2.0 WORKING GROUPS

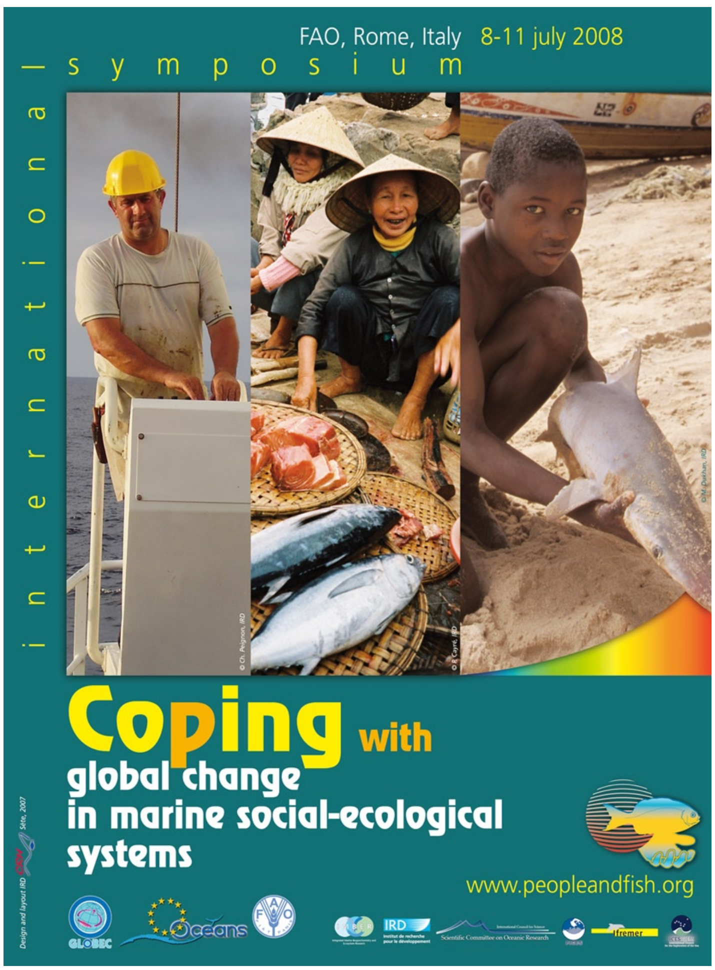
2.1 Disbanded Working Groups

2.1.1 WG 78--Photosynthetic Pigments in Oceanography

Work continues on the second volume of *Photosynthetic Pigments in Oceanography*. Approximately US$10,000 has been donated from various sources to offset the printing cost and/or buy copies. We are still seeking a non-profit publisher to handle the book. Island Press and Cambridge University Press have declined the book so far, but the editors are still contacting other potential publishers.

2.1.2 WG 119—Quantitative Ecosystems Indicators for Fisheries Management

SCOR approved the funds from WG 119's symposium to be used for the GLOBEC and IMBER related symposium on Coping with Global Change in Marine Social-Ecological Systems in July 2008. See GLOBEC report on **p. 3-3** for additional details.



2.2 Current Working Groups

2.2.1 WG 111: Coupling of Winds, Waves and Currents in Coastal Models (1996)

Terms of Reference:

- To review the present status of our knowledge on each component of coastal dynamics: coastal wave models, coastal circulation models, and the coastal atmospheric boundary layer models.
- To examine the existing coastal circulation and wave data from both conventional and remotely sensed sources to detect possible weaknesses of uncoupled models, and to address the issues of a coupled model.
- To build and strengthen a collaborative research effort on a coupled coastal dynamics model, between wave, circulation and coastal meteorology modelers, both among the members of the Working Group and with other existing groups.
- To estimate the contribution of coastal waters in heat exchange between the atmosphere and the ocean, which has importance for global modeling and climate studies.
- To prepare a final report summarizing the present status of our knowledge, recommending future research and observational studies of the coastal regions.

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Executive Committee Reporter: Lawrence Mysak

2.2.2 WG 115: Standards for the Survey and Analysis of Plankton (1999)

Terms of Reference:
This Working Group will help develop standards for sampling, analysis and storage of data and samples obtained by high speed and extensive sampling systems and assess current and future technological needs as a contribution to GOOS and GLOBEC. To achieve these objectives the working group will address the following activities:

- To review the present methods of collection, analysis and curation of plankton samples by agencies involved with time-series measurements and the uses which are made of the data.
- To overview the different instrumental approaches to measuring plankton, identify improvements that can be made to sampling strategies and make recommendations on how instruments can be improved and integrated with direct plankton sampling systems for calibration.
- To establish a strict methodology for inter-comparison/calibration of different sampling systems.
- To recommend a standard package of additional measurements that should be taken in association with plankton surveys to enhance the resulting products and assess logistical requirements, identify improvements that could be made in existing instrumentation for use in or attached to towed bodies for plankton survey.
- To encourage the use of the products of long-established surveys and the application of new strategies for large-scale and long-term sampling of zooplankton by organising an international symposium. Publish the products of reviews by members of the working group, selected presented papers and workshop reports in an internationally recognised, peer-reviewed journal or SCOR-sponsored book.

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The group's special issue was never completed and the members are unwilling or unable to produce it now. The SCOR Executive Committee will consider disbanding the group. One member, Carmen Morales (Chile) recently submitted her manuscript, "Plankton Monitoring and Analysis in the Oceans: capacity building requirements and initiatives in Latin-America" to the journal *Revista de Biología Marina y Oceanografía* (ISI since 2008).

2.2.3 WG 122: Estuarine Sediment Dynamics (with LOICZ and IAPSO) (2003)

Terms of Reference:

- Collect and analyze global data on sediment retention in estuaries versus export to the coastal ocean, based on climate, hydrologic, physical, geological, chemical, and biological, and human processes, and including estuarine systems of different types, from tropical to subpolar.
- Evaluate available models of estuarine sediment retention.
- Identify research, observation (including standard measurement procedures), and modeling activities needed to improve predictions of sediment retention in estuaries.
- Conduct the above three TORs through WG meetings and an international workshop of interested scientists.
- Document the work of the WG and the workshop through a Web-based database of river/estuary sediment characteristics and trapping efficiencies, a special issue of a peer-reviewed journal, and a short article written for research managers and policymakers.

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Final Report - July 2008
SCOR/LOICZ WG 122 on Mechanisms Of Sediment Retention In Estuaries

1.- Introduction

The interaction between fresh and salt water plays a critical role in determining the dynamics of estuarine circulation and sediment transport. Considerable research has been carried out on turbidity maxima, which form near the inside tip of the salt wedge as a result of strong density gradients. Only a few studies have addressed the role of turbidity maxima and other sediment retention mechanisms and the extent to which they are influenced by *i)* the geomorphology of the estuary, that is, the presence or absence of tidal flats, marshes, mangrove wetlands, and the morphology of tidal channels, and *ii)* the propagation of the tidal wave along the estuary and the asymmetry and change of water level, currents, and change of tidal range. The interaction between the estuarine geomorphology, on one hand, and river and tide advection processes, on the other, are highly nonlinear, making it almost impossible to predict the extent to which an estuary will retain sediment or deliver sediment to the coastal ocean.

Sediments are delivered into the coastal zone by rivers, although locally the effect of waves, tides, and storm-induced coastal erosion and alongshore transport are also important factors in establishing the sediment budget. Rivers and estuaries retain and deliver sediment to the coastal ocean at different rates. Rivers/estuaries are known to supply a highly variable portion of the riverine sediment load into the coastal ocean. Sediment not exported to the ocean is retained within *i)* the tidal portion of the river, *ii)* the estuary proper, *iii)* adjacent tidal flats and wetlands, and *iv)* deltas. Hardly ever has sediment retention been established along the total length of an estuary and explicitly for the different portions of the estuarine system from where tides are first measurable (typically ~100 km upstream) until the coastal ocean. It should be noted that the tidal portion of most estuarine systems typically exceed the portion of the estuary with measurable diluted salinity by a factor of 5-50.

The extent to which the river sediment load is retained within the lower reaches of a river system and the fraction of the sediment load that eventually escapes into the coastal ocean are a function of changing geomorphology as a result of a struggle between the relative energy supplied by the ocean-directed discharge of water and sediment and the dissipative energy of marine forces (tides and waves) acting on the discharge. The balance seldom reaches equilibrium as the relative energies of both fluvial and marine mechanisms continuously change on different time and space scales.

Many different sediment-trapping mechanisms act individually and in combination to retain sediment in estuaries. All can be related to the interplay between geomorphology and the major dynamic "participants", including tides, waves, river discharge, groundwater discharge, longitudinal density gradients, vertical stratification, atmospheric forcing, and sediment load. The role of changes in geomorphology is often downplayed or ignored, although it may be the most important factor. In fact, the shape of the coast and the estuary defines how tides propagate along the estuary.

As a corollary, sediment-trapping mechanisms vary along the estuarine zones from the coastal ocean to the tide-less lower river, because both geomorphology and the geomorphology-induced modifications of the dynamic factors vary. Measurements made in a single estuarine cross-section or along a longitudinal transect yield the end results of the interplay between geomorphology and the dynamics factors. It is usually very difficult to identify individual trapping mechanisms.

The question should be asked about how different sediment-trapping mechanisms, and mechanisms in synergism, affect the sediment retention index (R_i, Perillo, 2000; Perillo and Kjerfve, 2003) along the estuary. R_i is a function of space and time, because each factor, and their combined effects, are also functions of space and time. The most important factors probably include *i)* overall and local geomorphology; *ii)* overall sediment load and local sediment storage/erosion processes; *iii)* within-estuary tidal range, water level, and current variability; *iv)* tidal pumping; *v)* formation of turbidity maxima; *vi)* vertical and longitudinal salinity (density) gradients; *vii)* nearshore coastal dynamic processes; *viii)* climate dynamics; *ix)* relative sea level change; *x)* sediment-biological interactions; and *xi)* human structures in the estuary and coastal ocean.

Further complexities arise when time variability is considered. Events such as exceptional precipitation in river basins, hurricanes, the El Niño-La Niña cycle, and earthquakes are capable of producing large-scale modifications to the dynamic sediment equilibrium in estuarine systems. For example, the sediment input into the Chesapeake Bay during a couple of weeks of intense rainfall associated with the stalled Tropical Storm Agnes in 1974, has been estimated to equal the “typical” sediment input to the bay for 75 years.

In as much as natural processes are the major mechanisms controlling the dynamics and retention of sediment in estuaries, anthropogenic influences also require consideration. Sediment load is certainly controlled by dams. There currently are more than 2 million dams in existence globally. Reservoirs behind dams trap approximately 26 % of the global sediment delivery to the coastal ocean (Syvitski et al., 2005a), although this magnitude appears to be steadily increasing (Liquette et al., 2004). The actual volume of sediment being trapped is much greater when one considers that much sediment would be stored in alluvial fans and flood plains, and not normally reach the coastal zone. Developed countries are decommissioning dams, but the number of decommissioned dams remains small (Syvitski and Milliman, 2006).

Humans also disturb the global landscape through competing influences, for example, urbanization, deforestation, agricultural practices, and mining activities, but disturbance is a moving target, with each decade bringing a new environmental situation (Syvitski and Milliman, 2006). Other anthropogenic processes that influence sediment load, sediment retention, and estuarine geomorphology include irrigation, land clearing and deforestation, water and hydrocarbon extraction, sediment dredging and dredge material disposal, and artificial structures along river channels, within estuaries, and at estuarine mouths. For example, artificial structures such as harbors, jetties, and breakwaters have little or no capability to adapt to ever-changing water flow and sediment transport dynamics. Thus, the artificial “geomorphology” created by humans will only deteriorate with time, without becoming adapted to a system equilibrium. Artificial structures not only control circulation but actually change sediment erosion/deposition and the estuarine geomorphology through modifications of sediment trapping mechanisms and sediment retention.

2.- WG 122 Activities

2.1.- Constitution of WG

Although WG 122 was established in September 2003, actual constitution of their members was completed by March 2004.

2.2.- Meetings

2.2.1 - Faro Meeting

The first meeting of WG 122 was held at the University of Algarve, Faro, Portugal on September 12-16, 2004. The meeting was hosted by Dr Alice Newton and supported by funds obtained from SCOR, LOICZ and a special grant from the U.S. Office of Naval Research. The University of Algarve also proved extra support for meeting room facilities and lunch for the participants. The 10 Full Members and 2 Associate members participated at this meeting.

We identified two important needs requiring further consideration: (i) the linkage between river sediment load and estuarine sediment dynamics; and (ii) sediment influx from the coastal ocean into estuaries. The WG members were in agreement that this information is at best very poorly known and may only be available for a few estuaries from around the globe. In particular, little quantitative and observational information is available on sediment influx from the coastal ocean. River sediment input to estuaries may seem less complicated, but in reality most river discharge and sediment load estimates are obtained for non-tidal locations far upstream (often one or more hundred kilometers) from the head of the estuaries. The estuarine reach between maximum salinity intrusion and the most seaward gauging station is unknown with respect to sediment dynamics. Thus, to prepare for the next meeting, WG members attempted to gather all available and published information with respect to data, measurement methodology, and modeling procedures.

2.2.2 - Texel Meeting

The second meeting was held at Texel, The Netherlands on 23-25 June 2005. This meeting was only supported by SCOR and LOICZ. Six Full Members, 3 Associate Members and one guest, Dr Han Winterwerp (Delft University), participated in this meeting.

The meeting was mostly devoted to a round-table discussion regarding the TORs and how best to provide answers by the end of WG time limit. The decision was to elaborate a position paper to be submitted to *EOS* with a provisional title of “Estuarine sediment response to climate and land use” and a special issue of *Estuarine, Coastal and Shelf Sciences* (we have the agreement of the Chief Editor, Eric Wolanski) for a series of review papers.

2.2.3 - Third and Final Meeting

The last meeting of WG 122 was held on 23-25 September 2008 at the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado at Boulder. Prof. James Syvistki and his staff from the Community Surface Dynamics Modeling System (CSDMS) hosted the meeting by providing all logistical arrangements. The main objective of the meeting was to integrate the findings made by the WG and to define the integrated output of the WG to the scientific community as well as the larger community of estuarine stakeholders and decision makers.

Eight Full members, 3 Associate Members, and 5 local individuals participated in the meeting.

The agenda for the meeting was structured along the main topics the WG have considered to be the essential issues associated to the WG theme and terms of reference. Main topics were

- Sediment Input to Estuaries under human influence
- Morphodynamics and Evolution of Estuaries
- Sediment-biological interactions
- Estuarine Hydraulics
- Relative Sea Level Change
- The Physics & Models of Sediment Budgets in Estuaries
- Socioeconomic Impact of changes in Estuarine Sedimentation

Some of the main conclusions reached from the discussions in the meeting can be summarized as follows:

- Estuaries are being seriously affected by climatic and human impacts, as manifested by changes in the level of sediment input from the land and sometimes from the sea, and through sediment redistribution within the estuary.
- Some estuaries are starved of riverine sediment due to dams; others are enriched in sediment input such as through land clearing or glaciers retreat; others are sinking due to excess groundwater extraction.
- There are various scales from seasonal to millennia that are superimposed in the evolution of the mechanisms of sediment retention in estuaries, impacting the way the evolution of an estuaries geomorphology.
- The role of relative sea level has not been adequately addressed in our interpretation of an estuaries vulnerability.
- Increased storminess and a rise in sea level from climate change, partially or wholly man-made, may further destabilize an estuary.
- Some mature estuaries may have natural cycles, possibly tens to hundred of years in duration, with alternate periods of prevailing deposition and erosion for the whole system. Such estuaries are thus periodically rejuvenated by climatic events.
- Some estuaries are changing from exporter to importer and vice-versa due to human impacts.

- Present numerical models are not capable of predicting estuarine evolution over long periods (hundreds to thousands of years), as there remain many problems in defining and quantifying the conditions at the open boundaries. The future may be to advance toward coupling models operating across different spatial and temporal scales. Behind each model lies commonly used concepts like tidal pumping and scour and settling lags that require further improvements.
- The use of sediment core dating for estimating estuarine sediment accumulation rates and their temporal and spatial changes is important for the proper assessment of the sedimentological and morphological state of estuaries. Such accumulation estimates will also be useful in the process of assessing the results from numerical models being used to monitor changes.
- There is a need to analyze the sediment dynamics in estuaries within reaches rather than as a whole system, to quantify the internal redistribution of sediment within estuaries and to differentiate this from net sediment inflows/outflows at the open boundaries of the estuaries
- Although there has been significant progress, there is still considerable lack of integrated, multidisciplinary studies considering the biological-physical interaction in estuaries in general, and in wetlands in particular, with the sediment transport processes and modifications in the geomorphology and, as a result, the evolution of habitats.

2.3.- Web Page

A web page for WG 122 is operational within the server of the Centro Regional de Investigaciones Básicas y Aplicadas de Bahía Blanca (CRIBABB), Argentina (see http://www.criba.edu.ar/scorwg122), where the Instituto Argentino de Oceanografía (IADO) is located. This server is the main Argentine educational node for the southern portion of the country. The web is upgraded with information, references and links from WG members and news related to the TOR of the WG.

3.- Publications

The listed publications are papers made by members of the working group and they are directly related to the WG TORs.

3.1.- Published

Brunet, F., Gaiero, D., Probst, J.-L., Depetris, P.J., Gauthier Lafaye, F. and Stille, P., 2005. d13C tracing of dissolved inorganic carbon sources in Patagonian rivers (Argentina). Hydrological Processes, 19:3321-3344

Depetris, P.J., Gaiero, D.M., Probst, J.L., Hartmann, J. and Kempe, S., 2005. Biogeochemical output and typology of rivers draining Patagonia's Atlantic seaboard. Journal of Coastal Research 21(4):835-844.

El Mouden, A., Bouchaou, L. Snoussi, M. and Wildi, W., 2005. Comportement des métaux et

fonctionnement d'un estuaire en zone subaride: Cas de l'estuaire du Souss (côte atlantique marocaines). Estudios Geol. 61:25-31.
Escapa, C.M., Minkoff, D.R., Perillo, G.M.E. e Iribarne, O.O., 2007. Direct and indirect effects of burrowing crab activities on erosion of Southwest Atlantic Sarcocornia-dominated marshes. Limnology & Oceanography 52(2):2340-2349.
Kuehl., S.A., Alexander, C., Carter, L., Gerald, L., Gerber, T., Harris, C., McNinch, J., Orpin, A., Pratson, L., Syvitski, J.P.M., and Walsh, J.P., 2006. Understanding sediment transfer from land to ocean. EOS, Transactions AGU 87(29): 281-286.
Lumborg, U. and Pejrup, M., 2005. Modelling of cohesive sediment transport in a tidal lagoon - an annual budget. Marine Geology 218:1-16.
Minkoff, D.R., Escapa, C.M., Ferramola, F.E. y Perillo, G.M.E., 2005. Erosive processes due to physical - biological interactions based in a cellular automata model. Latin American Journal of Sedimentology and Basin Analysis 12(1):25-34.
Minkoff, D.R., Escapa, C.M., Ferramola, F.E., Maraschin, S.,Pierini, J.O., Perillo, G.M.E. y Delrieux, C., 2006. Effects of crab-halophytic plant interactions on creek growth in a S.W. Atlantic salt marsh: A cellular automata model. Estuarine Coastal and Shelf Science, 69(3-4):403-413.
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Perillo, G.M.E., Pérez, D.E., Piccolo, M.C., Palma, E. y Cuadrado, D.G., 2005. Physical characteristics of a human impacted estuary: Quequen Grande River Estuary, Argentina. Estuarine, Coastal and Shelf Science 62:301-312.
Perillo, G.M.E. and Kjerfve, B., 2005. Regional Estuarine and Coastal Systems of the Americas: An Introduction. Journal of Coastal Research 21(4):729-730.
Perillo, G.M.E., Minkoff, D.R. y Piccolo, M.C., 2005. Novel mechanism of stream formation in coastal wetlands by crab–fish–groundwater interaction. Geo-Marine Letters 25(4):124-220.
Perillo, G.M.E, Syvistki, J.P.M., Amos, C.L., Depetris, P., Milliman, J., Pejrup, M., Saito, Y., Snoussi, M., Wolanski, E, Zajaczkowski, M., Stallard, R., Hutton, E., Kettner, A., Meade, R., Overeem, I., y Peckham, S., 2007. Estuaries and the sediments: how they deal with each other. INPRINT 2007-3:3-5
Syvistki, J.M.P., Harvey, N., Wolanski, E., Burnett, W.C., Perillo, G.M.E., Gornitz, V., Bokuniewicz, H., Huettel, M., Moore, W.S., Saito, Y., Taniguchi, M., Hesp, P.,Yim, W.W-S., Salisbury, J., Campbell, J., Snoussi, M., Haida, S., Arthurton, R. y Gao, S., 2005. Dynamics of the coastal zone. In: Crossland, C. J., Kremer, H.H., Lindeboom, H.J., Crossland, J. I. M. and Le Tissier, M.D.A. (eds.) Coastal Fluxes in the Anthropocene. Springer-Verlag, Berlín 39-94.
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Syvitski, J.P.M., 2008. Deltas at Risk. Sustainability Science, 3: 23-32.

Victor, S., Golbuu, Y., Wolanski, E. and Richmond, R.H., 2004. Fine sediment trapping in two mangrove-fringed estuaries exposed to contrasting land-use intensity, Palau, Micronesia. Wetlands Ecology and Management 12: 277–283.

Wolanski, E., 2006. The evolution time scale of macro-tidal estuaries:Examples from the Pacific Rim. Estuarine, Coastal and Shelf Science 66:544-549.

Wolanski, E., Williams, D. and Hanert, E., 2006. The sediment trapping efficiency of the macro-tidal Daly Estuary, tropical Australia. Estuarine, Coastal and Shelf Science 69: 291-298.

3.2.- In press or submitted

Perillo, G.M.E., 2009. Tidal courses: classification, origin and functionality. En: Perillo, G.M.E., Wolanski, E., Cahoon, D.R. y Brinson, M.M., (eds.). Coastal wetlands: an integrated ecological approach. Elsevier, Amsterdam.

3.3.- Books and Special Issues of Journals

Perillo, G.M.E. y Kjerfve, B., 2005 (Editores). Regional and Coastal Systems of the Americas. Thematic Session, Journal of Coastal Research 21(4):729-859.

Wolanski, E., 2007. Estuarine Ecohydrology. Elsevier, Amsterdam.

Perillo, G.M.E., Wolanski, E., Cahoon, D. and Brinson, M.M. (Eds.), 2009. Coastal Wetlands: An Integrated Ecosystem Approach. Elsevier, Amsterdam (in press)

4.- References

Perillo, G.M.E., 2000. Sediment budgets and fluxes in estuarine and coastal areas. IGBP-LOICZ Water Workshop, Boulder, Co. (oral presentation).

Perillo, G.M.E. and Kjerfve, B., 2003. Mechanisms of Sediment Retention in Estuaries: New SCOR-LOICZ-IAPSOWorking Group 122 launched. LOICZ Newsletter 29:5-6.

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2.2.4 WG 124: Analyzing the Links Between Present Oceanic Processes and Paleo-Records (LINKS) (with IMAGES) (2003)

Terms of Reference:

- Use the new insights gained from contemporary ocean biogeochemical studies to identify or refine our understanding of key oceanic processes and develop or improve proxies for these processes for subsequent use in paleoceanographic studies.
- Refine established proxies, provide mechanistic understanding and foster the development of new proxies within integrated multidisciplinary process studies in the modern ocean.
- Use proxy evidence from the sedimentary records to test hypotheses of the oceanic response to climate change.

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2.2.5 WG 125: Global Comparisons of Zooplankton Time Series (2004)

Terms of Reference:

- Identify and consolidate a globally representative set of "long zooplankton time series" (selected from the data sets listed in Table 1, plus perhaps from additional regions for which time series can be pieced together from a sequence of shorter programs).
- Facilitate migration of individual data sets to a permanent and secure electronic archive.
- Develop and share protocols for within-region and within-time period data summarization (e.g., spatial, seasonal and annual averaging, summation within taxonomic and age categories).
- Based on the above, develop priorities and recommendations for future monitoring efforts and for more detailed re-analysis of existing sample archives.
- Carry out a global comparison of zooplankton time series using (in parallel) a diverse suite of numerical methods, examining

    1. Synchronies in timing of major fluctuations, of whatever form.
    2. Correlation structure (scale and spatial pattern) for particular modes of zooplankton variability (e.g., changes in total biomass, replacement of crustacean by gelatinous taxa, alongshore or cross-shore displacements of zoogeographic distribution boundaries).
    3. Amplitude of variability, both for total biomass and for individual taxa, and comparison to the amplitude of population fluctuations of predator species (fishes, seabirds, marine mammals). Is there amplification at higher levels of the food web?
    4. Likely causal mechanisms and consequences for the zooplankton variability, based on spatial and temporal coherence with environmental and fishery time series.
    5. Sensitivity and specificity of data-analysis tools.

Co-Chairs:

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Sanae Chiba	JAPAN	David Checkley	USA – Sponsored by GLOBEC
Young-Shil Kang	KOREA		
Todd O'Brien	USA	Harold Bachelder	USA – Sponsored by PICES
Mark Ohman	USA	Juha Flinkman	FINLAND
Chris Reason	SOUTH AFRICA	A. Lopez-Urrutia	SPAIN
Anthony Richardson	AUSTRALIA	Welbjørn Melle	NORWAY – Sponsored by ICES
Andy Solow	USA	Luis Valdes	SPAIN

Executive Committee Reporter: Annelies Pierrot-Bults

2-18

WG125 report on "Zooplankton and Climate: Response Modes and Linkages among Regions, Regimes, and Trophic Levels": May 15-23 2008, Gijon Spain

SCOR WG125 'Global Comparison of Zooplankton Time Series' held its final working group meeting on 15-16 May 2008 in Gijón Spain, hosted by the Gijón laboratory of the Instituto Español de Oceanografía. The two-day meeting was attended by most of the WG Full and Associate Members, plus by several IEO staff. We heard several short presentations on the first day, but the main purpose of this meeting was hands-on data analysis by various teams of investigators, and deciding how these analyses will ultimately be presented and published.

Preliminary versions of many of the comparative analyses were presented two days later (May 18) in a day-long open workshop on 'Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels'. This workshop was part of the week-long International Symposium 'Effects of Climate Change on the World's Oceans' (sponsors IOC, ICES, PICES, SCOR, GLOBEC, and WCRP). Although designed as a forum for viewing and discussion of WG125 methods and results (10 papers), the workshop also included six excellent presentations by authors not formally associated with the SCOR working group. The presentations covered a wide but relevant range of topics: data 'tools'; the spatial 'zones of influence' for different modes of physical climate variability; a between-region comparison of trends and amplitudes for anomalies of total zooplankton biomass/biovolume; several papers on temperature effects on community size structure and seasonal timing (phenology); 'invasions and outbreaks' by gelatinous zooplankton; spatial and interannual variability of isotopic composition and trophic level; variability of species composition and diversity; and poleward displacements of zoogeographic distributions. WG125 members (Chiba, López-Urrutia, Richardson, Ohman, Mackas) also gave five papers in the May 22 'Climate Impacts on Lower Trophic Levels' session of the main symposium. In the following paragraphs, we give a few graphical examples plus an overall 'highlights and conscensus' summary. The full list of presentation titles and abstracts (plus pdf copies of some of the presentations) can be accessed via the Symposium web page:
http://www.pices.int/meetings/international_symposia/2008_symposia/Climate_change/structure.aspx .
The WG125 goal of global comparison has received very good 'buy-in' by the international community of marine zooplanktologists. We currently have access to more than 100 multi-year zooplankton time series, from more than 25 different countries (and are continuing to gain more). One consequence of this massive response is that WG125 needed to assemble a suite of 'entry-level' data analysis and visualization tools that could be applied to compare across diverse sampling designs (frequent and regular sampling of a single nearshore station; seasonally repeated survey grids; and more irregular repeat coverage within defined statistical areas); sampling methods (horizontal, vertical or oblique net tows with different net designs and mesh sizes); and measurement currencies (displacement volume, dry-weight biomass, carbon biomass, numeric abundance at varying levels of taxonomic aggregation). Our step-wise approach (implemented mostly by Todd OBrien; illustrated in Fig. 1) has been to estimate average seasonal cycles from log-transformed raw time series, then use these to calculate anomaly time series (multiplicative deviations from the seasonal climatology), and finally to display both data and anomalies as color-coded month-vs-year pixel grids that show which seasons/years have unusually high or low values of the variable being measured. These simple graphical displays have been useful not only for comparison among time series, but also for within-time series quality control and hypothesis building.

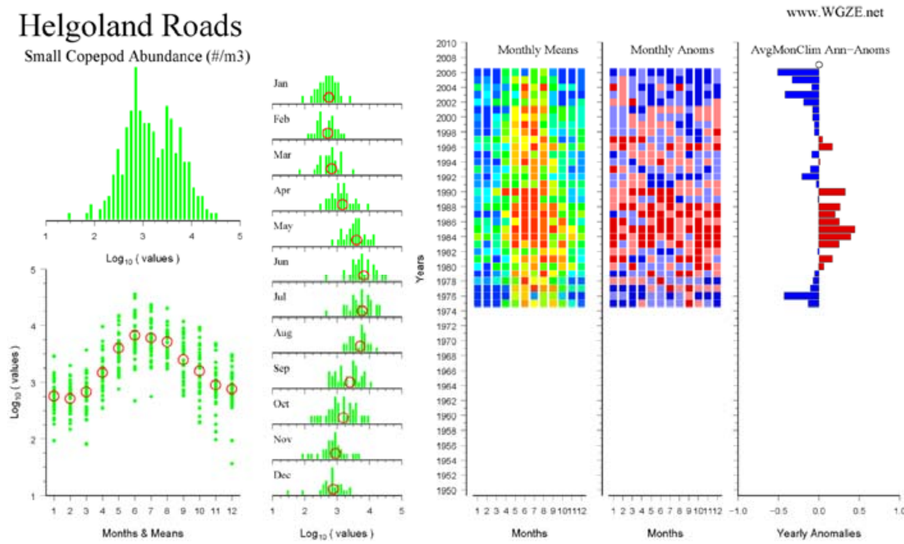

Fig 1. Graphical output from the WG125 toolkit, as applied to W. Greve's 'long and dense' Helgoland Roads North Sea time series. The green dots and bars in the three left-side panels show overall and within-month frequency distributions of individual data points. Red circles overlaid on the bottom-left graph show the average seasonal cycle. Color-coded pixels in the middle panel show ranking of within-month means. The right hand panels show monthly and annual-average anomalies from the seasonal climatology. [Note: the color figures in this report can be viewed in the online version of this section of the background book at http://www.scor-int.org/2008GM/2008GM.htm.]

Nearly all of our available zooplankton time series provide one or more indices of 'total amount': biovolume, biomass, or total abundance. One of our main comparisons was of how the amplitudes of fluctuations and trends differ among regions. To address this, we ranked time series based on the max-to-min or RMS 'span' of their anomaly time series (Fig. 2: ranking map from the O'Brien et al. presentation). We found that the strongest interannual variability was in the zooplankton time series from sub-polar regions, from the eastern boundary current upwelling systems, and from the ocean margins off Korea and Japan. Conversely, the smallest range of variation was found in the time series from mid-latitude continental shelf regions and from the European marginal seas.

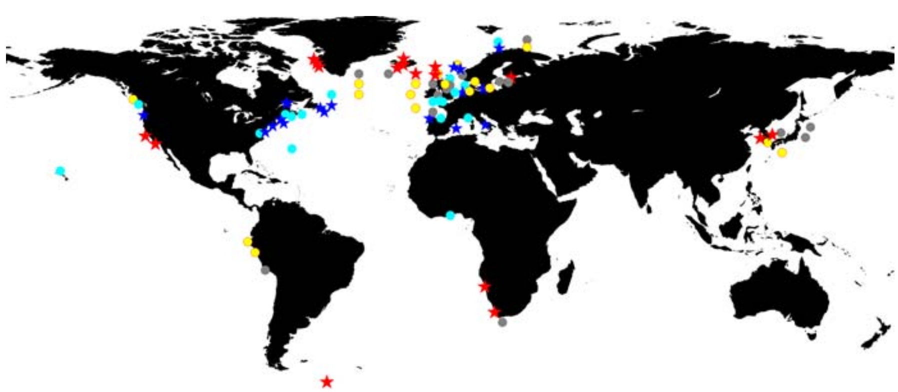

Fig. 2. Map of 'anomaly span'. Red and yellow symbols show locations of time series with a large interannual range, blue symbols have a much smaller range (some because they are brief). Grey symbols are intermediate.

Another important comparison is of which time series are most 'synchronous', and if and how their degree of temporal correlation varies with spatial separation. Hal Batchelder presented a preliminary, but interesting, spatial autocorrelation analysis (Fig. 3) of the 'biomass' time series. He found that the biomass time series are positively but relatively weakly correlated across separations smaller than a few thousand kilometers, that the spatial autocorrelation is stronger in the Pacific than in the Atlantic, but that there is no evidence supporting the 'global synchrony' suggested by catch time series of anchovy and sardines. Does this mean that fish 'regimes' are more teleconnected than zooplankton 'regimes'? Perhaps, but not necessarily – the zooplankton analysis is of a highly aggregated currency (total biomass), while the fish analyses are at species level. We are still working on the corresponding global species-level analysis for zooplankton, but comparisons within the California Current system show that the short-range spatial autocorrelation of zooplankton community variability is considerably stronger than the spatial autocorrelation of total zooplankton amount (Fig 3). We are seeking additional data to extend the species-level analysis to larger separations.

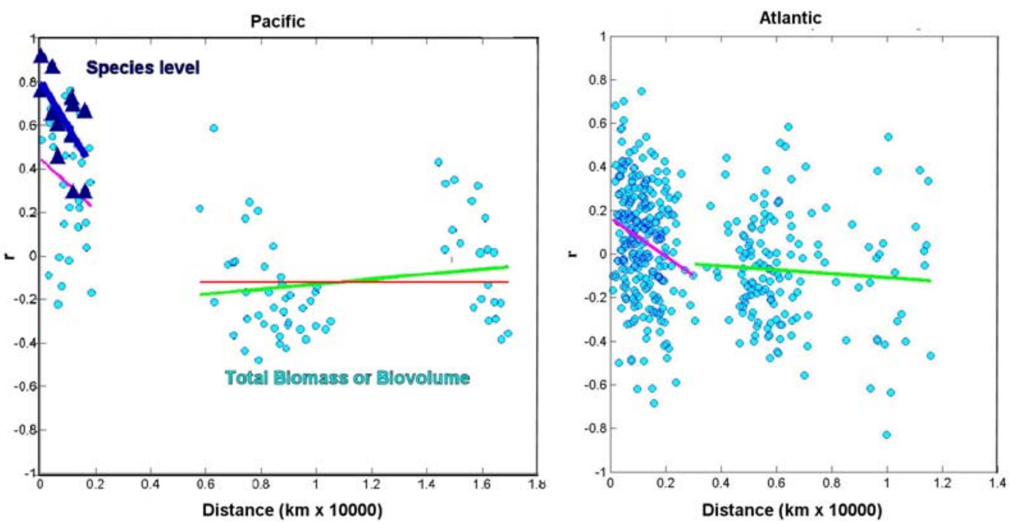

Fig 3. Spatial correlograms for zooplankton anomaly time series from the Pacific (left, total biomass and community composition) and Atlantic (right, total biomass only). In both oceans, correlation decays to zero at separations greater than a few thousand km (i.e, .there is little or no global synchrony). However, 'local' synchrony is stronger in the Pacific than in the Atlantic, and are much stronger at species level than for total biomass. From Batchelder et al. and Mackas et al. presentations.

What else stood out as strong climate linkages? As noted above, several papers (Conversi et al., Mackas et al., Schlueter et al.) examined changes in zooplankton seasonal timing. All found that zooplankton phenology is very sensitive to ocean climate as indexed by water temperature during the growing season for a given species. But a very interesting composite result was that the temperature dependence is not uniform across species and regions. High-latitude and 'spring' species show earlier seasonal maxima in years when temperatures are higher. However, subtropical 'fall bloom ' species showed the opposite pattern – later seasonal timing when temperatures are higher, suggesting that their population responses track autumn cooling and destratification rather than spring warming and stratification. Species richness, average body size, and success of 'invading' (or merely 'expanding') species also show strong relationships to ocean warming.

Most of the May 18 presentations, plus several additional by WG125 authors unable to attend the Gijón Symposium, will be written up for publication in an upcoming special issue of *Progress in Oceanography*, to be guest-edited by Pierre Pepin. Manuscript submittal dates are scheduled for the end of this calendar year, and on-line publication will probably occur before the end of 2009. This and the database at http://www.st.nmfs.noaa.gov/plankton/content/index.html will be the final products of the working group.

2.2.6 WG 126: Role of Viruses in Marine Ecosystems (2004)

Terms of Reference:

- Summarize past results on virus-meditated mortality of algae and prokaryotes and the impact on oceanic carbon and nutrient cycling.
- Coordinate data collection to assess the role of viruses in different water masses.
- Assess the methodological limitations of the techniques available for quantifying the virus-mediated mortality of microorganisms (eukaryotes and prokaryotes) and their impact on carbon and nutrient cycling, and make recommendations for the best available approaches to study viruses and viral processes in the sea.
- Establish and maintain a Web site as forum that can be used by the "viral community" for exchange of data and ideas and future plans.
- Convene an International Symposium that could include a published proceeding such as a special issue of *Limnology and Oceanography* or *Deep-Sea Research*.
- Write a "definitive" textbook on Methods in Marine Virology.

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Executive Committee Reporter: Jorma Kuparinen

2008 Report of SCOR Working Group 126 – *The role of viruses in marine systems*

Co-chairs Markus G. Weinbauer (France) Steven W. Wilhelm (United States)

Since our last report (June 2007), WG 126 has been focusing on the production of an online, freely available publication currently entitled ***Methods in Aquatic Virus Ecology***. The special volume (funded by the Gordon and Betty Moore Foundation) will be assembled and published by ASLO (*Advancing the Science of Limnology and Oceanography*, formerly known as the *American Society for Limnology and Oceanography*). Currently all authors for chapters have been identified (see Appendix I) and writing is in progress. To date four of the chapters have been received and are undergoing peer review to ensure the highest quality. We anticipate the receipt of all chapters in the next 2 weeks with an anticipate completion date of January 2009 for the project.

Due to the above book commitments, the working group organizers asked for and received a one-year hiatus from meetings. In July 2008, most members of the group had already planned to attend the Aquatic Virus Workshop at the University of British Columbia (see Appendix II); indeed, most of the invited speakers are Full or Associate members of the working group. As such, we are currently seeking venues for the 2009 meeting of WG126: it is anticipated that this meeting will either be held in January or May 2009 and decisions on this will be made by July 31, 2008 after the co-chairs have meet to discuss options. Leading options right now include the home institutions of the co-chairs.

As part of our progress this year, the SCOR WG also co-authored a commentary (published in the ISME Journal) with the EUR-OCEANS Marine Virus Workshop group which resulted from back-to-back meetings in Bergen, Norway in May 2007 (see Appendix III). The paper highlights pressing needs and research foci for coming years.

APPENDIX I: CHAPTERS AND AUTHORS FOR METHODS IN AQUATIC VIROLOGY

1. Concentration of free viruses from water samples (Wommack; Sime-Ngando)
2. Separation of free virus particles from sediments in aquatic systems (Danovaro & Middelboe)
3. Counts of viruses by epifluorescence microscopy (Suttle & Fuhrman)
4. Determining virus abundance by flow cytometry (Brussaard)
5. Isolation of viruses infecting photosynthetic and nonphotosynthetic protists (Nagasaki & Bratbak)
6. Isolation and life-cycle characterization of viruses infecting heterotrophic bacteria and cyanobacteria (Middelboe & Chan)
7. Temperate phages and lysogens (Paul & Weinbauer)
8. The isolation of viruses infecting Archaea (Stedmann and Dyall-Smith)
9. Purification of virus particles with centrifugal gradients (Lawrence & Steward)
10. Transmission electron microscopy of viruses and viral communities (Heldal & Ackerman)
11. Preparation and application of fluorescently labeled virus particles (Noble, Comeau)
12. Estimating viral-mediated mortality rates of prokaryotes method (Weinbauer, Rowe and Wilhelm)
13. Estimation of autotrophic mortality by the virus dilution method (Kimmance and Brussaard)
14. Isolation of nucleic acids from virus particles and communities (Steward & Culley)
15. Sequencing and characterization of viral genomes (Wilson, Schroeder and Johnson (Brode)
16. Construction and analysis of marker gene libraries (Short, Chen, and Wilhelm)
17. Fingerprinting virus communities by DGGE and PFGE (Schroeder, Saanda, Short)
18. Construction of microarrays and applications to virus analysis (Allen, Lindell)
19. Characterization of RNA virus communities (Culley)

APPENDIX II: OUTLINE FOR AQUATIC VIRUS WORKSHOP AT UBC

AQUATIC VIRUS WORKSHOP
Vancouver Canada – 6 to 11 July 2008
MEETING SCHEDULE

Sunday 6 July
Location: Peter Wall Institute for Advanced Studies, University Centre, 6331 Crescent Rd., UBC

1600 to 1900 REGISTRATION AND MIXER

Monday 7 July

Location: Michael Smith Lab, Auditorium, Rm 102, 2185 East Mall, UBC

0845 A BRIEF WELCOME AND MEETING LOGISTICS
Curtis A. Suttle and Amy M. Chan

Chair: Curtis A. Suttle
0900 KEYNOTE: MARINE VIRUSES: HISTORICAL PERSPECTIVE AND SOME NEW DIRECTIONS
Jed A. Fuhrman, University of Southern California, USA

0940 GENOMIC AND MORPHOLOGICAL CHARACTERIZATION OF UNCULTIVATED AQUATIC VIRUSES
Jennifer R. Brum, Alexander I. Culley, Grieg F. Steward

1000 BACTERIOPHAGES – A NEW TROPHIC LINK IN LAKE BAIKAL ECOSYSTEM
Valentin V. Drucker, N.V. Dutova

1020 HEALTH BREAK, RM 101

Chair: Steven W. Wilhelm
1050 KEYNOTE: COCCOLITHOVIRUSES; LIFE AND DEATH AFTER GENOME SEQUENCING
Willie Wilson, Bigelow Laboratory for Ocean Sciences, USA

1130 ARCHIVED PLANKTON SAMPLES REVEAL CHANGES IN *EMILIANIA HUXLEYI*-INFECTING VIRUSES OVER A 32 YEAR PERIOD
Andrea C. Baker, Steven J. Ripley, Peter I. Miller, Anthony W. Walne and Declan C. Schroeder

1150 LUNCH BREAK [on your own]

Chair: Keizo Nagasaki

1330 **KEYNOTE**: **VIRU**S **PHYTOPLANKTO**N **INTERACTION**S
Corina Brussaard, Royal Netherlands Institute for Sea Research, The Netherlands

1410 THE ROAD TO CHLOROVIRUS REPLICATION WITH BRIDGES AND BYPASSES
David D. Dunigan, Irina V. Agarkova, James R. Gurnon, Garry A. Duncan, Michael V. Graves, James L. Van Etten

1430 *CHLORELLA* VIRUS PBCV-1 RESPONSE TO ITS HOST'S OXIDATIVE ENVIRONMENT
Garry A. Duncan, James Eudy, Charles Kuszynski, Giane Yanai-Balser, David Dunigan, James Van Etten

1450 *EMILIANIA HUXLEYI* AND ITS VIRUSES: A NOVEL INFECTION STRATEGY REVEALED
Charlotte A Worthy, Gaia Biggi, Keith Ryan , Matt Hall, Willie H. Wilson, Arvind Varsani, Roy Moate, Declan C Schroeder

1510 HEALTH BREAK, RM 101

Chair: Jed Fuhrman

1540 DO VIRAL GENES INCREASE HOST FITNESS? PHOSPHATE STARVATION GENES IN THE ENVIRONAMENTAL VIRAL POOL
Ruth Anne Sandaa, Hilde Marie Kristiansen, T. Frede Thingstad

1600 VIRALLY-INDUCED SPHINGOLIPIDS REGULATE HOST PCD IN THE MARINE COCCOLITHOPHORE, *EMILIANIA HUXLEYI*
Assaf Vardi, Ben Van Mooy, Helen Fredricks, Liti Haramaty, and Kay Bidle

1620 HOW COME VIRUS-INOCULATED ALGAL CULTURES EXHIBIT REGROWTH?
Yuji Tomaru, Hiroyuki Mizumoto, Keizo Nagasaki

1640 ADJOURN FOR THE DAY

Tuesday 8 July

Chair: Jean-Michel Claverie

0900 KEYNOTE: HIGHLIGHTS OF 25 YEARS OF *CHLORELLA* VIRUS RESEARCH
James L. Van Etten, University of Nebraska-Lincoln, USA

0940 TRANSCRIPTION ANALYSIS OF PBCV-1 USING MICROARRAYS
Giane M. Yanai-Balser, Garry A. Duncan, James D. Eudy, James L. Van Etten

1000 THE INFLUENCE OF METACASPASE EXPRESSION AND ACTIVITY ON VIRAL SUSCEPTIBILITY IN THE MARINE COCCOLITHOPHORE, *EMILIANIA HUXLEYI*
Kay D. Bidle, C.J. Kwityn

1020 HEALTH BREAK, RM 101

Chair: Shannon Williamson

1050 A NON-SPECIFIC NUCLEASE FROM A *CHLORELLA* VIRUS SS-2
Tae-Jin Choi, Sang-Eun Jung, Kyungyong Lee

1110 FUNCTIONAL CHARACTERISATION OF A VOLTAGE-ACTIVATED SODIUM CHANNEL FROM THE *EMILIANIA HUXLEYI* INFECTING VIRUS -EHV86 *Frederic G. Verret, Matt J. Hall, Declan C. Schroeder*

1130 EFFECT OF CHLOROVIRUS-MEDIATED MEMBRANE DEPOLARIZATION ON ELECTROGENIC TRANSPORT OF SOLUTES IN *CHLORELLA* NC64A
Irina Agarkova, David Dunigan, James Gurnon, Gerhard Thiel, James Van Etten

1150 LUNCH BREAK [on your own]

Chair: James Van Etten

1330 KEYNOTE: MIMIVIRUS AND MIMIVIRIDAE: TOWARD A NEW FAMILY OF MICROALGAE VIRUSES
J.-M. Claverie, Mediterranean Institute of Microbiology, France

1410 THE GENETIC PROFILE OF CroV, A GIANT DSDNA VIRUS INFECTING THE MARINE FLAGELLATE *CAFETERIA ROENBERGENSIS*.
Matthias G. Fischer, Michael J. Allen, William H. Wilson and Curtis A. Suttle

1430 VIRUSES: AGENTS OF CORAL BLEACHING AND DISEASE?
Willie Wilson, Jayme Lohr, Colin Munn

1450 THE ROLE OF COCCOLITHOVIRUSES IN TRACE METAL SPECIATION
Turki Al-Said, Declan C. Schroeder, Alison Taylor And Eric Achterberg

1510 A COPPER/ZINC SUPEROXIDE DISMUTASE ENCODED BY *CHLORELLA* VIRUS PBCV-1
Ming Kang, Jessie Zheng, David N. Silverman, James L. Van Etten

1530 POSTER SESSION & MIXER [ROOM 101]: 3:30 to 6:00 pm

<u>Wednesday 9 July</u>

<u>Chair: Eric Wommack</u>

0900 KEYNOTE: VIRAL EFFECTS ON MICROBIAL MORTALITY AND DIVERSITY
Markus Weinbauer, Laboratoire d'Océanolographie de Villefranche, France

0940 KEYNOTE: METHODOLOGICAL CHALLENGES TO RESEARCH IN AQUATIC VIROLOGY
Steven W. Wilhelm, University of Tennessee, USA

1020 HEALTH BREAK, RM 101

1050 TOPIC FOR DISCUSSION: METHODOLOGICAL CHALLENGES
Steven W. Wilhelm

1150 LUNCH BREAK [on your own]

<u>Chair: Keizo Nagasaki</u>

1330 KEYNOTE: MARINE VIRAL ECOLOGY: METAGENOMIC APPROACHES AND NEW TECHNOLOGY
Shannon J. Williamson, J. Craig Venter Institute, USA

1410 GENETIC AND BIOCHEMICAL CHARACTERIZATION OF THE LYTIC ENZYMES FROM CYANOPHAGE MA-LMM01 INFECTING *MICROCYSTIS AERUGINOSA*
<u>Naohiko Hosoda</u>, Takashi Yoshida, Yoichi Kurokawa, Yukari Takashima, Hiroyuki Ogata, Keizo Nagasaki, Shingo Hiroishi

1430 TRANSCRIPTION OF THE PHYCOBILISOME DEGRADATION GENE IN CYANOPHAGE MA-LMM01 INFECTING *MICROCYSTIS AERUGINOSA*
<u>Yukari Takashima</u>, Takashi Yoshida, Mitsuhiro Yoshida, Hiroyuki Ogata, Shingo Hiroishi, Keizo Nagasaki

1450 HEALTH BREAK, RM 101

<u>Chair: Tae-Jin Choi</u>

1520 A GENOMIC APPROACH TO PROFILE THE ECTOCARPUS VIRUS LYSOGENIC TRANSCRIPTOME
<u>Declan C. Schroeder</u>

1540 STUDIES ON THE DIVERSITY OF *PROCHLOROCOCCUS* AND *PROCHLOROCOCCUS*-INFECTING VIRUSES IN THE ATLANTIC OCEAN
<u>Ellie Jameson</u>, Nicholas H. Mann, Ian Joint, Martin Mühling

1600 DIVERSITY OF MARINE T7-LIKE BACTERIOPHAGES IN WATER AND SEDIMENTS
<u>Jessica LaBonté</u>, Karen Reid and Curtis A. Suttle

1620 ADJOURN FOR THE DAY

Thursday 10 July

Chair: Corina Brussaard

0900 KEYNOTE: UNUSUAL VIRUSES INFECTING MARINE PROTISTS
Keizo Nagasaki, National Research Institute of Fisheries and Environment of Inland Sea, Japan

0940 THE RICHNESS AND DYNAMICS OF FRESHWATER ALGAL VIRUSES
Steven M. Short, Cindy M. Short

1000 IDENTIFYING FRESHWATER PHYCODNAVIRIDAE AND THEIR POTENTIAL PHYTOPLANKTON HOSTS USING DNA POL SEQUENCE FRAGMENTS AND A GENETIC DISTANCE ANALYSIS
Jessica L. Clasen, Curtis A. Suttle

1020 HEALTH BREAK, RM 101; Take down posters

Chair: Markus Weinbauer

1050 VIRUSES OF PRASINOPHYCEAE IN THE N.W. MEDITERRANEAN
Laure Bellec, Nigel Grimsley, Yves Desdevises

1110 ISOLATION AND CHARACTERISATION OF VIRUSES THAT INFECT THE MARINE PICOEUKARYOTES *MICROMONAS PUSILLA* AND *OSTREOCOCCUS TAURI*
Karen D. Weynberg, Michael J. Allen, David J. Scanlan, William H. Wilson

1130 GENOME AND LIFE-CYCLE OTV5, A PHYCODNAVIRUS OF THE PELAGIC MARINE UNICELLULAR GREEN ALGA *OSTREOCOCCUS TAURI*
Nigel H. Grimsley, Evelyne Derelle, Marie-Line Escande, Sophie Eychenié, Richard Cooke, Yves Desdevises, Laure Bellec, Conchita Ferraz, Hervé Moreau

1150 LUNCH BREAK [on your own]; Take down posters

Chair: Curtis A. Suttle

1330 KEYNOTE: MAKING SENSE OF THE CHAFF: WHAT WILL METAGENOMIC APPROACHES TELL US ABOUT VIRAL ECOLOGY?
K. Eric Wommack, University of Delaware, USA

1410 TOPIC FOR DISCUSSION: IF I HAD A MILLION DOLLARS……… Curtis A. Suttle

1425 SHORT BREAK

1440 FORM FOCUS GROUPS [RM 101]

1540 SYNOPSIS

1600 MEETING WRAP UP

1630 ADJOURN

1830 BANQUET – Peter Wall Institute for Advance Studies, University Centre, 6331 Crescent Rd., UBC

POSTERS:

1. DYNAMICS OF TOXIC BLOOM-FORMING CYANOBACTERIUM *MICROCYSTIS AERUGINOSA* AND ITS INFECTIVE CYANOPHAGES IN THE ENVIRONMENT
   Shingo Hiroishi, Aki Kashima, Mitsuhiro Yoshida, Yukari Takashima, Naohiko Hosoda, Yoshitake Takao, Keizo Nagasaki, Takashi Yoshida
2. INFLUENCE OF VIRAL LIFESTYLE ON HETEROTROPHIC BACTERIOPLANKTON IN THE COASTAL ARCTIC OCEAN: LYSOGENIC VERSUS LYTIC VIRAL INFECTION
   Jerome P. Payet, Curtis A. Suttle
3. VIRUS ADAPTATION TO EXTREME ENVIRONMENTS
   Petra Kukkaro, Dennis Bamford
4. DIVERSITY OF GENE TRANSFER AGENT SEQUENCES IN NATURAL MICROBIAL COMMUNITIES
   Andrew S. Lang, Dawne MacLeod
5. THE EFFECT OF MID-OCEAN EXCHANGE ON THE ABUNDANCE OF VIRUS-LIKE PARTICLES IN BALLAST WATER
   Janice E. Lawrence, Jonas Leichsenring
6. LARGE-SCALE PATTERNS OF PROKARYOTES AND VIRUSES IN THE ATLANTIC AND ARCTIC OCEAN
   Christian Winter, Curtis A. Suttle
7. FATEFUL ENCOUNTER OF VIROLOGY AND DIATOMOLOGY
   Yuji Tomaru, Yoko Shirai, Yoshitake Takao, Hiroyuki Mizumoto, Hidekazu Suzuki, Tamotsu Nagumo, Keizo Nagasaki
8. FIRST ISOLATION OF A CRYPTOPHYTE-INFECTING VIRUS, TAV (*TELEAULAX AMPHIOXEIA* VIRUS)
   Keizo Nagasaki, Jin-Joo Kim, Yuji Tomaru, Satoshi Nagai
9. PHAGES AND ALGAL VIRUSES IN THE BRAZILIAN AMAZON
   Manuela V. Gimenes, Jonas José Kisieliuy, Curtis A. Suttle, Dolores U. Mehnert
10. TEMPORAL AND SPATIAL VARIATIONS IN VIRAL PRODUCTION IN THE CHESAPEAKE BAY
    Danielle M. Winget, Rebekah R. Helton, Kurt E. Williamson, Shellie R. Bench, Kui Wang, Shannon J. Williamson, K. Eric Wommack

11. PHYLOGENETIC CHARACTERIZATION OF VIRUS GENES ENCODING TRANSLATIONAL COMPONENTS IN *CAFETERIA SP*. VIRUSES: FAST SUBSTITUTION RATE SUGGESTS A POSITIVE SELECTION FORCE
    Mang Shi Matthias G. Fischer, Curtis A. Suttle
12. IDENTIFICATION AND CHARACTERIZATION OF THE PUTATIVE COAT PROTEIN GENE IN CHAETOCEROS SALSUGINEUM NUCLEAR INCLUSION VIRUS
    Yunjung Park, Yuji Tomaru, Kyungyong Lee, Keizo Nagasaki, Tae-Jin Choi
13. CHARACTERIZATION OF HMV-1, A NOVEL PLEOMORPHIC VIRUS INFECTING HALOARCHAEA
    Maija K. Pietilä, Elina Roine, Dennis H. Bamford
14. VIRAL-HOST INTERACTIONS OF PBCV-1 AND *CHLORELLA* NC64A IN VIRAL DNA PACKAGING
    Suzanne L. Rose, James L. Van Etten
15. A TECHNIQUE FOR DETECTING CHIMERAS IN PYROSEQUENCING DATA
    Anna L. Chu and Curtis A. Suttle

APPENDIX III: SCOR WG 126 PUBLICATION IN THE ISME JOURNAL

The ISME Journal (2008) 2, 575–578 & 2008 International Society for Microbial Ecology

COMMENTARY

Global-scale processes with a nanoscale drive: the role of marine viruses

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Viruses, the smallest and most numerous of all biotic agents, represent the planet's largest pool of genetic diversity. The sheer abundance of oceanic viruses results in B10^{29} viral infections per day, causing the release of 10^{8}–10^{9} tonnes of carbon per day from the biological pool (Suttle, 2007). Still, how and to what extent virus-mediated nanoscale processes are linked to global-scale biodiversity and biogeochemistry is poorly defined.

Recently, two international panels—the EURopean network of excellence for OCean Ecosystem ANalysis (EUR-OCEANS) Marine Virus Workshop and the Scientific Committee for Oceanographic Research working group on marine viruses (SCOR WG126) brought together international scientists to focus on these issues and to identify future directions in marine virus research by defining important questions (EUR-OCEANS) and potential practical approaches (SCOR). The present commentary highlights open questions in marine viral ecology and illustrates how fusions between (meta)genomics and geochemistry may decipher the role of viruses in global-scale processes.

Viruses and marine biogeochemistry

A notable indication of the poor connection between viruses and biogeochemistry is that viral-mediated processes are ignored in most oceanic carbon flux models. While marine biogeochemical pools are relatively well quantified, the actual rates of viral-mediated carbon and nutrient regeneration on short (daily) time scales remain largely unknown (Suttle, 2007). The biogeochemical consequence of viral lysis is the diversion of carbon away from the classical food web toward microbe-mediated recycling processes (Figure 1). One predicted impact of this viral activity is increased net respiration, which decreases the production/respiration ratio of the ocean. By shunting biotic carbon toward the release of dissolved organic matter (DOM), viruses also accelerate the recycling of potentially growth-limiting nutrient elements in the photic zone (Gobler et al., 1997). Thus, a critical question is whether viruses hinder or stimulate biological production?

Both grazing and virus-mediated cell mortality regenerate nutrients but differences in the resulting physical (size classes of organic material) and chemical (organic or inorganic) speciation of released elements will ultimately regulate community diversity and productivity (Figure 1). Redistribution of nutrients to more organic species (by viral lysis) relative to inorganic forms (excretion by grazers) may also shift the competitive equilibrium for growth-limiting nutrients between phytoplankton and bacteria. Changes in nutrient availability (which is a combination of concentration and chemical speciation) can have large consequences for the rates of carbon accumulation in the photic zone, its release as CO_2 to the atmosphere or vertical export to the deep oceans.

From a biogeochemical perspective (Figure 1), there is an ongoing debate whether viruses (1) short-circuit the biological pump by releasing elements back to the dissolved phase (Poorvin et al., 2004), (2) prime the biological pump by accelerating host export from the euphotic zone (Lawrence and Suttle, 2004) or (3) drive particle aggregation and transfer of carbon into the deep sea through the release of sticky colloidal cellular components during viral lysis (Mari et al., 2005). Moreover, in a potential resolution to Hutchinson's 'The paradox of the plankton' (Hutchinson, 1961), current models predict that viruses can support the coexistence of organisms with parallel pathways for similar biochemical functions (Thingstad, 2000). By sustaining multiple species with similar or identical pathways, viruses can contribute to the resilience of ecosystems.

Moving forward: the fusion of biogeochemistry and genomics

Movement beyond lab-based studies requires tools that can dissect the traditional 'black box,' which is the structure and function of the microbial community. That microbial diversity and biogeochemistry are both affected by viral-induced mortality, and substrate transformation remains an important scientific issue that the oceanographic community needs to address (Figure 1). This is one area where viral ecology, biodiversity, biogeochemistry and genomics are coming together. Combining molecular techniques (for example, molecular probes and viral gene expression) targeting specific viruses and host ecotypes that perform discrete biogeochemical functions with lysis product labeling will allow researchers to separate the effects of mortality (production loss) from the release of nutrients during cell lysis and subsequent assimilation (production stimulation).

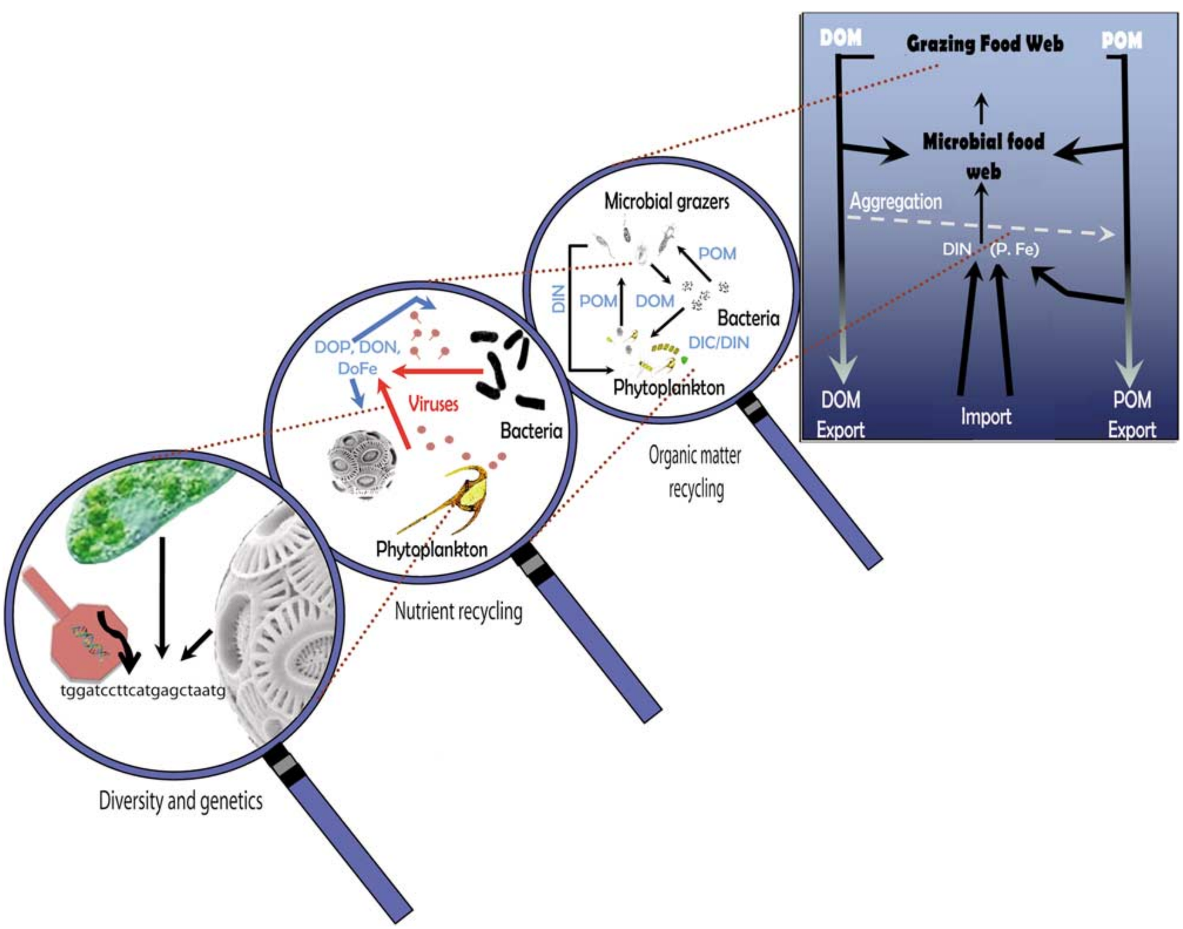

Figure 1 Schematic representation of the marine microbial food web illustrating ecological relevant processes influenced by viral activity and where important research questions remain unanswered. DOM, dissolved organic matter.

Recent developments in the application of (meta)genomic tools are also revealing a wealth of information concerning the overall scale of the viral genetic reservoir (Angly et al., 2006; Culley et al., 2006). The key question that remains is how the physiological functions encoded within viral genomes (viromes) influence biogeochemical cycles (Figure 1)? While individual viral genes are being identified that can influence carbon cycling (Sullivan et al., 2005), the blueprint for the role of viruses within biogeochemical cycles lies within burgeoning virioplankton metagenomic data sets. Reading this blueprint (deciphering metaviromes) is among the greatest challenges in understanding the role of viruses on global scales. As with the genomic sequencing of isolated viruses, novel or unidentifiable genes (not found in genomic databases) are compounded by uncertainty in recognizing genes (gene modeling) within viral sequence data. Despite the extraordinary diversity within metavirome data (Angly et al., 2006), it appears that a wide range of marine environments contain very few key viral genotypes, as exemplified by the abundant homologs of a single cyanophage P-SSM2. Thus, it is possible that a suite of evolutionarily related functions dominate the viral genomic space. Ultimately, new insight from growing genetic and functional data sets will form the foundation for the geochemical tools of the future.

Unraveling the connections between marine viruses and biogeochemistry will also depend upon communication between investigators within disparate disciplines. The development of new principles in viral biology and biogeochemistry can be certainly facilitated by the investigation of environmentally relevant marine virus–host systems. A critical component will be recovery of both the virus and host genomic sequence and to integrate gene expression within environmental studies. Other new tools include quantitative reverse transcription–PCR, which allows accurate measurement of messenger RNA and, thus potentially, the expression of genes that may be critical points of control in the flow of nutrient elements in the biosphere. In addition, metaproteomics should emerge as a valuable component of this research, and allow for a determination of how viral proteins influence host cell physiology and subsequently ecosystem scale processes.

Into the future

Modeling the role of viruses in biogeochemical cycles is currently difficult because of a dearth of data and our rudimentary conceptual models of virus–host interactions. As biogeochemical influences of viral infection are a property of the collection of virus–host interactions, aspects of virus–host biology need to be recognized as an important component of nutrient cycling and energy flow within oceanic ecosystems. Although a young research field, aquatic viral ecology will no doubt play an important role as we resolve the effect(s) of climate and anthropogenic forcing on the food-web dynamics (structure, functioning, diversity and stability) of pelagic ecosystems.

Much in the field of viral ecology remains unknown—indeed, there is still a dispute whether viruses themselves are a life-form or not. Current understanding implies, however, that the effect viruses have on organisms (either directly through infection or indirectly through biogeochemical cycling) makes them the ultimate nanoscale drivers/regulators of life. We foresee that the combined approach of viral ecology, biogeochemical measurements, (meta)genomics and modeling will enable elucidation of the emerging role of viruses in the biodiversity and biogeochemistry of our planet.

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2.2.7 SCOR/IAPSO WG 127: Thermodynamics and Equation of State of Seawater (2005)

Terms of Reference:

- To examine the results of recent research in ocean thermodynamics with a view to recommending a change to the internationally recommended algorithms for evaluating density and related quantities (including enthalpy, entropy and potential temperature). Such recommendations would take into account the reformulation of the International Temperature Scale (ITS-90).
- To examine the most accurate recent knowledge of the freezing temperature of seawater, the calculation of dissolved oxygen, and the behaviour of seawater at high salinity.
- To examine the feasibility of using simple functions of three-dimensional space to take account of the spatially varying concentrations of alkalinity, total carbon dioxide, calcium and silica place on the determination of density in the ocean.
- To extend these concepts to a wider range of physical/chemical issues of relevance to the internal working of the ocean and of its interaction with the atmosphere and to present and potential future observational techniques.
- To write a set of related recommendations on the above topics in the form of a report to SCOR/IAPSO and a review or series of reviews to be published in the scientific literature.

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Executive Committee Reporter: Lawrence Mysak

SCOR/IAPSO WG 127 on the Thermodynamics and Equation of State of Seawater

Progress Report to SCOR, July 2008

1. Working Group Meetings

SCOR/IAPSO WG127 was approved in 2005, had its first meeting at Warnemünde in May 2006, and its second meeting at Reggio, Italy in May 2007. The thrid (and possibly final) meeting is planned for 3-9 September 2008 in Berlin. The second meeting in May 2007 was attended by all Full Members except Valentina Gramm-Osipova. We expect the same members to attend the third WG meeting in Berlin in September 2008.

2. Requests to SCOR concerning membership or terms of reference

There are no requests for changes in membership or terms of reference at this time.

3. Activities between working group meetings

Many of the issues on our agenda are being pursued by individual members, and by subcommittees of WG127, and we expect substantial progress on many issues between meetings of the Working Group.

4. Next Working Group Meeting

The next meeting of the working group is planned for 4-10 September 2008 in Berlin. This meeting will consist of four days of exclusively WG127 meeting, followed by a day (a Sunday) in which members of WG127 will be observers at the executive meeting of IAPWS (the International Association of the Properties of Water and Steam). During this Sunday meeting we expect IAPWS to officially bless our saline Gibbs function, and release it as the Release IAPWS-08. On the following day (Monday, 8 September 2008) this saline Gibbs function developed by WG127 will be announced by IAPWS in a plenary public meeting and in the afternoon WG127 will meet with the executive director of IOC and we will finalize plans to have our work adopted as the standard oceanographic practice by all member nations of IOC. The next day (Tuesday 9 September) most members of WG127 will present scientific talks at the IAPWS symposium in Berlin. Dr Petra Spitzer and Dr Rainer Feistel of our Working Group are acting as local hosts for the WG127 meeting in Berlin.

If things go as we envisage, this third meeting of WG127 should be the last meeting that is needed of the full working group. One of us will need to attend the IOC General Assembly in June 2009 at which the member nations of IOC are expected to adopt the results of WG127 as recommended standard oceanographic practice in each of these countries. Given this schedule, the date on which journals should be expected to begin publishing in terms of Absolute Salinity is 1 January 2010. Hence we imagine that calendar 2009 will be another year of intense activity for WG127 as we assist the oceanographic world to implement the new approach via computer algorithms, advice and publications, manuals etc.

Beyond that, there are several aspects of the properties of seawater that remain in an unfinished state. For example, we believe that there is unrealized promise in accurate measurement of the refractive index of seawater. Such accurate refractive index measurement may be a valuable way of determining the difference between Absolute Salinity and Reference Salinity. We have also not yet addressed the issue of the saturation of seawater, when different salts come out of solution at high concentrations and low temperatures. While these issues are additional to the main thrust of the present WG127's main deliverables, they do pertain to the on-going need to fully charaterise the physical properties of seawater. We would like to explore with SCOR the possibility of an on-going affiliation with SCOR of a more durable and smaller Working Group or Study Group for this purpose

Quite apart from these additional tasks, we need to continue working intensively on the computer codes that implement our findings until about the middle of 2009, and the preparation of manuscripts regarding this work will continue through all of calendar 2009. Given that oceanographic practice will probably be changed to the new thermodynamics on 1 January 2010, we request that WG127 continue in its present form until 30 June 2010 so as to be a source of advice regarding the introduction of this new standard. This will also allow WG127 to act as a source of advice to SCOR, IAPSO and IOC on any issues that may arise concerning the practical implementation of the results of our existing activities.

5. Assessment of Progress

As of July 2008 WG127 has reached the point of having finalized the new definition of salinity (Absolute Salinity, publication #11 below), and of the saline Gibbs function (publications #2 and #7 below). When added to the existing official thermodynamic definitions of pure water substance (publication #5 below) and of ice (publication #6 below), the thermodynamic description of seawater is complete. In a real sense, the academic work required to address WG127's main objectives is virtually complete. The work remaining in order for WG127 to achieve its main goals is

(i) to document its work in a way that will assist oceanographers to adopt these advances,
(ii) to finalize the science and the algorithm that we recommend for the calculation of Absolute Salinity (reference #13, following on from #12)
(iii) to write, test and describe suitable sets of computer algorithms that implement the new seawater thermodynamics,
(iv) to assist IOC in the process of having all its member nations adopt the new practices for evaluating the thermodynamic properties of seawater, and
(v) to assist and guide the oceanographic community leading up to the anticipated change in oceanographic practice on 1st January 2010.

Regarding point (iv) above we expect that IOC will establish an Evaluation Committee in the coming weeks whose task will be

a. to read what WG127 is recommending as the new thermodynamic definition of seawater,
b. to decide whether the Absolute Salinity that WG127 is advocating is valid and appropriate,
c. to be cognisant of what IAPWS have already blessed through their official Release process,
d. to decide whether the changes to oceanographic practice that WG127 are recommending are actually, on balance, worthwhile for the whole oceanographic community to adopt, and
e. to write a report to IOC for distribution to its member nations recommending the adoption of the new thermodynamic description of salinity and of seawater.

In summary, WG127 has been working hard over the past year, and we expect to be also running very fast in the coming year. It is encouraging to see many of our efforts maturing and to be well along the path to adoption.

Trevor J McDougall
Chair, SCOR/IAPSO Working Group 127

References

Note that of these 13 references all but #5 have been written by members of the SCOR/IAPWS WG127 (although the two IAPSO publications, #6 and #7, are not officially authored by individuals but by IAPWS itself). Four of the above publications were written prior to the formation of the Working Group; the remainder have arisen out of our on-going activities in WG127. Publications #5, #6 and #7 are the official thermodynamic descriptions of water vapour, liquid water, ice and seawater. The key papers that underlie the seawater Release (#7) are the WG127 publications #11 and #2. To use the new thermodynamic description of seawater one first needs to calculate Absolute Salinity and publications #12 and #13 are the only way of doing so.

1. Feistel, R., 2003. A new extended Gibbs thermodynamic potential of seawater. *Progress in Oceanography*, **58**, 43-114. This paper is an earlier version of paper #2 below.

2. Feistel, R. 2009: A Gibbs Function for Seawater Thermodynamics for −6 °C to 80 °C and Salinity up to 120 g kg^{-1}. *Deep-Sea Research* I, **xx**, yyy-yyy, in press, available from Rainer Feistel at rainer.feistel@io-warnemuende.de and also from the web page http://www.sciencedirect.com/science/journal/09670637 as an article “in press”. This paper is the main science paper that represents the outcomes of WG127. The IAPWS-08 Release (paper #7 below) is the officially released version of this paper.

3. Feistel, R., Feistel, A., Guder, C., Jackett, D.R., Marion, G.M., Overhoff, U., Reissmann, J.H., Tchijov, V., Wagner, W., Wright, D.G., 2009. Numerical Implementation and Oceanographic Application of the Thermodynamic Potentials of Water, Vapour, Ice, and Seawater. *Ocean Science*, in preparation. This paper will be an on-line repository of all of the algorithms in several different computer languages. Many months of work remain to be done on this.

4. Feistel, R., D. G. Wright, K. Miyagawa, A. H. Harvey, J. Hruby, D. R. Jackett, T. J. McDougall and W. Wagner, 2009: Development of thermodynamic potentials for fluid water, ice and seawater: A new standard for oceanography. submitted to *Ocean Science* (and firstly to OSD). This manuacript is now "published" in *Ocean Science Discussions* and is available at http://www.ocean-sci-discuss.net/5/375/2008/osd-5-375-2008.html . This paper describes how the three different thermodynamic potentials of freshwater, ice Ih and the saline Gibbs function were made to be mutually self consistent. The paper lists the values of several key constants to twenty significant figures, and also many check values of the thermodynamic functions so that both double-precision and quadruple-precision numerical implementations can be unambiguously checked.

5. IAPWS, 1996. Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. The International Association for the Properties of Water and Steam. Fredericia, Denmark, September 1996. Internet: http://www.iapws.org/relguide/IAPWS95.pdf This is THE thermodynamic description of pure liquid water and pure water vapour. For good thermodynamic reasons it is in the form of a Helmholtz function (which has in situ density as one of its independent variables), which is a little inconvenient for oceanographic use. The paper Feistel (2003) [Ref #1] provides an alternative formulation for freshwater which oceanographers will mostly find more convenient, namely a Gibbs function of freshwater where the independent variables are the measured variables (salinity) temperature and pressure.

6. IAPWS, 2006. Release on an Equation of State for H2O Ice Ih. The International Association for the Properties of Water and Steam. Witney, UK, September 2006. Internet: http://www.iapws.org/relguide/Ice.pdf . This is THE thermodynamic description of the properties of ice Ih. It is the official IAPWS release based on the published research of Feistel and Wagner (2006). Ice Ih is the type of ice that is found in the oceanographic ranges of temperature and pressure.

7. IAPWS, 2008. Release on the IAPWS Formulation 2008 for the Thermodynamic Properties of Seawater. Berlin, Germany, September 2008, to be adopted, available from Rainer Feistel at rainer.feistel@io-warnemuende.de . This is THE thermodynamic description of the saline Gibbs function, that is, the difference between the Gibbs function of seawater and the Gibbs function of freshwater. This is the officially checked Release of Feistel (2009), Ref #2.

8. Jackett, D. R., T. J. McDougall, R. Feistel, D. G. Wright and S. M. Griffies, 2006: Algorithms for density, potential temperature, conservative temperature and freezing temperature of seawater. *Journal of Atmospheric and Oceanic Technology,* **23**, 1709-1728.

This paper is based on an older version of the Gibbs function of seawater. Ref #10 will be similar to this paper in that will provide an entry point for oceanographers to the work of WG127 and will summarize the increase in accuracy that comes from adopting the work of WG127.

9. McDougall, T. J., D. R. Jackett, D. G. Wright and R. Feistel 2003: Accurate and computationally efficient algorithms for potential temperature and density of seawater. *Journal of Atmospheric and Oceanic Technology,* **20**, 730-741. This paper was based on an earlier version of the seawater Gibbs function. Ref #10 will be similar to this paper in that it will provide an entry point for oceanographers to the work of WG127 and will summarize the increase in accuracy that comes from adopting the work of WG127.

10. McDougall, T J, R Feistel, D R Jackett, B A King, G M Marion, F J Millero and D G Wright, 2009: Oceanographic application of the Gibbs function 2008 of seawater. To be written. For publication in *Deep-Sea Research I*. This paper will provide an entry point for oceanographers to the work of WG127 and will summarize the increase in accuracy that comes from adopting the work of WG127. It will outline what is recommended for the storage and use of salinity.

11. Millero, F. J., R. Feistel, D. G. Wright and T. J. McDougall, 2008: The composition of Standard Seawater and the definition of the Reference-Composition Salinity Scale. *Deep-Sea Research* I, **55**, 50-72. also available from Frank Millero at fmillero@rsmas.miami.edu. This paper provides the rationale for the new definition of salinity, Absolute Salinity. To do so, the paper defines the composition of standard- or reference-seawater.

12. Millero, F. J., J. Waters, R Woosley, F. Huang and M. Chanson, 2008: The effect of composition of the density of Indian Ocean waters. *Deep-Sea Research I*, **55**, 460-470. also available from Frank Millero at fmillero@rsmas.miami.edu . This paper is the first to propose a practical expression for evaluating Absolute Salinity in terms of measured variables.

13. Millero, F. J., and unspecified co-authors, 2009: The effect of composition of the density and salinity in the global ocean. To be written by late 2008(?) *Deep-Sea Research I*, **xx**, yyy-yyy. This paper will provide an update to Ref #12, based on data from all the worlds' major ocean basins.

From 2008 IOC Executive Council Meeting:

I-GOOS Chair's report included:
In September 2008 the SCOR–IAPSO Scientific Working Group 127 on "Thermodynamics and Equation of State of Seawater" will complete its work and a peer-reviewed update to the thermodynamic potential of standard seawater will be available to the oceanographic community for the first time since the currently used UNESCO standard (Fofonoff and Millard, UNESCO 1983: *Algorithms for computation of fundamental properties of seawater*, UNESCO technical papers in marine science, 44) was universally adopted. The 25th Session of the IOC Assembly in

2009 will provide an opportunity to renew IOC's role as an international standard-setting body for oceanography, and for its 137 Member States to formally resolve to adopt the new standard.

Member State response report included:
Member States strongly supported presenting the Resolution concerning the SCOR–IAPSO Scientific Working Group 127 on "Thermodynamics and Equation of State of Seawater", to the 25th Session of the Assembly for its adoption as a universal standard.

Operative/Decision paragraph included:
The Executive Council **reaffirmed** IOC's commitment and **instructed** the Executive Secretary to work with the SCOR–IAPSO Scientific Working Group 127 with a view to presenting to the Assembly, at its 25th Session, the new Equation of State of Seawater, and to inviting the Assembly to adopt a Resolution to formally adopt this new standard.

2.2.8 WG 128: Natural and Human-Induced Hypoxia and Consequences for Coastal Areas (2005)

Terms of Reference:

- Synthesize the state of the science for the following aspects of coastal hypoxia:
  - prevalence and spatio-temporal variability,
  - natural and human causes,
  - effects on the biogeochemistry and ecology, and
  - resistance, resilience and recovery of ecosystems.
- Identify gaps in our understanding of hypoxia and make recommendations for future research;
- Determine the requirements for observing and modeling hypoxia and its impacts in coastal systems; and
- Document the work of the group in a special issue of a peer-reviewed international journal or a book by a major world publisher.

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Executive Committee Reporter: Robert Duce

Natural and Human-Induced Hypoxia and Consequences for Coastal Areas: Current Status

Annual Report – 2007/2008

1. Introduction
WG#128 was officially approved in August 2005. The first meeting of this Working Group was organized at Vienna, Austria on April 6-7, 2006, and coincided with the EGU Annual Assembly. During the Vienna Meeting, members of WG#128 revised the terms of reference of the group, discussed possible activities between the first and second WG meetings, final results to be expected from this Working Group, and the plan for its second meeting in 2007.

The second meeting of WG#128 was held 22-23 September 2007 at Shanghai, China, and coincided with the IMBER/LOICZ Open Science Conference on Continental Margins: "Impacts of Global, Local and Human Forcings on Biogeochemical Cycles and Ecosystems". During the Shanghai Meeting, members of WG#128 reported their progress on the preparation of syntheses that are related to the terms of reference of this SCOR Working Group through oral presentations and discussion, and then the preliminary list of synthesis papers was revised.

2. Activities since January 2007
Activities of WG#128 were mostly undertaken by e-mail among WG members, long-distance phone calls, and occasional simultaneous participation of several WG members to international conferences (e.g. PACKMEDS at Delmenhorst/Germany in 1-6 April 2007, and 4th IGBP Congress at Cape Town, South Africa in 5-9 May 2008). The outcomes of the second WG#128 Meeting at Shanghai in 22-23 September 2007 include

- revising the list of synthesis papers to summarize the work done by this working group,
- planning use of the web-site created by the LOICZ International Project Office (IPO) for the working group to sharing the references and posting the draft manuscripts for synthesis work,
- identifying contributions to other organizations (e.g., meetings and other activities) from members of WG#128 (e.g. Las Palmas Conference in Spain), and
- discussing the venue and time for the third WG meeting and final products of this group.

With regard to the third meeting of this Working Group, several suggestions were made during the Shanghai meeting. However, there is no decision made on the venue and time of the third and final meeting at this time.

3. Final results of WG#128
The major activity for this Working Group after its second meeting, in Shanghai, has been to prepare the manuscripts of synthesis papers. The preliminary list of 14 synthesis papers was discussed and revised during the Shanghai meeting. New contributions from WG#128 members were also considered and finally 12 titles were proposed, together with the names of lead authors (see below). Scientists from the broader scientific community were also approached and invited to participate in the synthesis work of the group and to contribute as co-authors of synthesis papers

led by members of WG#128. During this second WG#128 meeting, there was agreement to publish these synthesis papers in an EGU open-access journal such as *Biogeosciences*, although special issues of other oceanographic journals were also discussed as possible outlets for the papers. Later, when the first paper on historical records of hypoxia led by Dr. Andy Gooday was getting close to completion in May 2008, it was realized that publication of a special issue in *Biogeosciences* would be far too costly for the WG to fund. We have discussed page charges with the editorial office of *Biogeosciences* and efforts have been made to obtain extra financial support from other sources. However, these initiatives may not solve the problem of covering the publication costs for 12 papers in total. The Working Group is currently investigating the possibility of publishing a special issue on coastal hypoxia and its consequences in other international journals, for example, *Progress in Oceanography* and *Journal of Marine Systems*.

As for the progress of manuscript preparations, the latest information (as of July 2008) about the probable date of completion of synthesis papers is given below:

July 2008
Historical record of hypoxia from sediment proxies (Leading author: Andy Gooday)

August 2008
Effects of hypoxia on nekton and plankton (Leading author: Werner Ekau)
Benthic biological response to coastal hypoxia: comparison of natural versus human-induced hypoxia (Leading author: Lisa Levin)
Shelf hypoxia driven by open ocean boundary climate variability (Leading author: Pedro Monteiro)
Pelagic microbial communities and biogeochemical cycling (Leading author: Osvaldo Ulloa)

September 2008
Hypoxia effects on the benthic-pelagic coupling (Leading author: Jack Middelburg)
Global oxygen trends in the coastal ocean (Leading author: Denis Gilbert)
Dynamics and distribution of natural and human-induced coastal hypoxia (Leading author: Nancy Rabalais)

October 2008
None

November 2008
Modeling of hypoxia/anoxia (Leading author: Angelica Peña)
Overall summary (Leading author: Jing Zhang)

Unknown submission date
Hypoxia/anoxia as a source of N_2O and CH_4 greenhouse gases (Leading author: Wajih Naqvi)
Recovery following remediation efforts (Leading author: Mike Kemp)

It was suggested that the leading authors of synthesis papers post their draft manuscripts on the WG#128 web-site in September 2008, which would allow Working Group members to contribute and revise the manuscripts. Posting the draft manuscripts on the web-site will also help the internal review process that needs to be performed prior to final submission. Starting from April 2008, structures and/or draft materials for synthesis manuscripts for this Working Group have been circulated among WG members, as well as co-authors outside the group.

4. Web site of WG#128

A web-site (http://kopc01.gkss.de:8080/LOICZWG128Wiki/Wiki.jsp) for SCOR WG#128 has been created with the help of the LOICZ IPO through Nancy Rabalais, LOICZ SSC Vice-chair, to help establish the cross-link between the two organizations since early 2007. The idea is to have a joint facility for sharing the references of WG#128 and to have a password-enabled Web site that WG members can use for circulation of manuscripts and open discussion on WG-related activities. With help from the LOICZ IPO, information of this Working Group is cross-linked with the LOICZ Web site, which is highly appreciated by this WG. This is considered to be an active, dynamic link between SCOR WG#128 and LOICZ. With ID and passwords provided by LOICZ, every WG member can upload their synthesis manuscripts and/or check with papers led by other WG members. We take this opportunity to acknowledge once again the support that LOICZ has provided in establishing and maintaining this Web site.

5. Shanghai meeting in September 2007

On 17-21 September 2007, the IMBER/LOICZ Continental Margins Open Science Conference was held at East China Normal University, China with two full members, namely Nancy Rabalais and Jack Middelburg, as co-conveners. The co-chairs of SCOR WG#128 chaired a session entitled: "Low Oxygen on Continental Shelves" (i.e., Section No. S7), during which 6 oral presentations were delivered by members of this Working Group plus 5 talks by scientists from outside WG#128 (Annex 1).

The second meeting of SCOR WG#128 was held on 22-23 September 2007, immediately after the IMBER/LOICZ meeting and at the same venue. Eleven members and 4-5 additional experts from outside the WG, (including Angelica Peña, who was later approved by SCOR as an Associate Member) attended the meeting.. During the first morning, presentations were given on the papers that were agreed upon at the Vienna meeting in April 2006. In total, 9 presentations were made by WG members on their progress in preparing background material for the synthesis manuscripts. This was followed in the afternoon and the next morning by discussions on overlaps and possible synergies between papers (Annex 2). Finally, the meeting was closed by discussing the upcoming European Union FP7 call for proposals on oxygen monitoring and research in the ocean.

6. Other activities of WG#128

Contribution to other international conferences and organizations by this SCOR WG#128 include

- PACKMEDS (a chapter by Nancy Rabalais and Denis Gilbert on hypoxia)
- 4th IGBP Congress at Cape Town (5-9 May 2008)
- Eastern Boundary Upwelling Systems workshop (Pedro Monteiro, Lisa Levin, Werner Ekau and Angelica Peña) – 2-6 June 2008

a. Contribution to PACKMEDS: Rapid Assessment of Semi-Enclosed Marine Systems
Members of WG#128 were actively involved in the SCOPE-IAPSO-SCOR PACKMEDS workshop at Delmenhorst, Germany in 1-6 April 2007. A total of nine members from WG #128 (i.e. Denis Gilbert, Elva Escobar, Jack Middelburg, Jing Zhang, Nancy Rabalais, Temel Oguz, Wajih Naqvi, Venu Ittekkot and Werner Ekau) were invited to participate in this PACKMEDS Delmenhorst Workshop. The steering committee of PACKMEDS included Venu Ittekkot, Jack Middelburg, Temel Oguz, Wajih Naqvi and Jing Zhang, all WG #128 members, while Nancy Rabalais and Denis Gilbert from WG#128 were leading authors for a chapter dealing with hypoxia problems in semi-enclosed marine systems, which is very relevant to the TORs of this Working Group.

b. 4th IGBP Congress at Cape Town
Several members of this Working Group (Pedro Monteiro, Nancy Rabalais, Osvaldo Ulloa, Jing Zhang) attended the 4th IGBP Congress at Cape Town in 5-9 May 2008 and the previous meetings for IGBP Core Projects (i.e. LOICZ, SOLAS and IMBER). At this meeting, the poster by Nancy Rabalais on “Hypoxia in the Northern Gulf of Mexico” received the award of best poster of the conference. Congratulations to Nancy!

During the 4th IGBP Congress at Cape Town, Cisco Werner and Jing Zhang hosted a session on: “Biogeochemistry and Food Web Interactions along Continental Margins: Forcing and Feedbacks of Carbon Cycle in Land-Atmosphere-Ocean Systems” (i.e., Session B3). The themes for round-table discussion in this session included the role of marginal seas in ocean carbon cycling, efficiency of the “continental shelf pump” in present and past oceans, biogeochemistry in the evolution of ecosystem structures in continental margin environments, and coastal hypoxia and its role in global change. All of these topics are relevant to the TORs of this Working Group. Around 25 participants were involved in the presentations and the general discussion in this session.

c. Eastern Boundary Upewlling Systems workshop (Pedro Monteiro, Lisa Levin, Werner Ekau and Angelica Peña)

7. Links with other international programs
Communication of our activities to other scientific groups should be maintained to help move forward the study of coastal hypoxia and to establish partnerships with SCOR WG#128:

IMBER (Jing Zhang, Jack Middelburg, Wajih Naqvi)	GEOHAB (Pedro Monteiro)
LOICZ (Nancy Rabalais)	SCOPE (Venu Ittekkot)
GLOBEC (Werner Ekau, Anja van der Plas)	Argo (Denis Gilbert, Osvaldo Ulloa)
SOLAS (Osvaldo Ulloa)	IOC/WESTPAC (Jing Zhang)
VOCALS-Rex (Boris Dewitte)	

Additional international program links may potentially include

Census of Marine Life - COMARGE/CHESS (Lisa Levin) - link to OMZ;

8. Completion of the Working Group Activities

The major task at this time is to prepare for the draft manuscripts for the Hypoxia Special Issue, as this is the key final product of this Working Group. The first manuscript lead by Andy Gooday for the special issue will be ready for submission shortly in July 2008. As can be seen in section 3, leading authors for the proposed manuscripts have identified a target time of paper submission. The time and location of the third and final meeting remain to be decided.

Annex 1. Program of Section 7 for the IGBP-IMBER/LOICZ Open Science Conference on Continental Margins.

Programme

DAY 5 - Friday 21st

Yifu Building (Exchange Center)

	S7 - Low Oxygen on Continental Shelves
08:30 - 09:00	**Pedro Scheel Monteiro:** *A global review on the role of ocean – Shelf exchange in driving coastal hypoxia variability and long term change*
09:00 - 09:15	**Nancy Rabalais:** *Dynamics and distribution of natural and human-induced coastal hypoxia*
09:15 - 09:30	**Frans Jorissen:** *Benthic foraminiferal rsponse to natural and human-induced hypoxia*
09:30 - 09:45	**Jing Lin:** *Mechanisms of dissolved oxygen stratification in micro-tidal partically-mixed estuaries*
09:45 - 10:00	**Lisa Levin:** *Oxygen minimum zone influence on benthic shelf processes: A global comparison*
10:00 - 10:15	**Kit Yee Chong:** *Spring – neap tidal cycle on bottom do dynamics: implication of hypoxia formation*
10:15 - 10:30	**Denis Gilbert:** *Global oxygen trends in the coastal ocean*
10:30 - 11:00	Coffee break
11:00 - 11:15	**Ying Wu:** *Seasonal and spatial variability in the coupling of organic carbon and dissolved oxygen in the water of the Changjiang estuary*
11:15 - 11:30	**Mary Scranton:** *Cross-shelf processes as primary sources of oxidants and reductants to the suboxic zone in the Cariaco Basin*
11:30 - 11:45	**Jack Middelburg:** *Ecosystem function losses following defaunation of sediments*
11:45 - 12:00	**Qingji Li:** *A process study on the seasonal hypoxia adjacent to the Changjiang estuary: Possible effects of episodic storm events*
12:00 - 12:15	**Kateryna Ivanova:** *Marine meiobenthos under hypoxia treatment: laboratory microcosm experiment*
12:15 - 12:30	**Osvaldo Ulloa:** *Microbial communities within hypoxic zones*
12:30 - 14:00	Lunch
14:00 - 15:30	**Implementation discussion** - Science Tower A
15:30 - 15:45	**Conclusion** - Science Tower A
15:45 - 16:15	Coffee break

Annex 2. SCOR working group 128 on coastal hypoxia.
Minutes of second meeting, September 22-23, 2007
State Key Laboratory of Estuarine and Coastal Research
East China Normal University, Shanghai, China

WG members attending	Not attending
Werner Ekau	Boris DeWitte
Denis Gilbert	Ragnar Elmgren
Andy Gooday	Elva Escobar
Venu Ittekkot	Michael Kemp
Lisa Levin	Wajih Naqvi
Jack Middelburg	Temel Oguz
Pedro Monteiro	Silvio Pantoja
Nancy Rabalais	Anja van der Plas
Mary Scranton	
Osvaldo Ulloa	
Jing Zhang	

Also attending
K.K. Liu
Frans Jorissen
Angelica Peña
Ed Urban

Saturday, 22 September, 2007
Appointment of meeting **rapporteur**: Venu Ittekkot kindly accepts to take notes of discussions during the meeting. Post-editing done by Denis Gilbert and Jing Zhang.
To open the meeting, on behalf of co-chairs, Denis Gilbert welcomes SCOR WG#128 members and other participants. Then participants are asked to introduce themselves by giving their name, affiliation and main research interests.
Denis Gilbert states the main objectives of the two-day meeting. The first morning will allow us to hear presentations on the papers that were agreed upon at the Vienna meeting in April 2006. This will be followed in the afternoon and the next morning by discussions on overlaps and possible synergies between papers. Finally, we will close the meeting by discussing the upcoming European Union FP7 call for proposals on oxygen monitoring and research in the ocean.

Discussions arising from the presentations of paper outlines
Dynamics and distribution of natural and human-induced coastal hypoxia (Nancy Rabalais)
Nancy asks if she should be dealing with estuaries, or restrict her attention to the coastal oceans. Lisa Levin says that we need to include estuaries, especially because estuaries are considered as important recruiting areas for the fisheries.

Discussion of hypoxia definitions
Nancy lists about a dozen possible definitions of hypoxia and anoxia. Lisa Levin makes the point that we need to clarify our technical terms (hypoxia, anoxia, suboxia). Perhaps we should use the results of the discussion in Concepcion?
Action item – Osvaldo Ulloa will verify if a text arose from the discussion on definitions of hypoxia, suboxia and anoxia in Concepcion (October 2006 OMZ meeting). If so, circulate this text to all members of the working group.
Action item – Jing Zhang and Denis Gilbert should define the terms hypoxia, suboxia and anoxia in the 1-2 page introduction of the special issue of *Biogeosciences.* The context in which those definitions are being used should be made clear. This **introduction paper** should also include the terms of reference of SCOR WG 128 and a list of the activities undertaken by this working group (Vienna 2006, Shanghai 2007, third venue in 2009).
Question: Shall we reach agreement on definitions of hypoxia/suboxia/anoxia right now for this WG, so people will use the same definition in their papers?
With regard to the OMZ, point out in the paper that we focus mainly on the upper part of the OMZ (roughly speaking, depths less than 200m).
Include a table describing the spatial and temporal scales of hypoxia.
Describe the processes that lead to hypoxia (carbon production/accumulation), eutrophication.
Physical requirements for hypoxia: long residence times, stratification, basically weak resupply of oxygen.
Changes in boundary conditions affecting hypoxia-ocean currents were described in volume 13 of The Sea, Chapter 21 and in *Ambio*. (Check this)
Nancy asks if she should write about changing Si/N ratio? Do we need this? Denis and other said yes.
Jack Middelburg points out that in the global project NEWS, a map of potential hypoxia was presented. Compare this map with the Diaz map of current hypoxic areas.
There was a long discussion about the relevance of including (or not) the hypoxia coverage map from Diaz. For example, it's not clear why he included in his compilation a subarea of the Gulf of St. Lawrence where oxygen does not drop below 50% saturation. Jing points out that if our WG uses a definition of hypoxia that is different from Diaz, then it would be necessary to have a new map of hypoxic sites.

Historical record of hypoxia from sediment proxies (Andy Gooday)
This paper will focus on historical records (decades and centuries from the present to about 2000 years in the past. More explicitly, Andy will not deal with the paleoceanography timescales (interglacial to millions of years).
Temporal resolution of foram hypoxia records is subdecadal (1, 2 or 3 years resolution).
There are only a few subsets of data, mostly from North America and Europe.
The effects of hypoxia and eutrophication are difficult to disentangle from each other with biotic indicators.
Will focus on benthic organisms, including forams, ostracods and juvenile molluscs.
Will also include diatoms, dinoflagellate cysts, seeds of submerged vascular plants.
Lisa Levin then points out it would be preferable to refer to "biotic" indicators of hypoxia rather than "faunal" indicators.
Mary Scranton remarks that there are many environments which have been hypoxic in the past,

and we therefore need long timescales to detect the more recent anthropogenic influences.
Andy answers that the 2000-year long records of hypoxia proxies provide evidence of human impacts, as they often display 1500 years or more of "natural variability", followed by a strong departure from this background variability during the 20th century.
Mary Scranton points out that the present structure of the paper is such that biotic indicators of hypoxia in human-impacted systems appear first, and indicators of hypoxia in natural systems appear second. This sequence should be flipped, that is, the order be reversed. She would also like to see equal weight devoted to systems with natural and human-induced hypoxia.
Other hypoxia proxies considered by Andy include sediment laminations, bacterial pigments, organic carbon and nitrogen, biochemical indicators such as sulphur and sulfides, authigenic minerals, molybdenum and stable isotopes.
A suggestion is made for Andy to provide hypoxia proxy examples from the Gulf of California and the Northwest Shelf of the Black Sea.
Andy mentions the few attempts that have been made to quantify oxygen proxies in terms of oxygen concentration. Most hypoxia proxies are qualitative rather than quantitative.
Proxies of hypoxia are described in Cronin and Vann (2003) *Estuaries* 26, 196-209.
Hydrology – Do time periods with more intense precipitation lead to more frequent and more severe hypoxia?

Global oxygen trends in the coastal ocean (Denis Gilbert)
Denis says he needs to consider the possibility of a publication bias in favour of timeseries with decreasing oxygen because of the negative ecosystem impacts of hypoxia. Timeseries with stable oxygen concentration are hard to publish if this is to be the central focal point of the paper. Given this, Denis will attempt to look for unpublished oxygen datasets as well as published datasets. Monitoring sites with a regular sampling scheme will be the "preferred" datatype for the trends analysis.
Seasonal cycle correction – in some instances, it will be possible to compute the annual cycle and remove it from the observations to compute the interannual oxygen timeseries. In other cases, lack of data during certain months of the year will prevent the computation of the annual cyle. It will then be necessary to select data from a standard period of the year (e.g. month of August or February) to create the oxygen time series.
Bopp et al (2002) predicted oxygen out-gassing from the ocean to the atmosphere as a consequence of global warming. This would occur at a rate roughly 3 times greater than what one would predict from oxygen solubility as a function of temperature and salinity.
Denis wants to answer this question: Are oxygen concentrations on the shelf decreasing at a faster rate than in the open ocean?
Ed Urban asks if it would be possible to publish the original, raw oxygen timeseries in a SCOR or IMBER data report. Denis replies that some of the data providers would object to see their data being publicly available. As an alternative, he will produce a table identifying the data providers (individuals, public database, figure scanned from paper, etc.)
Very shallow (< 5 m deep) eutrophied areas with large diurnal cycles of oxygen, where there can be 200% saturation or more in the daytime and hypoxia/anoxia at night will not be considered in Denis's analysis.
Pedro Monteiro mentions the existence of long-term monitoring oxygen timeseries at these African sites:

1. Congo offshore oxygen time series
2. Congo coastal oxygen time series
3. Angola coastal system: Lobito
4. Cape Columbine

Hypoxia effects on the benthic-pelagic coupling (Jack Middelberg)
Paper will focus on

- diagenetic pathways
- fluxes of nutrients NO_3; NH_4; PO_4
- low oxygen bottom waters rich in nitrate
- chemoautotrophy
- organic matter quantity and quality, burial
- benthos responses
- changing biogeochemistry under hypoxic conditions

Water column biogeochemistry will not be included, but should instead be dealt with in the paper(s) by Osvaldo Ulloa and Wajih Naqvi.
Pelagic biology and its influence on benthic processes will not be included either.

Pelagic microbial communities and biogeochemical cycling (Osvaldo Ulloa)
This is a new chapter, not originally proposed at the Vienna meeting. Osvaldo agreed to write this paper when he met Denis at the Oxygen Minimum Zone (OMZ) symposium in Concepcion, Chile (October 2006).
Paper will focus mainly on water column processes under the influence of the OMZ off Chile and Peru.
However, as this is a synthesis paper, similar distributions of chemicals and microbes in other areas such as the Arabian Sea, Baltic Sea, Black Sea, Benguela and Cariaco Basin should also be included in the paper.
A lot of carbon is fixed in upper part of OMZ. What is the energy source? Possibly a lateral flux of organic matter along isopycnals?
Paper will focus on the nitrogen cycle (anammox, nitrification, denitrification, etc.). It will not deal with other nutrients such as P or Si.
Should this chapter on microbes be a part of the biogeochemistry chapter? There will clearly be a need to work closely with Wajih Naqvi and look at the possibility of a combined paper.
Remark: Wajih Naqvi's paper has a component of feed-back to atmosphere (e.g. CH_4 and N_2O), somehow the two papers need to have different foci and links.

Effects of hypoxia on nekton and plankton (Werner Ekau)
Check work from the Santa Barbara Basin. Lisa Levin will give you relevant author name(s).
Oxygen contents influence copepods – species change!!!
Resting stage-one year
Oxygen removes copepods/forcing hypoxia, accelerating hypoxia
Decapods need to be in there. Decapods in the oxygen minimum zone of the Arabian Sea (paper

reference from Gooday)
Also demersal fish (Denis)
Look at shrimp and their changes off Goa (ask Wajih Naqvi)
Recent MEPS paper in OMZ off Mexico about squids (Levin)
Information about swimming performances: the ability to catch food and avoid predators declines with hypoxia (Denis Gilbert). Denis will offer references.
Arabian Sea and Humboldt current need to be considered. There is information available from these areas in a Special Issue of DSR (Osvaldo).
Concentration of pelagic organisms near the upper boundary of OMZ in the Arabian Sea (Gooday).
Comments on Namibia – think about oxygen fluxes rather than concentrations – fluxes could be at time scales that we are not taking into account (Monteiro).

Shelf hypoxia driven by open ocean boundary climate variability (Pedro Monteiro)
Geographical distribution of these natural hypoxic zones is very different from the Diaz maps. In fact, it appears complementary (Levin)
Open ocean controls on coastal hypoxia need to be taken into account.
There are two categories of forcing:
1) Terrestrially influenced systems (human population growth)
2) Ocean-influenced systems (climate change and variability)
Include all the systems & how open ocean forcing affects them? Example: Baltic Sea is influenced by overflow from the North Sea.
Congo Offshore Time Series, short term reventilation
Should we engage in questions related to time scales of millions of years?
Perhaps it should be included. See the Federer *Science* paper.
California – Monterey, Upwelling in Miocene.
Comment:
- Are western boundary systems to be included in the synthesis paper?
- Some WG members ask if palaeo-environment should be considered.

Summary of all other papers (Jing Zhang)
It would be preferable to wait until at least the first draft of the chapters are ready before writing the summary paper.

Discussion on other papers (Denis Gilbert)
Paper by Wajih Naqvi will be provided
Mike Kemp (status of his paper is unknown)
Remark: It is necessary to identify what is missing in comparison to TOR of this Working Group, like the topics of modelling and observations.

Sunday, September 23, 2007
Budget of SCOR WG#128 (Ed Urban)
Venu Ittekkot will use his own budget to cover the cost for travel and accommodations, which will be considered as a contribution to SCOR.
Accommodations and per diems for Associate Members will be covered by Jing Zhang using

Chinese funds. This will help SCOR to use funding from this WG to pay for the travel of Associate Members.

Benthic system responses to hypoxia (Lisa Levin)
This is a new paper requested from Lisa by the Working Group on the previous day (Saturday) to address a knowledge gap.
Benthic biological responses to coastal hypoxia; structure of chapter presented; contributions are solicited.
Suggestions to work with examples (MScranton)
Is anything known on the genetics behind the physiological response of organisms at the species level? Things are known about enzymes. Little is written about natural hypoxia – population/on up.
Fossil record – responses to natural hypoxia; modern analogues on Pakistan continental margins (Lisa Levin)
Functional attributes, how to reconcile the contents of Jack Middelburg's paper with the proposed contents.
Examples from the sloping sides of volcanoes, the possible response to breakdown in stratification (Ed Urban)
Role of microbial mats.
Sulfate reduction high, H_2S systems.
Benthos associated with upwelling: There are two ways of looking at adaptation - individuals adapting, or the whole structure adapting (Monteiro)
Levin paper should take care of shellfish, scallops, etc.
Werner Ekau can look after shrimp and fish
Demersal fish could be the common link between Lisa's and Werner's papers.
Coastal Hypoxia – food (carbon) & low oxygen
Upwelling-related hypoxia
Benthos around the Indian coasts (information from the Cochin group)
Biogeochemistry, microbial ecology, trace gases

Publication of Special Issue and miscellaneous things (Denis Gilbert)
Presentation of chapters for *Biogeosciences*
Monitoring and managing hypoxia, hypoxia induced by human activities might be manageable, but climate-induced hypoxia may not be.
Publication
Jack Middelburg explains the procedure for publication in *Biogeosciences*.
It would be nice to have a **printed copy** of the WG 128 papers being published in *Biogeosciences.*
Ed suggests that WG 128 writes a formal letter to SCOR requesting support for the printing of such a publication.
However, page charges for publication will have to be met by individual authors. SCOR will not pay for the page charges. Ed Urban said why (WGs are allocated limited funding).
Capacity building in WG 128:
Hypoxia being a problem in developing countries, we need to enhance capacity and infrastructure.

Potential contribution from WG 128 members, in the form of a special course on hypoxia, highlighting the issues.

Deadline for Biogeosciences papers

Pedro Monteiro: June 2008
Rabalais: June 2008-09-23
Gooday: End 2007
Ekau:
Ulloa: June 2008
Naqvi:
Levin: Summer 2008
Middelburg: May 2008
Kemp:
Zhang:
(range from December 2007 to August 2008)

Information on EU FP7 oxygen initiative (Pedro Monteiro)

FP 7 /Theme 6 Environment (including climate change) (draft Version 2)
Area 6.4.1.2. Cross-cutting research activities
Possibility of coordinating EU and NSF calls for proposals (Ed Urban)

Options for the next meeting

Jing Zhang believes it is important to have the final product (*Biogeosciences* special issue) before holding the third and final meeting.

Ekau – Effects of hypoxia on nekton

- Shifts from cod-dominated to sprat-dominated system in the Baltic Sea.
- Denis suggests to include the effects of hypoxia on swimming capacity (send Dutil 2007, Herbert 2005)

Monteiro

- Availability of 50-year ocean model solutions.

Sunday, September 23, 2007
Pedro – Beggiatoa mats prevent sulphide from escaping to water column (*Thioploca* in Chile, possibly different species?)

Venue for the Third Meeting

Why ???

- Design of observational systems and identification of data gaps
- Capacity building - creation/consolidation of training material (stacks of slides)
- Synthetise the gaps in knowledge and understanding, and make recommendations for future.

Three venues suggested.
Conception, Chile, February 2009
Washington DC

Kiel, Germany
- next meeting can be coordinated to take place in conjuction with a training course (Osvaldo Ulloa and Lisa Levin)
Denis should contact Temel Oguz to check if he is willing to write a chapter on hypoxia modelling, and then inform Jack Middelburg and Osvaldo Ulloa.

Zhang Paper
- Map of Diaz
- Timeseries of the number of hypoxic sites across the world (classification according to estuaries, upwelling systems, open shelf, inland sea)

2.2.9 WG 129: Deep Ocean Exchanges with the Shelf (with IAPSO) (2006)

Terms of Reference:

1. Establish the current state of knowledge and make recommendations for future research related to the following topics:
   - Processes due to shelf waves, internal tides, shelf break upwelling, storms and extreme events that produce effects over time scales of weeks to one or two years;
   - Transport over the shelf and shelf break of riverine and estuarine input of sediment and fresh water (this aspect includes the Arctic and Antarctic coastal zones, but does not include investigating the sources of sediment and fresh water on the shelves);
   - Dissipation of tidal motion along the continental margins on time scales of hours to days;
   - The physical controls of chemical and biological fluxes between the shelf and the open ocean that can affect the ecology of such regions; and
   - Coupled physical-chemical-biological models, generally at local to regional scales, that have a more realistic description of the exchanges at the shelf edge;
2. Determine where further observational programmes (using improved technology) are needed to improve understanding of shelf break processes and to provide help with the formulation of more realistic models of the fluxes between the shelf and the deep ocean;
3. Serve as an international forum for oceanographers to discuss current research on the interaction between the coastal zone and the deep ocean, by using the services and membership data base provided by IAPSO;
4. Foster collaboration between developed and developing countries that have interest in the shelf zone; limited-area models are required to help scientists in countries that do not have access to large computers, and
5. Produce a comprehensive, published final report incorporating the latest results on the above topics. This report will be in a form of a special issue of a peer-reviewed journal or a book by a major publisher.

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Takeshi Matsuno	INDIA	John Middleton	FRANCE
Wajih Naqvi	USA	Pedro Monteiro	AUSTRALIA
Alex Orsi	CANADA	Jonathan Sharples	SOUTH AFRICA
Gordon Swaters	RUSSIA		UK
Olga Trusenkova			

Executive Committee Reporter: Mike MacCracken

SCOR/IAPSO WG 129 Deep Ocean Exchange with the Shelf

2nd Annual Report - 16 July 2008

1. Bibliography

Following the first meeting of WG129 in Perugia, Italy in July 2007, an extensive bibliography of publications related to DOES (Deep Ocean Exchange with the Shelf) was assembled. The bibliography consisting of over 600 papers has been made available via the SCOR WG129 web page (http://www.scor-int.org/Working_Groups/wg129.htm) and via the IAPSO web page (http://iapso.sweweb.net/_db/index.php). The lists of publications have been grouped under the following headings.

1. Early work and General Theory (including wind-driven up- and downwelling, coastal trapped waves, the surface and bottom boundary layers and general topographic effects).
2. Eastern Boundary Currents (including coasts of Chile, Peru, Western North America, Iberia, North West Africa, Namibia and South Africa, and West Australia),
    a. NE Atlantic,
    b. SE Atlantic,
    c. SE Indian Ocean,
    d. SE Pacific,
    e. NE Pacific, and
    f. general.
3. Eddies, filaments, meanders, fronts and separation.
4. Southern and Northern Boundary Currents (including Antarctica, Southern Australia and the Arctic Ocean):
    a. around Antarctica,
    b. southern Australian coast, and
    c. Arctic.
5. Western Boundary Currents (including the Gulf Stream, the Kuroshio, the East Australia and Agulhas currents),
    a. NW Atlantic,
    b. NW Pacific,
    c. East Australia Current,
    d. Agulhas Current, and
    e. Brazil current.
6. Canyons and Capes (including coastal and topographic features).
7. Density Driven Exchange (including outflows from shelves, large estuaries, straits).
8. Mixing by Internal Tides, Internal Waves and Solitons.
9. Miscellaneous (including Straits, Gulfs, Inland Seas and Islands).
10. Review Articles and Books.

2. DOES Workshop in Cape Town

A SCOR/IAPSO workshop on Deep Ocean exchange with the Shelf (DOES) will be held in Cape Town, South Africa on 6-8 October. The workshop is financially sponsored by SCOR, ONR, IAPSO, IUGG and UNDP. At the time of writing this report, there are about 60 registrants for the workshop. There will be 18 invited lectures, two poster sessions and two workshop sessions to discuss the future work needed to enhance our understanding of Deep Ocean Exchange with the Shelf, both through observations and modelling. A poster describing the meeting may be found at http://www.scor-int.org/CapeTownWorkshopPoster.pdf. A meeting of the Working Group 129 will be held during the Cape Town workshop.

Here is the programme for the workshop: **(to be updated for SCOR meeting)**

SCOR/IAPSO Workshop on Deep Ocean Exchange with the Shelf (DOES)

DETAILED PROGRAMME

Monday AM

0845 **Opening** - Johnson / Chapman / Sweijd

Theoretical / Qualitative Aspects of DOES
Session chair - Piers Chapman

0915 The challenge of shelf-ocean exchange - John Johnson (Norwich)

0945 Physical processes of wind-forced upwelling: time and spaced scales - John Middleton (Adelaide)

1015 **Coffee**

Session chair - (Dunxin Hu)

1045 The role of Canyons, promontories and topography - Susan Allen (Vancouver)

1115 Near-shore natural iron fertilization, distant deep-water carbon flux and benthic communities –
Mike Lucas (Cape Town), Raymond Pollard (Southampton) and the Crozet team

1145 Is the Benguela upwelling system pulling its weight in terms of global carbon sequestration into the deep ocean - Howard Waldron, Pedro Monteiro and Neil Swart (Cape Town)

1215 The role of deep eddies in offshore transfers - Isabel Ambar (Lisbon)

1245 **Lunch**

Monday PM

Well-studied DOES Systems
Session chair - (Xavier de Madron)

1400 The Benguela Upwelling system - Frank Shillington (Cape Town)

1430 The European North Atlantic shelf - John Huthnance (Liverpool)

1500 The eastern US and in the Gulf of Mexico- Piers Chapman (Texas)

1530 The North Indian Ocean - Wajih Naqvi (Goa)

1600 **Posters** (including refreshments)

1730 **Close**

Tuesday

0830 **Announcements** - Chapman / Johnson / Sweijd

Well-studied DOES systems
Session chair - Olga Trisenkova

0845 Antarctic cross-slope exchanges - Alex Orsi (Texas)

0915 Recurrent slope water intrusions onto the Patagonia continental shelf - Alberto Piola (Buenos Aires)

0945 Influence of the Kuroshio on the current fields in the shelf region of the South and East China Seas - Takeshi Matsuno (Fukuoka)

1015 **Coffee**

1045 **Working Groups**

(1) Exchange rates for heat, salt and fresh water, etc
Leaders: Alex Orsi, Takeshi Matsuno
Raconteur: (Dunxin Hu)

(2) Role of canyon and eddies, etc in DOES
Leaders: (Xavier de Madron), Gordon Swaters
Raconteur: Olga Trusenkova

1245 **Lunch**

1400 **Working Groups**:
(3) Carbon cycles
Leaders: (Wajih Naqvi), Michael Lucas
Raconteur: Howard Waldron
(4) Internal tides and mixing
Leaders: (John Huthnance), Michael Spall
Raconteur: (Glen Gawarkiewicz)

1600 **Posters** (including refreshments)

1730 **Close**

Wednesday

0830 **Announcements** - Chapman / Johnson / Sweijd

Models and Observational Tools
Session Chair - Gordon Swaters

0845 Fine scale numerical models applied to high-latitude Deep Ocean -Shelf Exchange – John Klinck (Virginia)

0915 Modelling multi-scale ocean dynamics with a new adaptive mesh ocean model- Matthew Piggott (London)

0945 The Australian integrated marine observing system - Gary Meyers (Hobart) and John Middleton (Adelaide)

1015 **Coffee**

1045 **Working Groups**
(5) Future modelling
Leaders: John Johnson, (Anne-Marie Treguier)
Raconteur: John Klinck
(6) Future observations
Leaders: Piers Chapman, Christopher Duncombe Rae
Raconteur: (Isabel Ambar)

1245 **Lunch**

Session chairs - John Johnson, Piers Chapman

1400 Report back of working group chairs

1500 Closing session (including details of Publications and Montreal meeting)

1530 **Tea**

1600 Meeting for members of SCOR/IAPSO WG 129

1700 Close

<u>Thursday</u> **<u>Meeting at University of Cape Town</u>**

Discussion for delegates from developing countries with overseas experts on organizing oceanographic cruises.

As the workshop will take place shortly before the SCOR annual meeting, a preliminary report on the workshop will be available at the annual meeting.

3. DOES Symposium in Montréal, July 2009

Piers Chapman and John Johnson will convene a symposium on Deep Ocean Exchange with the Shelf at the IAPSO meeting in Montréal in July 2009. The next meeting of WG 129 will be held in the same week.

4. Addressing the WG's Terms of reference

(1) and (2). The workshop in Cape Town will address the state of present knowledge and the need for future research for the DOES topics. The outcome from the working groups will be followed up during the coming year and will be the main topic for the WG meeting in Montréal in July 2009.
(3) All outputs from the WG are communicated to the international community through the SCOR and IAPSO web sites.
(4) Students and research staff from developing countries have been invited to the workshop in Cape Town, some with help with their travel support from our financial sponsors.
(5) All invited speakers at the workshop will be asked to submit a paper based on their talks to a special issue of the EGU open access journal *Ocean Science*. This will be ongoing though the next year.

2.2.10 WG 130: Automatic Visual Plankton Identification
(2006)

Terms of Reference:

- To encourage the international co-operation of software developers and marine scientists to use and enhance an appropriate open-source development platform, so that a common toolset can be built up over time that is of value to the community
- To evaluate the limits of taxonomic resolution possible from image-based classifiers and develop means of improving the taxonomic resolution that can be achieved from plankton images. The working group will establish a basis for standards in taxonomic reporting by automatic labelling instruments.
- To review existing practices and establish standards in the use of reference image data used for training automation machines and in training people.
- To establish a methodology for inter-comparison/calibration of different visual analysis systems.
- To develop open-source software for application by the marine ecology, taxonomy and systems developers. Publish the products of reviews by members of the Working Group, selected presented papers and workshop reports in an internationally recognised, peer-reviewed journal or a book by a major publisher

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Executive Committee Reporter: Peter Burkill

SCOR Working Group 130: Automatic Visual Plankton Identification
2008 Annual Report

Members and guests of SCOR WG130 on the beach at Ubatuba, Brazil. Missing is our photographer – Rudi Strickler.

Background

SCOR WG130 was initiated in 2007 to address research issues associated with automated approaches for identifying and classifying plankton from image datasets. Our first meeting was held in Hiroshima, Japan in 2007 following the 4th Annual Zooplankton Production Symposium. This was the second meeting of the working group and it is particularly notable that funding for this meeting was facilitated by a generous grant from the Brazilian petroleum company Petrobras to Rubens Lopes. The meeting was held near the town of Ubatuba at the Hotel Recanto das Toninhas on May 7–9, 2008. In addition to excellent attendance from within the working group, we were fortunate to have participation by graduate students from universities in Brazil and the United States as well as two visiting experts in the field.

As a scientific community and a SCOR working group we must emphasize the current status of automatic imaging and recognition of marine plankton. We need to emphasize to the taxonomic/biodiversity community that given the present state of development of machine vision technology, we are not attempting to develop imaging systems to address their problem of detailed taxonomic identification (i.e. to species level) of plankton in the ocean. Rather, we are going to provide more effective tools for the ecological marine research community.

The current available commercial imaging systems, such as FlowCAM, Zooscan and the Video Plankton Recorder (VPR), and the open-source Zoo/PhytoImage-scanner combination, are adequate for many marine scientists working on ecological research. There is no need to dramatically improve the image quality and resolution to the point that we might attempt to recognize morphologically similar species or classify organisms to fine levels such as the developmental stages of Crustacea. Taxonomic resolution to genus/family and even order may contain sufficient information to satisfy the research criteria of many ecological programmes. In some cases, where species diversity is low and species of interest possess distinctive morphologies, species-level classifications may be feasible.

The current imaging systems afford researchers practical tools that permit acquisition of samples with higher spatial and temporal resolution, greatly increase the numbers and throughput of samples, and provide meaningful results consisting of taxonomically explicit abundances and sizes in near-real time. Many also provide concurrent acquisition of other physical and chemical data at sea.

The plankton community is presently at a critical juncture. We have reached the point where suitable imaging hardware is available at reasonable cost and there are several commercially available instruments (e.g. Zooscan, FlowCAM, VPR) that are in service and under routine use. Innovative prototype imaging systems are also entering research programs at regular intervals. The greatest impediment to widespread adoption of new imaging hardware has been the availability of intuitive, low-cost/no-cost software capable of harnessing the torrent of information that imaging systems can provide. To this end, there are now several software packages that enable the user to acquire and isolate images of individual organisms. These images can be sorted into libraries of known taxonomy, which can then be used to train a classification algorithm. The accuracy of the classifier can be evaluated and when a satisfactory classifier has been developed, it can be used to classify large datasets of images containing organisms of unknown taxonomy, into classes of interest. The output counts of each class can then be combined with metadata on volume sampled, fraction of total sample imaged, and time, latitude, longitude, and depth to produce abundance estimates for each class of interest.

The challenge that our Working Group has accepted is to combine the best features of the currently available software packages – two of which are designed to work with specific imaging hardware and foster the development of new, flexible, open-source software suites capable of performing the complete series of tasks necessary to extract useful ecological information from raw data. It is essential that we obtain and distribute this software quickly so that the broader oceanographic community can begin the critical task of analyzing archived and recently collected data on plankton. This is the only way that we will be able to address questions relating to regional and global climate-related changes in ocean productivity, fluctuations in fish-stock abundance, carbon sequestration, and human-health linkages to ocean ecology.

Through the activities of our Working Group and research in related laboratories, we are rapidly moving to the point where we can demonstrate to the broader oceanographic community how automatic image classification can provide ecologically meaningful data that could not otherwise be obtained in a reasonable timeframe. These techniques compliment current genetic-based analyses and depend upon the continued cooperation and collaboration with taxonomists and systematists.

This second meeting of our working group afforded an opportunity to review and discuss the present state-of-the-art in plankton recognition and classification. It also allowed hands-on training with one of the commercially available instruments (Zooscan) and sharing of advances made in laboratories around the world.

Working Group 130 Terms of Reference

1. To encourage the international co-operation of software developers and marine scientists to use and enhance the open-source development platform, so that a common toolset can be built up over time that is of value to the community;
2. To evaluate the limits of taxonomic resolution possible from image-based classifiers and develop means of improving the taxonomic resolution that can be achieved from plankton images. The working group will establish a basis for standards in taxonomic reporting by automatic labeling instruments;
3. To review existing practices and establish standards in the use of reference image data used for training automation machines and in training people;
4. To establish a methodology for inter-comparison/calibration of different visual analysis systems; and
5. To develop open-source software for application by the marine ecology, taxonomy and systems developers. Publish the products of reviews by members of the Working Group, selected presented papers and workshop reports in an internationally recognized, peer-reviewed journal or a book by a major publisher.

Agenda

Wednesday, May 7

Overview, Welcome, Introductions, Logistics	Mark Benfield, Phil Culverhouse, Rubens Lopes
Review and Discuss Implementation of Terms of Reference	Mark Benfield, Phil Culverhouse
Review Report on the Establishment of a Reference Dataset	Maria Grazia Mazzocchi
From the sample to results in a perfect world	Rudi Strickler
Taxonomy, Ordination and Identification	Norm MacLeod
Plankton Analysis System (PAS) software demo	Marwan Mattar
Plankton Interactive Classification Tool (PICT) software demo	Steve Murtagh

Thursday, May 8

Non-linear classification and classifiers	Norm MacLeod
A wider perspective in object identification	Phil Culverhouse
FlowCAM Image Classification Webinar	Brian Thompson (Fluid Imaging Technologies)
Overview of advances in image processing in the Borrego Lab	Josue Borrego

Implementation and evaluation of new features for zooplankton identification (ZOOSCAN case study) — Esmeraldo dos Santos Filho

Use of the Laser Optical Plankton Counter and the Zooscan to determine zooplankton community structure in the Abrolhos ecosystem. — Sabine Schultes & Rubens Lopes

Real-time automatic identification and visualization of plankton taxa — Cabell Davis

Discussion: Addressing Critics of our Approach Via Targeted Studies for a Dedicated Journal Issue on Automated Plankton Identification — All

Friday, May 9

ZOOSCAN/Plankton Identifier Demo — Rubens Lopes, Esmeraldo dos Santos Filho

Future Work: Website Content — Phil Culverhouse

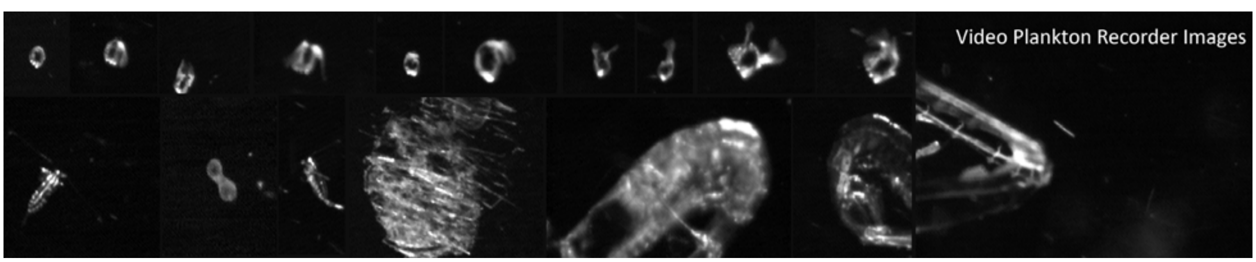
Future Work: Linkages to CMarZ — Mark Benfield

Future Work: Plan the establishment of expert taxonomic networks — Phil Culverhouse et al.

Future Work: Funding Sources — All

Future Work: Research and Papers for Themed/Dedicated JPR Issue — Phil Culverhouse

Future Work: Writing Assignments



Report on Establishment of a Reference Dataset

We presented some of the main points addressed in the Report that was distributed to the group during mid-February regarding the scope and objectives of this subgroup. Our overall scope is to integrate the taxonomic expertise, which is dwindling rapidly in most parts of the world, into the new automatic image devices. We will contribute to the implementation of the automatic recognition skills of the systems and machines currently available, as well as to validation of the products generated by imaging systems by providing guidelines and standards for the establishment of a global, validated reference dataset of machine-generated images ('image bank') of plankton taxa. A copy of the report is included in this document as Appendix C.

Discussion Summary: Website Content

The Working Group website is operational (see http://www.scor-wg130.net/index.cfm) but at the present it lacks sufficient content to effectively publicize our goals and progress. The first step in populating the website is to assemble brief biographical sketches of all participants. A template was distributed to all members of the group and their CVs will be uploaded to the site shortly after the meeting. A second goal was to assemble a comprehensive bibliography and PDF files (where possible) of all papers that directly address automated plankton identification, supplemented by relevant background papers from the larger machine vision community. Each member of the group was asked to contribute a publication list that will be collated and uploaded to the website. Images of activities from the first and second meeting will also be uploaded.

Copies of the PowerPoint presentations from this meeting will be placed in a members-only section of the website with PDF summaries of the talks available to the broader community through the public-access part of the site. As reference datasets begin to be assembled, these will be uploaded to the site. The Coffee Room section of the site contains tools for interacting via webcam and chat messaging so that virtual meetings among members can continue.

Discussion Summary: Establishing Expert Taxonomic Networks

Grazia reported that the group working on taxonomic networks published a report as requested. Different modes of image acquisition (i.e. the imaging systems) generate different classes of datasets. Two large classes of imaging systems can be identified on the basis of in situ or laboratory approaches. In the first case, live organisms are observed directly in the sea (e.g. using a VPR) and this is the best approach for imaging delicate gelatinous species and aggregates, whereas in the second case preserved samples are analysed by using a flatbed scanner (e.g. ZooScan or other machine) as a substitute for the classical microscope analyses.

As a practical starting point, datasets are likely to be established first for specific geographical regions/seas, oceanographic systems, and/or basins (e.g. North Atlantic, tropical Atlantic, North Pacific, Southern Ocean, North Sea, Baltic Sea, Mediterranean Sea, Black Sea, etc.). Ultimately, these image datasets could be merged and consolidated into a global digital archive. To that extent, appropriate funds may need to be sourced for particular regions. An important consideration that will contribute appreciably in this respect may be the so-called ‘data rescue’ programmes (e.g. in southern Africa, funded by the French-South African research programme ECO-UP, and in Europe, funded by the Network of Excellence EUR-OCEANS).

A good example of an EUR-OCEANS data rescue programme in progress is the re-analysis of the Bay of Villefranche (Ligurian Sea) time series (ongoing since 1957) in Villefranche-sur-mer, France using the ZooScan. It is envisaged that by mid-2008 the Villefranche ZooScan image bank will contain images of zooplankton from WP-2 samples collected during the period 1966-2008 (3 samples per month). The construction of a reference collection of ZooScan images of zooplankton from the Gulf of Naples (Tyrrhenian Sea; ongoing since 1984) is also underway. Once agreed upon by the local experts, these reference image collections will become available to the public at large (with reference to SCOR WG 130).

Other ongoing initiatives have lead to a compilation of comprehensive species identification ‘manuals’, for example, by NERC in the UK (cf. Steve Hay). These could also contribute to the establishment of a global image databank. For an on-line key see www.crustacea.net.

The WG's activities will initially focus on mesozooplankton, with the subsequent goal to stimulate and possibly involve a wider community that deals with other components such as microzooplankton and phytoplankton, recognising that other technical problems are inherent here. An important issue that needs to be addressed is the inter-calibration between humans and computers: not only do taxonomists contribute significantly to image validation, but likewise – vice versa – computer-based analysis of images can also be suggestive of new diagnostic characters that should be considered by taxonomists for the unambiguous identification of taxa.

The Subgroup may also need to consider – perhaps at a later stage – to incorporate images of barcode-validated taxa. To that extent, we will formulate recommendations to the Census of Marine Zooplankton (CMarZ) – through the WG – to establish such a dataset for all barcoded species.

Grazia concluded with a request for the working group to consider assisting with the Evolution2009 project, by supplying automatic identification facilities to the project.

Discussion Summary: Funding Sources

It is clear that obtaining funds to support the creation of networks of expertise and to support training of young scientists are available. Culverhouse reviewed a number of potential European sources, including Marie Curie, and the specialist Directorate Generals for Aquaculture and the Environment. It seems that funding from Aquaculture is slim as the strategic directions do not favor our work. The Water Quality Framework Directive, which has legal status in 2015, will offer opportunities for projects in monitoring instrumentation (that should be explored further by the working group). Benfield raised a number of potential funding sources in the United States that can also be explored.

Discussion Summary: Addressing Critics of our Approach Via Targeted Studies for a Dedicated Journal Issue on Automated Plankton Identification

As with any new technique, automatic plankton identification has attracted its share of criticisms. Most of these stem from a fundamental misunderstanding of our approach. A discussion of commonly voiced criticisms in peer reviews can be summarized as follows:

1. Automated classification cannot provide fine-taxonomic discrimination. In most cases, current resolutions of images do not afford sufficient resolution to distinguish morphologically similar species. This will undoubtedly improve as imaging technologies advance; in many regions of the ocean, species of ecological interest frequently possess distinguishing morphologies that can be recognized by machines (e.g., *Temora stylifera*). This criticism really misses the main point of our research. At present we are not advocating automated classification as a substitute for detailed taxonomy. Rather than being a high-resolution taxonomic tool, this approach is an ecological tool. Computer-based classifiers provide a means of obtaining useful estimates of the abundances of marine plankton at taxonomic levels down to families, genera and, in some cases, species as well as biomass, and size-frequency data. Such data are essential to address questions raised in most biological oceanographic and fisheries studies.

2. Automated systems cannot produce sufficiently accurate classifications to be of practical value and a related concern that the amount of time required to correct misclassifications reduces sample throughput to a point that traditional approaches are faster. At the core of this criticism is the assumption that the error rates of humans are far lower than the misclassification rates by machines. In reality, even expert humans do make mistakes (Culverhouse et al. 2003). Misclassification errors by humans are heavily influenced by prior experience, geographic familiarity with the sample, and fatigue. Routine sample processing is often performed by groups of scientists, each with different levels of experience and bias. Current machine classifiers are capable of achieving accuracies of 70 – 80% for 10 – 20 class problems. These error rates are well below the level of error associated with replicate net tows or subsampling (splitting) errors.

3. Automated classifications are locally specific and results produced in one laboratory on one type of instrument are not reproducible to another site and system. Intercalibration and reproducibility are critical for widespread adoption of imaging systems. The Zooscan system employs an optical standard that ensures that the distribution of grayscale values in each scanned image is consistent and reproducible. Standardization can also be achieved by sharing of reference image datasets acquired with calibration targets that enable normalization of grayscale values and sharing of classification algorithms.

4. Humans mistrust automated systems because machines base their identification on features that are often very different from those used by a human to recognize an organism. While the features used in automated classification are often not based on distinguishing characteristics that a human may find useful, it is nonetheless true that images contain a broad range of features that can be quantified and used to distinguish one organism from another. Many of these features include characteristics such as texture, length:width ratios, and contrast or color, which have parallels in features used by a human to identify an organism. In addition, computers are capable of quantifying substantially more features than a human can consciously detect and employ for identification. Multispectral techniques afford even greater opportunities for feature selection. While features may be different, they do work and can provide unbiased metrics for classification. Trust will develop over time through careful comparisons between machine and human output.

5. Identification of marine plankton is too difficult a task for a computer to perform. There is no doubt that automated recognition is a difficult problem. In fact, it is a far more challenging problem than most object recognition tasks undertaken by the machine vision community. For example the Pascal Challenge attempts to distinguish objects such as cars, people, bicycles, dogs, and cats. In spite of being a difficult problem, automatic identification of plankton is a worthy goal. We need information on the identities, distributions and abundances of plankton to address a broad range of ecological and societal questions. The present state-of-the-art suggests that machines can achieve classification accuracies of 70 – 80% for problems involving up to 20 classes. Moreover, they can achieve this in a much shorter time than a human and without fatigue.

6 Machine-based classifiers are too expensive and complex to support. The cost of currently available commercial systems, such as the Zooscan, is not high and is generally less than the cost of a good microscope. More sophisticated systems such as FlowCAM and the VPR are in

the $50,000 – 75,000 range; however, these prices will drop as volume increases. Right now these products are sold to a small market and the costs are consequently high. As software tools emerge to support the hardware, demand for the instruments will grow and prices will drop. Nonetheless, it is possible to set up an effective automated classification system for under $1000 using off-the-shelf scanner technology and free software such as Zoo/PhytoImage.

While these concerns hold little basis in fact, they underscore the need to reach out to the broader scientific community with targeted studies that demonstrate the fallacy of these arguments. One mechanism for this is a dedicated forum for studies addressing common concerns about automated techniques.

The group decided to approach *Marine Ecology Progress Series* or the *Journal of Plankton Research*, given our group's interest in reaching out to the broader marine ecology community. Consequently, the group assembled a list of studies which will either have been conducted, or can be completed within a year for submission to this special issue.

<u>A series of related studies that could be performed and written up within one year.</u>
These studies were selected based on the availability of hardware and software to complete them in a timely manner, and for their utility in rebutting common criticisms of the field. These will be the main focus of the group between its meetings in 2008 and 2009. In addition to these studies, we will solicit research articles from colleagues who are working in this field. Summaries of each study will be presented at the next meeting of the working group (mid-2009) with written manuscript submissions shortly thereafter.

A variety of experiments were proposed and discussed. These included two review articles and a series of targeted studies:

MacLeod, N., M. Mattar, and S. Murtagh. A review of classification techniques and features with utility for automated plankton recognition and classification.

Benfield, M.C., P. Culverhouse, and C.S. Davis. A review of hardware and software tools for automated plankton imaging and classification.

Briseno, C., M.C. Benfield, S. Murtagh, M. Mattar, C.S. Davis, R. Williams, and P. Culverhouse. Rapid processing of plankton images using semi-automated sorting with PICT software.

This will compare the amount of time that a human takes to process and sort Video Plankton Recorder data with the time required to achieve the same result using the PICT interactive sorting tool. Similar data from other images (e.g., HAB buoy or Zooscan) may also be incorporated.

Lopes, R., M.C. Benfield, M. Mazzocchi, H. Verheye and G. Gorsky. Consistent zooplankton classifications obtained from replicate Zooscan analyses around the world.

This study would use flatbed scanner imaging (e.g., Zooscan, ZOOIMAGE & PAS). Users of these systems will discuss, plan and execute an experiment in inter-calibration across the globe.

Culverhouse, P., H. Verheye, M. Mazzocchi, R. Lopes, M.C. Benfield, and P. Licandro. An evaluation of error rates from comparative human and automated plankton classification studies.

Human performance experiments will be prepared and completed by Zooscan and flat-bed scanner users across the globe. The results will be combined, analysed and compared to machine performance on the same specimens. The experiment will likely use freshly collected and preserved specimens.

Lopes, R., R. Williams, and C.S. Davis. Allometric coefficients for zooplankton biomass estimation using automatic plankton analysis.

At present, estimation of biomass coefficients from digitized images of zooplankton requires allometric relationships (length, width, perimeter, area) that can be used to estimate individual mass. Many of these relationships have been estimated and need to be collated. For other taxa, we lack appropriate parameters and these need to be determined.

Borrego, J., H. Verheye, and M. Mazzocchi. Discrimination of morphologically similar zooplankton taxa using automated classification techniques.

This study will require copepod specimens for optical image processing using matched filter technique as applied to specific key indicator species recognition.

Mattar, M., and S. Murtagh. The Plankton Analysis System (PAS): A Web-based software system for automatic plankton identification.

This will describe and evaluate the performance of a new Web-based automated plankton classification suite.

Araskavitch, A., P. Licandro, G. Gorsky, M. Mazzocchi, and H. Verheye. Gold, silver, and bronze: Creation of plankton image dataset standards.

A proof of process for standards creation will be completed, which will require taxonomists to create gold standard sets for a few key species/genera with sufficient specimens to be used for classifier training. Gorsky (or another) will scan these and produce both Zooscan parameters and vignette images for each gold standard type, and hence produce a silver standard. These silver standards will then be used to instantly extend the identification capabilities of all Zooscans across the world, and also provide images (the vignettes) for other ecologists using flat-bed scanners and ZOOIMAGE or other similar software. Issues to be resolved in this experiment include fixative and staining protocols, the provision of accompanying statistical data of these new standard data set, and means of linking to genetic barcoding.

dos Santos Filho, E., and G. Gorsky. A comparison of image features used by human and machine plankton classifiers with evaluation of new image features.

Software developers need to assess different classifiers and feature extractions for their discriminative power. There also needs to be an evaluation of how features used by humans for recognition of plankton are related to those used by machines.

Irigoien, X., R. Lopes, and M.C. Benfield. Using off-the-shelf scanners and digital cameras software for authomated zooplankton classification.

This will compare images from ZooScan, flatbed and macro-photography across fresh specimens and preservation methods and evaluate means of inter-calibrating the data.

Presentation Summaries

J. Rudi Strickler: From the sample to results in a perfect world

The presentation began with a brief introduction illustrating the complex behaviors and large size differences of zooplankton and phytoplankton based on Schlieren imaging. What then would we like an 'ideal' sampling system to be able to do? We would like to cruise at some moderate speed from point A to B and tow a device behind the ship which sends at a high frequency: the time that each target was encountered; the identity of that organism; whether the organism was alive or dead; and the environmental parameters associated with that organism. The device should allow estimation of the abundances and spatial distributions of all targets with an accuracy of ±10%. It should also be capable of independent operation on autonomous vehicles to cover larger areas at the same time. He called this hypothetical device the Dream System Biological Oceanography (DBSO).

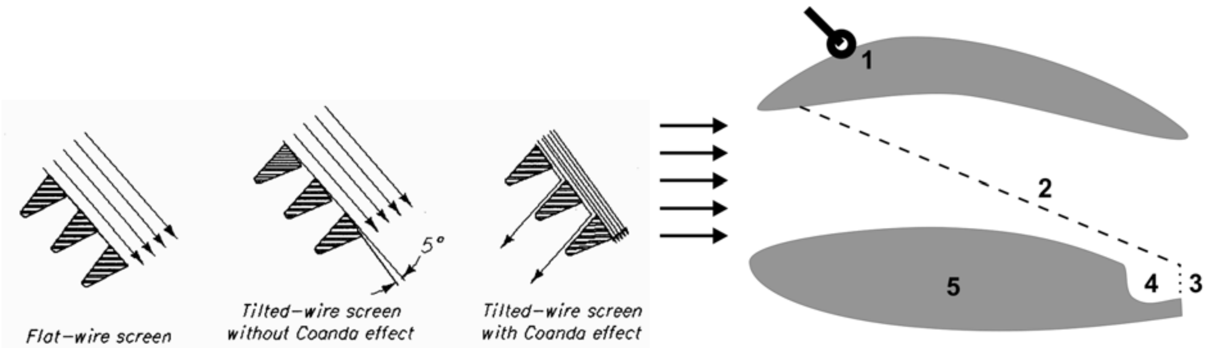
In designing such a device the following factors need to be considered:

(1) There should be no differential escape from the device by living entities – the DBSO should not provide organisms with any early warning of its presence;
(2) There should be a good number of detections even when the density of organisms is low – this means there must be some way of getting rid of the water and concentrating the organisms; however, the concentration ratio has to remain constant;
(3) The device must not clog – this means it must be self-cleaning;
(4) There must be enumeration of all organisms even when they are present at very high concentrations or appear at very short intervals;
(5) The data must be conducive for fast recognition and classification of organisms – this means we would like to have binary data if possible; and
(6) The output data must be small and contain only information associated with valid targets so that it can be sent back to the lab with a low-bandwidth connection.

Is there a basis for the DSBO? In fact the basking shark *Cetorhinus maximus* provides a very useful model sampler. When one models the hydrodynamic features of most plankton nets, they project a disturbance signature well ahead of the frontal area of the net. This signature can be detected by zooplankton, which enables some to avoid the net. When one modifies the frontal area of the net to resemble the profile of a basking shark, this avoidance signature is so reduced that by the time an organism has detected the net, it has already been captured.

The second issue relating to filtration and self-cleaning can be addressed by replacing the mesh in a plankton net with Coanda screens. These consist of offset wire spacers that channel organisms along the direction of flow while collecting and eliminating water from the surface of the mesh.

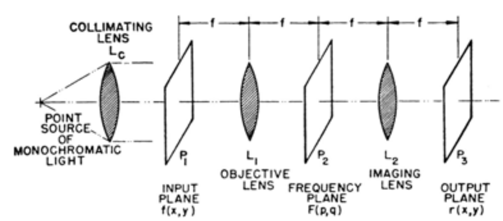
The incorporation of a Coanda screen within a shark-like sampling frame illustrated how both avoidance could be minimized while maximizing filtration and concentration.



Left: An example of a Coanda effect filter. Right: An example of how the Coanda effect filter could be incorporated into a hydrodynamically stealthy sampling frame. (1) towing bridle to minimize disturbance; (2) Coanda screen; (3) conventional plankton net to collect contents for subsequent analysis; (4) Sample imaging and analysis bay; (5) electronics pod.

An example of classification of using fractal mathematics was provided. Essentially a grid is superimposed over the animal. If each cell has a bit of the animal in it, it gets a one, and if it is empty it is scored zero. By varying the size of the grid, one can then plot the log of the fractal score versus the log of the grid size and the relationship is linear. In nature many animals have very simple shapes. Simple (spherical) organisms will have one slope while more morphologically complex shapes would have a different slope. We need to investigate this classification scheme because it may provide a useful way of distinguishing different classes of animals based on their shape.

Any classification scheme must work rapidly. Animals can have a lot of complexity. This can be reduced by eliminating color, reducing the background differences, doing a 2D fast Fourier transformation (FFT), thresholding the image, and then performing fractal analysis on the resultant image. Computers are far too slow to do this. Fourier transformations are frequency-based. Lenses are frequency-based. We can construct an optical computer to do this at the speed of light. A Schlieren-based imaging system that performs a real-time FFT was illustrated.



An example of the optical setup for a real-time FFT optical computer.

Examples of how this FFT analysis can be used to extract information from an image was provided using examples of copepods present against different levels of background noise. This also provides a means of detecting organisms in turbid water where there is a lot of high-frequency noise.

2-76

Norm MacLeod: Taxonomy, Ordination and Identification\Non-linear classification and classifiers

The recognition of organisms is logically based on (1) an objective and comprehensive assessment of the characteristics of individuals, (2) identification of particular characteristics (or combinations of characteristics) that are unique to particular groups (e.g., populations, species, genera, guilds), and (3) placement of unknown individuals into the group categories so defined on the basis of a comparison between their characteristics and those that delimit intra-group variation. Although there are examples of group recognition based on chemical, genetic, tactile, olfactory, and auditory signals, by far the most commonly employed features for the definition of biological groups are those pertaining to body morphology: the sizes and shapes of bodies and body parts.

Since morphological features are inherently geometric, it is possible to use the tools of applied geometry to aid in the assessment, delimitation, and comparison tasks (described above), and so to construct methods of automating the identification task. In this vein there is little practical distinction between the concepts of a taxonomic character and a statistical variable, though this identity has been disputed in the past by some (not all) taxonomists. In adopting this geometric approach to organismal group identification, employment of mathematical tools that have been developed for other purposes is both useful and efficient. There are a wide range of such tools, all of which have proven effective in addressing individual classification tasks and/or situations. Broadly speaking though, these tools can themselves be classified into those that enable complex data to be summarized and compared with each other (usually to test grouping hypotheses) and those that focus on assessing complex data to optimally delimit a priori-defined groups. The former task is termed ordination and the latter classification. A further subdivision of these tools is possible through the recognition of those designed to process linear data (and so represent/delimit geometric data in linear spaces; e.g., linear regression, principal components analysis, canonical variates analysis) and those designed to process non-linear data (and so represent/delimit geometric data in non-linear spaces; e.g., decision trees, neural nets, kernel methods incl. support vector machines).

In designing data analysis approaches using these tools it is of the utmost importance to keep the problem that is being addressed firmly in mind and using the tools—or combinations of tools—that best fit the particular analytic situation. There is no über approach that will handle all conceivable group-recognition situations successfully and efficiently. For example, it is well known that the most natural and most informative spaces within which to analyze shape variation are the surfaces of non-linear manifolds. This would seem to imply the use of non-linear data analysis methods to optimally represent and analyze shape data. However, if shape variation within a sample is constrained to well-defined limits, linear methods would be preferred owing to the close approximation of the manifold to a linear space, and the greater speed/efficiency of linear algorithms. Nevertheless, if shape variation exceeds the point where the inherent curvature of shape space is a critical part of the geometric problem, non-linear methods for representing the space and statistically testing group-level hypotheses will be required.

Based on the (quite extensive) work that has been published to date on this overall problem, it is interesting to note that excellent results can be, and have been, achieved by a wide variety of linear and non-linear methods. This mirrors in an intriguing manner the fact that humans also can achieve surprisingly good results using a range of different qualitative approaches to group delimitation and individual identification. Therefore, the selection of a particular analytic strategy may not be as important as has been assumed previously. Regardless, improvement in this area will depend on close cooperation among taxonomists, data analysts, mathematicians, computer scientists and oceanographers working as a team rather than as isolated individuals.

Marwan Mattar: The Plankton Analysis System (PAS)

Today Steve Murtagh and I are presenting software tools we have been developing at the University of Massachusetts for automated classification of plankton images. PAS stands for Plankton Analysis System and PICT stands for Plankton Interactive Classification Tool. PICT helps experts label images that will be used to train a classifier. PAS is a system that allows the users to manage their data, compute features, train classifiers and use the classifier on new unseen images. We're both PhD students in computer science on a joint collaborative project. The project is a 5-year collaboration between the University of Massachusetts, Louisiana State University and the Bigelow Lab.

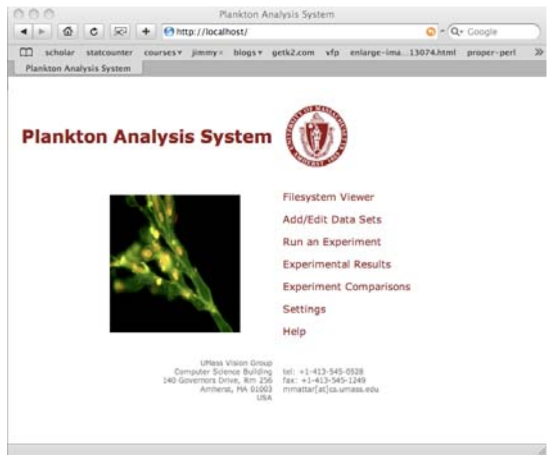
The goals of our project were two-fold: (1) to do research in image classification of plankton images; and (2) to develop software tools that can be helpful to marine biologists. On the research side we focused on frameworks that allow you to combine the information from different sources. We also worked on combining multiple classifiers, called ensemble algorithms. But today, we're going to focus on the two tools we have been developing recently. They are to be used together and eventually will be grouped into one main system. I must remind you that this is work in progress and we'd love to hear what people think.

What's the big picture? Here's an example from the FlowCAM that illustrates what happens when marine scientists interact with computer scientists. First, you collect some images, there are some automatic segmentation routines that produce single images. These are classified by a scientist who produces training datasets. Next is the learning part. You perform some segmentations on the training set data and this process includes feature extractions. These features are used to train a classifier. Now you have a trained classifier. The goal is to use this classifier to classify test images. You perform the same processing on the test image that you performed during the training phase and you get a predicted class for each image. This is what the classifier thinks this image is. We assume that every image is associated with a single category.

Image classification of plankton is a hard problem for a number of reasons: low resolution, high similarity of different classes of interest, which segmentations or features should be used. It's a dynamic problem too. Instruments change as do the interests of the marine scientists. There are also a limited number of expert-labelled training datasets.

PAS was developed to try to solve some of these problems. We can't use a black box. We have to give the user control. We also want to maximize sharing of resources (e.g., training sets) and expert knowledge. We need to have a system and we have elected to use a website model. A Web site allows for easy sharing of data and algorithms; a familiar easy-to-use interface; concurrent users; and it can be run on computers locally. It allows you to add algorithms and features. It is open-source (written in PERL using Java libraries and also allows the use of Matlab) and it is cross-platform. PAS consists of data, algorithms and classifiers.

PAS really just manages a filesystem. A filesystem consists of data, algorithms and classification tools. We've defined two types of data: collections and selections. Collections are obtained when you go to sea and have images and metadata. Selections are derived from collections. You select some images of interest, perhaps to train a classifier or to test a specific instance. Algorithms consist of image extractions that take the output of the instrument and separates it into separate images, a trash-finder (which determines whether an image contains anything of interest), image processors (which take an image and return a modified image), segmentation routines that isolate the organisms from the background via binarization, feature extractions take the segmented images and extract features associated with the object in the image, classifiers take features and try to predict a label, classification results contain the output of experiments.



The PAS interface uses a third-party software package that allows you to run a website locally. The basic PAS interface consists of a file system viewer; a way of adding and editing datasets; a means of running an experiment; an experiment result viewer; an experiment comparison module; system settings; and help.

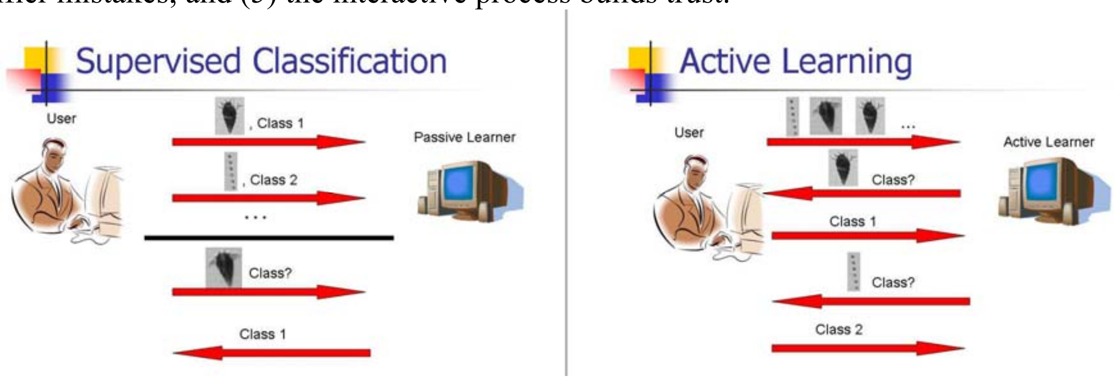
An example of PAS was demonstrated using data from the FlowCAM. Future work on PAS will include adding an interface to ImageJ; better handling of meta-data; the ability to create selections based on all meta-data; classification based on meta-data; and more 'bells and whistles.' Release 1.0 is expected in mid-2008 with future development dependent on user feedback.

Steve Murtagh: Plankton Interactive Classification Tool (PICT) software demo

Labelling data is tedious. It takes a lot of time and requires an expert or experts who may or may not agree. Every image must be examined. There are ample opportunities for error. Labels may be mis-recorded, fatigue is a problem, and there is the problem of concept drift. Concept drift is that your idea of what a particular class looks like may change over time. This is particularly true for people who are learning to identify organisms and whose concept of what an organisms looks like changes over time with more experience. Experts are also imperfect and make mistakes. Culverhouse et al. (2003) provides some examples. Experts not only disagree with each other but they also disagree with themselves. They may provide a different answer for the same data when tested at different times. This tells us (1) ground truth may not be true; and (2) the context in which labelling occurs is important.

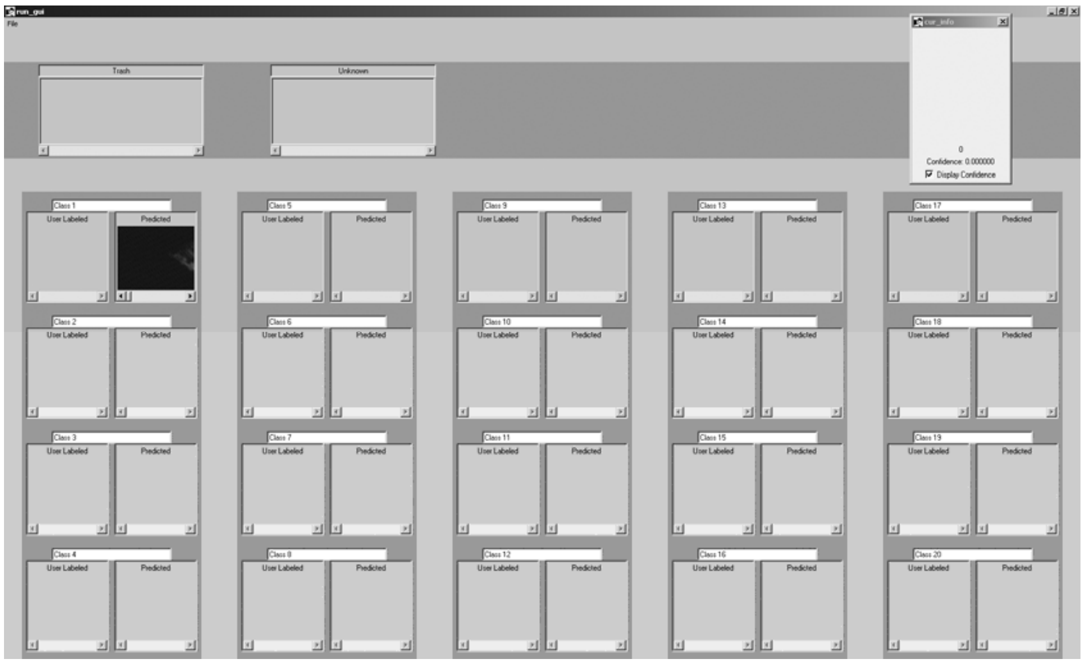
In supervised classification we have a user and a classification engine that serves as a passive learner. The user takes a dataset and classifies each image, which are then fed to the classification engine one at a time. Then the computer takes over and starts processing. It runs statistics over the features to distinguish the various classes. At some point the user presents the classification engine with an unknown image(s) and asks the classifier to what class it belongs.

What I am interested in, and what I will present today is Active Learning. Why should the classifier sit waiting for input? Why not have it do something useful like participate in the classification process? The user collects the dataset and gives the dataset to the learner. The active learner looks at the dataset, picks one image and asks: "what class is this?" The user responds with a classification. The learner takes that image and that label and starts building a model. Then it determines which image would be the best image to learn more about that class. The learner presents another image to the user, asks what class it is, and then receives input. As it proceeds it refines its model and starts to assign classes to unknown images. The advantages of active learning are (1) it is possible to build a better model with the same number of instances; (2) you get intermediate results; (3) it provides for real-time classification; (4) it allows experts to correct classifier mistakes; and (5) the interactive process builds trust.



Supervised classification versus active learning.

We want to move the expert from labelling data to correcting classifier mistakes. A demonstration of PICT followed. You begin by identifying where the images are on your computer and where the features associated with each image are located. The user is presented with images and a series of classes. Each class has two boxes: user-labelled and predicted. When it begins, all images are put into predicted for Class 1. The user takes the first image and places it in class 1 (and assigns the class a label). Next the user takes the second image and assigns it to a class, for instance class 2. Now the classifier presents the images to the user in the order that the classifier most wants to see them classified. This means that the classifier presents the user with the image about which it needs more information.



When the user first opens PICT, all images are assigned to Class 1: Predicted. As the user populates the different categories, PICT reassigns the unknown images to each of the classes while presenting the user with the images that have the lowest confidence of being in that class.

There are two other categories of interest: trash and unknown. The classifier will not train on either trash or unknown. Unknown is particularly useful in cases where one of the classes in the training set is 'unidentified.' If allowed to populate the classifier, this class can become noise, reducing the effectiveness of the classifier. By putting it into the unknown class, one avoids contaminating the dataset with images that contain features from a broad range of classes. The philosophy behind PICT is that the user's time is precious. We're going to show the user images that the classifier 'thinks' are probably wrong and encourage the user to focus on the difficult images.

Phil Culverhouse: A wider perspective in object identification

The talk was divided into two parts: a) a review of the marine plankton identification techniques and b) what machine vision researchers have been doing over the last ten years and what aspects of their work can be applied to the current biological systems.

a) A discussion on Cytosense—a scanning flow cytometry instrument—and a review of the various data sets from multispectral analysis of pigments to the various 'issues' in cytometry. Following with the use of digital images obtained with Zooscan, FlowCam and ZooImage and the quality of images and image feature extraction. The authors showed various examples from flatbed scanners and how morphological data can be extracted automatically. Application examples were given from Zooscan, such as time-series analysis of plankton samples. Details of the HAB system were given and how feature extraction by machine is accomplished. This section was concluded with a review of all existing systems and highlighted current problems of clutter/detritus and overlapping objects in images. Suggested that the way forward was the acquisition of 3D images using instruments such as the confocal microscope.

b) A review of research in the machine vision field. Discussion of Biological Models (emulating human brain models with neural networks) and Psychological or Cognitive Models and their research objectives. Finally, a review of other object recognition systems such as Active Appearance Models for face emotion analysis, Constellation Models, Generative Probabilistic Models, followed by the use of Star Models in subordinate class recognition, text analysis methods and semantic guide clustering and how the results from this area of research can be applied to plankton recognition. Finally, a discussion of what can be learnt from all of these approaches and how they could improve our own work in marine plankton recognition.

Brian Thompson (Fluid Imaging Technologies): FlowCam Image Classification Webinar

This remote presentation provided a general introduction to the FlowCam, and gave a demonstration of acquisition of images from a water sample in Maine. Brian and colleague showed the different content/parameters from the main window, opening a file from the GOM as an example and running an interactive classification of the images. Their classification was based on statistical filtering of the data. For example, the user can select a particle of a determined diameter and view the images associated to that size, or you can see all the particles of different size at once. The user can then further filter the dataset by selecting different parameters (e.g., length, round shape), selecting a few images to serve as a reference data set. The software then extracts all the images that have similar characteristics to the reference ones. One can see the classification done on a defined dataset that has been saved in a library according to different classification windows. The library can be updated with additional runs of a classification and used as a reference when analysing a sample in the future.

Josue Borrego: Pattern Recognition

Borrego's laboratory has focused on optical pattern recognition methods, achieved through laser illumination, and specialized Fourier signal processing. Recent work has focused on matched template techniques using Fourier processing. Borrego showed, using a simple ASCII character-based example, how the method works and the mathematics behind its operation. Trials using zooplankton have been successful in demonstrating identification of a particular species and discriminating between male and female specimens. However, these tests have been limited in scope and the robustness of the methods has not been fully explored.

Borrego also demonstrated a powerful new technique for de-blurring images taken from optical microscopes. He showed several videos of the method, which appeared to be particularly useful for a number of the working group participants.

Sabine Schultes & Rubens Lopes: Use of the Laser Optical Plankton Counter and the Zooscan to determine zooplankton community structure in the Abrolhos ecosystem.

A series of sixty stations were sampled with a plankton net containing a Laser Optical Plankton Counter (LOPC). Preserved mesozooplankton samples from the net were post-processed in the laboratory using a Zooscan. Images were processed to a lower limit of 250 μm ESD. The LOPC-derived biomass suggests high biomass over the Albrohlos bank and along its southeastern flank. The high biomass over the Bank was associated with small particles while the high biomass along the southeastern was associated with particles >500 μm ESD. The percentage contribution of small particles increased towards the coast. When the biomass spectra from the LOPC and Zooscan were compared, there was a large discrepancy between the two systems in the coastal stations, which was interpreted to be due to the presence of suspended sediments seen by the LOPC but not enumerated by the Zooscan. There was better correspondence between the two systems for the larger size classes in the offshore stations. For all stations, the Zooscan- and LOPC-derived biomasses agreed within a factor of two, but there was a lot of variation and a station-by-station analysis was necessary. For example, at one station (stn 8) the Zooscan provided a 4x greater estimate of biomass than the LOPC. This overestimation was in the large size bins. The high concentrations of large zooplankton in the net relative to the LOPC was interpreted by the 7cm x 7cm (49 cm^2) area of the LOPC relative to the 60cm diameter of the net (2827cm^2). At station 8, the Zooscan provided an 8x greater estimate than the LOPC. This was attributed to the presence of large concentrations of salps in the net. The transparency of the salps likely contributed to underestimation of their size in the LOPC. At station 24, the Zooscan biomass estimate was 4x greater than the LOPC and this discrepancy was present across all size classes. This may have been due to the morphological diversity of the organisms in the Zooscan, which uses a 3:1 biomass to length ratio for the biomass calculation. In summary, the best agreement between the two systems was in offshore, low-biomass stations. The high amount of data generated by the LOPC and the Zooscan requires software for efficient data extraction, analysis, and presentation.

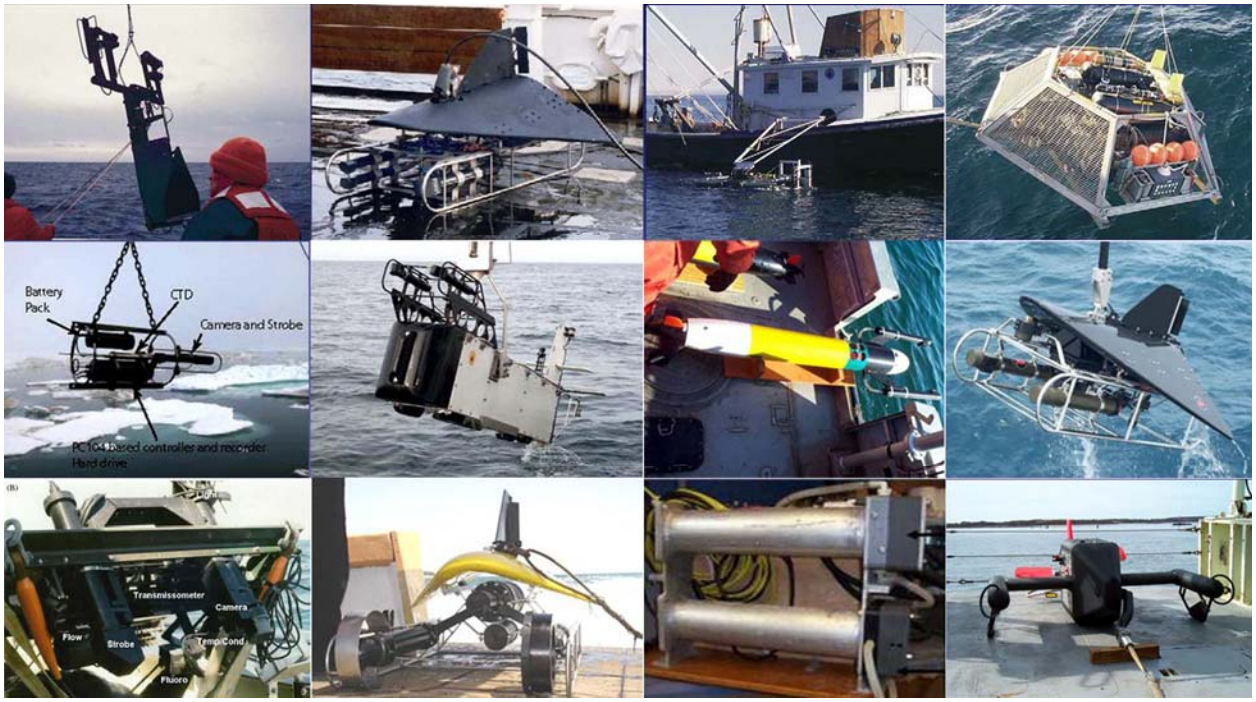
Esmeraldo dos Santos Filho: Implementation and evaluation of new features for zooplankton identification (ZOOSCAN case study)

This presentation summarized the steps required for automated zooplankton recognition using

Zooscan software. The software consists of ZooProcess, which is based on ImageJ and Plankton Identifier, which utilizes Tanagra. The features currently extracted in ZooProcess were summarized, along with new features that are being explored. The new features include (1) Texture contrast – neighborhood – grey contrast; (2) cumulative histograms; (3) convex area; (4) Symmetry; and (5) Thickness ratio. There was a demonstration of Plankton Identifier and an example of how training sets are prepared. A confusion matrix provided an evaluation of the value of the new features. This is a work in progress and they expect to improve classifier performance based on the addition of new image features.

Cabell Davis: Real-time automatic identification and visualization of plankton taxa

Provided an overview of the VPR family of instruments. The latest version is housed in a high-speed (12knots) tow-body with a camera operating at 30 Hz providing a horizontal resolution of 30 cm at top speed. The camera images a volume of $10cm^3$ (1 cm x 1cm x 10 cm depth of field). Fared cable allows the system to reach ~100m at 12 knots and deeper with slower tow speeds. The VPR family includes towed and autonomous systems with analog VPRs: surface skimming, profiling, towed, mounted with acoustics, on an AUV, in a shipboard flowthrough system and mounted on a MOCNESS net. The VPR software is called Visual Plankton, which is written in Matlab. There are five stages to this software: calibration, focus detection, training, automatic classification, and visualization of results. The system has two classifiers: neural net and support vector machine. Features include shape-based and texture-based classifications. The classifiers vote. When they agree, the object is classified and when they disagree it is put into an unknown category. Examples of images were provided, including small, fragile taxa that are not well sampled by nets. The latest version of the VPR includes a color camera and it will require new algorithms for processing color data. Data from a VPR mounted on a MOCNESS provided comparable vertical distributions and abundances. A study across the flank of Georges Bank illustrated the capability to document the fine-scale, vertical distributions of different taxa. The application of the VPR on an ROV illustrated the micro-scale complexity of planktonic systems. A cross-Atlantic transect from the Azores to Woods Hole (5500 km) provided evidence of deep populations of *Trichodesmium*, which has implications for nitrogen fixation rate estimates. A new system based on holography is in the prototype stage. This low-powered system provides 9-micron resolution in the x-y plane. An example of the application of Visual Plankton from a transect across part of the Caribbean Sea was illustrated. Classification was performed on a 19-class problem with 250,000 rows using a training set made of ~200 individuals per class. Future work will require color algorithms, orientation variance, holographic techniques to obtain a virtual image, reduce noise, and combine multiple slices. A real-time capacity is needed for common software tools, and there is a need to migrate from Matlab to open-source code.



A collage of VPR systems. The VPR is the most widely used, and one of the only commercially available in-situ imaging systems.

ZooScan Training Workshop

This workshop was held at the University of São Paulo, Institute of Oceanography laboratory at Ubatuba. Prior to the training, Rubens Lopes explained the rationale for using automated imaging systems. The Institute has a large repository of zooplankton samples dating back to the 1960s. These were collected for fish larvae and eggs but have not been enumerated for zooplankton. Moreover, there is a lot of interest in morphometrics to obtain biomass estimates and instruments such as the Zooscan can potentially provide such information.

The workshop was designed to demonstrate the methodology for obtaining data from a plankton sample so that all members of the group could better understand the general procedures in automated plankton identification. A plankton sample collected off the coast that morning provided an opportunity to go through the steps of automated analysis system beginning with the sample.

Zooscan training workshop held at the University of São Paulo, Institute of Oceanography lab in Ubatuba.

Appendix A: List of Participants

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Members:

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Josué Alvarez-Borrego, Optics Department, Division of Applied Physics, CICESE, Mexico
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Rubens Lopes, Instituto Oceanográfico, Universidade de São Paulo, Brazil
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Associate Members:

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Hans DuBuf, Machine Vision Laboratory, University of Algarve, Portugal
Gabriel Gorsky, CNRS, Laboratoire Océanologique de Villefranche sur mer.
Xabier Irigoien, AZTI (Institute for Fisheries and Food Science), Spain
Norm McLeod, Department of Palaeontology, The Natural History Museum, UK
Sun Song, Institute of Oceanology, Chinese Academy of Sciences, PRC
Robert Williams, Plymouth Marine Laboratory, UK

Appendix C: Report from the subgroup on 'The Establishment of a Reference Dataset'
Final Version 15.02.2008

Subgroup membership:

- Elena Arashkevich (full WG member, Russia)
- Phil Culverhouse (WG co-chair, United Kingdom)
- Gabriel Gorsky (associate member, France)
- Maria Grazia Mazzocchi (full WG member, Italy)
- Priscilla Licandro (associate member, United Kingdom)
- Hans Verheye (full WG member, South Africa)

Background

Increasing awareness of relevant ecological issues such as global climate change and declining biodiversity has prompted the scientific community of marine biologists and oceanographers to direct major research efforts toward a better understanding and management of marine ecosystems. In this global change scenario, it has emerged among zooplanktologists that there is an urgent need for devising effective approaches and practical solutions to improve our ability to track the variability of ecosystems at appropriate spatial and temporal scales. Large-scale synoptic surveys and long-term time series are among the traditional approaches that are very costly and time consuming, but they remain the only useful tools for the proper monitoring of zooplankton distribution and the variability in marine biota. These tools would be much more effective if the biological results were to become available within a short time frame, thus rapidly providing a status picture of communities and eliciting an early warning in case of anomalous situations or patterns. This is not possible through the use of traditional sample analysis methods using a microscope, which is labour intensive and time consuming, although it allows detailed investigation of species occurrence and abundance.

The automatic visual identification of plankton is a compelling alternative approach which, in this early phase of application, still needs to be tightly coupled with and complemented by taxonomic work. Taxonomy is vital to the study of biodiversity and to the monitoring of it changing in time and space, but taxonomic expertise is dwindling rapidly in most, if not all, parts of the world, to the extent that the few remaining plankton taxonomists have now made it onto the list of 'Endangered Species'…! Therefore, there is an urgent need for the integration of this remaining, precious taxonomic expertise into new, automated devices and this is the overall scope of this Subgroup of SCOR WG130.

Sets of reference images need to be created to capture human expertise in the form of labelled images gathered from *in situ* imaging instruments, which lack any means of capturing the imaged specimen (for subsequent identification). The reference datasets are needed both for training existing and future taxonomists, and as training sets for automatic plankton classification instruments. This is crucial for interdisciplinary research on marine pelagic ecosystems where the biological data should be treated at the same speed as the physical and chemical data.

Aims and objectives

This Subgroup will contribute to the implementation of the automatic recognition skills of the systems and machines currently available, as well as to the validation of the products generated by imaging systems, by providing guidelines and standards for the establishment of a global, validated reference dataset of machine-generated images ('image bank') of plankton taxa. A likely long-term goal will be the training of a new generation of plankton taxonomists using these resources.

More specific objectives will be

1. to identify which plankton taxa should be targeted in order to promote and expand a global reference collection of images;
2. to establish, for each taxon, which features should be taken into account in organism morphology and image features for unambiguous automatic identification of organisms; in other words, towards a 'new practical' (automatic and necessarily simplified for now) taxonomy;
3. to establish which type of dataset should be considered that will ultimately constitute a global reference collection of images for each targeted taxon (e.g. dorsal, ventral, lateral views; adults, juveniles, larvae);
4. to determine the minimum requirements in terms of the number of images related to the image source that is needed per taxon to be recognised unambiguously by machine-based recognition systems;
5. to promote and contribute to an intercalibration process among different machines and systems;
6. to promote a worldwide network of taxonomic experts who work in close collaboration with the end-users of automatic recognition systems, including the linking up with certain other ongoing initiatives;
7. to explore future prospects for the further development, or expansion, of this image dataset;
8. to report on the Subgroup's activities, findings, and recommendations to WG 130 and SCOR, and ultimately to disseminate information to a broader community by preparing a paper to be published in the scientific literature.

Proposed activities

Different modes of image acquisition (i.e. the imaging systems) generate different classes of datasets. Two large classes of imaging systems can be identified on the basis of *in situ* or laboratory approaches. In the first case, live organisms are observed directly in the sea (e.g., using a VPR) and this is the best approach for imaging delicate gelatinous species and aggregates, whereas in the second case preserved samples are analysed by using a flatbed scanner (e.g., ZooScan or other device) as a substitute for the classical microscope analyses. The images provided by the two instrumental categories differ in their technical characteristics and information content, and each dataset class is therefore likely to require a different approach toward the determination of appropriate, class-specific standards. Both classes, the *in situ* images and the laboratory-generated images, will be considered separately but in parallel, for the establishment of two reference datasets (see Annex 1 for a discussion of taxonomic issues) that will be based on fresh and preserved material respectively. In addition, new imaging systems will continue to develop, each requiring a reference image dataset, so that any standard or requirements specification will need to account for this. Therefore, perhaps a future approach might be to provide a high-resolution 3D reference dataset, and then to generate views of these data for each machine, based upon the machine's optical characteristics.

As a practical starting point, datasets are likely to be established first for specific geographical regions/seas, oceanographic systems, and/or basins (e.g., North Atlantic, tropical Atlantic, North Pacific, Southern Ocean, North Sea, Baltic Sea, Mediterranean Sea, Black Sea, etc.). Ultimately, these image datasets could be merged and consolidated into a global digital archive. To that extent, appropriate funds may need to be sourced for particular regions. An important consideration that will contribute appreciably in this respect may be the so-called 'data rescue' programmes (e.g., in southern Africa, funded by the French-South African research programme ECO-UP, and in Europe, funded by the Network of Excellence EUR-OCEANS).

A good example of an EUR-OCEANS data rescue programme in progress is the re-analysis of the Bay of Villefranche (Ligurian Sea) time series (ongoing since 1957) in Villefranche-sur-mer, France using the ZooScan. It is envisaged that by mid-2008 the Villefranche ZooScan image bank will contain images of zooplankton from WP-2 samples collected during the period 1966-2008 (3 samples per month). The construction of a reference collection of ZooScan images of zooplankton from the Gulf of Naples (Tyrrhenian Sea; ongoing since 1984) is also underway. Once agreed upon by the local experts, these reference image collections will become available to the public at large (with reference to SCOR WG 130).

Other ongoing initiatives have lead to a compilation of comprehensive species identification 'manuals', for example, by NERC in the UK (*cf.* Steve Hay). These could also contribute to the establishment of a global image databank. For an on-line key see www.crustacea.net.

In the preparation of datasets it should be aimed at including all zooplankton groups but, for practical purposes, it will probably be necessary to adopt a stepwise approach by considering some specific target groups first. It is likely that the taxa will be selected on the basis of their importance, notably in terms of their abundance and the functional role they play in the most relevant processes (e.g., trophic interactions, biogeochemical cycles) that are taking place in marine systems.

Within the targeted taxonomic groups, the level of taxonomic resolution may be driven by specific objectives or questions to be answered by end-users, such as ecological questions that focus on, for instance, community size structure, functional groups, and diversity, in relation to critical issues such as long-term climate change, fisheries, impacts of pollution, impacts of eutrophication, introduction of alien/invasive species, HABs, marine aquaculture, etc. Image dataset preparation should therefore be prioritised first in terms of its value to the community, and then to the imaging system developers. This is a very important objective that we can reach within the lifespan of this SCOR WG and for which we can produce some concrete outcomes.

The WG's activities will initially focus on mesozooplankton, with the subsequent goal to stimulate and possibly involve a wider community that deals with other components, such as microzooplankton and phytoplankton, thereby however recognising that other technical problems are inherent here. For example, whereas some protozoo-plankton (e.g., tintinnids) can be treated by imaging techniques in a preserved state, other ciliates (such as the small naked oligotrichs) should necessarily be imaged when alive. Also, phytoplankton includes nano- and picoplankton size classes that dominate the phytoplankton in most oceans but are considerably difficult to image; this is in contrast with the larger diatoms and dinoflagellates that are more easily imaged so that their datasets are likely to be utilised for monitoring purposes such as vertical flux in productive regions and impact of HABs respectively. These aspects need to be further discussed.

For numerous investigations (e.g., studies on the role of zooplankton in carbon fluxes and biogeochemical cycles, pollution effects, etc.) it would be very useful, in imaging preserved samples, to consider distinction between live and dead organisms. To that extent, samples can be stained using, for example, the simple Neutral Red staining method implemented by Tang *et al*. (2006).

An important issue that needs to be addressed is the inter-calibration between humans and computers: not only do taxonomists contribute significantly to image validation, but likewise – *vice versa* – computer-based analysis of images can also be suggestive of new diagnostic characters that should be considered by taxonomists for the unambiguous identification of taxa.

The level of confidence of taxonomically validated datasets will be determined by applying appropriate statistical tools.

The Subgroup may also need to consider – perhaps at a later stage – to incorporate images of barcode-validated taxa. To that extent, we will formulate recommendations to the Census of Marine Zooplankton (CMarZ) – through the WG – to establish such a dataset for all barcoded species. Although imaging is a "now thing", and barcoding more of a "future thing", we should already start seeking ways to tie genetic analysis data with image analysis data. Some global barcoding initiatives are already gathering data, and the extra effort required for confocal imaging of each specimen prior to barcoding is minimal [Peter Wiebe has already expressed a strong interest in this]. The Subgroup proposes to the future CoML-2, to create a confocal imaging network associated to a barcoding network accompanied by the construction of a common taxonomic database (barcode with reference image collection).

Annex 1: Issues for taxonomic standards

There are a number of issues that need to be considered:

1. <u>Gold-, Silver-, and Bronze-standard reference datasets</u>

Gold standards are collections of voucher specimens. Voucher specimens (see Annex 2 for a definition) exist in plankton collections that are prototypical of the species. That is, they possess all the characteristics that are expected for an unambiguous identification. Although this is a convenient reference source for experts, it is of little value to machine-learning algorithms.

The problem is that genetic and environmental pressures cause changes in the morphology of some species. It is more pronounced in microplankton, nanoplankton, bacteria and viruses, but even zooplankton can exhibit differences among geographically separate populations.

The solution is to have reference collections of specimens, rather than one example. Gorsky and co-workers are developing this archive for taxa studied at Villefranche. These need to be set up in laboratories across the world, perhaps as part of the CoML initiative, in parallel with imaging each DNA-processed specimen.

Silver standards are collections of specimens gathered by one laboratory, internally validated and used for reference against the ZooScan or other devices. Silver-standard reference specimens are less likely to have effort invested in them to have DNA validation. The only recourse is to have a panel judgment on each label to define a consensus opinion; a minimum of two experts need to review the specimens to confirm the labels given.

Bronze standards are collections of images gathered by *in situ* imaging systems. They are normally used to train classifiers deployed with the imager, for real-time identification of plankton. No physical specimens exist to reference these standards. Hence the need for training reference sets using expert consensus as a means of validating the data sets. An example reference source is under development at www.pleione.nocg.cis.plymouth.ac.uk.

2. Human expert inter-calibration

Voucher specimens are physical entities and so can be DNA analysed for confirmation of species. Although not free from interpretation issues, DNA analysis does validate the label given to the specimen. An explicit link to the CoML initiative is required here.

3. Training data validation

The images used to train a classifier need to be quality assured, that is, their label must be accurate. Mislabeled specimens add noise to the training process. There are no studies at present that explore the effect of this noise on the training quality.

4. Biomass equation standards

Fast taxon-related biomass estimates are one important reason for using automated visual identification of plankton. Biomass reference data can only be compiled when using a laboratory-based system (ZooScan, other devices using the ZooImage software, etc.) where the physical specimen can be recovered. Dry weight of taxon-specific samples must be calculated and the conversion coefficients used for example by ZooScan and ZooImage softwares published. Conversion factors that allow these values to be used within *in situ* samplers must also be developed and published.

These data must be created for all common taxa classes used by ecologists and taxonomists. For example, at present the common zooplankton classes for automated analysis are (i) copepods, (ii) euphausiids, (iii) chaetognaths, (iv) salps and doliolids, and (v) appendicularians.

5. Taxonomic audit trail from training data

A taxonomic audit trail will need to be maintained to ensure that results from automatic visual plankton identification can be quality assured, as is the case for any laboratory instrument. This is becoming possible for ZooScan. Protocols for auditing need to be developed and published, so that any instrument developer can assess the instrument quality to a common format.

Annex 2: Voucher Series

A *voucher series* is a series of reference specimens for each reported taxon, including those taxa tentatively identified as "Genus A" or "species B". A voucher series should be established that includes a sufficient number of individual specimens to display all typical intra-specific variability encountered in that taxon for that study area. Whenever feasible, the series should include ovigerous and non-ovigerous adult females, mature males, juveniles and larval stages. If the taxon exhibits habitat-related phenotypic variability, representatives from each habitat should be included in the voucher series for that taxon. The voucher series for a taxon is as important to an ecological study as a taxon's type series is to a taxonomic study.

A *voucher collection* is a taxonomic reference collection composed of one or more lots of specimens (i.e., a voucher series) of each reported taxon for a given ecological, biogeographic, physiological or other scientific study. The primary purpose of a voucher collection is to ensure taxonomic consistency. A voucher collection should be established early in the taxonomic phase of a project. The greatest number of voucher specimens will be derived from the first cruises or first collecting efforts. However, new specimens will continually be added to the various series as taxonomically important variations are encountered or as new taxa are identified. The voucher collection for each major taxon should be established by competent, professional taxonomists. Ideally, the same taxonomists would be responsible for the identification of all non-voucher specimens. Taxonomic references used in the identification of the voucher series as well as the voucher specimens themselves must be available for use during the identification of the general (non-voucher) collections. All specimens in the general collection identified to any taxonomic level must exhibit taxonomically important characters identical to those characters exhibited by specimens in the corresponding voucher series. The re-identification of a voucher specimen/series by the taxonomic contractors will require that all corresponding specimens in the general collection be re-evaluated and, if necessary, re-identified to ensure consistency between the names used for specimens in the voucher collections and those used in the general collections.

(from United States Antarctic Program, Smithsonian National Museum of Natural History. See http://invertebrates.si.edu/usap/usapspec.html)

2.2.11 WG 131: The Legacy of in situ Iron Enrichment: Data Compilation and Modeling (2007)

Terms of Reference:

- Compilation of a database for open access (via the Internet) of the following experiments:
    - the 1999-2001 era (IronEx-1, IronEx-2, SOIREE, EisenEx, SEEDS-1), plus 1992 S.O. JGOFS;
    - the 2002 experiments (SOFeX-North, SOFeX-South, SERIES); and
    - the 2004 experiments (Eifex, SEEDS-2, SAGE, FeeP), plus natural fertilizations CROZEX, KEOPS

This effort will include a commonly agreed data policy for users to best acknowledge the original data producers (e.g., by offering co-authorship and perhaps assignment of digital object identifiers for individual data sets). Obviously, a practical description of methods used, calibration etc. (so-called metadata) will also be included. In essence, the WG members are committed to send their data files to the common data centre, and encourage their colleagues in any given experiment to do the same. Finally, an official data publication or publication(s) will be placed in a suitable venue, for example, in the special issue on the SCOR WG (see item 4. below) and in *Eos* (Transactions Am. Geophys. Union). In 2006-2007 efforts are already underway for compilation and rescue of the EisenEx dataset, also there is very good progress for SEEDS-2, SERIES, CROZEX and KEOPS. However, the statement in the original proposal that no meeting would be necessary to achieve the first term of reference was overly optimistic. It appears that a face-to-face meeting sponsored by SCOR or some other internationally recognized organization is necessary to work out the details of bringing together the data sets in a way that will make it possible to achieve the other terms of reference.

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SCOR WG 131 Annual Report 1 August 2008

"The Legacy of in situ Iron Enrichments: Data Compilation and Modeling".
http://www.scor-int.org/Working_Groups/wg131.htm

This report has three sections
a) Accomplishments in 2007/8
b) Planned activities for 2008/9
c) Issues for SCOR to consider

a) Accomplishments in 2007/8

The co-chairs and a part-time assistant (Dr. Doug Mackie, funded by SCOR) have liaised with the PIs from each of the eleven in situ iron enrichment experiments and made encouraging progress in locating and examining both metadata and data from the experiments. In October 2007 co-chair Boyd met with Dr. David Glover of the Biological and Chemical Oceanography Data Management Office (BCO-DMO) in Woods Hole, MA, USA. The detailed discussions that followed led to an offer from BCO-DMO to become the common data centre for the efforts from WG 131. Cyndy Chandler, the data manager at BCO-DMO, has been instrumental in bringing her experience in the construction of relational databases, and of the associated issues, common problems and timescales that accompany such database development. Significant progress has been made in:

i) ingestion of all metadata and most of the data from three of the eleven studies – SOFEX-North, SOFEX-South and SOIREE (see accompanying progress report from BCO-DMO)
ii) ingestion of some metadata and baseline data from all of the eleven experiments
iii) PIs of each study setting up web links or importing data summaries onto CD-ROM for experiments as an intermediate step (i.e., prior to data manipulation and quality assurance by Dr. Mackie and submission in standardized form to BCO-DMO).

A summary of the progress in data compilation of the eleven experiments follows.

IronEX I: Metadata and baseline data have been compiled and are available on http://www.mbari.org/sofex/IronEx_I.htm

IronEX II: Metadata and datasets have been compiled and are available on http://www.mbari.org/sofex/IronEx_II.htm

SOIREE: Most of the metadata and data (80%) have been added to the BCO-DMO website http://cis.whoi.edu/science/bcodmo/program.cfm?flag=view&id=10&sortby=program

EisenEx: Metadata and most baseline data have been compiled and are available on the PANGAEA/WDC-MARE database and have been submitted to BCO-DMO. Submission of additional data to PANGAEA is ongoing. Rainer Sieger, Hannes Grobe (PANGAEA) and

Benjamin Pfeil (CARBOOCEAN data manager, Bjerknes Center, Norway) have been assisting us and liaising with BCO-DMO. For examples see:
http://store.pangaea.de/Projects/EisenEx/EisenEx_metadata.zip,
http://store.pangaea.de/Projects/EisenEx/EisenEx_2008-07-28.zip,
http://doi.pangaea.de/10.1594/PANGAEA.701279 (ADCP data, 122 MB).
http://doi.pangaea.de/10.1594/PANGAEA.288115 is a useful data conversion tool.

Seeds I: A CD_ROM with a summary of the metadata for the voyage and all of the baseline data has been compiled by the PIs and sent to Doug Mackie for further manipulation followed by data submission.

SOFEX-S: Most of the metadata and data have been added to the BCO-DMO website http://cis.whoi.edu/science/bcodmo/program.cfm?flag=view&id=10&sortby=program

SOFEX-N: Most of the metadata and data have been added to the BCO-DMO website http://cis.whoi.edu/science/bcodmo/program.cfm?flag=view&id=10&sortby=program

EiFEX: Metadata and some baseline data are have been compiled and are available on the PANGEA database. For examples see http://www.pangaea.de/search?count=10&q=Eifex&minlat=&minlon=&maxlat=&maxlon=&mindate=&maxdate=&env=All&offset=60

Benjamin Pfeil, the CARBOOCEAN data manager, based at the Bjerknes Center, Norway, and Hannes Grobe at the PANGEA database have been assisting us and liaising with BCO-DMO.

SERIES: A DVD with a summary of the metadata for the voyage, all of the baseline data, and some level 3 and 4 data has been compiled by the PIs and sent to Doug Mackie for further manipulation.

SEEDS II: Electronic files containing a summary of the metadata for the voyage and some baseline data has been compiled by the PIs and sent to Doug Mackie for further manipulation.

SAGE: Electronic files containing a summary of the metadata for the voyage and most of the baseline data have been compiled by the PIs and sent to Doug Mackie for further manipulation.

Co-chair Boyd and Cyndy Chandler had a further progress meeting during the ASLO/TOS Ocean Science meeting in Orlando, Florida in February 2008, and more recently a series of conference calls.

b) Planned activities for 2008/9

We have two planned activities for next year. The first is to increase our rate of progress on data ingestion into BCO-DMO. We have discussed a timeline of progress with Cyndy Chandler at BCO-DMO (see attached letter). We are agreed that based on the good working relationship that is developing between Doug Mackie (Otago) and Steve Gegg (BCO-DMO, commenced in May

2008), and the continued wherewithal evident from the lead and other PIs of the iron studies that most of the experiments should be onto the common database by the end of 2008. Due to the difficulties in predicting our progress, Cyndy and the WG co-chairs have agreed on a fall-back position of having all of the polar experiments (SOFEX-N, SOFEX-S, SOIREE, EisenEX and EifEX) loaded onto the database first, followed by the subpolar and tropical studies. This will, at the very least, enable the polar datasets to be used by modelers in phase II of our WG activities.

Second, we shall move into phase II of the WG – modeling. This will be progressed as follows:

August to December 2008

Finalize the other members of the working group (a mix of modelers and observationalists – based on the lists compiled for the original submission – see Appendix 1).

Ask the modelers within the WG to provide feedback on the utility of the BCO-DMO relational database (which will have three completed studies available by end of August 2008). Use the feedback to fine-tune the relational database as required.

Plan the first meeting of WG131 for January 2009 (in conjunction with the ASLO Aquatic Sciences meeting, Nice, France, January 25-30 2009).

Circulate a discussion document (from the co-chairs) by October 2008 on the key issues that need to be considered by modelers (feedback will be strongly encouraged).

Themes will probably include a) influence of iron on the ocean's carbon cycle; b) meeting the challenge of the uncertainties raised by commercially driven large-scale ocean iron fertilization; c) the role of nested suites of models in providing more reliable simulations at the basin and global modeling scales.

This working document will be based on the de Baar et al. (2005, *JGR*), Boyd et al. (2007 Science) overviews of the eleven in situ iron experiments and the published proceedings of two recent syntheses (Powell 2008 *Oceanus*, summary of the WHOI iron Fertilization meeting on "Exploring Ocean Iron Fertilization: the scientific, economic, legal and political basis" www.whoi.edu/conference/OceanIronFertilization/, and (Boyd, 2008 Marine Ecology Progress Series *THEME SECTION: Implications of large scale iron fertilisation of the oceans*, 12 papers http://www.int-res.com/abstracts/meps/v364/)

January to July 2009

The first meeting of the WG131 for January 2009 (in conjunction with the ASLO Aquatic Sciences meeting, Nice, France, Jan 25-30 2009). Prof. Stéphane Blain at CNRS Banyuls (near Nice) has been approached to host this WG meeting (he is on vacation at present). Additional funds are being sought through various European agencies by Prof. de Baar and the WG co-chairs.

The workshop will probably be of 4 days' duration.

Day 1
Introduction and Welcome
Summary of the present modeling approaches to ocean iron fertilization – from 1D to 3D, from ecosystem to regional to coupled-ocean atmosphere models.
Discussion of the relational database and updates on its use with models.
Discussion of working document on key issues to be addressed by modelers.

Day 2
Break out groups of both observationalists and modelers to address the two discussion items from Day 1
Feedback from groups

Day 3
Discussion of and identification of multi-stranded approaches to address the key themes (if these are still applicable)of:

a) influence of iron on the ocean's carbon cycle
b) meeting the challenge of the uncertainties raised by commercially driven large-scale ocean iron fertilization
c) the role of nested suites of models in providing more reliable simulations at the basin and global modeling scales

Day 4
Action items and the development of a timeline for the next 12 months
End of meeting

Other activities for the next year include

- Complete any outstanding data ingestion into BCO-DMO.
- Prepare an article to publicize the WG data archive at WHOI and report on the modeling WG meeting either through *EOS* and/or SCOR.
- Write a detailed report outlining the progress made at the first WG modeling meeting, and plans for modeling activities in 2008/9 and beyond.

c) Issues for SCOR to consider

Funding of the WG 131 in 2008/9. We request to split that funding as follows - 10 K US to continue part-time funding for the post-doc (Mackie in New Zealand) to complete the data collation and transfer to WHOI (by Dec 08). The remainder of the funding (>35 K US) to go towards funding the first workshop that brings together modelers and observationists in early 2009. We will endeavor to use the SCOR funding to lever additional funding to support a successful workshop. Also having the WG workshop around the time of the ALSO meeting will help to reduce costs.

We thank SCOR for funding this WG131 in 2007/8

Yours sincerely

Philip Boyd

Dorothee Bakker

Appendix 1

List of proposed members from the original WG 131 submission

Name	Major Relevant Expertise	Experiment(s)	Nation
Co-chairs:			
Bakker, Dorothee	CO_2 system	S.O.JGOFS,SOIREE, EisenEx,CROZEX	UK
Boyd, Philip	plankton ecology	SOIREE, SERIES	New Zealand
Other Full Members:			
Bathmann, Uli	polar mesozooplankton	S.O. JGOFS,EisenEx, Eifex	Germany
Coale, Kenneth	iron-biota experiments	Ironex-1&2, SOFeX	USA
De Baar, Hein	iron and CO_2, Geotraces	S.O. JGOFS, EisenEx	Netherlands
Dittert, Nicolas	data management EUR-OCEANS and WDC-MARE		European Union
Minhan Dai	ocean cycling of carbon and metals, Geotraces		China-Beijing
Levasseur, Maurice	DMS(P) and plankton	SEEDS-2, SERIES	Canada
Takeda, Shigenobu	iron chemistry & biology	SEEDS-1&2, SERIES	Japan
Pollard, Raymond	physical oceanography	CROZEX	UK
Associate Members:			
Assmy, Philip	diatom responses	EisenEx, Eifex	Germany
Blain, Stephane	iron biogeochemistry	KEOPS	France
Buesseler, Ken	export production	IronEx, SOFeX	USA
Croot, Peter	iron chemistry	Eisenex, SOFeX, Eifex	Germany
Denman, Ken	modeling	SERIES	Canada
Goldson, Laura	tracer dispersion & mixing	EisenEx, SOFeX	UK
Follows, Mick	various modeling including OBCM's		USA
Fujii, Masahiko	simulation modeling	SEEDS-1&2, SERIES	Japan
Hong, Huasheng	ocean biogeochemistry		China
Kozyr, Alex	ocean CO_2 data management at CDIAC, Oak Ridge		USA
Law, Cliff	tracer dispersion & mixing	SOIREE, SERIES	New Zealand
Marchetti, Adrian	diatom responses	SERIES	Canada
Nishioka, Jun	iron physical chemistry	EisenEx, SEEDS-1&2, SERIES	Japan
Rijkenberg, Micha	iron photoredox chemistry	SOIREE, EisenEx	UK

RutgersVanDerLoeff, Michiel, dr.	export production/Geotraces	S.O. JGOFS, EisenEx	Germany
Schoemann, Veronique	iron-phytoplankton, Phaeocystis		Belgium
Strass, Volker	polar physical oceanography	EisenEx, Eifex	Germany
Tsuda, Atsushi	zooplankton ecology	SEEDS-1&2, SERIES	Japan
Tung, Yuan-Ho	marine chemistry and ecology		Taiwan
Turner, Sue	DMS(P) cycles	IronEx,SOIREE, EisenEx	UK
Timmermans, Klaas	iron-diatom interactions	EisenEx, KEOPS	The Netherlands
Twining, Benjamin	intracellular iron	SOFeX	USA
Watson, Andy	CO_2 system, tracer dispersion	IroneEx I, SOIREE, EisenEx	UK
Wingenter, O.	rarely studied trace gases	SOFeX	USA
Wang, Wen-Xiong	trace elements uptake and transfer in phyto-zooplankton		China
Zhong, Shaojun	Geotraces Standards and Intercalibration task team		China

Liaison Scientist:
(*Liaison Scientists will be informed about and invited to all activities, they will submit datasets and/or are involved as simulation modeling experts. The below names merely are the beginning of a growing list of enthusiastic colleagues, each with excellent scientific credentials)*

Gnanadesikan, Anand	ocean modeling including OBCM's, iron cycle		USA
Le Clainche, Yvonnick	ecosystem DMS(P) modeling	SERIES	Canada
Nightingale, Philip	tracer dispersion, air/sea	IronEx, EisenEx	UK
Rivkin, Richard	bacterial responses	SERIES	Canada
Sanders, Richard	carbon export	CROZEX	UK
Sarmiento, Jorge	ocean modeling including OBCM's, iron cycle		USA
Savoye, Nicolas	export production	Eifex	France
Vezina, Alain	ecosystem inverse modeling, DMS(P)		Canada

Appendix 2

Terms of Reference for WG 131

- Compilation of a database for open access (via the Internet) of the following experiments:
  - the 1999-2001 era (IronEx-1, IronEx-2, SOIREE, EisenEx, SEEDS-1), plus 1992 S.O. JGOFS;
  - the 2002 experiments (SOFeX-North, SOFeX-South, SERIES); and
  - the 2004 experiments (Eifex, SEEDS-2, SAGE, FeeP), plus natural fertilizations CROZEX, KEOPS

This effort will include a commonly agreed data policy for users to best acknowledge the original data producers (e.g., by offering co-authorship and perhaps assignment of digital object identifiers for individual data sets). Obviously, a practical description of methods used, calibration etc. (so-called metadata) will also be included. In essence, the WG members are committed to send their data files to the common data centre, and encourage their colleagues in any given experiment to

do the same. Finally, an official data publication or publication(s) will be placed in a suitable venue, for example, in the special issue on the SCOR WG (see item 4. below) and in *Eos* (Transactions Am. Geophys. Union). In 2006-2007 efforts are already underway for compilation and rescue of the EisenEx dataset, also there is very good progress for SEEDS-2, SERIES, CROZEX and KEOPS. However, the statement in the original proposal that no meeting would be necessary to achieve the first term of reference was overly optimistic.
It appears that a face-to-face meeting sponsored by SCOR or some other internationally recognized organization is necessary to work out the details of bringing together the data sets in a way that will make it possible to achieve the other terms of reference.

Biological and Chemical Oceanography Data Management Office
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To: Dr. Ed Urban
Subject: BCO-DMO 2008 Progress Report: Construction of Iron Synthesis Database
Date: September 19, 2008

Please accept this letter describing progress to date on the data recovery efforts in support of the Iron Synthesis program, developed in response to the 2005 SCOR Working Group proposal, "The Legacy of *in situ* Iron Enrichments: Data Compilation and Modeling" (SCOR WG 131). Recovery of data from projects identified as being of interest to the Iron Synthesis program is progressing at the Biological and Chemical Oceanography Data Management Office (BCO-DMO) in Woods Hole, MA, USA. Thus far, program and project level metadata have been collected and entered in the online database (URL for the top level BCO-DMO Data Collection: http://cis.whoi.edu/science/bcodmo/index.cfm) for these iron enrichment projects:

European Iron Enrichment Experiment (EisenEX)
European Iron Fertilzation Experiment (EIFEX)
Iron Experiment I (IronEx I)
Iron Experiment II (IronEx II)
Southern Ocean Iron Experiment (SOFeX North and South)
Southern Ocean Iron Release Experiment (SOIREE)
Sub-Arctic Ecosystem Response to Iron Enrichment Study (SERIES)
Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study I (SEEDS I)
Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study II (SEEDS II)
Surface-Ocean Lower-Atmosphere Studies Air-Sea Gas Exchange (Experiment) (SAGE)

We are in frequent communication with Philip Boyd, lead PI, and his Post-doc, Doug Mackie, (Department of Chemistry, University of Otago, New Zealand) and are working to add datasets for the projects listed above. We have nearly completed work on the SOFeX North and South project data sets (only eleven data sets have not yet been added). We expect the SOFeX project database to be complete by the end of August 2008. Data from the SOIREE project were published on CD-ROM as a final data report (Deep Sea Research Part II: Topical Studies in Oceanography Volume 48, Issue 11-12, 2001, “The Southern Ocean Iron Release Experiment (SOIREE)”, Guest Edited by C. S. Law, P. W. Boyd, A. J. Watson), and BCO-DMO staff members have already added 80% of the SOIREE data to the BCO-DMO database.

In collaboration with Philip and Doug, we have worked out a phased plan for ingestion of datasets into the BCO database. Steve Gegg, a new BCO-DMO team member, was hired in May 2008 and his top priority project for 2008 is to build the Iron Synthesis database. As data are received from the originating investigators, they are organized into four overlapping categories, and contributed to the BCO-DMO: (1) Level 1, basic metadata (e.g., description of project/study, general location, PI(s), participants); (2) Level 2, detailed metadata and basic shipboard data and routine ship's operations (e.g., CTDs, underway measurements, sampling event logs); (3) Level 3, detailed metadata and data from specialized observations (e.g., discrete observations, experimental results, rate measurements) and (4) Level 4, remaining datasets (e.g., highest level of detailed data available from each study). We have developed customized forms to assist in the recovery of data and information from the identified projects and we expect to have made sufficient progress on the data recovery process to support a synthesis workshop in early 2009.

One advantage to having these data published in the BCO-DMO database is that they will share a common access point with datasets published from ocean science investigations that share common science themes and research goals. The BCO-DMO database already includes data from several other ocean biogeochemistry projects that were conducted in the Southern Ocean (an area of particular interest for *in situ* iron fertilization work) over the past two decades. All data managed by the BCO-DMO are made publicly available as soon as they have passed quality control assessments and are released by the originating investigator.

Best regards,

Cynthia Chandler

Cyndy Chandler
Data Manager, BCO-DMO

2.2.12 SCOR/LOICZ WG 132: Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems
(2007)

Terms of Reference:

1. Integrate the existing IOC-HAB database and nutrient loading databases into a compatible GIS format.
2. Advance the development of a GIS coastal typology database.
3. Interrogate the above databases for relationships between HAB species, nutrient loading/forms/ratios, and coastal typology and develop broad relationships between nutrient loading and distributions of specific HABs.
4. Explore possible changes in HAB occurrences in the future (year 2030), using the relationships developed above (3.) and global nutrient export patterns under the Millennium Assessment scenarios for 2030.
5. Publish the results of these analyses in peer-reviewed scientific journals. Papers will be developed on 1) the global perspective, including the next generation of global nutrient and HAB maps; 2) regional highlights; and 3) individual case studies. We will also develop articles for the GEOHAB newsletter and for the GEOHAB and Global News websites, and a graphic-rich report (under the GEOHAB umbrella) that will be targeted for management.

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Executive Committee Reporter: Jorma Kuparinen

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Report of the First Meeting of SCOR/LOICZ Work Group 132

Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems

28-31 July 2008
GKSS-Forschungszentrum, Geesthacht GmbH, Geesthacht, Germany

Patricia Glibert, University of Maryland Center for Environmental Science
Lex Bouwman, Netherlands Environmental Assessment Agency
Working Group Co-Chairs

1. BACKGROUND

To date, attempts to relate the occurrence of particular HAB species with nutrient loading have largely been based on a limited amount of data from the literature on HAB occurrences where nutrient loading and other parameters could also be found. Most available studies lack specific information on nutrient loading rates and often details of the coastal typology. Initial efforts combining literature data on HAB species occurrences with the outputs of global nitrogen loading models suggested a high degree of correspondence for one group of HABs, as represented by the dinoflagellate *Prorocentrum minimum*, but a lesser correspondence for the species that tend to form paralytic shellfish poisoning (Glibert and Burkholder 2006). Comparable relationships for other nutrients or nutrient forms are not yet available, and these initial efforts represent only a small portion of HAB species groups and the data were not geo-referenced.

Major efforts have been underway that will enable study of the relationships between HAB occurrences and nutrient loading. The IOC-HAB program is developing a global database on the occurrence of species, along with many site characteristics. Maps based on frequency of occurrence are also available for ICES nations for the past ten years. There are also a number of excellent databases for particular regions that have not yet been submitted to the IOC-HAB program and thus are not yet included in the database.

The UNESCO-IOC GlobalNEWS work group has developed models of nutrient export for dissolved inorganic, organic and particulate nitrogen, phosphorus and carbon, as well as for dissolved silica (Seitzinger et al., 2005; and more recent work). These models account for nutrient sources (natural as well as anthropogenic, including fertilizer, atmospheric depositon, crops, manure and sewage), hydrology and physical factors; watershed characteristics such as river discharge, land use, precipitation intensity, human population and in-river processing and removal. The Global NEWS workgroup is currently developing input databases for their nutrient export models that are consistent with the four scenarios for the year 2030 and 2050 outlined in the Millennium Ecosystem Assessment.

Several classification schemes of estuarine and coastal typology are now available that have been related to algal composition, but not necessarily HABs (e.g., the global LOICZ typology, the typology used in the U.S. assessment of coastal ecosystems and an extension of the LOICZ work in the GNUX project at Utrecht University).

This SCOR working group on "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems" was formed to use the Global NEWS data, coastal typologies and available information on HAB occurrences to investigate and establish possible relationships between nutrient loading, nutrient forms and sources, and HAB occurrence. In this working group the Global NEWS future scenarios will also be used in concert with the relationships to be established between nutrient loading and HAB occurrence to explore future scenarios of HAB occurrence. Hence, this effort also will begin to link human dimensions with coastal ecosystem effects.

This is the report of the first working group meeting hosted by LOICZ at GKSS-Forschungszentrum, Geesthacht GmbH, Geesthacht, Germany, 28-31 July 2008. The list of participants and the meeting programme of the first meeting is added as Annexes 1 and 2 to this report. The Working Group wishes to underscore its appreciation to LOICZ and the Institute for Oceanology of the Chinese Academy of Sciences (IOCAS) for co-sponsoring this working group and for its logistical support of the first meeting.

2. REPORT OF THE MEETING

The terms of reference in the original project proposal to SCOR were discussed by the working group. The result was the following, slightly modified list of terms (no change in intent; wording clarified) which was agreed upon by the working group. The proposed changes are shown.

Terms of reference for the working group

1. Integrate ~~the~~ existing HAB ~~IOC-HAB database~~ and nutrient loading databases into a compatible GIS format;
2. Advance the development of a GIS coastal typology ~~database~~and its relationship to HABs;
3. Interrogate the above databases for relationships between HAB species, nutrient loadings/forms/ratios and coastal typology and develop broad relationships ~~between nutrient loading and distributions of~~with specific HAB species;
4. Explore possible changes in HAB occurrences in the future (for example, year 2030) using the relationships developed above ~~(3.)~~ and global nutrient export patterns under the Millennium ~~Assessment~~ Scenarios ~~for 2030~~;
5. Publish the results ~~of these analyses~~ in peer-reviewed scientific journals and develop articles for the GEOHAB and LOICZ newsletters as well as other outlets~~.~~ Papers ~~will be~~

> ~~developed on 1)~~may cover the global perspective, ~~including the next generation of global nutrient and HAB maps; 2)~~ regional time series ~~highlights;~~ and ~~3)~~ individual case studies. ~~We will also develop articles for the GEOHAB newsletter and for the GEOHAB and Global News websites, and a graphic-rich report (under the GEOHAB umbrella) that will be targeted for management.~~

A large part of the discussions concentrated on the key questions that need to be answered by the working group that cover the issues formulated in the terms of reference and that can be translated in a workable approach. Four key questions evolved from these discussions:

Key Questions
Do relationships exist between HABs and nutrient loading and can we quantify those with respect to:

1. Typology of coastal marine ecosystems (based on physical and biological parameters)?
2. Spatial variation of nutrient loading, forms and ratios?
3. Temporal variation of nutrient loading, forms and ratios?
4. Relative contribution of different nutrient sources, including aquaculture, to nutrient loading?

Approach and work plan
Together with the key questions, the group also discussed the approaches to be followed in the three years of the project. First of all, the available information on the occurrence of HAB species will need to be brought together by this working group. For this purpose the work will be organized by world region, that is, Europe, North and Central America, South America, and Asia. Possibilities to incorporate African data and data from Oceania will be investigated during the first months of the first year of the working group. The idea is to bring together information from ICES/PICES, HAEDAT, CERAC (UNEP) for Korea, Japan, Russia and China, Gulf of Oman and Arabian Sea, data for North America, the Gulf of Mexico and the Pacific coast from California to Peru, Chile, including information available through the members of the working group and their contacts. Where available, the data will also include time series. The identification of databases, querying the availability to this group, and assessing the quality and completeness, and collection of the data will be performed within the first year.

One of the products evolving from the collection of the HAB occurrences information is a series of maps of HAB occurrences and, if data allow for that, their extent and magnitude. Production of a map for the occurrence of *Noctiluca* was already planned to be completed within the first year. Plans for the production of maps for other HAB species will evolve from the data collection.

Satellite data on chlorophyll, ocean colour, and sea surface temperature will be collected, transformed to a common format and resolution, and used to investigate and establish possible relationships between algal biomass and nutrient loading, using a global coastal ocean model as a framework. In the first year this will be performed, and on the basis of these results further work will be planned.

A task force of the working group will work on a common structure of the HAB database, so that eventually a global database will be compiled from the regional data. Parallel to this, and depending on the database structure and the completeness of the data, specific statistical techniques will be proposed in the first year to be used for the analysis of the data to investigate relationships between species-specific HAB occurrences and nutrient loading, nutrient ratios and increasing nutrient loading and changing ratios (questions 2-4).

The working group will use the GNUX coastal typology, which is an extension of the LOICZ typology, based on more detailed information such as bathymetry, and including models and approaches for describing flushing time and nutrient retention, aspects that are highly relevant to the work of this group. The GNUX typology will be completed in spring 2009.

The Global NEWS data are being prepared for 1970-2000 by that working group, and data will be made available in spring 2009, together with the projections of nutrient loading following the four Millennium Ecosystem Assessment scenarios.

Global NEWS data include river nutrient export to coastal marine ecosystems. In the working group it was agreed that there is a need to develop spatially explict maps for the nutrient loading caused by aquacultural production of fish, and nutrient uptake and transformations caused by production of seaweeds and shellfish. Since the information to produce such maps is readily available from FAO's FISHSTAT, together with information from FAO reports and literature of feeding regimes, management and nutrient use efficiencies in fish farming enterprises, the working group will produce these maps within the first 15 months of this project. This is of particular interest because aquacultural activities are strongly concentrated spatially, and are thus "point" sources of nutrients.

The actual analysis of the HAB occurrences data and maps, and Global NEWS nutrient loading data is foreseen for the period after the second workshop in October 2009. Hence, the first 15 months will be used for data collection and database structure. However, some products that will be completed in the first 12-15 months are already specified below.

Key Question 1. The first key question relates to the possibility that certain types of coastal ecosystems (estuaries, lagoons, fjords, deltas, etc.) show a propensity to the development of HABs or specific HAB species. For this purpose overlays will be made of the spatially explicit maps of HAB occurrences and coastal typology to investigate possible relationships. For those maps of species-specific HAB occurrences this exercise is planned to be completed in the second year of the project.

Key Question 2. A similar exercise is needed to answer the second question on the impact of nutrient loading. Overlays will be made of the HAB occurrences maps and the Global NEWS nutrient loading data including data on nutrient loading and nutrient transformations caused by aquaculture for the year 2000, using the coastal typology map as a framework. Hence, the river nutrient export and loading within a specific type and location will be related to the HAB occurrences map.

Key Question 3. For answering the third question the working group will use the data covering the period 1970-2000 for nutrient loading which will be made available by Global NEWS, including the aquacultural nutrient loading and transformations and available time series data on HAB occurrences in manner similar to that used under Key Question 2.

Key Question 4. For investigating possible relationships between the sources of nutrients and the occurrence of HABs, the working group will use the Global NEWS data on the relative contribution of point sources (households, industries), fertilizer, animal manure, natural vegetation, atmospheric deposition, and aquaculture. Where relevant, these relationships will be established.

A first paper for LOICZ, SCOR and GEOHAB (Global Ecology and Oceanography of Harmful Algal Blooms Programme) newsletters will be prepared in autumn 2008. Possibilities for making a website for this working group for advertising the work and for data exchange will be investigated.

Timing of activities

Detailed planning of the activities for the first 15 months was conducted during the meeting. The time schedule is summarized below.

	Aug-08					Jan-09			Apr-09			Jul-09			Oct-09
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coastal typology															
Global NEWS nutrient loading data															
Development of maps for nutrient loading by aquaculture															
First analysis of satellite data vs. nutirent loading															
Map of *Noctoluca* occurences															
Database structure															
Selection of statistical techniques															
Collection of HAB data															
Analysis of avaibable HAB maps related to Key Question 1															

Detailed planning by task for the period after October 2009 will be developed at the Beijing meeting of the working group.

3. DATES OF MEETINGS

1. 13-16 October 2009 in Beijing, in conjunction with the 2nd Open GEOHAB Meeting on HABs and Eutrophication—The second meeting will be to critique and interpret the maps and data collection, and to outline the data analysis and the projections of future scenarios required; and
2. Fall 2010, in conjunction with the 14th International HAB meeting in Greece—The third and final meeting will be to assess the scenarios developed from applying the Millennium Ecosystem Assessment projections; to critique, interpret and discuss all the findings of the working group; and to prepare the final manuscripts and report.

References

Glibert, P.M. and J.M. Burkholder. 2006. The complex relationships between increasing fertilization of the earth, coastal eutrophication and proliferation of harmful algal blooms. pp 341-354 in: E. Graneli and J. Turner (eds), *Ecology of Harmful Algae*. Springer.

Seitzinger, S.P., J.A. Harrison, E. Dumont, A.H.W. Beusen, and A.F. Bouwman. 2005. Sources and delivery of carbon, nitrogen and phosphorous to the coastal zone: An overview of global nutrient export from watersheds (NEWS) models and their application. *Global Biogeochemical Cycles* 19:GB4S09.

Annex 1.

List of Attendees for Working Group Meeting 1
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Annex 2. Draft Program of the first meeting of the working group in LOICZ, GKSS Geesthacht, Germany, 28-31 July 2008.

AGENDA

Day 1: Introductions

8:45 Introduction and welcome: Hartwig Kremer, Franciscus Colijn, Pat Glibert and Lex Bouwman
9:00 Introductory overview talks and introduction of the task of the group (30 min each)
Sybil Seitzinger
Pat Glibert
Lex Bouwman
10:30 Break
11:00 Introductory talks by working group members (20 min each)
12:40 Lunch
2:00 Continue introductory talks
3:00 Break
3:30 General discussion

Day 2: Small group discussions

8:45 Overview of goals for the day: Pat Glibert, Lex Bouwman
9:00 Groups 1 and 2 (1.5 hours)
HABs: good candidate, and data availablity
Land-based nutrient export: status and data sources
10:30 Break
11:00 Reconvene and report
11:30 Groups 3, 4 – by region (1.5 hours) : data availability
1:00 Lunch
2:00 Reconvene and report
2:30 Groups 5,6 – data bases and time/space scales (1.5 hours)
Export models
Time series
4:00 Reconvene, report and group discussion

Day 3: Moving forward

8:45 Overview of goals for the day: Pat Glibert, Lex Bouwman
9:00 Case study
10:30 Break
11:00 Case study continued
12:30 Lunch
2:00 Beyond the case study- how to realistically bring data together; other data sources

Day 4: Moving forward and next steps

8:45	Overview of goals for the day: Pat Glibert, Lex Bouwman
9:00	Group discussion on additional expertise required
10:30	Break
11:00	Review of working group terms of reference; tasks and time line
12:30	Lunch
2:00	Content for the web site; SCOR report drafted

2.3 Working Group Proposals

2.3.1 Working Group on Evaluating the Ecological Status of the World's Fished Marine Ecosystems

Abstract

There has been a strong move worldwide towards the Ecosystem Approach to Fisheries (EAF). To make progress towards implementing the EAF, carefully selected and appropriate indicators are required to translate ecosystem impacts and changes into management measures that can be assessed for their effectiveness. The scientific community grappling with the EAF is challenged to provide a generic set of integrated ecological indicators to accurately reflect the effects of fisheries on marine ecosystems, to facilitate effective communication of these effects to the public and policymakers, and to promote sound management practices. Building on the work of SCOR/IOC Working Group 119 on “Quantitative Ecosystem Indicators” (2001-2004), this proposal of a SCOR WG "Evaluating the status of the world's fished marine ecosystems" aims at applying the concepts and theories developed previously to set up concrete worldwide applications: review of a minimal set of ecological indicators to assess fishing effects, consolidation and review of available data across world marine ecosystem's, comparative analyses of the exploitation status of world's marine ecosystems, transfer of scientific knowledge to the general public and stakeholders through the delivery of a publicly accessible website, building bridges with other research fields (sociology, economics, climate change, biodiversity/conservation) to promote an integrative ecosystem approach to marine resources.

Background and Rationale

Societal and scientific background

After decades focusing on the study and management of single species, fisheries management is evolving towards ecosystem-based approaches. These regard the ecosystem as the most relevant unit for management, emphasising that resilient ecosystems are crucial to maintain the sustainability of marine goods and services. Efforts are now being made to measure and alleviate the ecosystem effects of fishing (Hall 1999) and focus is very much on how an ecosystem approach to fisheries may be implemented (Garcia and Cochrane 2005). The FAO Reykjavik declaration of 2001, reinforced at the World Summit on Sustainable Development in Johannesburg in 2002, requires nations to develop and start implementing an Ecosystem Approach to Fisheries (EAF) for reconciling conservation and exploitation objectives by the year 2010. Nations are further required to restore depleted fish stocks by 2015, and to establish representative networks of Marine Protected Areas by 2012.

To fulfill these objectives, a strategy based on innovative and integrated science is urgently needed to translate the complexity of marine ecosystems into comprehensible signals and to propose operational management frameworks (e.g. FAO 2003, Link 2005). The scientific community is therefore challenged to provide a generic set of integrated ecological indicators to accurately reflect the effects of fisheries on marine ecosystems, to facilitate effective communication of these effects and to promote sound management practices.

The groundwork has been established by the SCOR/IOC WG 119 (Cury and Christensen 2005) which reviewed the relevance of a wide range of ecological indicators according to the following criteria:

- ecological significance (i.e. are the underlying processes essential to the understanding of the functioning and the structure of marine and aquatic ecosystems?)
- measurability: availability of the data required for calculating the indicators
- sensitivity to fishing pressure
- awareness of the general public.

It also provided some of the ecological background to understand which processes and fishing effects are captured by ecosystem indicators. This review categorised ecosystem indicators into three main types: size-based (Shin et al. 2005), trophodynamic (Cury et al. 2005) and species-based indicators.

What is now needed to implement EAF worldwide is a concrete framework to facilitate the application of ecosystem indicators as a tool for diagnosing the ecological state of the world's marine ecosystems and subsequently as a means of initiating appropriate fisheries management responses that would address and alleviate the impacts of fishing on ecosystems.

Objectives

The goal of this proposed working group "Evaluating the ecological status of the world's fished marine ecosystems" is to develop a concrete framework for the application of ecosystem indicators to assess ecosystem state and develop management guidelines using a comparative approach. Specifically we propose to (i) publicly launch a generic dashboard of ecosystem indicators using a common set of interpretation and visualisation methods and populate it with data from diverse marine ecosystems around the world, (ii) test the performance of indicators and develop reference points, (iii) add climate, socio-economic and biodiversity/conservation indicators to a set of integrative ecological indicators developed during Eur-Oceans meetings (see below), and (iv) evaluate the exploitation state of marine ecosystems in a comparative framework from all three tiers of an EAF (ecological, social, economic).

The most concrete initial deliverable of this Working Group is the creation of a website informing the public at large, as well as scientists, about the impacts of fishing on the state of world's marine ecosystems. Communication is widely recognised as key to successful EAF (Degnbol 2005). A common protocol for interpreting, representing and communicating a carefully selected suite of indicators needs to be established for a wide range of ecosystems. This will require development and adoption of generic syntheses of indicators to represent adequately and simply the state of an ecosystem. The syntheses will be graphic (use of colors, graphics etc), will necessitate the adoption of common statistical methods within the working group for standardising indicators, interpreting combined sets of indicators, interpreting the trends in indicators, and transforming quantitative information into semi-quantitative and qualitative information in a multidisciplinary framework.

The following questions will be addressed by the WG:

- How should ecological indicators be interpreted and scientific knowledge be best integrated?
- How should ecological indicators be analysed for moving towards ecosystem diagnosis and formulating recommendations for management purposes?
- Which indicators should be used to synthesize and communicate ecosystem status in terms of climatic change, socio-economics and biodiversity/conservation?
- How can we compare the status of exploited marine ecosystems?
- How can the knowledge gained from indicators be best represented and communicated to decision-makers and the general public?

There are several reasons why a comparative approach is adopted in this WG:

- With the difficulty in establishing baseline levels and reference points for most ecosystem indicators, the comparative approach across ecosystems will provide a range of reference values against which each ecosystem can be assessed;
- The comparative approach will also help in selecting robust ecological indicators that will be meaningful and measurable over a set of diverse and contrasted situations;
- The comparative approach between ecosystems, together with the communication of results to the public at large are also aimed at creating an incentive for politicians to consider their management options, with informed responsibility for the ecological, social and economic quality of marine world ecosystems.

Timeliness and relevance to other international activities
The proposed WG will greatly benefit from the advances made by the previous SCOR/IOC WG 119 in 2001-2004. While SCOR/IOC WG 119 focused on theoretical and conceptual studies, the selection of relevant ecological indicators and on local empirical studies, the present proposed WG will focus on the concrete application of indicators to the diagnosis of marine ecosystems, on a global evaluation of marine ecosystems, and on the transfer of knowledge to the general public and to stakeholders. This is seen as a substantial step towards implementation of an Ecosystem Approach to Fisheries. The products of this group will be useful for any future marine assessments, such as the Global Marine Assessment.

In 2007 and 2008, the European Network of Excellence (NoE) EUR-OCEANS (www.eur-oceans.eu) supported the organization of two meetings dedicated to the first stage of a worldwide comparative approach. Yunne Shin and Lynne Shannon were co-leaders of these meetings, which facilitated clarification of the objectives of the present proposal and assembled expertise from 20 ecosystems around the world. Building on the results of the Eur-Oceans meetings and the collaborative networks that have been established as a result, we are presently ready to propose a common list of indicators to be calculated in each ecosystem, and to propose the structure of a first prototype of a website. This proposed list of indicators and prototype website will help to attract experts from other ecosystems to join the analyses, and will allow us to concentrate on the methods for establishing a diagnosis, for comparing ecosystems' status, testing indicator performance and for the expansion into other disciplinary areas (climate change, sociology, economics and biodiversity/conservation). This expansion of the initial indicator suite based on fisheries data is seen as a major challenge and highly necessary if we are to progress with EAF worldwide. Through associations with experts in these fields, the proposed SCOR WG will facilitate parallel selection and analyses of indicators from these additional disciplines.

The SCOR "label" will ensure the success of the WG as it will provide an international visibility which will attract top scientists across several fields working on a common ecosystem approach to marine resources and will ensure that the scientific analyses are undertaken with rigour and complete neutrality. This last point is critical as we aim at transferring our scientific knowledge to other spheres.

The comparative approach is global in its focus so we plan to extend our initial network to other ecosystems in the world, and a SCOR WG provides this capacity of community building. Finally, we also plan to build bridges with other research fields (socio-economics and climate change) so again, having the visibility of SCOR will greatly facilitate conducting inter-disciplinary studies.
Additional sources of funding are already identified: IRD (Institut de Recherche pour le Développement) and the European project MEECE (2008-2012, www.meece.eu) will provide the persons-month necessary to develop the website. We also contacted AIRD (Agence Inter-établissements de Recherche pour le Développement) to request funding the travel expenses of scientists from developing countries, and we plan to contact FAO.

Terms of reference

The proposed working group would work towards:

1. **Defining a common protocol using ecosystem indicators for elaborating a diagnosis of the exploitation state of marine ecosystems.** This stage involves the development and selection of adequate statistical methods for characterizing trends in indicators (autocorrelated regression, GAMs, first and second-order derivatives), for detecting similarities between indicators (PCA analyses, mutual information index) and for establishing a classification of marine ecosystems according to fishing impacts (decision tree analysis, scoring and ranking ecosystems).
2. **Developing a common, generic visualisation and communication tool for synthesizing the exploitation status of marine ecosystems.** A website will be developed, aiming at documenting the exploitation status of world's marine ecosystems and communicating scientific results to the general public and stakeholders.
    a. **Testing the performance of ecosystem indicators in fisheries management.** How do we know that ecosystem indicators can walk to talk, that is, how do we know how well an indicator indicates and guides management decisions? This is a crucial question in the development of indicators and is often ignored. Performance testing is a formal procedure to assess whether an indicator and accompanying decision rule actually guides decision-makers to make the "right" decision. Performance testing scores the ratio of "right" decisions to "wrong" decisions. The suite
3. of indicators collected under the EUR-OCEANS initiative provides a unique opportunity to test these indicators across a range of ecosystem types. Conclusions should be very robust.

4. **Developing reference points for indicators.** Establishing reference points for ecosystem indicators has proven to be a major challenge to implementing EAF, due to the complexity of ecosystems and their response to fishing. A key benefit of the comparative approach proposed for this SCOR WG is that it provides empirical data on ecosystem indicator behaviour across a range of ecosystem types and states. These data will be used to explore whether, minimally, limit thresholds can be identified, and whether possible target reference points can be proposed.
5. **Building bridges with other scientific fields to assess the usefulness of the set of selected ecological indicators and to complete the diagnosis by providing additional non-ecological indicators.** This will provide a more integrative evaluation of ecosystems states to support an ecosystem-based fisheries management. Three specific tasks will be addressed:

   5.1- studying the joint effects of climate and fishing changes on the selected indicators. Time-series analyses will be undertaken of fishing effort and regional climate indices. Ecosystem models will also be used to assess the specificity of ecosystem indicators to fishing effects versus climate effects: EwE, Osmose and Atlantis models will be used in this regard.
   5.2- integrating conservation and biodiversity issues in the diagnosis of ecosystem states. Biodiversity is a key ingredient for resilient, robust ecosystems. All too often however, species, habitats or even whole ecosystems are negatively affected by fishing and mitigation approaches are necessary in addition to avoiding damage through wise management. We plan to add a set of indicators that will quantify the biodiversity and conservation risks in ecosystems.
   5.3- integrating socio-economic issues EAF has many facets, and one which is too often ignored is the realm of socio-economic indicators of the effects of fishing on ecosystems. As yet, the development of socioeconomic indicators lags that of ecological indicators, and thus there is less to work with. However, we aim to review existing socio-economic indicators then apply the criteria outlined above to select a subset of socio-economic indicators for inclusion in the generic dashboard of indicators.

Planned activities and Products

If the SCOR proposal is successful, the first steps will be to set up 5 task groups to address each of the TORs and to plan for three annual meetings. All terms of reference will be addressed at each of the annual meetings. However, the main emphasis of meeting 2 will be on TORs 2 and 4, and the main emphasis of meeting 3 will be on TOR 5. It is proposed that the first annual meeting takes place in Sète (IRD-CRH) or potentially back-to-back with the GLOBEC Third Open Science Meeting in Victoria (June 2009, Canada).

We propose the WG to have 3 co-leaders, Yunne-Jai Shin, Alida Bundy and Lynne Shannon. In addition to assuming current coordination tasks (delivering annual reports, searching for additional fundings, distributing documents and data to each participant, organizing annual meetings, coordinating activities between meetings), each co-leader of the WG would assume the main responsibility of each of the following deliverables and for TORs as indicated.

- Yunne-Jai Shin (TORs 1,2,3,5.1) will be responsible for the delivery of the **website** dedicated to inform the general public about world's marine ecosystems. We have already booked the website address www.indiseas.org which will be accessible to the general public and stakeholders. Based on the two Eur-Oceans meetings that occurred in 2007 and 2008, we can ensure that at least 14 marine ecosystems will be fully documented during the first year of the SCOR WG. The website will be made accessible from the first year (2009) of the WG to provide international visibility and to attract more scientists to contribute to enriching the website with their ecosystem data and syntheses. The objective is to provide a broad geographical coverage by the end of the WG.
- Alida Bundy (TORs 1,3,4,5.3) will be responsible for the organization of an **international symposium** at the end of the WG (2012). It will be the opportunity for the worldwide network to present their results on the use of ecosystem indicators in diagnosing ecosystems' states and implementation of Ecosystem-based fisheries management.
- Lynne Shannon (TORs 1,3,4,5.2) will be responsible for the edition of a **special Journal issue** following the international symposium (2012).

Working Group Composition

The composition of the WG is necessarily international in accordance with the objectives of the WG, which is comparative in nature. Participation by an expert from each ecosystem is a pre-requisite for adequate comparative analyses and proper scientific guidance in each ecosystem. With the proposed list of members, at least 22 marine ecosystems will be considered from the first year of the WG. All scientists proposed have comprehensive, expert knowledge of ecosystem functioning and the ecosystem approach to fisheries. The WG also includes scientists having expertise in socio-economic, biodiversity and climate indicators. The geographical coverage ensures that each type of ecosystem is well represented, as well as three major oceans (Pacific, Atlantic, Indian oceans). Among the Full Members, the group has 3 scientists from developing countries and 7 women, providing good geographic and gender balance. Additional breadth will be achieved through Associate Members.

Full members

Name	Country	Institution	Expertise ecosystem	indicators
Yunne-Jai Shin, co-chair	France	IRD	upwelling	size-based
Alida Bundy, co-chair	Canada	DFO	temperate	trophodynamic
Lynne Shannon, co-chair	South Africa	MCM	upwelling	trophodynamic
Ratana Chuenpagdee	Thailand	CDC	tropical	socio-economic
Marta Coll	Spain	ICM/CSIC	temperate	trophodynamic
Erich Diaz	Peru	IMARPE	upwelling	fisheries
Nick Dulvy	Canada	SFU	temperate	biodiversity
Beth Fulton	Australia	CSIRO	temperate	fisheries
Jason Link	US	NOAA	temperate	climate
Verena Trenkel	France	IFREMER	temperate	fisheries

Associate members

Name	Country	Institution	Expertise ecosystem	indicators
Vera Agostini	US	Nature Conservancy	upwelling	biodiversity
Kerim Aydin	US	AFSC	high latitude	climate
Julia Blanchard	UK	CEFAS	temperate	size-based
Fatima Borges	Portugal	IPIMAR	upwelling	fisheries
John Cotter	UK	CEFAS	temperate	fisheries
Philippe Cury	France	IRD	upwelling	trophodynamic
Ibrahima Diallo	Guinea	CNSHB	tropical	fisheries
Sheila Heymans	Scotland	SAMS	temperate	biodiversity
Louize Hill	Portugal	IPIMAR	upwelling	biodiversity
Astrid Jarre	South Africa	UCT	upwelling	socio-economic
Edda Johannesen	Norway	IMR	high latitude	fisheries
Didier Jouffre	France	IRD	tropical	biodiversity
Pierre Labrosse	Mauritania	IMROP	tropical	socio-economic
Jae-Bong Lee	Korea	NFRDI	temperate	fisheries
Steve Mackinson	UK	CEFAS	temperate	climate
Hicham Masski	Morocco	INRH	upwelling	fisheries

Christian Möllmann	Germany	U Hamburg	temperate	climate
Sergio Neira	Chile	U Concepcion	upwelling	trophodynamic
Henn Ojaveer	Estonia	EMI	temperate	fisheries
Khairdine Ould MA	Mauritania	IMROP	tropical	fisheries
Ian Perry	Canada	DFO	temperate	fisheries, climate
Jake Rice	Canada	DFO	temperate	fisheries
Marie-Joëlle Rochet	France	IFREMER	temperate	size-based
Djiga Thiao	Senegal	CRODT	tropical	fisheries
Dawit Yemane	South Africa	MCM	upwelling	biodiversity

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2.3.2 OceanScope Working Group

Summary
This proposal outlines a new paradigm for the systematic and sustained observation of the ocean by working in close collaboration with the merchant marine industry. The overall objective will be to establish a global network of ocean observation platforms on selected commercial ships. The aim will be to encourage the maintenance, expansion and integration of existing volunteer observing ship programs (e.g. CPR, pCO2, ADCP, and XBT) while developing in parallel VOS initiatives that use sophisticated new technology, with real time data streams and data analysis facilities. The proposed SCOR working group will be unique as it will bring together ocean scientists with experience of VOS programs, engineers, instrumentation experts, economists, shipping company representatives and senior merchant marine officers as committee members and associate members of the working group. A developing partnership with the merchant marine will be mutually advantageous as observations reported in real time will be used to enhance ocean forecasting services for the shipping industry on the one hand, and to improve our understanding of the ocean's structure and variability for weather and climate studies on the other.

The oceans cover over 70% of our planet and the merchant marine has a presence on the high seas second to none covering millions of miles each year. In contrast research vessel tracks cover a fraction of this distance and rarely repeat their tracks. Freighters, tankers and cruise ships traverse all major oceans on a regular basis, some on well-defined schedules for 'just in time' delivery. Analogous to satellites probing the earth's atmosphere and ocean surface, merchant marine vessels could serve as 'orbiting' platforms for monitoring the interior of the ocean. We do this already to a limited extent, but rather inefficiently because most of the tools available to us were developed for use on research vessels, not for long-term unattended service. But experience has shown that such programs are possible, and with today's technical know-how the opportunity to make a quantum leap in the observation of the ocean is not only a realistic ambition but an extremely cost effective way to obtain the data sets so critically needed to address the challenges posed to society by global environmental change.

The development of an integrated approach to the monitoring of the global ocean is central to the proposal with as a primary goal the construction of a plan of action to implement the concept. Focusing on four interlocking themes: **ORGANIZATION**, **OBSERVATION**, **COMMUNICATION**, and **INTEGRATION** the working group (with the assistance of other experts) will:

1. address and prioritize the scientific challenges that can be best addressed by an integrated VOS program,
2. outline, and promote appropriate and necessary sensor, instrument and software development,
3. develop an institutional framework that enhances the links between the merchant marine and ocean observation communities including ongoing VOS and SOOP programs, and
4. identify and develop an integrated framework for data management and distribution.

To ensure sustained interest and follow-through, a SCOR working group with its international participation, well-defined terms of reference and ability to maintain focus for several years will form an ideal framework to achieve these objectives. Initial responses to the ideas presented above from contacts at IOC and other international links have been positive.

The Marine Environment

The extensive regions of the ocean interior continue – despite their enormous climate and biochemical importance - to be extremely difficult to probe and monitor on a regular basis due to the high cost of research vessels and fixed moorings, and hence the very low density of marine measurements, especially in horizontal dimensions. This stands in complete contrast to the extraordinary ability of satellites to provide frequent and detailed views of the space-time evolution of the surface of the ocean, including temperature, color, roughness and elevation. However, these systems sample only the surface. It has been said many times before that we know less about the ocean interior than we do of the moon! Oceanographers have sampled and studied the oceans from research vessels for well over a century, but our knowledge of how the ocean behaves over a very wide range of space and time scales remains very poor. How do currents vary in time, shift in position, how much mass and heat do they transport, how do basic biogeochemical processes and biological space/time distributions differ between ocean basins and regional seas - all questions of enormous importance to our understanding of the atmosphere-ocean system that regulates our climate.

Our inability to sample and resolve fields in the horizontal continues to be a major challenge in oceanography. All the more so given that the very energetic mesoscale eddy field not only serves to maintain mean distributions in the ocean, but also to expel gradients to the perimeters of homogenized regions where strong physical and biochemical contrasts develop. Thus mixing can create uniform regions on the one hand (the standard view of eddy processes) yet create strong contrasts on the other. But we know very little about the latter due to the lack of high-resolution subsurface sampling techniques. To take but one example, we still know surprisingly little about zooplankton and myctophid distributions except in a very few areas of the open ocean. We also see growing (and surprising) evidence that the shape of the ocean bottom can play a significant role in constraining ocean currents, not merely at depth but also in the upper ocean. Measuring ocean currents, temperature, and a wide suite of biochemical properties concurrently at high resolution in the horizontal remains a fundamental challenge.

Background

For more than a century officers of the merchant marine have - as part of their watch at sea - sent in weather reports on a regular basis. These observations of air and sea surface temperature, barometric pressure, winds and sea surface conditions have been of enormous importance to the forecasting services of neighboring countries. Further, the archives of these marine observations have formed the basis for much of what we know about the climate of the seas including the enormously important early charts of prevailing winds and ocean currents (e.g. Maury, 1855). But these early observations were largely limited to the ocean surface. Some 80 years later, starting in 1931, Alistair Hardy began a remarkable program to monitor plankton variability by arranging for freighters and ferries to tow Continuous Plankton Recorders on regular routes on a monthly basis (www.SAHFOS.ac.uk). These repeat tows along selected routes have allowed researchers to construct an accurate measure of biomass and various species in the surface waters and how they vary spatially, seasonally and over longer periods of time. A little later in the century mechanical bathythermographs were developed allowing observers to obtain upper ocean profiles of temperature from ships underway. This was followed by the development of the Expendable Bathythermograph (XBT) in the 1960s (e.g. Baker, 1981) that made it possible to develop an understanding of low-frequency variability in the ocean down to the depth of the main thermocline (e.g. Molinari, 2004). And more recently yet, a few commercial vessels have been equipped with Acoustic Doppler Current Profilers (ADCP) to measure and monitor upper ocean currents and their variability, e.g. across the Kuroshio (Hanawa et al., 1996) and the Gulf Stream (Rossby et al., 2005 and Beal et al., 2008). Similar repeat sections have been operated since the mid-1960s (but mostly later) and are now coordinated as part of the International Ocean Carbon Coordination Project (IOCCP) (See CAVASSOO website below.)

Repeat sampling along designated lines confers a tremendous advantage because patterns of change and their magnitudes can be identified and quantified with unparalleled accuracy. These above examples from volunteer observing ships (VOS) indicate the enormous potential of merchant marine vessels for probing the ocean water column on a regular schedule. Discussions that took place at a well-attended session on VOS-based observations held at the 2008 AGU Ocean Sciences Meeting highlighted an increased interest in working with the merchant marine, while at the same time noting the difficulties and challenges in doing so. Research vessels cannot in any way provide a comparable service.

The above encouraging examples notwithstanding, the use of merchant marine vessels to observe the oceans synoptically is far from achieving its considerable potential. One can summarize the reasons for this in a few words: lack of suitable instruments and access to ship platforms, each checkmating the other in a catch-22 loop. In terms of physical measurements temperature profilers are not optimized for merchant ships, so XBTs are used. In most cases their deployment requires a technician to be in attendance, greatly increasing the cost of measurement. Widespread use of VOS has been discouraged by these high costs plus the challenge of accessing merchant ships on regular routes in selected regions of the world. In consequence there has been little effort to develop an automated technique for profiling temperature. ADCPs, although they work reasonably well on their own, are not designed for the 'industrial' environment of freighters. More precisely, the ADCPs at present need considerable protection with industrial-strength uninterruptible power supplies (UPS). It is possible to build ruggedized instrumentation, but this won't happen until a broader demand for such equipment develops. A number of vessels were equipped with 'Ferry-boxes' as part of an EU project (http://www.ferrybox.org/) that included e.g. thermosalinographs, flurometers for chlorophyll and other instruments to measure, turbidity, oxygen, nutrients and pCO2 with real-time transmission of raw data via satellite. Some of these ships are still operating with research funds, but the program has not moved into operational mode now that the funding for the original project has stopped. The Ferry Box project provided useful information about surface water properties, but the equipment was expensive to install and maintain and generally required regular technical support. Finally, a substantial planning effort and installation cost in dry dock had to be covered for each vessel with little economy of scale or sharing.

The Concept

We propose a fresh start that addresses the need to develop sensors and systems that are optimized for the rigorous environment of routine operation on merchant ships, suitably packaged and easily maintained. To employ an obvious analogy, the atmosphere and ocean surface is probed on a routine and systematic basis with highly reliable instruments developed for satellite application; the same approach should be possible for the sub-surface ocean using ships as 'satellite' platforms. With fresh thinking, and taking full advantage of the possibilities offered by modern technology, a much-improved coverage of the ocean interior can be achieved for a comparatively small additional expense. Just to give a hint at what might be possible, with instruments mounted in the hull one could measure a wide range of physical, biological and chemical properties. Some techniques exist today; others would require considerable development. Much as is done today for remote sensing satellites we need to let loose our creative instincts and engineering skills to develop the instrumentation that could take full advantage of these ocean platforms. Instruments topside would measure a wide range of atmospheric properties providing ground-truth to satellite-based remote sensing systems. As experience grows expectations and requirements will evolve (precipitation being an obvious example). All measurements would be forwarded to a central unit, which would handle shipboard data archiving as well as all communications between ship and shore. Communications will work both ways: ship-to-shore (near-) real time transmission of data for post-processing and distribution, and shore-to-ship for system performance analyses and corrective action as required. But, as with satellites, a very high level of hardware reliability and software robustness must be built into these systems so that they can provide unattended operation over periods of months to years. We offer the following vision statement:

"In partnership with the merchant marine shipping industry develop an integrated approach to the observation of the global ocean on regular and sustained basis. This effort, which might be called 'OceanScope' - to give it a name - will equip commercial ships with instrumentation to automatically measure and report on currents and the physical, chemical and biological state of the water column throughout the water-covered planet. These data will in time become a fundamental resource for studies of the climate and health of our planet."

Proposal

The above concepts are all feasible, but cannot be implemented on a one-by-one basis, they beg for concerted action. Furthermore, all partner countries in SCOR share a common interest in the ocean, for reasons of commerce, optimal ship routing, fisheries, defense, and on the longer time scale the ocean's role in climate. The SCOR approach to resolving issues of common interest seems eminently well suited to the issues posed above. We propose to establish a SCOR working group to develop the concept of a merchant marine-based global observing system of the ocean interior. The working group would bring together experts from science, technology, and the marine industry to develop an entirely new paradigm for working with the merchant marine that incorporates and builds on the past and ongoing experience of current practitioners. Rather than thinking in terms of volunteer observing ships, a very modest concept, we propose a pro-active or purposeful approach, namely the development of new technologies and new modes of cooperation with the merchant marine. A fundamental point should be emphasized here. Experience has shown that the operators of merchant ships are receptive to the presence of ocean and atmosphere observing instrumentation onboard their vessels. They see this as providing a service that will provide feedback to their own benefit as well as, in many cases, giving green credentials. Ship operators invariably only require that the equipment makes no demands on their costs, insurance, time, people or operations. This is where the analogy with orbiting satellites comes in: satellite-borne instrumentation has been designed, optimized and tested for these platforms before they fly so that they can and will perform without any need for hands-on human intervention. The working group will identify suitable scientific objectives and translate these into what might be called 'mission' requirements. The group will be tasked with identifying mechanisms for stimulating the development of 'mission-proof' instrumentation as well as exploring and documenting necessary communications requirements and developing parameters for selecting vessels to be equipped (vessel type, route, hull shape, etc). And, perhaps most important of all, to develop a flexible, easy-to-implement international infrastructure for cooperation between existing and new VOS programs with the merchant marine and the institutions responsible for the instrumentation. The first goal of the working group will be to produce a Development Plan and a procedure for its implementation. This work will take some time, and in order to provide the plan with both support and supervision it is recommended that the working group be active for at least three years or until such time that an operational structure has been implemented that can assume these oversight and management responsibilities.

Issues and Organization

At this stage we propose that the SCOR working group be organized around four central themes, organization, observation, communication and integration. The first refers to developing appropriate frameworks for collaboration between the maritime industry and the marine research communities, the second to the development and implementation of observational programs, the third to shore-based supervision of shipboard systems, and data transfer, distribution and archiving and the fourth to the integration of the proposed development with existing ocean observing programs into a global collaborative system that contributes to the Global Ocean Observing System (GOOS). Each of these areas spans a wide-range and overlapping set of issues. The following subheadings: scientific requirements, instrumentation, networking, platforms and institutional links show how intimately they are linked.

1. *Scientific requirements:* Under this heading the working group will review emerging scientific questions in relation to our present observational skill. For example, what aspects of the ocean interior do scientists think are the most important issues for which more information is required? The intention will be to focus upon the desirability of particular

measurements, sensors and technologies rather than their current availability. Historically, scalar or state variables have occupied center stage as researchers have endeavored to characterize the present state of the ocean. However, vector information has much to offer as changes in currents and property fluxes can help presage future changes in state – variations in currents and state tend to be out of phase with the former leading the latter. And recent advances in modeling have shown that assimilating deep velocity profiles using Kalman filtering or 4D methods can be just as fruitful as assimilating temperature or salinity. To meet future scientific and operational forecasting needs, it may be essential to reach below the main thermocline to resolve the weakly-sheared deep velocity field. Measuring currents at great depth is technically possible today but will require some development to become operational. Experience has taught us that long-term averages of Eulerian time series of currents do not settle down due to the red nature of the velocity spectrum. Eulerian current measurements also suffer from topographic biases. Averaging currents across space gets around both sources of uncertainty so that degrees of freedom accumulate far more rapidly.

Repeat sampling at suitably high-resolution of such biological parameters as upper ocean phytoplankton and mid and upper ocean zooplankton is essential to characterize their temporal and spatial variability. High resolution species data for these taxa are virtually restricted to the near surface northern North Atlantic sampled by the CPR. Given the stress that is being put on marine living resources by commercial fisheries in concert with climate change, there is a need to routinely measure biomass distribution in a wide range of size classes along selected routes. This information is needed to predict shifts in community composition that may profoundly affect the availability of the living marine resources constituting a major fraction of the protein diets in many nations as well as providing information on the changing composition of the plankton that is so crucial for understanding the carbon cycle. Just as the towed plankton recorder opened the window to surface plankton distributions and documented population shifts related to environmental changes, acoustic techniques might be able to do the same for the entire water column. This is just a brief hint of what could be done.

A supplementary need for improved information on the changing role of biota in the biological pump by use of new and existing technologies is noted. The processes involved in the biological pump and its variability are poorly understood on a regional, never mind global scale, and quantifying its role is crucial to an improved understanding of oceanic uptake of CO2. The information provided will be invaluable to modelers and for validation of satellite remote sensing products.

2. *Instrumentation:* Here we address the state of the technology from the perspective of merchant marine-based applications (i.e. robustness and reliability) and explore avenues for future development. Focusing again on currents, what technologies might be available for their measurement at depth - even if at low vertical resolution? What techniques might be developed to monitor thermocline biomass variability? Can we develop low cost (recall that unit cost is a very steep inverse function of numbers) probes of temperature, conductivity, oxygen, ..., that telemeter their data back acoustically to a dedicated hydrophone in the hull of the ship? With the entire circuitry for a probe on a single silicone wafer production costs could be reduced enormously. In addition to this one-way data transfer from expendable probes, ships can also serve as acoustic modems to receive and retransmit underwater

instrumentation in their vicinity.

3. *Networking:* Several issues need to be addressed here. First, communication within a vessel. This could be done through ethernet communications between instrument sites and the bridge or wireless through a series of transmitters distributed throughout the ship. These solutions are much easier to accomplish during the original construction. Second, communication with the outside world. Here, Iridium and Inmarsat will go a long way towards system monitoring and low-bandwidth data transfer with high data rates reserved for when a vessel arrives in port. A choice or balance between the two band-width options might be possible depending upon priorities. Large shipping companies most probably have standard communications methodologies already in place for vessel tracking, routing and data transfer, but if not, the option to promote this capability in conjunction with data messaging may be attractive to them. Communication issues also may involve shipboard data processing at various levels of detail, inclusion of data description and identification (metadata) and shipboard data archival and retrieval. Much has been done in this area in the satellite community, and further relevant technology will be available as a result of the nascent U.S. NSF-sponsored Ocean Research Interactive Observatories Network (ORION) program.
4. *Platforms:* This topic would include a review of vessel designs and an evaluation of the advantages and disadvantages of different hull forms. In so far as acoustic observations of the water column from the vessel is concerned, a major requirement will be to identify vessel hull types that are relatively free of bubble sweep-down, including measures that might be employed to ameliorate this limitation. What comparatively inexpensive preparations might be built into a vessel during construction in anticipation of use? Here we have in mind features such as reserved hull plate areas for very low-profile external sensors, standard sea-chests with cofferdams to accommodate expected hull-mounted instrumentation, seawater plumbing connections in anticipation of flow through surface water analysis equipment and cable channels and pass thru's for interior wiring (electrical and fiber-optic). At construction time these costs are very modest but as retrofits they can become prohibitive. Vessels with particular silhouettes may be advantageous for some kinds of meteorological measurements requiring "clean" air and air flow. Consideration may also need to be given to superstructure arrangements and access for sensors requiring a clear view of the skies and options for fitting gyro-stabilized platforms for stable horizon requirements. The overarching consideration is that standardized procedures, technologies and approaches need to be developed to facilitate easy installation, removal and (when necessary) servicing, and to take advantages of economies of scale to enable the establishment of a large-scale integrated network of instrumented commercial vessels.
5. *Institutional:* This is a large and important topic with many subtopics. Institutional links are needed between research, government and international agencies charged with ocean and climate monitoring and the maritime industry. Almost certainly this will require a program office that searches for, develops and provides a liaison between appropriate ship operators and the scientific community. Second, development of formal arrangements or letters of understanding between the parties to avoid misunderstandings and/or subsequent confusion. It is understood that vessel operators may at any time shift vessels from one route to another for commercial reasons, but with proper lines of communications it may be possible to anticipate or minimize the impact of such changes in operation. For example, given adequate warning (and stand-by response capability) even underwater hardware can be removed by scuba divers without a dry-dock. Conversely the same capability would permit equipment installation to take advantage of newly available commercial routes and opportunities.

Third, given justifiably heightened security concerns it will be important for the scientists and technicians to prepare in advance. Obtaining prior clearance (and documentation) to enter port facilities has become the rule rather than the exception. Fourth, it will be important to educate both communities (scientific and industrial) of the operational, personnel and logistical needs of the other. A key to success will be recognizing and honoring each other's needs and concerns.

Summary of Activities <u>Mode of Operation of the Working Group</u>

	Organization	**Observation**	**Communication**
Scientific requirements	User community; real-time forecasting/ climate studies	Type of parameter; scalar/ vector; air/water; accuracy; sampling frequency	Real-time/ delayed/ distribution networks
Satellite validation	Remote sensing developers/ users/ tech. designers/developers	Atmosph/oceanic spectral parameters, chlorophyll fluorescence, currents	Real-time/ delayed/ processed products
Instrumentation	Developers/ users/ partnerships	Type of sensors/ atmosph/ oceanic/ acoustic/ optic/ towed systems	Development/ evaluation/ testing
Networking	Shipboard/ ship-to-shore/ user communities/ GTS?	Data collection/ software/ prewire ships at construction time	Transmission/ software
Platforms	Designers/ users/ vessel owners	Type of observable topside/ hull-based/ towed	Design and approval process
Institutional links	Merchant marine/ science/ gov't/ regulatory	Shipboard activities	Establish formal lines of communication

Most of the work outlined above can be achieved by the working group over a two-year period with two face-to-face meetings, one in the early months of the group's formation and a second one after roughly a year. It is envisaged that at the first of these meetings the specific issues listed above will be developed through pre-prepared presentations and discussions. Lead writers will be nominated to draft section contributions for a Development Plan in collaboration with others as appropriate. This work will be reported and discussed at the second meeting of the working group. At this second meeting the members will be in a better position to determine the time scale for completing any remaining tasks, including a possible role in the supervision of the development and implementation of the recommendations in the Development Plan.

The Working Group

The proposed SCOR working group would include experts in all the areas addressed above. A key to success will be to find people who have the time and interest to contribute in a practical way to the objectives of the working group. We note that the response to discussions outlining the basic plans of the proposal, held with a wide cross section of ocean science researchers, representatives of the instrumentation, communication and maritime industries and more recently attendees at the JCOMM/SOT-IV meeting in Geneva (April, 2007), have been strikingly positive. Additional voluntary or independently aided contributors to the meetings of the Working Group, or by correspondence will be sought with, where appropriate, nominations from international organizations such as IAPSO, IOC, ICES, PICES, POGO, GEO and of course SCOR. If possible, funding will also be obtained to enable an environmental economist to participate in the working group meetings. In advance of each meeting, the basic agenda for the discussions, time and venue will be advertised to enable participation of additional experts with relevant experience from countries adjacent to the meeting venue. Funds will also be sought, independently of SCOR, to enable participation of representatives from developing countries and some young scientists/engineers.

Full Members

- Prof H. Thomas Rossby (GSO/URI, USA) - Chair Physical Oceanography and technology
- Prof Philip C. Reid (U. Plymouth, SAHFOS, UK) – Co-Chair Marine Biology and Fisheries
- Int'l Chamber of Shipping Industry expert
- Dr David Hydes (NOC, SOTON, UK) VOS technologies
- Mr. Markku Kanerva (DeltaMarin, Finland) Naval architect
- Prof. Fred Soons (Utrecht Univ) Marine Law
- Prof. Doug Wallace (GEOMAR, U. Kiel, Germany) Ocean carbon
- Prof. Rod Zika (U. Miami) Chemistry, instrumentation
- TBD Passive optics
- TBD Active optics/bioacoustics/communication?

We have approached several groups in China, Japan and Korea for participation in the working group.

Associate Members

- TBD IAPSO representative
- Prof. Peter Ortner (Univ. Miami) Biological Oceanography and Technology
- Dr. C. Flagg (SUNY, Stony Brook Univ.) Physcial Oceanography
- Dr. J. Churnside (NOAA, Boulder) Active optics
- TBD (JCOMMOPS, Paris, France) Marine operations, communications
- Dr. Gwyn Griffiths (NOC, SOTON, UK) marine technology, bioacoustics
- Dr. Rik Wanninkhof (NOAA) Global Ocean Carbon Budget
- Dr Joaquim Goes (Bigelow Laboratory) Remote sensing expert
- Marine technology experts

Other members and areas of expertise will be sought as plans continue to develop.

We should mention here a few companies that have been actively supporting sustained ocean observation:

- Maersk Line (Copenhagen, Denmark)
- The Brittany Ferries (Roscoff, France)
- The DFDS Tor Line (Copenhagen, Denmark)
- P&O Ferries (Dover, U.K.)
- The Royal Arctic Line (Nuuk, Greenland)
- The Bermuda Container Line (Hamilton, Bermuda)
- Royal Caribbean Cruise Line (Miami, Fl, USA)
- The China Navigation Company (Hong Kong, China)
- The Smyril Line (Torshavn, Faroes)

We also have contact with several shipping companies and marine activities, including:

- Wallenius Marine AB (Stockholm, Sweden)
- Neste Shipping Oy (Keilaranta, Finland)
- Skaugen Marine Construction (Skaugen, Shanghai, China)
- V.Ships Leisure S.A.M. (Monaco)
- Color Line Marine (Sandefjord, Norway)
- Teekay Shipping (Vancouver, BC, Canada)
- Höegh Autoliners (Oslo, Norway)

Suggested Terms of Reference
The overall objective will be to develop an integrated plan for systematic observation from merchant marine vessels. To achieve this means addressing and resolving issues of which the list below includes some of the major ones mentioned in the text. Of course, once the working group convenes, it should begin with a review of the ToR and approve/modify them as appropriate.

- Identify ocean observation and scientific needs in terms of parameters and locations
- Identify and prioritize marine routes for sustained ocean observation
- Classify and identify merchant vessel types suitable for sustained observation
- Identify technologies that can enhance vessel capability for ocean observation
- Identify and prioritize instrument needs to meet *future* mission requirements
- Identify and develop procedures (hardware and software) to meet communication needs
- Develop procedures and algorithms for managing data flow, handling, and archival
- Develop information and advisory links with the scientific and government communities for input and feedback
- Identify and resolve EEZ questions, including data ownership, release and sharing
- Design a structure – an Ocean Space Center – to coordinate and implement a merchant-marine based ocean observation program. This would ab initio be conceived as a stand-alone 'center' to avoid the complications of embedding (and/or losing) its needs in a larg-

er existing structure. But, once the exercise has been completed, it might either be merged into or designed with strong ties to existing ocean observing systems.

- Identify and develop procedures for creating the funding structure to start up and sustain the proposed merchant-marine ocean observation program.

Timeline (assuming a once/year meeting schedule)

Year 1:

- Review and adjust as necessary the TOR
- Produce three year work/action plan for the Working Group
- Complete tasks as defined at first meeting
- Begin discussion and conceptual design of Ocean Space Center (OSC)
- Review OSC paradigm in relation to existing ocean observing systems
- Explore funding sources/structures
- Develop a website for the Working Group

Year 2:

- Issue first interim report
- Develop and review as necessary the Work Plan for years 2 and 3.
- Complete a proposal for the Ocean Space Center.
- Develop funding (Prepare and submit proposals to government agencies using interim report)

Year 3:

- Issue final report
- Complete and submit a series of papers a special edition of a journal or book.
- Revise – as appropriate – proposal for Ocean Space Center.
- Explore further funding sources. It is hoped by this stage that some initial funding will be in place to start program. If this is the case, start-up of Ocean Space Center, initial funding to industry for instrument and software development.
- Review and decide what structures will need to be put in place to carry forward the deliberations and plans of the Working Group into the future.

In Summary

There is little doubt that a partnership between the International Oceanographic Community and the merchant marine fleet to equip an appropriate set of vessels to systematically and repeatedly probe the ocean interior at high resolution both horizontally and vertically will have a fundamental impact on our knowledge and understanding of the marine environment and ocean interior. The time is right. First, activities by various groups have clearly shown that partnerships between vessel operators and the scientific community can work well, in many cases over decades. Second, experience from both marine and satellite-based technologies show that systems can be developed for long-term reliable operation, an essential requirement for autonomous operation on merchant marine vessels, and third, (if we ever doubted it), the oceans play a fundamental role in regulating and modulating our climate. The richness of circulation patterns in the ocean and their time scales of overturning imply a continuous spectrum of variability. The best way to understand how the ocean responds to and impacts our climate is through accurate measurement.

The ocean scientific community and merchant marine, working together in partnership, with the help of the SCOR Working Group proposed here will provide the means of helping to make the ideas presented in this proposal a reality.

Web Sites
Sir Alistair Hardy Foundation for Ocean Science
www.SAHFOS.ac.uk
CO2 program: http://tracer.env.uea.ac.uk/e072/publications/first_annual_rep.pdf
Worldwide Merchant Marine Fleet http://www.cia.gov/cia/publications/factbook/fields/2108.html

Information on present volunteer observing ship programs
www.bom.gov.au/jcomm/vos/vos.html
Two academic programs:
http://www.rsmas.miami.edu/rccl/ http://www.po.gso.uri.edu/rafos/research/ole/index.html

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2.3.3 Working group on the Coral Triangle: The centre of maximum marine biodiversity

Background

Tropical marine ecosystems are well known for their high biodiversity. Mangroves, seagrass beds, coral reefs, and adjacent pelagic communities depend on each other for the interchange of organisms, food and nutrients. They play a role in the protection of shorelines during storms and they are sources of income in local economies through fisheries, ecotourism, and mining (Adey 2000, Cesar 2000, White *et al.* 2000, Burke *et al.* 2002, Cesar *et al.* 2003, Hoeksema 2004). Coral reefs become damaged by unsustainable exploitation and increased siltation through river outlets, caused by land erosion. Corals as main reef-builders, have increasingly endured various kinds of illnesses and plagues. Climate change also appears to have impact. Since 1983, reefs have suffered from coral bleaching during periods of elevated seawater temperatures. Increased acidification of sea water will eventually hinder the production of calcium carbonate in corals and other reef-dwelling organisms with limestone skeletons. Because of their extreme high biodiversity, the protection of coral reefs is important for the conservation of global marine biodiversity. Even so, it is unknown which reef areas are most species-rich and it remains to be seen which reefs earn the highest priority in conservation.

The extreme species richness of reefs is predominantly resulting from complex species interdependencies. Reef corals and some other reef-dwelling organisms harbor algal symbionts (zooxanthellae). With the help of sunlight in transparent warm seawater, these algae are responsible for reef formation by limestone accumulation in corals. Corals and many other sedentary organisms, serve as food and hiding place to other organisms. Many host-symbiont relationships appear very specific. In order to study the evolutionary (phylogenetic) history of species associations, both the host and the symbiont species groups need to be known. Such studies require the molecular (DNA) analyses in order to reveal sibling species (look-alikes) and to indicate evolutionary interrelationships (Gittenberger & Gittenberger 2005, Schiaparelli *et al*. 2005, Fransen 2007).

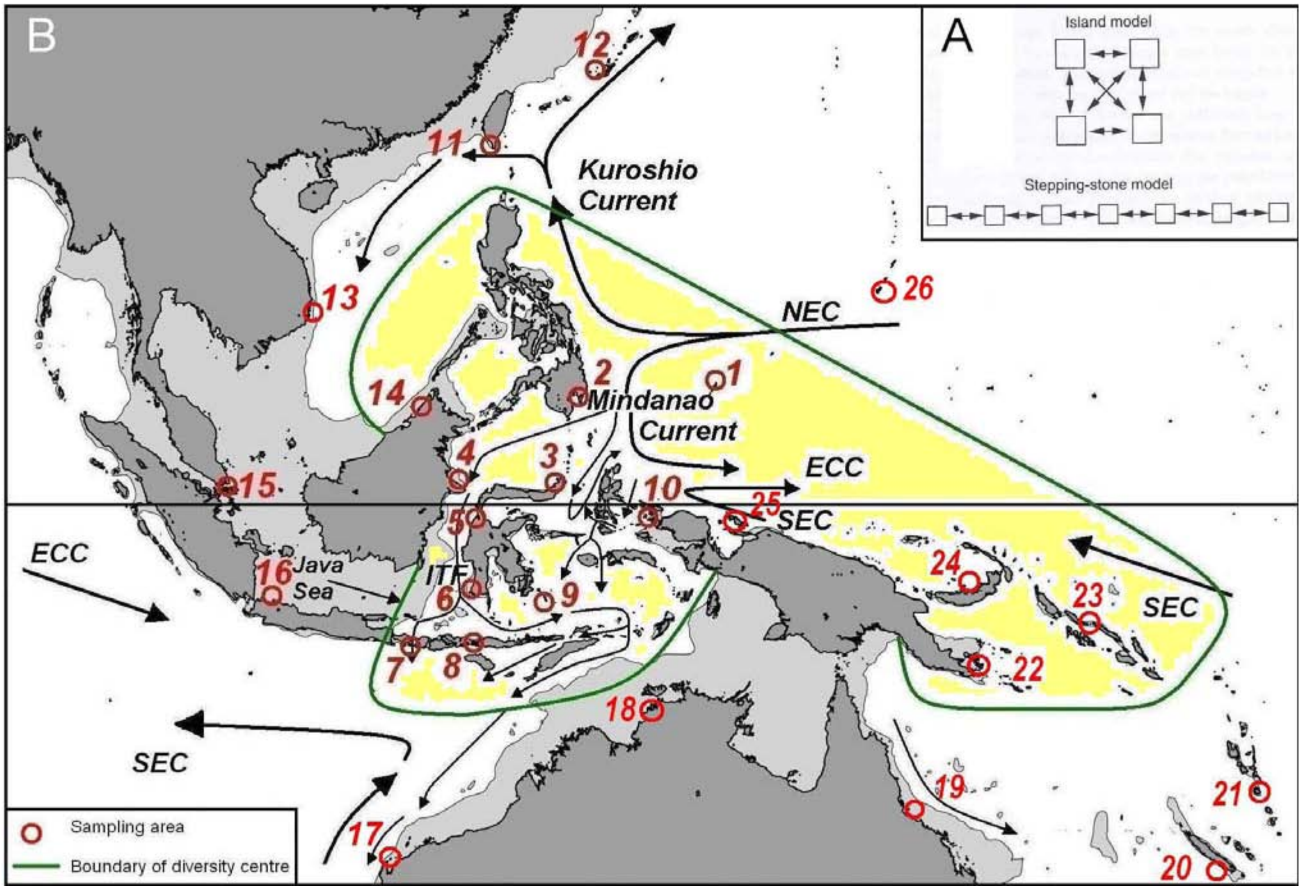

Fig. 1. A Coral Triangle model: a search for patterns and processes. A. Possible mechanisms of connectivity between populations (Palumbi 2003). B. The Southeast Asian - West Pacific centre of maximum marine biodiversity with hypothetical boundaries (Hoeksema 2007). Oceanic currents are indicated to show most likely major pathways of gene flow. Areas indicated in and outside this hypothetical Coral Triangle are candidates for data sampling.

Coral reefs of the Indo-Pacific are more species-rich than Atlantic reefs. The world's highest concentration of marine species occurs in the Southeast Asian – West Pacific (SEA-WP) region, which has been dubbed 'The Coral Triangle', signifying the importance of coral reefs. The distribution ranges of species (especially endemic and endangered ones), is relevant for the design of marine protected areas (MPAs). However, due to a lack of data, it is unclear where the boundaries of this centre of maximum marine biodiversity are located (Green & Mous 2004, Hoeksema & Putra 2002, Hoeksema 2007). This delineation of the Coral Triangle has to be based on reliable species records. Observations of only benthic organisms are not sufficient since most marine species are also represented by a free-living phase (usually larvae) in the open water in between reefs (Paulay & Meyer 2006). The dispersal of reef organisms is largely determined by the duration of this free-living phase and by the direction and speed of currents.

Rationale: integration of taxonomic expertise and assessment methods

Knowledge on the position of the Coral Triangle will benefit from cooperation by specialists of various marine taxa and by physical oceanographers who know about past and present oceanic currents. At present, different assessment methods are used for marine biodiversity analyses. Although diversity patterns among various groups of marine organisms appear to show much congruence, there is little data to substantiate unifying conclusions. Many marine species show large geographical distribution ranges, especially if a high dispersal capacity is linked to a long-lived larval stage. Other species show very restricted ranges, due to a short larval stage or its absence (such as in brooding species). However, most reef-dwelling species show widespread (Indo-West Pacific = IWP) ranges, although range expansion was probably interrupted and maybe reversed during low sea level stands, such as during the last Glacial Maximum (Hoeksema 2007).

In order to get a better insight in Indo-West Pacific species richness patterns, marine biodiversity specialists need to cooperate in order to compare species richness patterns of various reef taxa. For some taxa, various assessment methods should be used to enable calibrations. Assessments of large taxa have as disadvantage that they are less reliable and nearly irreproducible due to unresolved taxonomies. Specimens of such taxa need to be deposited in reference collections. The use of presence / absence data is another method, which is mostly applied to smaller taxa (at genus or family level). Their assessments can done with little effort in a relatively short time.

Since present species range boundaries are maintained by gene flow, it is important to find species suitable for phylogeographic studies that indicate connectivity among populations. The outcome may support the design of networks of marine protected areas (MPAs), which not only conserve gene pools for areas surrounding MPAs (replenishing by spill-over), but also make MPAs themselves resilient in case local extinction requires the replacement by larval recruits from an upstream source.

Scientific background

For the designation of a network of Marine Protected Areas (MPAs) and for other conservation efforts, it is important to know which areas are particularly rich in species (Ferrier 2002, Allen & Adrim 2003, Green & Mous 2004, Briggs 2004, 2005), especially in endemic species that show relatively small ranges (Myers *et al*. 2000, Allen 2002, Roberts *et al*. 2002; Hughes *et al.* 2002, Beger *et al*. 2003, Mora *et al.* 2003, Myers & Ottensmeyer, 2005, Allen 2007). The biodiversity assessment approaches that are used to distinguish areas fit for MPA status, usually rely on data from areas that have been selected a priori for MPA destination. They are intended for local conservation efforts and do not give complete information for biogeographic comparisons of species richness between areas. They are supposed to be rapid and just produce species lists made by individual observers through a visual census to support species richness numbers as high as possible without supporting proof (such as voucher specimens, photographs). Such records may contain synonymies, different names for the same species, which inflates the species numbers but devaluates their quality. The observers in such biotic surveys are usually generalists who are trained in the identification of species, but they may not be able to solve taxonomic problems and publish on this.

Marine biodiversity assessments for scientific biogeographical studies serve to gain knowledge on the species richness of a selected area and to collect records for the analysis of individual species ranges. Families, genera, and other species groups that have undergone taxonomic revisions are ideal for use in surveys since synonymies have been minimized. Such taxa should be used a models (key taxa, exemplars, etc.) but have as disadvantage that they may not be completely representative.

Species diversity patterns may change as a result of Global Change, which may effect the outcome of assessments. Historical data on occurrence records are usually stored in museum collections. Species containing limestone skeletons are very suitable since they can most easily be preserved in dry condition. In order to find long-term changes in species composition, extensive collections per locality are needed. For the Coral Triangle itself no specific localities are known to show long-term changes. Examples of documented changes in marine biodiversity (in connection to sedimentation, pollution and dredging) are known from densely populated cities, such as Singapore and Jakarta, with a long history of sampling and monitoring (Hoeksema & Koh, subm, Meij *et al.* in prep.). Even if the present position of the centre of maximum marine diversity becomes more clear, very little remains known about its origin during the Cenozoic (Renema 2007).

Different assessment methods need to be compared for biogeographic and phylogeographic studies:

1 ATBI (= All Taxon Biodiversity Inventory) aims at giving an overview of as many species as possible in an area with maximum effort, including the use of many scientists and methods. This method may help to approach the real number of species present in an area. Not all species need to be identified directly in the case of morpho-species counts (Bouchet *et al.* 2002). Material is usually deposited in a scientific reference collection for further investigation.

2 RAP (= Rapid Assessment Program) or REA (= Rapid Ecological Assessment) aims at giving species overviews within a limited time frame of dominant key groups per area surveyed, such as reef coral species, reef fish, etc. (Werner & Allen 2000, Allen & McKenna 2001, McKenna *et al.* 2002, Allen *et al.* 2003). Since these taxa are represented by high species numbers (> 500), no precise estimate of the real species number can be found, depending on the time available. Records of new species remain unclear unless material has been sampled for study by a specialist. Oherwise, the claims remain untested. There is a likely occurrence of false records, due to the use of synonyms. The reliability of the results depends heavily on the experience of the observers.

3 PAR (= Presence – Absence Records) aims at giving a complete overviews of species present and absent in a surveyed area. Model taxa of 50-100 species are used (genera, families) that have been taxonomically revised. Since species presence and absence records are obtained per sample unit within a surveyed area, statistically reliable species richness estimators can be given (with error margins). The specialized observer needs to spend much time per survey area (2-4 weeks) and preferably the same observer needs to complete the surveys for each area included in the comparison. Species records are represented by voucher specimens in reference collections and/or by photographic evidence. New species are rare since the model taxon has been taxonomically revised already, which minimizes the

risk of overlooked species. This method is not commonly used (Hoeksema 1993, 1997, Hoeksema & Putra 2002, McKenna, 2006, Hoeksema 2007).

4 Phylogeography. Molecular methods using suitable genetic markers (e.g. micro-satellites) are used to map species boundaries and affinities between populations of selected reef organisms in different reef areas (Knowlton 2000, Benzie 2000, 2001, Lessios et al., 2001, 2003, Hellberg et al. 2002, Williams *et al.* 2002, Uthike & Benzie 2003, Chen *et al*. 2004, Froukh & Kochzius 2008, Kochzius & Nuryanto 2008, Timm *et al.* 2008). The sampling should be based on the direction of ocean currents and the position of continental shelves (Fig. 1). In addition to long-term changes in oceanic currents due to sea level fluctuations (Hantoro *et al.* 1995, Hantoro 1997), also seasonal variation in oceanic currents and salinity of the surface water might be relevant in order to explain present distribution patterns and connectivity (Wolanski 2001, Gordon *et al.* 2003, Fang *et al* 2005, Susanto *et al.* 2007, http://www.earth.columbia.edu/news/flash/itf2004.html). Results so far indicate a major genetic distinction between populations at both sides of the Sunda shelf margin, separating west and east Indonesia from each other (Barber *et al.* 2000, 2002, Lourie & Vincent 2004, Lourie *et al.* 2005, Collette 2005, Knittweis *et al.* 2008, Kochzius & Nuryanto 2008). A design of MPA networks would benefit from information on species diversity, endemism and gene flow in relation to oceanic current patterns (Ablan *et al.* 2000, 2004, Beger *et al.* 2003, Palumbi 2003, Roberts *et al.* 2006).

Terms of reference

Within the proposed four year of existence, the WG plans to achieve results on

- -integrating methods for coral reef biodiversity assessments
- -integration of coral reef biodiversity research and conservation
- -areas suitable for biodiversity assessments and DNA sampling for connectivity studies
- -reef organisms that are suitable for connectivity studies
- -genetic markers for organisms in phylogeographic connectivity studies
- -oceanic currents and their seasonal variation at depths that are relevant for larval transport

Three meetings in the SEA-WP region in collaboration with local institutes and nature conservation organizations working on coral reef biodiversity management. Objectives are

- to develop an integrative research strategy in order to determine the boundaries of the Coral Triangle
- to present results on marine biodiversity, phylogeography, and relevant oceanic current patterns (past and present)
- to collaborate in fieldwork, to assist each other in sampling from various localities
- to assist in the organization of workshops in the SEA-WP region dealing with the identification of coral reef model taxa. Publications in peer-reviewed journals using examples of various model taxa.

Time line
The meetings will be organized in conjunction with already planned symposiums and workshops. Proposed examples:

2009. World Ocean Conference, Manado, North Sulawesi, Indonesia.
2010. Second Asia-Pacific Coral reef Symposium, Phuket, Thailand.
2011. Opening of new building Coral Triangle Centre, Bali, Indonesia.
IOC/WESTPAC symposiums are very relevant for the region and may offer possible opportunities.
The 7th symposium (2008) was in Kota Kinabalu, Sabah, Malaysia.

Prologue: open scientific meetings that completely or partly have dealt with coral reef biodiversity
(non-integrative)
9th International Coral Reef Symposium, Bali, 2000. Relevant mini-symposiums:

- The East Indies Triangle of maximum marine biodiversity: Definition and origins
- Molecular phylogeny and population genetics in coral reefs
- Coral reef biodiversity: assessment and conservation

10th International Coral Reef Symposium, Okinawa, 2004. Relevant mini-symposiums: -Biodiversity and diversification in the Indo-West Pacific -The Coral Triangle: Global center of coral reef richness -Connectivity in coral reef systems – scientific challenges and management consequences

1st Asia-Pacific Coral Reef Symposium, Hong Kong, 2006. Relevant mini-symposium: -Investigating connectivity and meaningful scales for managing coral reef resources 11th International Coral Reef Symposium, Fort Lauderdale, 2008. Relevant mini-symposium: -Biodiversity and diversification of reef organisms 1st World Conference on Marine Biodiversity, Valencia, 2008. Relevant session: -The Coral Triangle: patterns and processes in marine species richness and habitat diversity

The SCOR working group

Many specialists on IWP reef organisms are based outside this region (where most of the old reference collections and libraries are). The SCOR working group should represent many nations and specialties (taxa). Meetings and workshops should preferably occur in the SEA-WP region in order to make information available to local scientists, NGO’s, and park managements.

Nature conservation organizations, such as TNC since 1951 (The Nature Conservancy, at http://www.nature.org/), WWF since 1961 (World Wildlife Fund, at http://www.panda.org/), and CI since 1987 (Conservation International, at http://www.conservation.org/), should link to the SCOR working group by assigning their marine biodiversity and MPA specialists to SCOR meetings as associate members. TNC is establishing a Center (http://www.coraltrianglecenter.org/) at Bali in order to "generate knowledge on marine biodiversity conservation and on sustainable use of marine resources in the Coral Triangle, and to ensure that this knowledge is applied in on-site MPA management, in awareness and communication, and in policy". The results of the SCOR meetings should become available as technical information that can be applied to help in the development of monitoring protocols and content for training programs according to the latest scientific insights as effective management tools for biodiversity conservation.

The WG on the Coral Triangle may be able to link up with the Census of Marine Life's (CoML), Census of Coral Reef (CReef) http://www.creefs.org/. It also plans to link with EU FP6 network of excellence, the European Distributed Institute of Taxonomy (EDIT), Work Package 7 on Taxonomy for Conservation. http://wp7.e-taxonomy.eu/. Meetings will be announced via relevant e-mail lists.

Name F/M Expertise Institute / Country

Co-chairs:				
Dr. Bert W. Hoeksema	m	Marine biodiversity	National Museum of Natural History Naturalis, Leiden	The Netherlands
Dr. Annadel Cabanban	f	Reef fish /conservation	WWF-Malaysia, Kota Kinabalu	Malaysia
Members:				
Dr. R. Dwi Susanto	m	Physical oceanography	Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, (Indonesian Research Coordination)	USA
Dr. C.L. Villanoy	m	Physical oceanography	Marine Science Institute, University of the Philippines, Quezon City,	Philippines
Dr. W.S. Hantoro	m	Climate change	Research Centre of Geotechnology (LIPI), Bandung	Indonesia
Dr. Marc Kochzius	m	Connectivity	University of Bremen	Germany
Dr. Philippe Bouchet	m	Molluscs	National Museum of Natural History, Paris	France
Dr. Peter Ng	m	Crustaceans	Raffles Museum of Biodiversity, National University of Singapore	Singapore
Dr. Paul Barber	m	Crustaceans/connect.	Boston University, Boston	USA
Dr. Sara Lourie	f	Reef fish / connect.	McGill University,	Canada

			Montreal	
Associate members:				
Dr. Nancy Knowlton	f	CReefs, CoML	Smithsonian Institution, Washington, D.C.	USA
Dr. Alison Green	f	Coral Triangle	The Nature Conservancy, Brisbane	Australia
Dr. Lida Pet-Soede.	f	Coral Triangle	WWF-Indonesia, Bali	Indonesia
Dr. Gerry Allen	m	Reef fish	Western Australian Museum, Perth	Australia
Dr. Kent E. Carpenter	m	Reef fish	IUCN / Old Dominion University, Norfolk	USA
Dr. Teguh Peristiwady	m	Reef fish	Marine field station RCO-LIPI, Bitung	Indonesia
Dr. Terry Donaldson	m	Reef fish	IUCN / University of Guam	Guam
Dr. Ronald Fricke	m	Reef fish	State Museum for Natural Sciences, Stuttgart	Germany
Dr. Tatyana Dautova	f	Corals	Institute of Marine Biology, Vladivostok	Russia
Dr. Wilfredo Licuanan	m	Corals	De La Salle University / University of the Philippines, Manila	Philippines
Dr. Mark Erdmann	m	Crustaceans	Conservation International, Sorong	Indonesia
Dr. Bertrand Richer de Forges	m	Crustaceans	Research Institute for Development (IRD)	New Caledonia
Dr. Jim Thomas	m	Crustaceans	Nova Southeastern University, Fort Lauderdale	USA
Dr. Charles H.J.M. Fransen	m	Crustaceans	Naturalis, Leiden	The Netherlands
Dr. Chris Meyer	m	Molluscs	Smithsonian Institution, Washington, D.C.	USA
Dr. Terry Gosliner	m	Molluscs	California Academy of Sciences, San Francisco,	USA

Dr. Gustav Paulay	m	Molluscs, invertebrates	Florida Museum of Natural History, University of Florida, Gainesville	USA
Dr. David Lane	m	Echinoderms	University of Brunei Darussalam,	Brunei
Dr. Chris Glasby	m	Bristle worms	Northern Territory Museum, Darwin	Australia
Dr. John Hooper	m	Sponges	Queensland Museum, Brisbane	Australia
Dr. Nicole J. de Voogd	f	Sponges	Naturalis, Leiden	The Netherlands
Dr. Willem Renema	m	Foraminifera	Naturalis, Leiden	The Netherlands

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2.3.4 Working Group on Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time-Series Observations

1. Introduction

A. Background & Rationale

Marine ecosystems are changing rapidly in response to natural processes, human activities, and climate change. These drivers of change have become subject of increasingly intense focus from both research and management perspectives. There are some important scientific questions that need to be addressed with regard natural vs human-induced change including 1) the qualitative character of the ecosystem responses ("what changes?"), 2) their amplitudes ("by how much?"), and 3) their timing and spatial and temporal scales ("when and where are rates of change most profound?"). Phytoplankton are excellent indicators of marine ecosystem change. They are ecologically and biogeochemically important and relevant indicators, since they conduct a large share of system-scale primary production and hence C cycling, and they are highly sensitive to a suite of environmental stressors. There is much accumulated evidence that diverse ocean regions undergo strong and sometimes abrupt changes in phytoplankton composition, and productivity at roughly decadal intervals (i.e. regime shifts). This variability is associated with corresponding changes in atmospheric, hydrologic, chemical, and higher trophic-level biological processes and state variables. However, our understanding of global change is incomplete because we have not adequately explored, inventoried or compared available observational data. Nor do we know how to anticipate the timing and direction of the next major shifts.

In October 2007, nearly 100 phytoplankton ecologists gathered in Rovinj, Croatia and attended the AGU Chapman Conference: "Long Time-Series Observations in Coastal Ecosystems: Comparative Analyses of Phytoplankton Dynamics on Regional to Global Scales" (http://www.agu.org/meetings/chapman). They analyzed and compared phytoplankton changes in many coastal marine ecosystems around the world.

A recent example of a climate change-induced shift in biological communities was reported by Cloern et al. (2007) for San Francisco Bay. The abrupt change in the biological communities was first detected as increasing phytoplankton biomass and the occurrences of new seasonal blooms that began in 1999, overriding the influence of changes in the input of nutrients. There were coincidental higher level biotic changes, including sharp declines in the abundance of bivalve mollusks, the key phytoplankton consumers in this estuary, and record high abundances of several bivalve predators: Bay shrimp, English sole, and Dungeness crab. The phytoplankton increase is consistent with a trophic cascade resulting from heightened predation on bivalves and suppression of their filtration control on phytoplankton growth. These community changes in San Francisco Bay across three trophic levels followed a state change in the California Current System in the form of sudden increased upwelling intensity, amplified primary production, and strengthened southerly water flows. These diagnostic features of the East Pacific ‘‘cold phase’’ led to strong recruitment and immigration of juvenile flatfish and crustaceans into estuaries where they feed and develop. This study utilized three decades of observations to reveal a previously unrecognized mechanism of ocean–estuary connectivity. This shows that interdecadal oceanic regime shifts can propagate into estuaries and coastal waters, altering their community structure and efficiency of transforming land-derived nutrients into algal biomass.

B. Proposed SCOR Working Group

We are proposing to form a SCOR Working Group to focus on coastal ecosystems (estuaries, fjords, bays, sounds, open waters of the continental shelf, etc.) where perturbations from terrestrial, atmospheric, oceanic sources and human activities converge to cause changes that ramify across local and global scales. Human pressure on coastal regions and continental margins is increasing with expanding urbanization and the conflicting demands of tourism, agriculture and aquaculture, water diversions, wind parks and other developments. This idea to develop a SCOR Working Group grew out of the recent AGU Chapman Conference: “Long Time-Series Observations in Coastal Ecosystems: Comparative Analyses of Phytoplankton Dynamics on Regional to Global Scales” (convened by James Cloern and Nenad Smodlaka, October 8-12, Rovinj, Croatia). There was a strong consensus at this conference that a more detailed and more global comparison of phytoplankton time series would be timely, technically feasible, and an extremely valuable next step to more fully understand commonalities and contrasts with regard to ecological responses to natural and man-made changes captured in our global network of coastal phytoplankton time series.

Such an analysis must be an international cooperative effort – the relevant data sets are in many places and have been collected by many independent researchers, agencies and nations. Many of the necessary data are available now, and the Working Group can begin immediately. Endorsement and sponsorship by SCOR will help us attract and retain approvals and financial support from national agencies.

We will try to establish a strong interaction and working relationship with the SCOR WG on zooplankton time series and SCOR WG 132 on HABs. This interaction will be very beneficial as they are dealing with the similar challenge of analyzing global time series data sets.

We also expect to attract co-sponsorship and additional financial support in the form of travel funding for associate WG members from various organizations such as IMBER, GEOHAB, PICES, IOC and Census of Marine Life. We have invited the organizations to nominate associate members. We will maintain our interactions with these organizations during the WG active period, for example, we will send them our annual meeting notices before meetings and our annual reports for their feedbacks.

2. The Nature of the Scientific Opportunity

Phytoplankton

Phytoplankton are dominant marine primary producers; they mediate nutrient flux and cycling as well as transfer of organic matter to higher trophic levels, including invertebrate grazers, planktivorous fish, and carnivores. Hence they are a key link between nutrients and secondary production. As key primary producers, phytoplankton reflect immediate effects of changes in the input of nutrients in coastal ecosystems. Because different phytoplankton groups require different nutrient ratios, their composition responds to changes in the ratios of ambient nutrients. For example, diatoms require silicate and their relative abundance may be regulated by Si concentrations relative to other nutrients. Phytoplankton productivity and floristic composition are subject to physical forcings such as horizontal exchange between estuaries and the open sea (Cloern et al. 2007) and vertical mixing regimes, and they are also regulated by light fluctuations, and temperature. Changes in phytoplankton productivity and composition can be driven by climatic forcing and variability such as monsoons (Yin 2002), typhoons or hurricanes (Paerl et al. 2001, 2006) and rainfall (Paerl 1995). In addition, phytoplankton are broadly distributed and abundant, and can be quantified by relatively simple and intercomparable sampling methods. Finally, demographic traits of phytoplankton make them particularly suitable for comparative analysis of ecosystem changes across regional to global scales.

Availability and diversity of phytoplankton time series

Many researchers and governmental agencies around the world have relied on phytoplankton as a key indicator of water quality monitoring programs and many data sets have been presented in the Croatia AGU Chapman conference. Those data sets included:

Working Group 1: dominant scales of variability in phytoplankton biomass, abundance, floristic composition, species composition, and/or species diversity			
Name	**Country**	**Ecosystem**	**Series**
Paulo C. Abreu	Brazil	Patos Lagoon Estuary	1986-1990, 1993-2007
Susan I. Blackburn	Australia	Huon Estuary, Tasmania	1996-2005
H. O. Briceño	U.S.	Biscayne Bay, Florida Bay, Florida Shelf	1989-2007
Francisco.P. Chavez	U.S.	Monterey Bay	1988-2007
James E. Cloern	U.S.	North & South San Francisco Bay	1969-2007

Valerie David	France	Gironde Estuary	1978-2003
S. Fonda Umani	Italy	Gulf of Trieste	1986-2005
Miles Furnas	Australia	Great Barrier Reef Lagoon	1992-2007
S.A. Gaeta	Brazil	Brazil Coastal Waters	2004-2007
Charles L. Gallegos	U.S.	Rhode River Estuary	1969-2007
Amatzia Genin	Israel	N Gulf of Aqaba	1988-2007
Rita A. Horner	U.S.	Washington Coast	1997-2007
Arantza Iriarte	Spain	Bilbao & Urdaibai . Estuary	1997-2007
Jacco C. Kromkamp	The Netherlands	Oosterschelde/Westerschelde	1987-2006
Robert Le Borgne	France	Ivory Coast, New Caledonia	1969-1979, 1979-1989
WKW Li	Canada	Bedford Basin	1967-2007
Michael W. Lomas	U.S.	Bermuda Atlantic Series	1989-2007
Emma Orive	Spain	Nervion River Estuary	2000-2006
Elgin S. Perry	U.S	Chesapeake Bay	1985-2004
N. Ramaiah	India	Bay of Bengal	1962-1965, 2001-2006
Diana Sarno	Italy	Gulf of Naples	1984-1991, 1995-2008
Dietmar Straile	Germany	Lake Constance	1980-2006
Sanna Suikkanen	Finland	Northern Baltic Sea	1979-2003
Alexander Vershinin	Russia	NE Black Sea	2001-2006
Hidekatsu Yamazaki	Japan	Tokyo Bay	1996-2006
Working Group 2: evidence for external forcings of variability and change			
Name	Country	Ecosystem	Series
Ana B. Barbosa	Portugal	Ria Formasa Lagoon	1991-1993
Vanda Brotas	Portugal	Tagus Estuary	1999-2007
Rita B Domingues	Portugal	Guadiana River Estuary	1999-2005
Naomi Greenwood	U.K.	Liverpool Bay	1989-2006
Malcolm S. Robb	Australia	Swan Canning Estuary	
Bradley Eyre	Australia	Moreton Bay & Brunswick Estuary	1984-1991; 1995-2007

David G. Borkman	U.S.	Narragansett Bay	1959-1997; 1999-2006
Jonathan H. Sharp	U.S.	Delaware Bay	1980-2003; 1950s – present
Larry W. Harding, Jr.	U.S.	Chesapeake Bay	1989-2007
Hans W. Paerl	U.S.	Neuse River-Pamlico Sound	1993-2006
Clarisse Odebrecht	Brazil	Patos Lagoon Estuary, Cassino Beach	1987, 1989-1990, 1992-2006
M Ribera d'Alcalà	Italy	Gulf of Naples	1979-2006
Alina Tunin-Ley	France	Ligurian & Tyrrhenian Seas	1908-1914, 1929-1931, 1969-1970, 1984, 1988, 2002-2005
Nenad Smodlaka	Croatia		1987-2007
Jacob Carstensen	Denmark	Kattegat	1993-2007
Daniel Conley	Sweden		
Hans Christian Eilertsen	Norway	Norwegian Coast/Barents Sea	1974-2007
Karen Helen Wiltshire	Germany	North Sea Helogland	10 years
Xavier Desmit	The Netherlands	North Sea	1975-2003 ; 1990-2006 (Phyto)
Martina Loebl	Germany	Belgian, Dutch, German Coastal	1990-2005
C J M Philippart	The Netherlands	Wadden Sea	1995-2004
Jennifer L. Martin	Canada	Bay of Fundy	1980-2007
Michael L. Parsons	US	N Gulf of Mexico	
Trevor Platt	Canada	NW Atlantic, remote sensing	1990-2005
Working Group 3: consistent patterns among ecosystems in terms of relationships between environmental parameters, phytoplankton biomass and changes in species/floristic composition			
Name	Country	Ecosystem	Series
Malcolm C. Baptie	U.K.	North Sea, UK NE coast	1969-2007

Mauro Bastianini	U.K.	Gulf of Venice	1986-2007
Suncica Bosak	Croatia	N Adriatic Sea	1998-2006
Eileen Bresnan	Scotland	NE Scotland Coastal	1997-2007
Maria Degerlund	Norway	Norwegian coast/Barents Sea	3 decades
R. H. Freije	Argentina	Bahía Blanca Estuary	1978-2006
Inga Hense	Germany	Baltic Sea	1975-2006
Carlton D. Hunt	U.S.	Boston Harbor, Cape Cod Bay, Massachusetts Bay	1992-2008
Tapan Kumar Jana	India	Sundarban Mangrove Forest	1988-2001
R. Kraus	Croatia	Northern Adriatic	1972-2006
Dongyan Liu	China	Jiaozhou Bay	
A. Lincoln MacKenzie	New Zealand	Marlborough Sound, Tasman & Golden Bays	1993-2007
Ivona Marasović	Croatia	Northern Adriatic	1962-1982
Snejana P. Moncheva	Bulgaria	Black Sea	1954-2003
Patricija Mozetic	Slovenia	Gulf of Trieste	1984-2006
Tatyana Osadchaya	Ukraine	Black Sea	1998
Edward J. Phlips	U.S.	Indian River Lagoon	1997-2007
Igor G Polikarpov	Ukraine	Sevastopol Bay	1937-1938, 1960-1968, 2001-2007
Kevin G. Sellner	U.S.	Chesapeake Bay	1984-2007
Ted Smayda	U.S.	Narragansett Bay	1974-2007
Kuninao Tada	Japan	Seto Inland Sea	1991-2006, 1973-2005
Norbert Wasmund	Germany	Baltic Sea, Mecklenburg Bight	1979-2006
Kedong YIN	Hong Kong	Hong Kong Coastal	1991-2004
A. Zingone	Italy	Gulf of Naples	1984-1991, 1995-2009

Currently, intensive comparative phytoplankton data analyses are underway as a result of the AGU Chapman Conference. The central questions being addressed in these analyses include:

(1) What are seasonal patterns of phytoplankton biomass variability?

(2) Do these patterns change over time?
(3) What is the magnitude of seasonal vs interannual variability?
(4) Is there evidence for interdecadal changes as trends or regime shifts?

Our goal is a global-scale analysis, and synthesis of chlorophyll and phytoplankton biomass/composition time series sustained for at least a decade in nearshore coastal marine waters. Here is a table of data sets we have acquired already. (salinity and temperature are the routine parameters monitored in all monitoring programs)

Country	Place	Start	End	Gaps	Chla	Nuts	Turb	DO
Argentina	Bahia Blanca	1974	2007	Y	Y	Y	Y	Y
Denmark	Baltic-Kattegat	1967	2006	Y	Y	Y	Y	N
US	Barnes Sound							
Canada	Bedford Basin	1967	2006	Y	Y	Y	Y	N
Spain	Bilbao Estuary	1997	2006	N	Y			
US	Biscayne Bay	1993	2006	N	Y	Y	Y	N
Denmark	Bornholm Bay	1987	1997	N	Y	Y	Y	
US	Chesapeake Bay	1984	2004	N	Y	Y	Y	N
US	Delaware Bay	1978	2003	Y	Y	Y	Y	Y
France	English Channel Roscoff	1997	2007	Y	Y	Y	Y	N
France	English Channel Wimereux	1997	2007	Y	Y	Y	Y	N
US	Florida Bay	1989	2007	N	Y	Y	Y	Y
US	Georgia Strait	1990	2005	Y	Y	Y	Y	Y
France	Gironde Estuary	1997	2007	Y	Y	Y	Y	N
France	Golfe de Lion	1997	2007	Y	Y	Y	Y	N
France □	Golfe de Marseille	1997	2007	Y	Y	Y	Y	N
US	Palmer Stn	1990	2005	Y	Y	Y	Y	Y
Israel	Gulf of Aqaba	1988	2006	N	Y			N
Italy	Gulf of Naples	1984	2006	Y	Y			~~N~~
US	Hood Canal	1990	2005		Y	Y	Y	Y
Australia	Huon Estuary	1996	2005	Y	Y	Y	Y	N

US	Indian River Lagoon							
US	Long Island Sound	1988	2005	Y	Y	Y		Y
US	Manatee Bay							
US	Massachusetts Bay, Boston Harbor	1992	2007	N	Y	Y	Y	Y
Ireland	Mulroy Bay	198 8	2005	Y	Y	Y	N	N
US	Narragansett Bay	1968	2006	Y	Y			N
Spain	Nervion River Estuary	2000	2006	Y	Y			N
US	Neuse River Estuary	1994	2006	N	Y		Y	Y
US	New York Harbor & Bight	1972	1993	N	Y	Y	Y	Y
US	North Inlet Estuary	1981	2001	N	Y	Y	Y	N
Netherlands	Oosterschelde	1991	2004	Y	Y	Y	Y	Y
W Antarctic	Palmer Station	1991	2006	Y	Y	Y		
US	Parker River Estuary	1994	2007	Y	Y	Y	Y	
Brazil	Patos Lagoon	1986	2006	Y	Y	Y		N
US	Puget Sound	1989	2006	Y	Y	Y	Y	Y
France	Rade de Brest	1998	2007	Y	Y	Y	Y	N
France	Rade de Villefranche	2007	Y	Y	Y	Y	N	
US	Rhode River Estuary	1969	2006	Y	Y			N
Denmark	Ringkoebing Fjord	1980	2007	N	Y	Y	Y	Y
US	San Francisco Bay	1975	2007	N	Y	Y	Y	Y
US	St. Lucie Estuary							
US	Tampa Bay	1974	1998	Y				
Hong Kong		1985	2007	Y	Y	Y		Y
US	Tomales Bay	1987	1995	N	Y	Y		N
Spain	Urdaibai Estuary	1997	2006	N	Y			N
Germany	Wadden Sea	1984	1996	N	Y	Y		N
Netherlands	Westerschelde	1978	2006	Y	Y	Y	Y	Y
US	Willapa Bay	1990	2005	Y	Y	Y	Y	Y

Guiding Questions

We believe that large-scale (between-region and between-ocean) comparisons of phytoplankton time series are the essential next step. Local- and regional-scale observational programs are maintained in coastal marine waters of all continents, but their data remain largely isolated. Our goal is to locate, assemble, and synthesize multi-decadal observations to obtain quantitative and descriptive depictions of phytoplankton variability as an indicator of environmental change. We envision a global phenology of phytoplankton at the land-sea margin and a conceptual model from which coastal ocean observing systems can be built. As a logical outgrowth of (and next step following) the Chapman Conference, the working group will focus on a comparative analysis of ecosystems to address three guiding questions:

1. *What are the dominant scales of variability in phytoplankton biomass, abundance, floristic composition, species composition, and/or species diversity? Is there evidence for secular trends or regime shifts? With which criteria can we best differentiate long-term from episodic, seasonal and interannual signals?*

2. *Is there evidence for external forcings of variability and change (e.g., effects of climate change, basin scale oscillations, land-based inputs, atmospheric deposition, alien species)? Are changes coherent in space and/or time?*

3. *Are there consistent patterns among ecosystems in terms of relationships between environmental drivers, responses in phytoplankton biomass and changes in species/floristiccomposition?*

To date, relatively few between-region comparisons of phytoplankton time series have been completed. All previous comparisons have been at smaller scales (within an individual current system, or at most one ocean basin), compared to the global scale that include inter-regional comparisons that we are proposing. We now have access to both the data and the tools needed to carry out a global synthesis.

Methodological opportunities and issues

Several methodological issues affect the analysis of phytoplankton time series and only a brief summary is given here. However, even though these issues will complicate our work, we can still obtain a meaningful global comparison.

The first issue is diversity of the sampling methodology. No phytoplankton sampling method is perfect, and there have been differences in sampling methodology both within and between data sets, particularly for earlier data. However, we do not expect these differences to be a serious technical barrier to between-region comparisons. A key reason for this is that our analysis focuses on comparisons of anomaly time series rather than of regional climatologies. Hence, we are primarily interested in the temporal variability of relative abundance, not the spatial variability of absolute abundance. Several of the proposed WG members have expertise in evaluating effects of changes in sampling methodology within individual time series.

A second issue is consistency of taxonomic identification within and among data sets. Again, we are primarily comparing anomalies relative to local norms, and looking for when, where, and how long the community changes. We also expect that all or most of our analyses will be weighted on the better-known taxa that dominate the community in each region.

A third issue is the volume, accessibility, and diversity of data. The situation here is much improved over even a few years ago. Good computer tools for dealing with the diverse origin and moderately large data sets are now more available, cheaper, more flexible and user-friendly. We anticipate that this trend will continue. Although data management work will be necessary, we do not expect that electronic assembly and consolidation of the phytoplankton data sets will be a major technical problem. In fact, we have already assembled several key data sets as part of the Chapman Conference.

The final issue is the use of statistical tools. During the Chapman Conference, a few statistical experts were invited to help participants to perform statistical analyses on their own data set. They demonstrated how to deal with temporal and spatial autocorrelation, and with data gaps. This knowledge will be utilized by our SCOR WG in the next phase of global time series analysis. Application, evaluation, and bundling these statistical tools for distribution/publication will be another important WG product.

Regional and Global Comparisons

Phenology, the study of biological life cycles and their connection to weather- and climate-driven environmental variability, is a key ecological discipline that is being applied to the documentation and understanding of global-scale changes in the distribution and abundance of terrestrial species. A prominent example is the European Phenological Network (http://www.dow.wau.nl/msa/epn/); planning for a U.S. National Phenology Network has begun (*Eos* 86(51):539). These observational and research programs are motivated by recognition that biological seasonal cycles are sensitive and powerful integrative indicators of environmental change, and by observations of significant phenological changes over the past century manifested as shifts in the timing of plant flowering, bird migrations, and hibernation patterns of mammals.

This working group will be a step toward forming a coastal phenological network, a potential component of a global ocean observing system, to identify patterns and underlying processes of phytoplankton community change in the world's estuaries, bays, lagoons, and continental margins. We will follow the lead of terrestrial scientists who are advancing the application of phenological studies as a cornerstone of global efforts to measure, predict and ultimately manage changes in the Earth's living resources. As coastal oceanographers, we feel a sense of urgency because implementation of this essential approach in these important aquatic ecosystems lags behind the applications on land.

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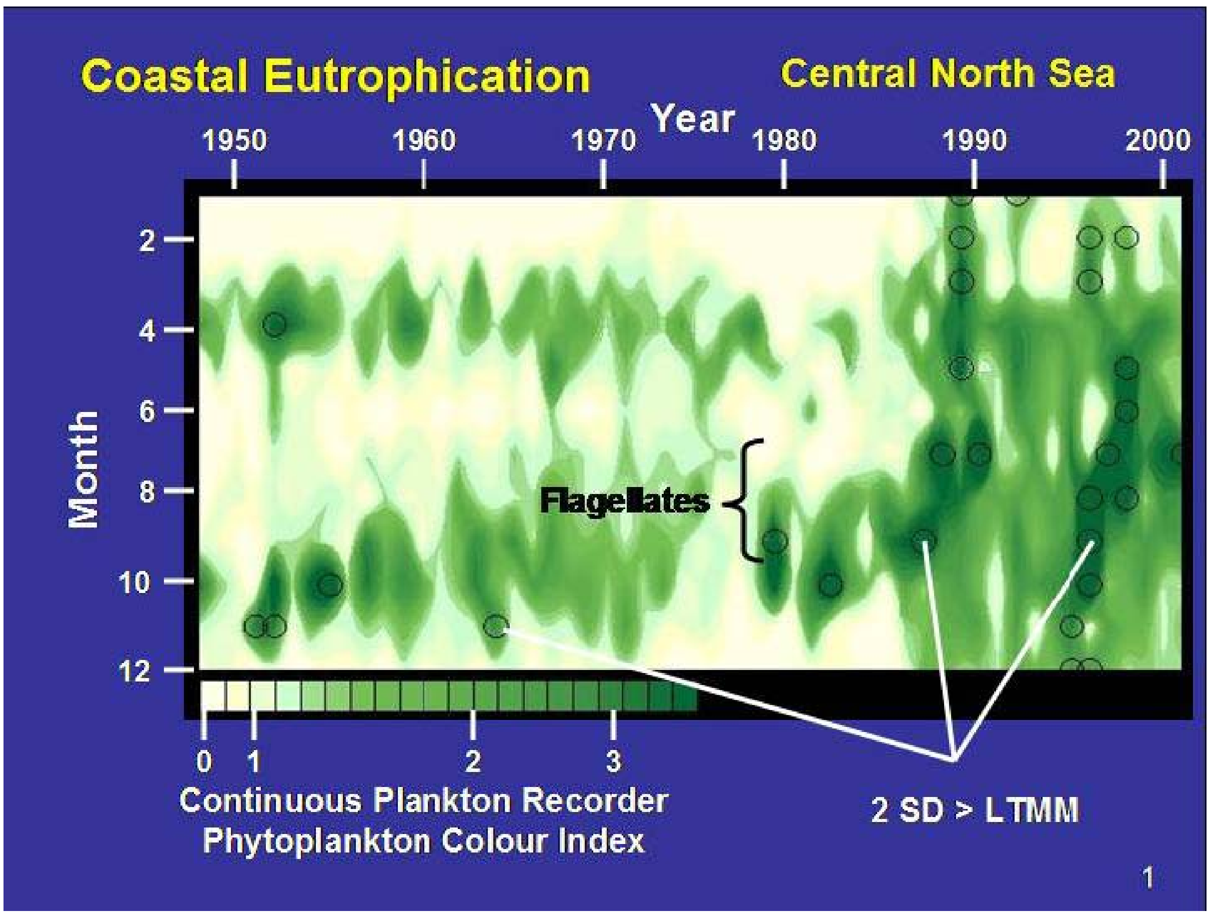
The textbook depiction of coastal phytoplankton phenology is a recurrent annual cycle of high diatom biomass in winter or spring, leading to a successional shift toward flagellate/dinoflagellate dominance in summer or autumn. However, site-based studies reveal sharp departures from this idealized pattern in many coastal waters, including winter dinoflagellate blooms, summer diatom blooms, sustained multi-year blooms of single species, or perennial dominance by small flagellates. The few published reports of multi-decadal observations reveal significant variability in annual cycles as trends or discrete regime shifts as shown below for the central North Sea.



This figure shows annual and interannual variations in phytoplankton biomass in the North Sea. Before the mid 1980s, the annual cycle was characterized by spring and fall blooms that were usually less than 2 standard deviations from the long term monthly mean (LTMM) and dominated by diatoms.

Beginning in the late 1980s, the annual cycle did not exhibit the summer decline as seen in previous years due to sustained blooms of flagellates. There was also an increase in frequency of monthly means that exceeded 2 SDs above the LTMM. This can be interpreted to indicate the effects of increases in anthropogenic (land-based) inputs of nutrients, perhaps exacerbated by increasing temperature and/or vertical stability. The colour index is well correlated with surface chlorophyll concentrations estimated from SeaWiFS imagery (Cloern, unpublished)

Our conceptualization of coastal phytoplankton phenology is mainly biased by the large number of studies in the Northern Hemisphere, especially in Europe and North America; hence there is uncertainty about its generality at the global scale. This working group will bring together knowledgeable scientists and managers with observational data sets from northern and southern hemispheres to establish a global phenology of phytoplankton in coastal ecosystems. This working group has four main objectives:

2) Quantitative depictions of phytoplankton community variability that consider all ecologically relevant time scales of change and the broad diversity of phenologies expected across the habitat variability that is characteristic of the world's coastal zone.

3) A conceptual framework for understanding the environmental drivers of phytoplankton community variability, including climate change, but also other modes of global change, including translocation of species, eutrophication, aquaculture, habitat transformations, hydrologic manipulations and landscape changes in watersheds.

4) Compilation and dissemination of observational data from which the conceptual framework was developed and can be rigorously tested.

5) A set of 'rules' that defines coastal phytoplankton dynamics from which coastal observing systems can be designed and implemented.

There is a clear need for long-term time-series observations that are "operational" in the sense that data streams are sustained, routine, of high quality, and used to support management decisions concerning water quality and living resources, as well as advances in science.

3. Proposed Terms of Reference

1. Identify and consolidate a globally representative set of "long phytoplankton time series".
2. Facilitate the migration of individual data sets to a permanent and secure electronic archive.
3. Develop and share protocols for within-region and within-time-period data summarization (e.g. spatial, seasonal and annual averaging, summation within taxonomic and age categories). The goal is to clarify what level of details provides the optimal

tradeoff (i.e. information gain vs. processing effort).

4. Based on the above, develop priorities and recommendations for future monitoring efforts and for more detailed re-analysis of existing sample archives.
5. Once regional data sets are compiled and collated, we will carry out a global comparison of phytoplankton time series using (in parallel) a diverse suite of numerical methods. We will examine:

   - Synchronies in timing of major fluctuations, of whatever form.
   - Correlation structure (scale and spatial pattern) for particular modes of phytoplankton variability (e.g. changes in total biomass, species composition shifts, alongshore or cross-shore displacements of geographic distribution).
   - Amplitude of variability, both for total biomass and for individual taxa, and a comparison to the amplitude of population fluctuations.
   - Likely causal mechanisms and consequences for the phytoplankton variability, based on spatial and temporal coherence with water quality time series.
   - Sensitivity and specificity of data analysis tools.

4. Time Frame and Expected Products

We will begin work in 2009 and will continue for three years. We will convene annual WG meetings (each about 4-5 days), and a larger open attendance workshop or conference in the final or penultimate year. For each year, expected activities and products include:

Year 1: Summarize and evaluate methods, results, and questions arising from the phytoplankton time series analyses that have been completed to date. For the proposed new comparative analyses, select and prioritize the set of regional time series, and the suite of variables from each time series that will be compared (e.g. total phytoplankton biomass, major groups and/or species-level phytoplankton taxonomic composition, phenology, and physical and biological environmental indices). Identify and address obstacles to pooled analyses (e.g. incomplete processing, differences in formatting, differences in resolution). Develop recommendations for data exchange, and feasible enhancements of sample processing.

Year 2: Begin comparative analyses. Evaluate sensitivity and specificity of data analysis (statistical) tools, and improve their availability and “user-friendliness”. Identify time scales and time intervals of particular interest. Post selected tools and data on a web or ftp site (initially closed, and eventually public).

Year 3: Complete comparative analyses of phytoplankton and environmental time series, incorporating any new data that have become available during years 1-3. Identify synchronies (if any) in timing of fluctuations, and quantify correlation time and space scales.

Prepare interpretive paper(s) for symposium presentation and publication. Prepare recommendations for "best practice" time series sampling and analysis methodologies.

5. Proposed Working Group membership

Our primary selection will be based on broad experience in phytoplankton time series, combined with local knowledge of the content and quality issues for each regional data set. Our suggested list of full members (total 10) includes the following candidates:

Co-Chair, Kedong Yin, Australian Rivers Institute, Griffith University, Brisbane, Queensland, Australia, k.yin@griffith.edu.au

Yin's research interest includes: coastal dynamics of nutrients; eutrophication processes; ecology and oceanographic processes of harmful algal blooms, in coupling processes with environmental variability, and climate changes; and a plenary speaker on "the dynamics of phytoplankton species composition in subtropical waters of south China during the last 15 years",

Co-Chair, Hans W. Paerl, Institute of Marine Sciences, University of North Carolina at Chapel Hill, Morehead City, North Carolina, USA, hpaerl@email.unc.edu

Kenan Professor of Marine and Environmental Sciences, Paerl's research includes; microbially-mediated nutrient cycling and primary production dynamics of aquatic ecosystems, environmental controls of harmful algal blooms, and assessing the causes and consequences of man-made and climatic (storms, floods) nutrient enrichment and hydrologic alterations of inland, estuarine and coastal waters. His studies have identified the importance and ecological impacts of atmospheric nitrogen deposition as a new nitrogen source supporting estuarine and coastal eutrophication. In 2003 he was awarded the G. Evelyn Hutchinson Award by the American Society of Limnology and Oceanography for his work in these fields and their application to interdisciplinary research, teaching and management of aquatic ecosystems.

Susan I. Blackburn, CSIRO Marine and Atmospheric Research and the Aquafin CRC, Hobart, 7001, Australia; susan.blackburn@csiro.au

Dr Susan Blackburn is a Principal Research Scientist with CSIRO Marine and Atmospheric Research and Head of the CSIRO Collection of Living Microalgae. Her research spans phytoplankton environmental issues and bioapplications of microalgae. Working with harmful algal bloom (HAB) species for over 20 years, Dr Blackburn has combined ecophysiological studies in culture with field studies to elucidate regulation of HABs and interrogate life history details, toxin production, molecular characterization and processes, and trophic interactions, particularly of HAB species in south eastern Australian waters. Within CSIRO, nationally and internationally Dr Blackburn research informs system-wide environmental management and prediction of phytoplankton dynamics and algal blooms through biogeochemical modelling.

Jacob Carstensen, National Environmental Research Institute, Denmark, jac@dmu.dk

Carstensen is a statistician working within marine ecology, in particular long-term trends of ecosystem quality indicators in response to anthropogenic pressures. Particular scientific fields of interests are: biogeochemical processes, phytoplankton community structure and bloom mechanisms, hypoxia, and nutrient management for marine ecosystems.

James E. Cloern, U.S. Geological Survey, Menlo Park, California, USA, jecloern@usgs.gov

Cloern has strong expertise in phytoplankton ecology, particularly phytoplankton response to eutrophication and climate changes. He is very experienced in the synthesis of long term data set, and wrote “Phytoplankton bloom dynamics in coastal ecosystems: a review with some general lessons from sustained investigation of San Francisco Bay, California” in 1996. In 2001, He comprehensively reviewed global data in coastal waters and wrote “Our evolving conceptual model of the coastal eutrophication problem”, which has greatly promoted coastal eutrophication research. The paper has been cited 373 times.

Paul J. Harrison, Atmospheric, Marine and Coastal Environment Program, Hong Kong University of Science and Technology, Hong Kong SAR, China Harrison@ust.hk

Harrison is a biological oceanographer with expertise in nutrient dynamics and phytoplankton ecology and recent interest in eutrophication, harmful algal blooms and hypoxia. He is a member of SCOR WG 132 “Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems” and will coordinate activities between the two WGs if this one is funded.

Pia Moisander, Ocean Sciences Department, University of California Santa Cruz, Santa Cruz, CA 95064, USA

Moisander is a microbial ecologist, and her work focuses on planktonic cyanobacteria. She uses molecular approaches in detection of diversity, abundances, and gene expression. Her laboratory has been collecting monthly samples along a transect from the Monterey Bay to the coastal ocean for 3 years and the other time series cruises. Her efforts have focused on picocyanobacteria and other taxonomic groups using the approach based on archived and extracted DNA samples. These data are used in the development of probes to the Environmental Sample Processor, an instrument detecting microbes autonomously in situ while moored.

Clarisse Odebrecht, Department of Oceanography, Federal University of Rio Grande-FURG, Cx.P. 474, 96201-900 Rio Grande, RS, Brazil, doclar@furg.br

Clarisse Odebrecht, professor and leader of research group: Ecology of Marine Phytoplankton and Microorganisms at the Federal University of Rio Grande-FURG, Brazil. Her main research topics include: taxonomy and ecology of marine phytoplankton and microalgae, phytoplankton ecology and coastal eutrophication, studies on harmful microalgae in marine aquaculture.

Katja Philippart, Royal Netherlands Institute for Sea Research (The Netherlands), Texel, The Netherlands, katja@nioz.nl

Philippart is a marine ecologist and her research combines laboratory experiments, field studies, statistical analysis of long-term field observations and modeling techniques to investigate the underlying mechanisms of long-term dynamics within shallow marine coastal communities. Her emphasis is on understanding the role of human influences (eutrophication, fisheries and global warming) within these ecosystems in regulating primary and secondary producers, within the North Sea, Venice Lagoon and the Banc d'Arguin. At present, she coordinates relevant research projects, viz. JetSET (long-term field observations in the western Wadden Sea), and the recently funded national research project (2008-2013) dedicated to monitoring primary production in the western Wadden Sea as a baseline for management of human activities in coastal waters (IN PLACE). She is the Editor-in-Chief of the Journal of Sea Research since 2000, co-author of Marine Coastal Dimension of Climate Change in Europe (EU-IES, 2006, Ispra), and leading author of Climate Change Impacts on the European Marine and Coastal Environment (ESF-Marine Board, 2007, Strasbourg).

Adriana Zingone, Stazione Zoologica A. Dohrn, Villa Communale, Italy, zingone@szn.it

Zingone is an expert in taxonomic and morphologic studies on marine microalgae, and spatial distribution of phytoplankton diversity in marine waters. Her research finding based on biological time series data contributed to revising paradigms and myths of phytoplankton ecology. She also reviewed seasonal patterns in plankton communities in a pluriannual time series at a coastal Mediterranean site (Gulf of Naples): an attempt to discern recurrences and trends.

Potential Associate Members include:

Lawrence Harding, Univ. of Maryland, Center for Estuarine and Environmental Sciences, Cambridge, Maryland, USA, larry@hpl.umces.edu

My expertise is in phytoplankton ecology of estuarine and coastal waters. Research the past 20+ years has focused on Chesapeake Bay using a combination of shipboard and remote sensing measurements. The main theme of my laboratory has been climatic forcing of phytoplankton floral composition, biomass, and primary productivity, drawing on extensive long-term data sets.

Thomas C. Malone, OceanUS Office for Integrated and Sustained Ocean Observations (US), Washington, DC, **USA**, t.malone@ocean.us

Malone has published over 100 peer-reviewed papers on phytoplankton and coastal ecosystem dynamics, science and policy, and integrated ocean observing systems. Chair, IOC-WMO-UNEP-ICSU Coastal Global Ocean Observing System Panel (1998-2000), and Co-Chair, IOC-WMO-UNEP-ICSU Coastal Ocean Observations Panel (2002-2005)

Elgin Perry, USA, eperry@chesapeake.net

Dr. Perry is a statistics consultant providing experimental design and data analysis expertise to researchers involved with environmental research and regulation. Dr. Perry trained in the applied mathematics at the Univ. of Maryland in a interdisciplinary program that included course work and research in mathematical statistics, numerical analysis, and zoology. The majority of Dr. Perry's consulting experience involves collaboration with clients conducting research and monitoring of the Chesapeake Bay. These clients include: the U.S Geological Surve, USEPA Chesapeake Bay Program, Maryland Sea Grant, Maryland Department of Natural resources, Horn Point Laboratory, Chesapeake Biological Laboratory, Wye Research and Education Center, Virginia Department of Environmental Quality, and U.S. Army Corps of Engineers.

Theodore J. Smayda, Graduate School of Oceanography University of Rhode Island Kingston, RI 02881 USA tsmayda@gso.uri.edu

Smayda is a well known phytoplankton ecologist. His major research themes include seminal works on phytoplankton suspension, species succession in marine environments and population dynamics related to diatom and harmful algal blooms. Armed with the skills of knowing the major marine species, an enviable knowledge of the international literature and a constantly inquisitive mind, Smaydea continues to delve into insights related to the dynamics driving phytoplankton blooms. His recent collaborations with the freshwater phytoplankton ecologist Colin Reynolds in generating his present concepts on species strategies, community assembly and development of blooms offer another cornerstone from which to examine the HAB paradigm. His first comments on the importance of life cycles, nutrients and eutrophication in driving the spreading of the bloom phenomena on a global basis were quickly adopted by others and presented or reiterated in their publications. In this regard, he has been a trend setter of ideas that have stimulated others to explore further. In 2002, he received **XHAB2002/ISSHA Yasumoto Lifetime Achievement Awards.**

Sinjae Yoo, Korea Ocean Res. & Dev. Inst. Sa-Dong 1270, Ansan, South Korea sjyoo@kordi.re.kr

Yoo has been studying interannual variation of chlorophyll *a* in the North Pacific ecosystems using satellite image data. He also has been studying primary productivity of the Yellow Sea and East Sea by using ship-board and satellite observations.

We have invited various organizations (GEOHAB, IMBER, PICES, IOC and CoML) to nominate associate members and we are actively working to identify sources of travel funding for the Associate Members. We will be updating SCOR on our progress.

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2.3.5. Working Group on Hydrothermal energy transfer and its impact on the ocean carbon cycles

Summary

The importance of hydrothermal energy transfer to the biosphere through chemosynthetic primary production has long been recognized. Initially, this was only considered to occur at discrete, isolated, hydrothermally active hotspots around the global ridge crest and to have minor impact on the global ocean carbon cycles. But recent results suggest that this assumption may not be correct. We now know that hydrothermal venting can be widespread throughout all oceans, along the entire thermohaline conveyor, and that both the local fixation of carbon and the export of bio-limiting nutrients to the broader ocean may be much greater than previously recognized. For too long, fragmentation of our understanding of bio-geochemical interactions in hydrothermal systems has prevented any quantitative estimation of hydrothermally driven primary production. Now, however, recent advances in molecular methods as well as *in situ* and *in vivo* experimentation provide us with new opportunities for a coordinated, integrating effort in which interdisciplinary approaches and modelling can be brought to bear. Consequently, we believe that it is very timely to plan a revised consideration of the diverse pathways of biomass generation driven by hydrothermal processes and the potential contribution that they may make to the global ocean carbon cycle.

Terms of reference

The objective of the proposed SCOR WG is to bring together an interdisciplinary group of marine scientists, ranging from geochemists to biologists to modellers, with three key goals:

- to **synthesize** current knowledge of chemical substrates, mechanisms and rates of chemosynthetic carbon fixation at hydrothermal systems as well as the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean.
- to **integrate** these findings into conceptual models of energy transfer and carbon cycling through hydrothermal systems which would lead to quantification of primary production in view of a future assessment of the contribution of these systems to the global-ocean carbon cycle.
- to **identify critical gaps** in current knowledge and proposing a strategy for future field, laboratory, experimental and/or theoretical studies to bridge these gaps and better constrain the impact of deep-sea hydrothermal systems on ocean carbon cycles.

Objectives and Timeliness

Our approach will focus on the mechanisms and rates of chemosynthetic carbon fixation in the subsurface, at the seafloor, and in the overlying water column of hydrothermal systems, as well as appraising the extent of iron/nutrient transfer to the global ocean. Such an interdisciplinary and integrative approach is now timely because 1) the recent discovery of widespread hydrothermal venting indicates that such systems may be more important to ocean budgets than previously assumed, 2) the recent developments of deep-sea *in situ* instrumentation and molecular biological techniques provide new methods for investigating the energy transfer pathways used to fix inorganic carbon at hydrothermal vents, 3) we can develop integrative models that will explore critical limits to current knowledge and generate preliminary quantitative estimates of primary production from hydrothermal activity. The ultimate goal will be to identify an integrated body of new research that needs to be conducted, to bridge gaps in our current knowledge and allow us to better constrain the role of hydrothermal venting in global-scale ocean carbon cycling.

Scientific background and rationale

A huge amount of energy (~1 TW of heat-flow and approximately 10^{14} kJ available from hydrothermal fluids for biomass production per year) is delivered from the geosphere to the ocean at mid-ocean ridges. Magmatic and tectonic processes drive hydrothermal circulation which leads to both the extraction of some chemical constituents from seawater into altered oceanic crust as well as the export of heat and crustal elements from beneath the seafloor into the overlying water column (see review by German and Von Damm, 2003).

At any site where hydrothermal circulation brings reduced components from the Earth's interior into contact with oxidising (electron acceptor-rich) seawater, chemical disequilibria arise; from these, energy can be gained by microbes to fix inorganic carbon into biomass. This microbial process is termed *chemosynthesis*. Wherever large fluxes of thermogenic methane are supplied to the seafloor, methane could also constitute a significant carbon source for chemosynthesis. At hydrothermal vents, chemosynthetic primary producers fuel large animal communities with standing crops as high as those of the most productive ecosystems on Earth. Many vent invertebrates and microbial communities on the seafloor display exceptionally fast growth and high production rates for organic biopolymers (Gaill et al. 1997, Taylor et al., 1999; Girguis and Childress, 2006).

Chemosynthetic primary production is now known from a wide range of submarine geotectonic settings, such as mid-ocean ridges, intraplate volcanoes, forearcs, backarc basins, submarine arc volcanoes, and ridge flanks. Additionally, hydrothermally derived dissolved and particulate material has the potential to sustain chemosynthetic carbon fixation in hydrothermal plumes as they disperse through the water column, tens or even hundreds of kilometres away from vent sites (Bach et al. 2006).

Even at sites remote from spreading axes and thermal vents, chemosynthesis is now recognized to play an important role wherever oxidized seawater comes into contact with cooling oceanic crust (Edwards et al., 2005; Santelli et al., 2008).

Despite its potential relevance to ocean-wide ecosystems and the ocean carbon cycle, the quantitative importance of hydrothermally driven carbon fixation and its biogeochemical implications has been largely overlooked. In addition to the potential importance of *chemosynthetic* primary production, recent studies have revealed that vent-derived compounds, such as organic iron complexes, could have residence times in the water column that are longer than originally predicted (Statham et al., 2005; Bennett et al., 2008) such that this vent-derived iron may even impact upon *photosynthetic* primary production in the upper ocean.

In the last decade, the widespread use of molecular techniques and the development of *in situ* and *in vivo* experimental approaches have provided important clues to the pathways involved in carbon fixation or nutrient export, improving our understanding, at the molecular level *and* at the micro-habitat scale, of the interactions between microbes and the chemical environment. Our challenge, now, is to integrate these discoveries at the systems level to provide a mechanistic basis for modelling hydrothermally driven primary production.

Proposed work and products

We propose a coordinated effort that will provide the framework to assess the contributions of submarine hydrothermal venting to the ocean carbon cycles and which will be documented through review papers in a special issue of a peer-review journal or a book. Specifically, we plan to: *i)* synthesize current knowledge on carbon cycling in the different components of hydrothermal systems and integrate these findings into conceptual models; *ii)* use these models to quantify hydrothermal primary production and assess the contribution of hydrothermal systems to the ocean carbon cycles; and *iii)* identify the key novel investigations needed to better constrain these models.

We will achieve this by bringing together key marine biologists, biogeochemists and modellers with a range of field, laboratory, experimental and theoretical expertise to ensure a thorough integration of the current state of the art that can be captured into robust conceptual models. There is no doubt that even this activity, in isolation, would already be enough to stimulate the development of a wealth of original international and interdisciplinary efforts. What we also expect to achieve in the proposed Working Group, however, is to use the resulting numerical models to obtain first-order quantification of the carbon flux through hydrothermal systems on the global-ocean scale. Finally, by testing the sensitivity of this model, we will identify key gaps in our current knowledge. From this knowledge base the WG will then be in a position to recommend which aspects of deep-sea hydrothermal ecosystems are most in need of concerted future studies to better constrain their global oceanic significance.

Timeline of the group's activities

The working group will meet three times over a four-year period. To ease travel and equilibrate costs for members (including associated members), meetings will be organised in Asia, Europe and the USA. We will also combine these meeting with international conferences of interest to the WG participants, such as the regular AGU, ALSO and EGU meetings held in North America & Europe.

At the first meeting we will finalize the agreed agenda and timeline for the WG activities as a whole and organise our discussions into multidisciplinary sub-groups dedicated to the seafloor, sub-seafloor and water column compartments of the hydrothermal system.

At the second meeting we will set up an outline and time schedule for the publication of a special issue or monograph on the role of deep sea hydrothermalism on global ocean carbon cycles. Candidate journals for this special issue include *Limnology and Oceanography*, *PLoS*, *Deep-Sea Research* and *Biogeosciences*.

The third meeting will identify and plan new interdisciplinary initiatives which would benefit from SCOR support for a large-scale international programme of deep-ocean research. Combined with the third meeting we will organise a workshop (seeking sponsorship from, among others, SCOR, InterRidge and national programs) on chemosynthetic primary productivity and mechanisms of CO_2-fixation. Such a meeting would allow many more scientists, including from developing countries *and* from a wider spectrum of the marine sciences to participate in, benefit from, and contribute to, our initiative.

Why a SCOR Working Group?

While international coordination already exists for both the multidisciplinary study of mid-ocean ridges as a whole (InterRidge), chemosynthetic ecosystems' biogeography and biodiversity (ChEss program, Census of Marine Life), and for some aspects of the deep-biosphere research (IODP), this is the first time that an integrative interdisciplinary effort has been focussed upon the impact of hydrothermalism on the global carbon cycle. We are convinced that a dedicated SCOR working group would provide the most efficient vehicle to achieve this goal, by providing an ideal context for cross-cutting discussions between scientists from different disciplines and research areas on this focussed issue.

Within SCOR, we will benefit from the complementary expertise of other SCOR groups and panels of experts dealing with the issues of carbon biogeochemistry, energy transfer in marine ecosystems and trace element cycling in the oceans. Favouring collaborations between scientists from largely separated communities, approval of this SCOR WG would help provide the basis for a new field of research at the interface between the mid-ocean ridge and open-ocean science domains. Including an established ocean carbon cycling modeller in our group is just one action we propose to help facilitate the development of this interaction. We do not expect to achieve full integration within the lifetime of the WG but to educate our own community on how to prepare to integrate more fully with other global-scale ocean programs.

In addition, much can be gained from our proposed integrative effort for the definition and coordination of future interdisciplinary projects. Simultaneously, newly discovered vent sites, with highly heterogeneous chemistries, provide natural laboratories in which to investigate modes of carbon fixation in a variety of environmental and/or biological settings (Takai et al. 2006). Given the inherent difficulties in gaining access to the deep seafloor, as well as the large facilities and state-of-the-art instrumentation required for the work envisaged (both in the deep-sea and in the laboratory), our community will need strong international leadership and collaboration. Focussing our efforts through the auspices of a SCOR working group presents the ideal opportunity to help this proceed in a timely fashion and bring our efforts to the wider global ocean science community's attention.

We are expecting that this integrative and coordination effort will be encouraged by national agencies and international organisations through complementary funding. Furthermore, an increased emphasis is put on integration and synthesis in the final phase of the US Ridge2000 NSF programme and efforts directed on interdisciplinary model conception and testing are explicitly recommended. It can therefore be expected that proposals related with the activity of this SCOR WG may benefit from NSF support.

Relevance to other SCOR activities

There are obvious links between our program and other SCOR programs. In terms of current activity we are relevant to, but different from, both InterRidge and the Census of Marine Life ChEss program. There are also clear links with the new GEOTRACES initiative, particularly in terms of understanding the export from hydrothermal systems of trace elements and isotopes that play key roles in global ocean – e.g., Fe as a bio-limiting micronutrient. As currently conceived, however, the scope and ambitions of GEOTRACES (in particular, a long section extending across the south Pacific from the East Pacific Rise) will need to focus upon ocean chemistry with little opportunity to expand the emphasis to include microbiology and *bio*geochemical cycling. On a much larger scale, where our group would differ from all of InterRidge, CoML and GEOTRACES is that we would focus on ocean-scale carbon cycling. From that perspective, our group represents a natural "dark energy" complement to past and present SCOR programs focussing on *photosynthetically* driven carbon cycling, primary productivity and ecosystem functioning, such as JGOFS and IMBER. We will keep InterRidge, ChEss, GEOTRACES, IMBER and other relevant programs informed of the group's activities.

Composition of the group

Only a few nations to date possess major oceanographic fleets and technologies suitable to access hydrothermal environments at great depths: the composition of the core membership of our proposed WG reflects this (N. America: 3; Europe: 4; Asia: 3). By contrast, our gender balance is much more even (Female: 5; Male: 5) and an effort will be made to associate, wherever possible, more scientists from developing countries which have recently joined the group of nations conducting ridge-research programmes.

Full Members

1. Nadine Le Bris (IFREMER, FR) (co-chair)
2. Chris R. German (WHOI, USA), (co-chair)
3. Wolfgang Bach (Uni. Bremen, Germany)
4. Loka Bharathi (National Institute of Oceanography, Goa, India)
5. Nicole Dubilier (Max Planck Institute-Marine microbiology, Bremen, Germany)
6. Katrina Edwards (U. South Cal., USA)
7. Peter Girguis (Harvard Univ., USA)
8. Xiqiu Han (2nd Institute of Oceanography, SOA, Hangzhou, China)
9. Louis Legendre (LOV-UPMC-Paris 6, Villefranche, France)
10. Ken Takai (JAMSTEC, Japan)

Associate Members

We identified here key scientists whose expertise is required for the WG, for whom funding will be seek from other sources. More associated members, particularly from emerging countries, will be proposed at the first working group meeting.

1. Françoise Gaill (CNRS, Paris, France)
2. Julie Huber (Marine Biology Laboratory, Woods Hole, USA)
3. Stefan Sievert (WHOI, USA)
4. Margaret K. Tivey (WHOI, USA)
5. Andreas Thurnherr (U. Columbia, USA)

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2.3.6 Working Group on Coupled climate-to-fish models for understanding mechanisms underlying low-frequency fluctuations in small pelagic fish

Abstract

The low-frequency variability of small pelagic fish is one of the most emblematic and best-documented cases of fish population fluctuations not explained wholly by fishing effort. Over the last 25 years, diverse observations have been integrated into several hypotheses; however, due to limited-duration time series, hypothesis testing has proven extremely difficult with the available statistical and empirical tools. The Working Group (WG) we propose aims to incorporate and couple ad hoc modeling tools and expertise to tackle this scientific problem, including the gathering and updating of available datasets, historical information and knowledge from the different oceanic systems (e.g., Eastern and Western North Pacific, Southeast Pacific and Southeast Atlantic). The models we will use are a well-known physical circulation model (ROMS) already implemented in some of the systems (Curchitser et al., 2005), a recently developed Nitrogen-Phytoplankton-Zooplankton-Detritus model (NEMURO; Kishi et al. 2007), and its extension in NEMURO.SAN (Rose et al., 2006) to include individual-based models (including bioenergetics) for the small pelagic fish populations (sardine and anchovies) and their predators and fishing pressure. The WG requests three years of support to hold annual meetings, produce two scientific reports and at least one paper in a primary literature journal. Furthermore, we are committed to search for complementary financial support to broaden our capacities and outreach. The results of this WG will contribute to the understanding and managing small pelagic fish stocks in the context of climate change.

Scientific rationale and relevance

Climate-scale variability and its impact on fish resources have only recently become widely accepted (e.g., Lehodey et al. 2006), although they were first detected in the 1880s, by Ljungman. At the time, he published an analysis of the Baltic herring catch fluctuations showing a 55-year cycle due to natural conditions, apparently forcing the schools to change their spawning and feeding places (Parrish et al., 2000). The most compelling example of climate-driven fish stock changes is probably the fluctuations of sardines and anchovies described since the early 1980s, the so-called Regime Problem (Lluch-Belda et al., 1989, 1992; Schwartzlose et al., 1999). Landings of sardines show synchronous variations off Japan, California, Peru, and Chile, with populations flourishing for 20 to 30 years and then practically disappearing for similar periods. Periods of low sardine abundance have coincided with increases in anchovy populations. Benguela Current sardine and anchovies, in the Atlantic Ocean, appear to be in synchrony with Pacific stocks, but in opposite phase (i.e., Benguela sardine stocks flourishing during periods of high anchovy in the Pacific, and vice versa). As demonstrated through paleo-reconstructions based on sardine and anchovy scales deposited in anaerobic marine sediments

(Baumgartner et al., 1992), and also because synchrony takes place even when different fishery management schemes exist among systems (Schwartzlose et al., 1999), fluctuations appear to be fishery-independent. Further, because of the large spatial and coherent temporal scales involved, a single global driver linked to large-scale atmospheric or oceanic forcing has been proposed to explain the variations in the different systems. The Regime Indicator series (RIS; Lluch-Cota et al., 1997), synthesized from the catch series of the four mentioned systems, has been related to the low-frequency component of different climate series, including the PDO and the NAO (Chavez et al., 2003) and the low-frequency signature in global ocean temperature (Tourre et al., 2007), but no mechanism linking the physics to the biology and synchronously operating in widely separated systems has been demonstrated. Understanding the mechanisms underlying these fluctuations is necessary for any projection or forecast of the naturaldriven amplitude and timing of stock fluctuations, and their responses to human interactions (fisheries) and climate change.

Background and proposal

It has been 25 years since the paper by Kawasaki (1983) first called attention to the synchrony among catch series of the three main sardine fisheries in the Pacific basin (Japan, California and Humboldt), and 20 years since SCOR WG 98 on Worldwide Large-scale Fluctuations of Sardine and Anchovy Populations was formed to explore the then-called Regime Problem. Other significant events were the development of the GLOBEC SPACC program (SPACC, 2008) and the IRI workshop in Honolulu in 2001 (Bakun and Broad, 2001). The early reports were highly successful in documenting the fluctuations, alternation and synchrony, and in pooling existing hypotheses to explain them; however, testing was out of their reach, mainly because a) retrospective studies are limited, in the best of the cases, to less than a century of catch series, to a few decades of physical oceanography and climate registers, and to even fewer long-term ecosystem observations; and b) the development of reliable modeling tools that allow adequate exploration of this problem have been developed only during the last few years.

The primary question for this working group is which model forcings can generate low-frequency variations in the abundance of small pelagic fish (periods of increasing, high, decreasing, and low abundance), and whether or not they correspond to prevailing conditions observed during the different regimes in the four systems?

We will approach this question by testing and contrasting what we consider the two main synthetic hypotheses of the Regime Problem today.

1 The flow-based hypothesis (MacCall, 2001) relates long-term variability signals in the biology to alternating strong and weak modes of boundary current flow, through the conditions of two distinct habitats (nearshore and offshore). In an extremely simplified version, the idea is that during conditions of slow-meandering boundary current flow, offshore habitat becomes suitable, due to increased retention of eggs and larvae and increased food concentrations offshore. This offshore habitat can then be used by the larger species (sardine) and is reflected in long-term increased biomass of sardines. When flow is stronger

the only suitable habitat is the coast.

2 School mix feedback (Bakun, 2001), which is actually a suite of hypotheses based on rapidly evolving adaptive response mechanisms, where individuals' affinities, ethological inertia (school trap), and strong selection pressure (fishing or predation) are used to explain low-frequency biomass and distribution changes.

We are convinced that these modeling comparisons will contribute to the solution of the Regime Problem.

Justification of the group

Our proposal is timely because state-of-the-art information on the topic is to be delivered by GLOBEC and SPACC in the very near future, as part of their syntheses. We can also capitalize on the recently established inter-disciplinarity between physical oceanographers, modelers, and fisheries scientists owing in part to international initiatives. Of particular relevance is that, during the last few years, some of the proposed WG members, fisheries and physical oceanography scientists, have already collaborated in workshops organized by PICES, GLOBEC, APN and CAPaBLE projects (Werner et al. 2005, 2007; Kishi et al., 2006), to discuss strategies and possibilities to deal with the Regime Problem with a completely fresh approach and a brand new toolbox of models and analysis techniques.

Our proposal is also opportune because small pelagic fish remain the most important large fishery and source of marine protein (about one third of total marine catch), as well as one of the most unpredictable and difficult to manage. These difficulties are occurring in times when fisheries management paradigms are changing rapidly, when yearly technological advances result in new levels of observational and analysis capabilities, and most importantly, when nations are fully committed to reduce extreme poverty and hunger in less than a decade (UN Millennium Development Goal).

Terms of reference

To accomplish our goals we propose meeting once a year for a three-year period, with participation of Full Members and (when possible and based on other funding sources) Associate and Corresponding members. The working group will

- Gather and update available datasets, historical information and knowledge from the different sardine-anchovy systems (e.g., Eastern and Western North Pacific, Southeast Pacific and Southeast Atlantic).
- Develop climate-to-fish models for some or all systems (depending on data availability), and test and compare the two synthetic hypotheses described above, the flow-based hypothesis (MacCall, 2001) and the school mix feedback hypothesis (Bakun, 2001), in each of the different systems (different study cases).
- Produce two technical reports, one on the state of the art of climate-to-fish models and the other on modeling tools and a final scientific paper to be published in a peer-reviewed journal. The technical reports will be published as digital books.
- Establish a Web site that can be accessed by WG members, other scientists interested in the topic of this group, and the public. This Web site will provide access to the two technical reports and any modeling tools and data compilations that are developed by the group.

Timetable

- Meeting 1 (2009)—Update methods, data and contacts, establish experimentation, data-gathering and modeling strategies, and generate a technical report on the topic's state of the art. We propose to hold this first meeting linked to the final International GLOBEC SSC meeting, taking place in either autumn or summer 2009.
- Meeting 2 (2010)—Discuss preliminary modeling results, make systems comparisons, deal with modeling milestones, and generate a second report on the modeling tools.
- Meeting 3 (2011)—Integration, discussion and writing of the final report, which will be a scientific paper reporting our results. We will further transmit our results through diverse scientific presentations at congresses and symposia, and in particular by bridging to as many related programs and groups as possible (PICES-FUTURE, IMBER, other SCOR WGs, etc.).

The chairs will be responsible for 1) implementing and maintaining a website for the working group, for members to share information, data and tools, and for other scientists and general public interested in the topic. 2) Delivering the annual reports and the scientific paper, 3) Dissemination of progress and main achievements through specialized newsletters, maintaining an updated calendar of events, and facilitating documents and material to all members willing to present at congresses or seminars, and interacting with other groups.

Deliverables

- Yearly reports to SCOR during the duration of the WG
- Contributed papers and presentations in scientific meetings
- One paper (final report) in a primary literature journal
- Publicly available data and modeling tools
- A web site for the group

Additional products may be possible as we rise complementary funding and incorporate more experts.

Membership

Membership was designed to cover knowledge on the regime problem and the four main small pelagic systems (California Current System, Japan, Humboldt, and Benguela), and expertise in each of the models and tools to be used. Also, we are including a socioeconomics modeler, eco

Fisheries Oceanography: **Salvador Lluch-Cota** (Mexico)/ Northeast Pacific fisheries. Co-Chair **Akinori Takasuka** (Japan)/ Northwest Pacific fisheries **Carl van der Lingen** (South Africa)/ Southeast Atlantic fisheries **Luis Cubillos** (Chile)/ Southeast Pacific fisheries

Physical Oceanography and modeling: **Enrique Curchitser** (USA)/ North Pacific ROMS model. Co-Chair **Alejandro Parés** (Mexico)/ Mexican Pacific ROMS, climate scenarios **Julia Blanchard** (UK)/ Size-based models, Socioeconomic modeling QUEST_Fish **Kenneth Rose** (USA)/ NEMURO.SAN model, bioenergetics and Individual based models **Yunne Shin** (France) / Ecosystem models **Shin-ichi Ito** (Japan)/physical oceanography and climate; NEMURO model

Associate Members. This is a preliminary list of participants fully involved in the activities, but not financed by SCOR. The number will depend on our ability to obtain funds from other sources. **Bernard Megrey** (USA) / Fisheries scientists, ecosystem modeling **David Checkley** (USA) / California Current System and small pelagic fish expert **Manuel Barange** (UK)/ Ecological and socioeconomic models **Morgane Travers** (France)/ Ecosystem indicators, end-to-end models **Michio Kishi** (Japan) / NEMURO; coupled physical-biological modeling **Samuel Hormazabal** (Chile) / Physical oceanography **Yasuhiro Yamanaka** (Japan) / Climate change, Earth System Modeling **Francisco Werner** (USA) / Physical modeling, coupling NEMURO
Corresponding Members. These are scientists with long experience in the Regime problem. All were members of SCOR WG98 that we will attempt to bring into the discussions, at least through electronic means.

Alec MacCall (USA)
Andrew Bakun (USA)
Daniel Lluch-Belda (Mexico)
Jurgen Alheit (Germany)
Tuyoshio Kawasaki (Japan)

Notes and considerations:

Relevant supporting material for this proposal is posted at the website http://www.ecosystemico.org/scogroupproposal/index.html, including suggested members short CVs, relevant publications, and key web links.

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2.3.7 Working Group on The Microbial Carbon Pump in the Ocean

Abstract
The utilization of labile dissolved organic carbon (DOC) and production of refractory DOC by heterotrophic prokaryotes can shape the chemical composition of organic carbon and thereby influence the residence time of carbon in the ocean. This process is analogous to the better-known "biological pump". To better understand the microbial processing of carbon and its possible impacts on oceanic carbon sequestration, microbiologists and biogeochemists need to work together to bridge the fields of microbial ecology and organic biogeochemistry. This working group (WG) will document the state of the art in microbial processing of organic carbon and acquire new insights through analyzing the available data on microbial biomass, production and diversity along with dissolved organic matter (DOM) data from a variety of marine environments. The goal of the WG is to identify priority scientific questions and the corresponding technical needs, and establish or standardize protocols for the observations of key microbial and DOM parameters, to advance interdisciplinary research on the microbial carbon pump in the ocean.

Rationale
The "biological pump", a key mechanism for atmospheric CO2 fixation by the ocean, is based on particulate organic carbon (POC) transport from the surface to the deep ocean and burial in seafloor sediments. Recent studies have revealed that dissolved organic carbon (DOC) may also be a potential mechanism for carbon sequestration in the ocean. Besides the known physical and chemical processes transporting DOC from surface to deep sea, biological processes play a central role in DOC dynamics. Labile DOC (LDOC) can be utilized by heterotrophic prokaryotes and then transported to higher trophic levels through the "microbial loop" (Azam et al., 1983), consequently forming sinking POC. Refractory DOC (RDOC), either left or produced by microbial processes, can remain in the water without returning to the atmosphere for up to thousands of years (Bauer et al., 1992). In contrast to the "sinking biological pump", RDOC does not sink, and can be coined "non-sinking biological pump" (Jiao, 2006). Since DOC is the largest organic carbon pool in the ocean, and RDOC is the majority of total DOC, the non-sinking biological pump is one of the keys in understanding the carbon sink of the ocean. As a major pathway to generate RDOC, microbial processes have been identified (Ogawa et al., 2001; Kawasaki and Benner, 2006). This RDOC production process can also be coined "microbial pump" (Jiao et al., 2007; Jiao et al., 2008). Although this new research line is beginning to emerge, studies on the non-sinking microbial pump are still in its infancy compared with the well-documented sinking POC-based biological pump. Detailed information about interactions between microbial processes and organic carbon is required. Scientists from different disciplines need to work together on the interdisciplinary scientific questions and protocols to measure these newly recognized processes and parameters. A SCOR working group on the microbial carbon pump would be the best forum to bring together outstanding scientists from marine microbial

ecology and biogeochemistry, bridging the gaps between different disciplines. Such a WG will not only benefit the members in addressing scientific and technical aspects of the problem, but also benefit the general fields of biological and chemical oceanography, and global biogeochemical modeling, by producing new angles of view, new concepts, and new methods.

Scientific Background

The ocean acts as a global buffer system mitigating increases of anthropogenic CO2. The known biological mechanism is the "biological pump", which is responsible for the transfer of particulate organic carbon (POC) from the surface to deep waters and even to the sediment, and thus can hinder carbon from returning to the atmosphere for hundreds and even thousands of years. In addition to the "sinking particle"-based biological pump, recent studies have revealed that dissolved organic carbon (DOC) is another potential mechanism that needs to be studied regarding carbon cycling in the ocean. The DOC pool in the ocean is estimated to be 700 Gt (Ogawa and Tanoue, 2003), the second largest carbon reservoir in the ocean and approximately equivalent to the carbon stock of atmospheric CO2 (~750 Gt) or terrestrial biomass (~600 Gt) (Hedges, 1992). However, DOC consists of a plethora of different compounds with different availability to microbial degradation. Total DOC can be roughly divided into LDOC that is readily utilized by heterotrophic microorganisms and RDOC that is resistant to biological decomposition. DOC does not sink except for the portion adsorbed to sinking particles. The fate of much of the LDOC is to be taken up by heterotrophic prokayrotes and transformed into particulate organic carbon (POC) through microbial loop and then transported to upper trophic levels (Azam et al., 1983). However, RDOC will stay in water until being further decomposed by non-biological processes, like photochemical degradation (Benner and Biddanda, 1998). Approximately 650 Gt of the DOC in the ocean is RDOC (Ogawa and Tanoue, 2003) accounting for the majority of marine DOC (more than 90%). Compared with inorganic carbon storage, RDOC is much less sensitive to environmental changes, and there are no chemical equilibrium limitations for increase of RODC in the water. With a turnover time of about 4000-6000 years (Bauer et al., 1992), RDOC is the most persistent carbon form and could be one of the keys to the understanding of carbon sequestration in the ocean. Although the precise mechanism for generation of RDOC is still unclear, microbial processes are known to play an important role in generating RDOC (Kawasaki and Benner, 2006). Microbial activities pump a fraction of the available organic carbon pool from low-concentration bioactive LDOC pool to the high-concentration RDOC pool, a process coined "microbial pump" (Jiao, 2006). There are at least two major consequences of microbial pump processes. First, it pumps organic carbon from low concentrations to high concentrations and keeps the organic carbon in the ocean for a longer time. Second, the microbial pump shapes the chemical composition of DOC and alters the ratio of carbon to other elements, such as nitrogen and phosphorus. Stoichiometric analyses of marine organic matter have shown that the C:N:P ratio of RDOM (3511:202:1) is quite different from LDOM (199:20:1) and POM (106:16:1) (Hopkinson Jr and Vallion, 2005). That means that the microbial pump sequesters more carbon relative to nitrogen and phosphorus from the active organic matter pool into inert organic matter. In contrast to the biological pump accomplished by sinking particles, the microbial pump is a "non-sinking biological pump". Quantification of the relative importance of the two paths is mandatory for a better understanding of the mechanisms controlling carbon cycling and sequestration of CO2 by the ocean.

Two major disciplines are involved in studying the microbial carbon pump: microbial ecology and organic biogeochemistry. In the past few years, substantial progress has been made in both of these fields. Some new techniques have been introduced:

- Micro-FISH (Microautoradiography and Fluorescent In Situ Hybridization) for simultaneous observation of abundance and carbon uptake rate of major bacterial groups (Cottrell and Kirchman, 2003), addressing "who are out there and what they are doing" simultaneously.
- CARD-FISH (Catalysed Reported Deposition Fluorescence *in situ* Hybridization) and rolling circle PCR-FISH for in situ identification of environmental microbes and for simultaneous detection of mRNA and rRNA in environmental bacteria, thereby linking the identification of single cells to the expression of particular functional genes (Pernthaler and Amann, 2004).
- Micro-CARD-FISH (Microautoradiography and Catalyzed Reporter Deposition Fluorescence *in situ* Hybridization Combined with Microautoradiography) for determination of specific carbon metabolism of different functional groups of bacteria. Applications to meso- and bathypelagic realm of the ocean have revealed that archaea play a significant role in deep sea carbon cycling (Herndl et al., 2005).
- TIREM (Time Series Observation-Based Infrared Epifluorescence Microscopy) for accurate quantification of aerobic anoxygenic photosynthetic bacteria (AAPB) (Jiao et al., 2006), resulting recognition of distinct global distribution pattern of AAPB against theoretical speculations (Jiao et al., 2007) and consequently evoking further studies on the role of AAPB in energy flow and carbon cycling in the surface ocean.

- HTC (DOC), HPAEC-PAD (amino Sugars) to document chemical dynamics of marine DOM when exposed to microbial transformation (Benner and Opsahl, 2001; Benner and Kaiser, 2003)
- HPAEC-PAD (neutral sugars), HPLC (amino acids) to profile bioreactivity of marine DOM (Amon et al., 2001) (Sempéré and Kawamura, 1996; Sempéré et al., 2003; Sempéré and Kawamura, 2003).

- Fluorescence spectroscopy and parallel factor analysis (PARAFAC) for the detection of optically active component of marine Chromophoric DOM (CDOM) (Stedmon et al.,2003)
- SPE-DOM (solid-phase extraction of dissolved organic matter) for extraction of DOM in seawater (Dittmar et al., 2008).

A perfect combination of technique development and scientific theory can be found in the case of the “Microbial Loop” and microscale interactions of bacteria with organic matter and its influence on carbon export flux in the ocean (Azam and Worden, 2004).

In spite of the above achievements, there are still great needs for interdisciplinary interactions between scientists studying microbial processes and organic carbon cycling. New theories and concepts could be generated and validated through exchange and interactions between scientists from different disciplines and new techniques could be worked out or standardized for comparable observations. A SCOR working group would bring together scientists with the expertise required to address the newly merged scientific questions, and to work out protocols for measurement of the newly recognized processes and parameters.

Relevance to Other Activities of SCOR or Other International Organization

SCOR has a long history of support of research in ocean carbon cycling. Relevant past SCOR Working Groups that are related to the present one include

WG 62: Carbon Budget of the Ocean;
WG 79: Variations in Carbon Dioxide and the Carbon Cycle
WG 116: Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination

WGs 62 and 79 worked on CO2 budgets and dynamics and WG116 worked on sinking POC-based biological pump. The outputs of these WGs provide an important basis for the proposed WG on the microbial carbon pump. The proposed WG will extend the topic of carbon cycling and deepen our understanding of the mechanisms. Another distinct feature of the proposed WG is the interdisciplinary interactions among scientists from microbial ecology and biogeochemistry, which will bridge the gaps between different fields that hinder progress on this topic, and will hopefully bring breakthroughs in new angles of view, new concepts, and new methods.

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Terms of Reference

- Summarize representative microbial data on biomass, production and diversity as well and DOC data along environmental gradients, establish the current state of knowledge and identify essential scientific questions regarding the role of microbial processing in carbon cycling in the ocean;
- Assess the available techniques for quantifying functional groups of prokaryotes and different types of DOC, document state-of-the-art techniques and parameters addressing microbial processing of organic carbon, and establish/standardize key protocols for the essential observation/measurements;
- Convene International Workshop(s) and publish a special volume in an internationally recognized peer-reviewed journal, or a protocol book (practical handbook) by a major publisher on measurements of the key parameters related to microbial processing of carbon in the ocean.
- Make recommendations for future research related to the microbial carbon pump in the ocean, toward development of a large-scale interdisciplinary research project.

Working Group Membership

Full Members

Nianzhi Jiao (China) – Co-Chair – Marine Microbial ecology
Farooq Azam (USA) – Co-Chair –Microbial Oceanography
Gerhard J. Herndl (Netherlands) – Microbial Oceanography
Ronald Benner (USA) – Marine Biogeochemistry
Bernhard Fuchs (Germany) – Molecular Microbiology
Colin Stedmon (Denmark) –Marine biogeochemistry
Michal Koblizek (Czech) –Marine microbial ecology
Susan Ziegler (Canada)–Marine biogeochmistry
Ingrid Obernosterer (France) – Marine microbial ecology
Gerhard Kattner (Germany) –Marine Biogeochemistry

Associate Members

David L. Kirchman (USA) – Marine Microbial ecology
Simon Meinhard (Germany) – Marine Microbiology
Feng Chen (USA) – Marine Virus and Molecular Ecology
Richard Sempéré (France) – Marine Biogeochemistry
Tron Frede Thingstad (Norway)- Microbial ecology
Danyun Ou (China) – Marine Microbial Ecology

Steven W. Wilhelm (USA) – Virus Ecology
Paul Harrison (Canada) – Phytoplankton Ecology
Rainer Amon (USA) – Marine Biogeochemistry
Sang-Jin Kim (Korea) –Microbiology and Genomics
Nagappa Ramaiah (India) – Microbiology and Marine Ecosystem
Carol Robinson (UK) Marine microbiology

Key items to examine and corresponding members

- The following issues would fall within the Terms of Reference of the proposed working group and would be the focus of the WG. （Necessary sampling for methodological intercalibrations and field observations will be carried out with samples from a cruise to the West Pacific Warm Pool supported by the Ministry of Science and Technology of China (MOST) and the National Natural Science Foundation of China (NSFC) (see "Operation Mode and Timeline" item 4 and 5）

1. Discrimination and quantification of functional microbial groups

- Flow Cytometry (FCM) recognition, sorting, and enumeration of functional microbial groups on board and in lab (Jiao)
- Time-series observation-based infrared epifluorescence microscopy (TIREM) analysis of aerobic anoxygenic photosynthetic bacteria (AAPB) (Jiao)
- Catalyzed reported deposition fluorescence in situ hybridization (CARD-FISH) for discrimination of functional microbial groups and the application of Nano-SIMS (Fuchs/Herndl)
- *in situ* dual fluorescence monitoring of bacterial chlorophyll and chlorophyll (Koblizek)

2. DOC analysis methodology
   - Solid-phase extraction of dissolved organic matter (SPE-DOM) from seawater, especially from the deep sea (Kattner)
   - DOC composition bioassay method-sugars, dicarboxylic acids, amino acids (Obernosterer)
   - CDOM extraction, measurement and indications (Stedmon)

3. Contribution of bacteria to the marine DOM transformation
   - Bacterial colonization and enzyme action affect aggregation potential with consequences for carbon export flux (Azam)
   - Shaping of marine DOM composition under exposure to microbial transformation (Sempéré/Obernosterer)

- Bioreactivity of marine DOM to natural microbial community (Benner)

4. Carbon metabolism of functional groups of microorganisms
   - Microautoradiography and fluorescent in situ hybridization (Micro-FISH) for simultaneous observation of abundance and carbon uptake rate of major bacterial groups (Kirchman)
   - Archaeal carbon fixation, Micro-CARD-FISH for determination of specific carbon metabolism of different functional groups of bacteria (Herndl)
   - Stable isotopes in combination with microbial assay studies toward the role and fate of marine and terrestrially derived DOM in the ocean (Ziegler).
   - Virus-host interaction and the role of virus in the ocean carbon cycle (Chen)
   - Selective use of carbon sources by functional groups of prokaryotes as seen from Biolog bioassay (Ou /Jiao) and by Nano-SIMS (Fuchs)
   - Bacterial utilization of phytoplankton exudation as carbon or energy source (Harrison/Jiao)

Prospective Products:

1. A few review papers by the whole group or subgroups on the following topics

   a. Microbial pumping process of carbon in the ocean
   b. DOC (including CDOM) measurements
   c. Carbon metabolism of functional groups of microorganism

2. A handbook of practical protocols for observation of marine microorganisms and microbial processing of carbon in the ocean. The following items should be included:
   a. Flow cytometry analysis and sorting
   b. Specialized/modified epifluorescence microscopy
   c. Atomic force microscopy
   d. Fluorescence probing techniques (Micro-CARD-FISH, Card-FISH)
   e. Isotopic tracing techniques
   f. Functional gene probing
   g. DOC extraction approaches
   h. Bioassay on microbial shaping of DOM composition
   i. Bioassay on microbial carbon utilization spectrum
   j. Bioreactivity of environmental DOM to natural microbial community
   k. Interaction between phytoplankton and bacterioplankton (carbon/electron donor test)
   l. Virus-Host interaction system (carbon lysis bioassay)
   m. Bacterial colonization/aggregation test system
   n. Carbon metabolism at community and functional groups (Micro-CARD-FISH)

o. Application of genomics and proteomics to microbial carbon use

3. A special volumes of a major international peer-reviewed journal for papers presented at the WG workshop(s). (The group will decide at its second meeting whether or not to develop a workshop with its final meeting).

Operation Mode and Timeline of the Working Group

1. Since its initiation last year, interactions among the potential members at individual level has been going well, and **a group of interest has been gradually formed naturally,** Continuing discussions are taking place this year:

- Exchange ideas between potential members at individual level by emails (Jan-Apr, 2008);
- Partial group discussion and planning at the 10th International Estuarine Biogeochemistry Symposium (Xiamen, May 18-22, 2008);
- Partial group discussion among prospective members at ASLO meeting (Canada, June 8-13, 2008) and AOGS meeting (Korea, June 16-20, 2008);
- Partial group study at summer school in Xiamen and Qingdao, China (July 8-22, 2008).
- Partial group members meet in Xiamen for preparation of ISME-12 round table session (see 2) (China, Aug 7-11, 2008).

2. A **round table session** as **a pilot WG meeting at the ISME-12 conference** (International Symposium for Microbial Ecology) (Australia, 2008.8.12-17) has been approved officially by the ISME-12: Four WG members are invited speakers: Farooq Azam (USA), Nianzhi Jiao (China), Gerhard Herndl (The Netherland), and Feng Chen (USA).
3. Partial group members meet at the “Xiamen Ocean Festival”（Nov.2-8, 2008）for exchange and preparation of sampling on a cruise to the West Pacific Warm Pool (see 4).
4. **Cruise opportunity** will be provided by Chinese research projects for necessary field sampling and methodological intercalibrations. The most recent one will be a 30-day cruise along environmental gradients from the Yangtze Rive estuary to the the Kuroshio Currents and the West Pacific Warm Pool (so called “the engine of climate changes”) which will be carried out from November to December,2008. Once-a-year oceanic cruises to the Pacific and Indian Oceans (R/V Ocean No.1, 3800 ton) are another opportunities (Participation of scientists outside China need to go through official formalities for approval).
5. **Support from inside China**. The idea of this SCOR WG was approved and recommended by the Chinese SCOR Committee at the last annual meeting (Suzhou, Sept. 15-26, 2007). The NSFC and the State Key Lab for Marine Environmental Science will provide partial financial support (200K-300K RMB) for the WG related academic activities and WG meeting/workshops held in China.

6. **The first official WG meeting**, will be taking place in Xiamen, China in early 2009. A detailed WG four-year work plan will be made in accordance with the assignments of the above-listed missions to each member. Face-to-face interactions between members with microbiology and biogeochemistry expertise would take place on the hot topics regarding the role of microbial processes in carbon cycling in the ocean. A review paper will be initiated during this meeting.
7. **The second official WG meeting** will be held approximately one year after the first one targeting on examination of implementation of the assignments and problems-solving toward the planed outputs. The group will decide at this meeting whether or not to develop a **workshop** with the final meeting for a special volume of a major international peer-reviewed journal.
8. **The final meeting** will be convened in the last year (early 2012) to complete the group's work.

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SCOR SCIENTIFIC SUBSIDIARY BODIES - as of September 19, 2008

		CHAIR / CO-CHAIR	***REPORTER***
WORKING GROUPS			
WG 111	Coupling Waves, Currents and Winds in Coastal Models	Huang/Mooers	Mysak
WG 115	Standards for the Survey and Analysis of Plankton	Heaney	Pierrot-Bults
WG 122	Mechanisms of Sediment Retention in Estuaries	Perillo/Syvitski	Sundby
WG 124	Analyzing the Links Between Present Oceanic Processes and Paleo-records (LINKS)	Lochte/Sicre	Labeyrie
WG 125	Global Comparisons of Zooplankton Time Series	Mackas/Verheye	Pierrot-Bults
WG 126	Role of Viruses in Marine Ecosystems	Weinbauer/ Wilhelm	Kuparinen
WG 127	Thermodynamics and Equation of State of Seawater	McDougall	Mysak
WG 128	Natural and Human-Induced Hypoxia and Consequences for Coastal Areas	Zhang/Gilbert	Duce
WG 129	Deep Ocean Exchanges with the Shelf	Johnson/Chapman	Mysak
WG 130	Automatic Plankton Visual Identification	Benfield /Culverhouse	Burkill
SCIENTIFIC STEERING COMMITTEES, PANELS, etc			
GLOBEC	Global Ocean Ecosystem Dynamics SSC	Perry	Burkill
GEOHAB	Global Ecology and Oceanography of Harmful Algal Blooms SSC	Raine/Kudela	Hong
SOLAS	Surface Ocean - Lower Atmosphere Study SSC	Wallace/Takeda	Hong
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research TT/SSC	Hall/Roman	Duce
LOICZ	Land-Ocean Interactions in the Coastal Zone SSC	Pacyna	Hong
	GEOTRACES	Anderson/ Henderson	Duce
	The Ocean in a High-CO_2 World Symposia	Orr	Duce
IOCCP	International Ocean Carbon Coordination Project	Sabine	Sundby
	Panel on New Technologies for Observing Marine Life	Rogers	Pierrot-Bults
	SOLAS/INI Review of Anthropogenic Nitrogen Impacts on the Open Ocean	Duce/La Roche	MacCracken

PACKMEDS	Physics and Chemistry as the Key to Marine Ecosystem Dynamics and Structure	Mellilo/Rizzoli	Sundby
	Committee on Capacity Building	Ittekkot	
	SCAR/SCOR Expert Group on Oceanography	Rintoul/Hofmann	Kuparinen

AFFILIATED PROGRAMS

CoML	Census of Marine Life	Poiner	Burkill
iAnZone	International Antarctic Zone	Orsi/Bergamasco	Kuparinen
IMAGES	International Marine Global Changes	Rohling	Labeyrie
InterRIDGE	International RIDGE Studies	Lin/German	Labeyrie
IOCCG	International Ocean Colour Coordinating Group	Yoder	Kuparinen
	InterMARGINS	Soh	Labeyrie

PARTNER ORGANIZATIONS

IGBP	International Geosphere-Biosphere Programme	Nobre	Sundby
POGO	Partnership for Observation of the Global Oceans	Haymet	Duce
SCAR	Scientific Committee on Antarctic Research	Kennicutt	Kuparinen
SCOPE	Scientific Committee on Problems of the Environment	Sala	Pierrot-Bults
IOC	Intergovernmental Oceanographic Commission	Valladares	Sundby
WCRP	World Climate Research Programme	Busalacchi	MacCracken
PICES	North Pacific Marine Sciences Organization	Wada	Akulichev
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection	Bowmer	Duce
AOSB	Arctic Ocean Science Board	Loeng	