertake data gathering and training exercises. Another would be for roaming taxonomists to visit the various observing sites to train local staff, who would

subsequently be able to get supplementary help by exchanging electronic images with experts back in their home laboratories. This approach would tie in well with the NSF PEET programme (http://web.nhm.ukans.edu/peet/) in the USA, which requires experts to train 5 students.

NaGISA is likely to have both sorting and archiving problems, given the wide range of material (macrophytes to meiobenthos) that it proposes to collect and the lack of basic facilities (electricity and microscopes) in some areas. A basic data collection protocol based on digital images and sequences from stereoscopy and mosaics (underwater archaeology) offers the prospect of cheap storage in minimal space. Physical samples might perhaps be archived at regional nodes. But, regardless of the location of the archive, sub-samples must be preserved for subsequent genetic analysis. This is a simple process, which entails fixing material quickly in formalin and then transferring it to ethanol. Although it is possible to travel with amplified DNA, local archives will probably increase in importance of as it becomes progressively harder to ship samples, because of CITES regulations or security precautions.

(iii) GoM: At the previous meeting of the WG in Mar del Plata, Ken Foote had identified four challenges for the development and application of acoustics for use during CoML. The first two were to make good acoustic measurements and quantitative biological measurements; the third was to classify and identify acoustic targets. The fourth challenge was to extend the range of observation of optical instruments by integrating optical and acoustic technology. It was quickly apparent in discussion that, although no new technology could be recommended to GoM (Census of Marine Life in the Gulf of Maine) in the short term, there was considerable scope for acoustic species identification over the next 5-10 years. At high latitudes with a simple ecosystem, it was already feasible to distinguish between three dominant species of fish. In the tropics, however, with 2-300 species the problem was rather different. Here it was necessary to widen the scope of diagnostic features to include both the schooling behaviour of the fish and their behaviour in response to environmental factors, such as tides. Multi-beam sonars offered exciting prospects, although the instruments currently made by Raison and Simrad, which could be used in a towed body as well as from a ship, were expensive and limited in range by their operating frequency. Decreasing this from 200 kHz to 80 kHz would give significant improvements.

Progress with acoustic identification in tropical regions, which would inevitably be slow, if tackled by individual research institutes, would be much faster and better co-ordinated if tackled by regional centres of excellence, which should be favourably regarded by international funding agencies. Molecular biology, optical technology and taxonomy would be other obvious candidates for centres of excellence, each with its own range of expertise and matching technology. Although it would still be necessary to provide technology appropriate to local problems, the South American participants agreed that there was strong support for international collaboration between their countries. They welcomed the proposal for a system of complementary centres of excellence, which they saw as a means of obtaining advanced technology and improving the infrastructure for marine research. At present, whilst some countries (e.g. Mexico) had good research vessels but poor technology, others had neither the vessels nor the technology. At David Farmer's suggestion, Mariano Gutiérrez Torero *agreed to set up a sub-group to discuss possibilities for centres of excellence and prepare an agreed statement of needs.* In addition to the World Bank, support might be forthcoming from the EU, which had apparently provided resources to single laboratories when arrangements were made to ensure collaboration with institutes in neighbouring countries. Another way of stimulating development would be for SCOR/CoML to bring international meetings to the centres of excellence. For example, Bill Karp suggested that FA,ST would welcome an invitation to hold its 2004 meeting in Peru now that country was an observer at ICES. Sponsorship from FAO might also be possible. Although Venema's retirement had removed FAO's internal driver for acoustics, FAO had recently joined the Fishing Technology and Fish Behaviour (FTFB) working group as a co-sponsor. FTFB and FA,ST both reported to the Fishing Technology Committee (FTC) at ICES.

(iv) POST: The concept underlying the Pacific Ocean Salmon Tracking project is a series of acoustic listening stations on the seabed off the west coast of Canada and the USA. Stations laid in lines across the narrow continental shelf will detect the passage of fish marked with a simple acoustic 'pinger'. Tagged salmon smolts will be detected as they pass the listening stations on their way to Aleutian Islands and the open ocean and the date and time of passage recorded. Whilst this system works well in confined bodies of water, it may not be so practical in the open sea. The effective range of the listening stations is determined by the size and power of the tag, which is inevitably limited when tags are used with small fish; there is also an inherent weakness with the blind transmission technique. There are various solutions, one of which is to use a more intelligent system, for example a transponding tag, as widely used in Europe for many years, and as discussed at the previous meeting in Mar del Plata. Another is the passive 'fish chip' recently designed by the University of Rhode Island, which will record the reception time of signals from a series of fixed transmitters and track fish in the same way that oceanographers track RAFOS floats. The new chip, which is very cheap to make, has been designed and tested in the laboratory. Funds are available for further development, including a miniature hydrophone, and it is planned to test the system in the sea in 2003, using a research vessel. This system has tremendous potential for the animal tracking community and it was agreed to *recommend that the PIs of the POST project should evaluate it as soon as it was possible to do so*.

In response to questions from Carlos Robinson and David Mellinger about possible effects of acoustic signals on other animals, Van Holliday and David Farmer pointed out that small fish tags produce no more noise than snapping shrimps and this will merge with the background noise within a few hundred metres. RAFOS signals are different, being transmitted in code at low power and at a much lower frequency, which changes with time. Neither is likely to have much effect on other animals, however, despite the problems of public perception that there have been with the ATOC experiments.

During further discussion, direct questions from David Farmer established that, although electronic tags are not currently used in South America, there was considerable potential to use them with both fish and marine mammals. Mariano Gutiérrez Torero explained that he wanted to use pop-up satellite-detected tags with tuna and hake and David Farmer drew attention to the opportunity to record oceanographic data from diving mammals at the same time as recording their behaviour. David Mellinger commented that Bruce Mate was keen to train people in South America to use electronic tags with marine mammals. Electronic tags were also highly suitable for benthic organisms as well as fish and mammals. As had been shown in Europe, where electronic tags had been applied to fisheries investigations for several decades, it was necessary to acquire descriptive data with individuals before trying to construct testable models of population behaviour. An automated tagging system allowed large numbers of pelagic fish to be tagged with PIT (passive integrating transponders) tags, which could detected relatively cheaply by scanning the catch on board the purse seine fleet. Data could be sent ashore by radio and the technique could provide a quantitative estimate of the stock, as well as information on its distribution. After discussion, it was *the agreed to recommend the uptake of electronic tags in South America.*

Landers can be used to estimate the number of species and individuals in an area, using bait, a flash camera and a simple current meter, all relatively cheap and simple technology. More sophisticated systems (e.g. the AUDOS system developed by the University of Aberdeen in Scotland) are available with scanning sonar and other advanced technology. The are many opportunities to develop innovative methods of attraction and repulsion, using light, sound and other factors. For exploited species, landers can be combined with long-lines to obtain much better estimates of fish density than can be provided by the lander itself. Conceptually, too, there is no reason why landers should not be used in midwater as well as on the bottom. Because they are likely to provide new insights and support new research projects at low cost, *development and application of landers was recommended as a technical area deserving support.*

(v) MAR-ECO: This project (Patterns & Processes of Ecosystems in the Northern Mid Atlantic) planned to use acoustic surveys and a variety of other technologies, including landers and longlines, to investigate the ecology of the mid-Atlantic Ridge. Olav Rune Godø explained that the first major problem was to extend the operating depth of 38 kHz echosounders to 2000 m; at present the TVG (time varied gain) only worked to 800 m. There were also problems in deciding how to get an idea of seasonal variation, how to analyse results and get the maximum benefit from photo transects of the seabed recorded by ROVs and AUVs, and how to increase range by, for example, acoustic imaging. In the subsequent discussion, Van Holliday suggested that using a sweeping system on the timer might increase the range of the TVG and David Farmer commented that seasonal changes might be revealed by looking for differences between assembled images, using military technology developed for mine hunting. Sidescan sonar with accurate positioning and good data processing was also an appropriate and proven technology. Questar Tangent and Roxann, two commercially available systems used by the fishing industry to identify the nature of the seabed, were empirical and of questionable scientific value. A physics-based investigation of the causes of backscatter, which was currently underway and which had been reported to IEEE Oceans in recent years, was likely to produce reliable tools for investigating bottom sediments within about 10 years (see IEEE Journal of Ocean Engineering 27(3): 341-601, July 2002, Special Issue on High Frequency Sediment Acoustics; E.I. Thorsos et al., An overview of SAX99: Acoustic Measurements, IEEE J. Oceanic Engineering 26(1): 4 - 25, 2001; M.D. Richardson et al., An overview of SAX99: Environmental Considerations, IEEE J. Oceanic Engineering 26(1): 26 - 53, 2001). These new tools would permit accurate descriptions of habitats, of the sort already required by EU governments ahead of the relevant technological developments. Changes in populations of benthos could already be recorded by sequential surveys using a sidescan sonar and good quality GPS, a point illustrated by Van Holliday, who showed tracks of dispersing animals recorded with a 100 kHz sidescan sonar in a patch of the burrowing urchin *Brisaster.* Emmanuel Boss pointed out that LIDAR and laser line-scan could also be used for habitat mapping and Bill Karp mentioned that scientists at the NMFS laboratory in Seattle are evaluating technologies for characterizing demersal habitat including video, sidescan sonar, multibeam sonar, and laser line-scan. Laser line-scan also holds promise for assessment of crab abundance.

commented there was a seabed group in Seattle pursuing this subject. Jorge Castillo drew the group's attention to two requirements in South America, the first to survey fish populations around sea mounts using a combination of acoustics and optics, and the second to measure the size of fish with a stereo camera. As Van Holliday pointed out, the second problem could be solved by using the camera in conjunction with two parallel laser beams, separated by a known distance.

(vi) TOPP: This aim of this project was to understand how marine animals from several trophic levels use the distinct oceanic regions in the North Pacific. Advanced electronic tags would be used to identify migration routes and critical habitats and link behaviour and distribution to oceanographic processes. Available technology included archival tags that could record high quality data for several years and pop-up tags that could transmit data via the Argos satellite system. Whilst only a proportion of archival tags were ever recovered, pop-up tags could, at present, only transmit a limited amount of the data they recorded because of technical limitations of the Argos system. This problem might be solved in future, now that the IRIDIUM system, which could transfer 100 times more data than Argos, was live again. The float and glider community was converting to IRIDIUM and the US government had purchased a block of time, which was free to all PIs in the USA. At present, however, IRIDIUM could not be recommended to TOPP, or any other tracking project with marine organisms, because the transmitters were too large.

Although not of specific relevance to TOPP, there followed a general discussion of ways of transmitting oceanographic data via the IRIDIUM system using Argo floats and gliders, whose characteristics were summarised by Emmanuel Boss. Both platforms offered exciting possibilities for biological oceanography, if the physicists could be persuaded to add the extra sensors. There were many Argo floats in use in the open ocean, costs were coming down and programmes were underway to add optical sensors (e.g. beam transmissometer). Biofouling problems could be solved with copper shutters and floats could remain at 1000 m for 10 days. Gliders contained a bladder and were able to change their buoyancy and centre of gravity with moving internal parts. They had small wings and were designed to make double-oblique dives at speeds of 20-25 cm s^{-1}. On surfacing, they recorded their position by GPS and transferred data by IRIDIUM, or cellular phone link. Gliders could currently carry a CTD sensor and developments were underway to add sensors for measuring oxygen, fluorescence and backscatter (at two frequencies). They could maintain station for up to two weeks in a tidal regime with currents of 2 knots. Gliders were being developed in the USA by three groups, one of which was a commercial company. At present, costs were about $30-40 k.

In discussion, it was concluded that gliders had considerable potential for investigating smaller, coastal ecosystems at a much lower cost than a research vessel. They were non-intrusive, could be used for adaptive sampling and could be launched from a zodiac in shallow water. At present they were power-limited and could probably not carry a sonar. However, as Van Holliday pointed out, the power requirements of electronic devices decreased by an order of magnitude every few years. With appropriate sensor development, there was therefore considerable scope for the use of gliders over the next decade. More information is available from www.webbresearch.com/slocum.htm.

(b) Synergies between technologies

In the subsequent discussion, a number of synergies between the various technologies were identified. The interpretation of acoustic observations of secondary production can be assisted by rapidly profiling the water column with optical and other physical instruments on a winch-driven cable. The range-gating properties of LIDAR match those of sonar and offer excellent prospects for synergy. It can be used to map the seabed and is also an excellent search tool for identifying aggregations or other nodes of interest. This property suggests that LIDAR's primary role in CoML is likely to be in directing sampling to best effect and especially to sub-metre scale features that now appear to be of very great importance. Greatly under-sampled, these features can contain as much as 80% of the local biomass, extend over tens of kilometres and persist for several weeks. Neither LIDAR nor acoustics will, however, take samples of the organisms making up these thin layers and this remains a challenge; a similar challenge exists in the benthos.

6. DISCUSSION AND CONCLUSIONS

The main discussion concentrated on ways of finding support for collaborative work in developing countries. This followed the structure suggested in David Farmer's preamble, which suggested the foundation of regional Centres of Excellence (CoE) coupled with a major training initiative that could also help develop the scientific and technical infrastructure in these countries. CoEs could act as a focus for selected topics, develop links with other institutes, both regionally and world wide, and co-ordinate bids for international funding. Visiting scientists could leave instruments behind for subsequent use by newly trained staff in developing countries and could also demonstrate the benefits of collaborating with local university engineering departments to develop new equipment. Both initiatives ought to encourage scientists from temperate regions to work in tropical waters, share their expertise with developing countries and gain experience of different ecosystems, an initiative already underway via the Smithsonian Institute in the USA.

(a) Centres of excellence

At David Farmer's invitation, Mariano Gutiérrez Torero agreed to lead *a small sub-group that would identify suitable subjects (e.g. acoustics, biotechnology, optics, taxonomy) for the proposed CoEs and investigate where they might be located and how they might be constituted*. To do this, it would be necessary to find out what facilities were already available in university departments and government institutes in various countries, and identify the range of available skills. Involving specialists (e.g. physicists & engineers) with complementary skills would be an important task for nascent CoEs, as would solving the problem of accessing literature, which required a two-way link between developed and developing countries.

It was agreed that Mariano Gutiérrez Torero should select colleagues from South America and other parts of the world to form the sub-group. A brief statement and background notes would be needed for the SCOR report, followed later by a fuller proposal for action.

(b) Training

At David Farmer's invitation, Bill Karp agreed to co-ordinate *a sub-group to develop a training initiative for developing countries, with particular reference to South America*. Carlos Robinson also agreed to join the group. It was agreed that this group should work in close conjunction with Mariano Gutiérrez's group, from which they would be able to get details of the skill sets currently available in the developing countries. Bill Karp's group would need to identify sources of funding, as well as institutes and agencies (e.g. UNESCO's International Ocean Colour Group) able to provide suitable training. One initiative might be to set up a SeaWifs station in South America via the University of South Carolina. This would provide valuable data (ocean colour & SST) for the region and should be quick and easy to set up, although three people would be needed to manage the station. Funding might be available from national governments or international aid programmes (e.g. from the EU).

Training in taxonomic skills was a major priority and one aim could be to set up teams of specialists within regional CoEs. This approach had worked very well some years ago when an expert team had been created in Poland to identify ichthyoplankton from temperate seas. In addition to supporting Poland's own needs for biological oceanography, this initiative had resulted in an influx of taxonomic work from research institutes in developed countries. Institutes that could offer training in taxonomy included UNESCO, the National Museum of Natural History in Paris, the British Museum of Natural History in London, the *???* in Monaco and the Smithsonian Institute and California Academy of Sciences (http://www.calcademy.org) in the USA. Ken Sherman (CMER Program Director, National Marine Fisheries Service, Narragansett, RI 02882, USA) had contacts with both US institutes and also experience of getting funding for plankton programmes from the World Bank and similar agencies. David Farmer offered to speak to Ken Sherman and seek advice.

In addition to training taxonomists, regional CoEs would be good places in which to provide both general and specific training, which could also be used as a way of developing collaborative research programmes with institutes in developed countries. Given the necessary funding through scholarships and similar schemes, training could also be provided by sending scientists to work on projects in developed countries, where they could register for higher degrees. Practical drivers of this sort were required to develop collaboration between the developed and the developing countries, which needed to be a two-way process.

(c) Funding

An approach to the World Bank would undoubtedly be needed and David Farmer agreed to discuss tactics with Ken Sherman (see also previous section). Private foundations could also help and the Sloan Foundation, which was sponsoring CoML, was particularly adept at using its funds to leverage money from major sources around the world. The most appropriate approach would therefore be to frame any case for financial support in terms of CoML's needs. The Lima meeting had shown that were strong regional needs in South America.

The session concluded with brief discussions of several other items:

(d) Technology

Picking up from earlier discussions, it was agreed that considerable benefit would accrue to CoML, if LIDAR and Autonomous Underwater Vehicles could be brought into routine use. Despite their great potential, neither technology was at the level at which it could be used as standard equipment and there was, as yet, no commercial version of LIDAR. *An initiative was needed to define CoML's needs and accelerate the transition to routine use and this could entail setting up another sub-group.* Nanotechnology, an area of future interest, was a speciality of the Center for Ocean Technology at the University of South Florida, which was involved in the application of microelectromechanical systems (mems) and nanotechnology in harsh environments (http://cot.marine.usf.edu/mems/?sectionid=1).

(e) Links with OBIS ~~workshop~~

Whilst data fusion and data visualisation had been funded in other areas of science, these topics still presented a great challenge for marine science, where there were so far few examples. One exception was Larry Meyer (University of New Hampshire), who was analysing 3-D images of fish schools and might be able to provide advice. Visualisation, which was an important first step prior to quantification, was an area in which OBIS could be expected to offer a solution, if it had the appropriate tools. So far, however, OBIS had not been able to implement acoustic data, which was disparate in nature, and this was *an area that required mutual discussion in the context of the future development of OBIS.*

(f) Website

CoML's ultimate goal was to offer Spanish, French and Japanese versions of the items on its web sites. As a first step, it was agreed that WG 118 needed to produce its material in both English and Spanish and, in response to a request for help, Jorge Castillo offered *to co-ordinate the production of translations.*

It was suggested that the WG 118 site should have links to those of the other CoML working groups and this was agreed. A primer about plankton diversity should also be provided and Jan Rines offered to identify a suitable location that dealt with marine biodiversity. She subsequently provided links to two National Research Council publications entitled *Marine Biodiversity* and *Perspectives on Biodiversity* (http://www.nap.edu/catalog/4923.html and http://www.nap.edu/catalog/9589.html, respectively).

(g) Use of CoML's name

In response to a question from Emmanuel Boss, David Farmer agreed to enquire if CoML would be prepared to lend its name to relevant activities, such as RV cruises.

7. RECOMMENDATIONS AND SUPPLEMENTARY COMMENTS

The WG agreed the following recommendations:

(a) a sub-group should investigate the idea of regional Centres of Excellence for developing countries and produce a pilot proposal to cover Latin America;

(b) a second sub-group should investigate the training needs of developing countries and recommend ways and means by which these could be met and funded;

(c) the PIs of POST and TOPP should encouraged to evaluate the RAFOS 'fish chip' as soon as it is possible to do so;

(d) the uptake of electronic tags to investigate distribution, migration and behaviour of marine mammals, fish and other organisms in Latin America should be encouraged;

(e) the development and application of landers is recommended as a technical area deserving support;

(f) a sub-group(s) should be set up to expedite the adoption of emerging technologies needed for the CoML programme, in particular LIDAR and Autonomous Underwater Vehicles (formulated after conclusion of meeting);

(g) a representative from MBARI should be invited to join WG 118 to assist expedite the development and uptake of new technologies (suggested by Dave Mellinger after conclusion of meeting).

(h) a representative of OBIS should be asked to brief WG118 on present and future developments and, if appropriate, join WG118 (suggested by Jan Rines after conclusion of meeting).

The WG placed on record the following supplementary comments:

(i) all biological samples should be preserved in a form suitable for genetic analysis.

The WG identified the need for technological developments in the following areas:

(j) sampling of zooplankton in thin layers;

(k) automated species identification by multi-frequency acoustics, in particular development of appropriate algorithms.

8. SUMMARY AND CLOSING REMARKS

David Farmer thanked Mariano Gutiérrez Torero for organising the meeting and for agreeing to take the lead with the development of future initiatives. Mariano Gutiérrez in turn thanked his wife and colleagues for the support and help they had provided him.

In the immediate future, the next steps were for Mariano Gutiérrez Torero to produce a short report recommending steps for the introducing new technology into Latin America and for Geoff Arnold to produce a report of the meeting. This should include references to sources of material presented to the meeting, which should be in the form of web site addresses if at all possible. David Farmer urged participants to provide Geoff with this information, as soon as possible.

The meeting closed at 3 p.m. on Wednesday 30 October.

ANNEX

Participants

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De Sa, Elgar	National Institute of Oceanography (NIO), India
Farmer, David	University of Rhode Island (URI), USA
Gaffney, Pat	University of Delaware (UDEL), USA
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Holliday, Van	BAE Systems, USA
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Robinson, Carlos	Universidad Autonoma de Mexico (UNAM), Mexico
Sawada, Kouichi	National Research Institute of Fisheries Engineering (FRA-NRIFE), Japan
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Ramirez, Argiro	Instituto Nacional de Pesca y Acuicultura (INPA), Colombia
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