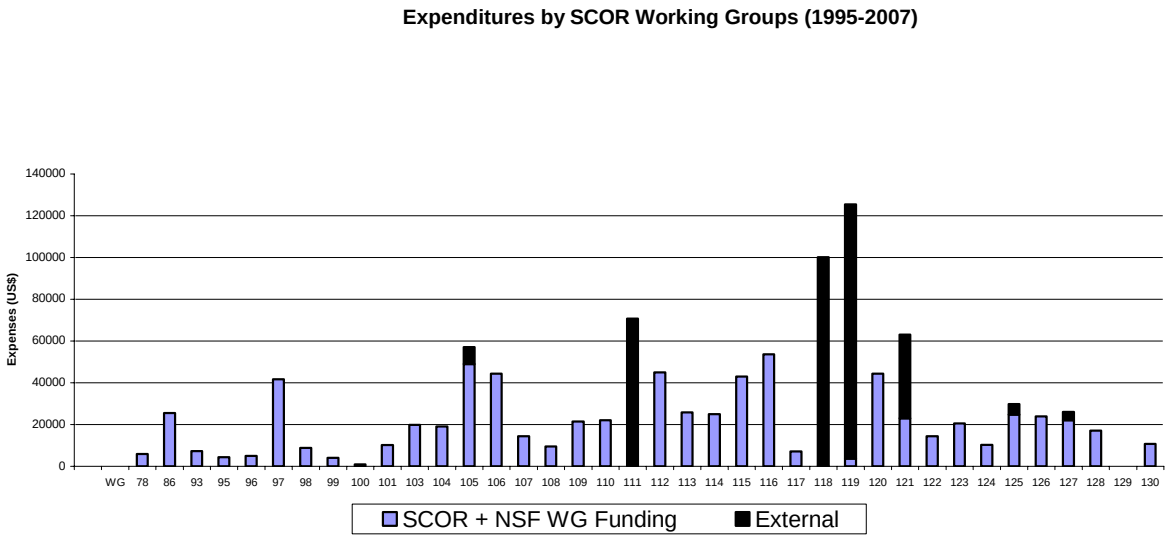
2.0 WORKING GROUPS REPORTS



These figures only account for funds that were spent through SCOR. Several working groups, such as WGs 105, 109, and 119, had additional funding that was spent directly by cooperating organizations or funding agencies.

2.1 Disbanded Working Groups

2.1.1 WG 78--Photosynthetic Pigments in Oceanography

SCOR contributed funding for a scoping meeting for a Volume 2 of the SCOR book from WG 78, entitled *Phytoplankton Pigments in Oceanography*. The report of the scoping meeting follows. So far, promises of contributions have been made from the International Atomic Energy Agency, the University of Quebec, Bodø University College (Norway), Plymouth Marine Laboratory, and DHI Pigment Standards (Denmark).

The results of SCOR activities are normally published as special issues of peer-reviewed journals and, less commonly in recent years, in books. Most previous books have been produced by commercial publishers, sometimes resulting in very high price books. The book that resulted from the WG 78 on Photosynthetic Pigments in Oceanography was published by UNESCO Press. Given the difficult process for that book and more recent difficulties with a book related to the GEOHAB project, we have decided to proceed under the assumption that SCOR will publish Volume 2 of Phytoplankton Pigments in Oceanography through a private publisher, Clyvedon Press in the United Kingdom, which published the GEOTRACES Science Plan.

The following proposal is offered to deal with the shortfall and perhaps serve as a model for future books, to reduce the cost of SCOR publications and make them more available to the scientific community.

Proposal for Funding Pigments Book
(by Ed Urban)

SCOR has decided to publish Volume 2 of Phytoplankton Pigments in Oceanography through a private publisher, Clyvedon Press in the United Kingdom, rather than have UNESCO Press publish the book.

Clyvedon Press has estimated that 2000 copies of the book, in hardback and including Volume 1 as a DVD in a pocket within the report, would cost $33,785. The current income for the book includes $20,000 budgeted from SCOR in 2007 plus about $9,600 that members of the editorial group have raised from a variety of sources. These two sources leave a gap of about $4,000 between funding committed and the projected cost of the book. This does not include the cost of mailing the book to recipients, which could total tens of thousands of dollars more. SCOR cannot absorb this kind of cost and it may be difficult to raise the funds outside of SCOR. In the past, when SCOR working groups published their results in a book, SCOR was captive to commercial presses, whose books can be very expensive (and thus unavailable to most scientists) and for which we cannot get pdf files to put on the SCOR Web site. For example, *The Biogeochemistry of Iron in Seawater*, published by Wiley, is now listing for $440 per copy and we cannot obtain the pdfs.

The following proposal for the pigments book is meant to give SCOR more control over its publications, making them more affordable and accessible, and eventually linked to the SCOR

Web site. The proposal is to sell the books at the cost of production, postage, and the time in the Secretariat to handle the requests. The production cost of the book is estimated to be US$17.59 per book (including the cost of the planning meeting). Postage should cost approximately US$20/book at today's rates and handling should cost approximately $5.00 per book, so that the total cost we would have to charge to re-coup costs would be US$43/copy. UNESCO Press is selling copies of Volume 1 for 48.80 euros (US$65.39 at the current exchange rate) each.

SCOR would pay the cost for publication up front and would recoup the cost as books are sold or as donations for the books are received. The donations received will reduce the cost of the books by almost $5 per copy from what they otherwise would be. We will send 5 free copies to each of the donors listed above. SCOR would purchase copies using its discretionary funds, to distribute to the editors, authors, developing country libraries, etc.

The book could be marketed directly through various SCOR projects, IOCCG, IOC, etc. Volume 1 sold out its first print run and had to be reprinted.

Advantages

- Publication would be clearly identified with SCOR, as it would not be published by UNESCO Press.
- SCOR would have the ability to set the price of the publication and could sell it for less than the UNESCO Press price.
- SCOR would be able to shift the cost of publication and mailing to the buyers of the book, except for books that SCOR chooses to distribute for free.
- SCOR could put the pdfs of the book on the SCOR Web site, most likely after all or most of the hard copies have been sold.

Disadvantages

- We may not be able to obtain the electronic version of Volume 1 from UNESCO Press if we do not have them publish Volume 2.
- SCOR will have to store books, handle the distribution, and bear the risk of not selling all the copies. However, we will have space in the new office for such storage.
- SCOR would probably have to obtain a business license in Delaware (this should not be expensive) and perhaps file additional tax forms. Our accountant has verified that we are allowed to sell books within our non-profit status.
- SCOR would not have the advantage of having a commercial publisher to market the book, but we have access to enough relevant email lists that this should not be a problem.

I believe that the advantages outweigh the disadvantages and that the risks are rather small. This would be a perfect book for which to test the concept, as it should be a popular product. We would have to evaluate this approach for future books based on our experience with this one and projections of the demand for any given book.

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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Roger Flather	UK	Yeli Yuan	CHINA-Beijing
Vladimir Gryanick	RUSSIA		

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Michael Banner	AUSTRALIA	Eloi Melo	BRAZIL
Jurjen Battjes	NETHERLANDS	Yoshiaki Toba	JAPAN
Carlos Garcia	BRAZIL		

Executive Committee Reporter: Lawrence Mysak

2007 Annual Report for SCOR Working Group 111: Coupling Waves, Currents, and Winds in Coastal Models

Co-Chairs, Norden E. Huang, Taiwan and Christopher N.K. Mooers, USA

Our effort is solely focused on completion of a book on this subject for Cambridge University Press. Substantial progress has been made on all chapters, thanks to the Herculean editorial efforts of Peter Craig (Australia). However, the material needs to be refreshed and submitted to peer-review. Hence, it has been decided recently that Chris Mooers will take the editorial lead, as of 1 July, to push the book to completion within the year. He and Peter will serve as Co-Editors. Other members of the Editorial Group are Norden Huang (Taiwan) and Satish Shetye (India).

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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P. Christopher Reid	UK		

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Executive Committee Reporter: Annelies Pierrot-Bults

From: Ivan Heaney [mailto:ivan@heaney35.wanadoo.co.uk]
Sent: Tuesday, July 17, 2007 9:33 AM
To: ed.urban@scor-int.org
Subject: RE: WG 115 Publication

Dear Ed

I am sorry but have to tell you that I have had a very poor response to my efforts to get the publication for WG 115 completed. So far, only [one member has] completed a manuscript. I have e-mailed reminders to the others but sadly I only received a reply from [a second member] who promised his MS but it has yet to arrive. I know that it is hard to get scientists to complete manuscripts as there are so many other distractions now and symposium papers are not as highly regarded as mainstram research papers. If you have any advice as to how to get manuscripts or replies out of busy scientists I would appreciate this. It is a pity that there is not a better response as I thought that the quality of the presentations at the meeting and subsequently put out as PowerPoints on the SAHFOS Web site was very high.

With kind regards

Ivan

2.2.3 WG 116: Sediment Trap and ^{234}Th methods for Particulate Organic Carbon Export in the Upper Ocean (1999)

Terms of Reference:

- To explain the terms "export production" and "new production" and their inter-relation. How does the carbon flux determined using traps and ^{234}Th relate to export production?
- To review the current status of carbon export flux determination using moored and floating sediment traps, their advantages and problems, associated uncertainties and their magnitudes.
- To suggest suitable trap designs and necessary protocols to get reliable flux data.
- To review the basis of ^{234}Th-based carbon export flux measurements, models, assumptions and parameters used in the calculations. To assess the reliability of these assumptions/parameters, the sources and magnitudes of associated uncertainties. (For example: How do the time scales of sampling, temporal variability in ^{234}Th fluxes, POC/^{234}Th ratio in different particulate pools affect the flux data?).
- To compare the carbon export fluxes determined by trap and ^{234}Th methods. If they differ, what are the main causes of discrepancy and how can they be resolved?
- To suggest experimental design and protocols to be followed to obtain quantitative and reliable carbon export fluxes based on the above methods. Can ^{234}Th serve as a global survey tool to determine carbon export fluxes?
- To prepare a final report within 4 years and interim report within 2 years.

CHAIR:

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Deborah K. Steinberg	USA
Tom Trull	AUSTRALIA
Michiel Rutgers van der Loeff	GERMANY

Associate Member:

Anthony F. Michaels USA

Executive Committee Reporter: Laurent Labeyrie

WG 116 on Sediment Trap and Th-234 Methods for Carbon Export Flux Determination
Final Report

Our last WG meeting was at Ocean Sciences 2006 in Honolulu. Since that time we have been working on submittal and revisions to our main synthesis paper on upper ocean trapping, and it is now in press for appearance in June 2007 in the *Journal of Marine Research* (even though it will be dated May 2007):

K. Buesseler et al. 2007. An assessment of the use of sediment traps for estimating upper ocean particle fluxes. *Journal of Marine Research* 65:345-416. (full copy available on my web site http://cafethorium.whoi.edu)

In addition to publication in JMR, we have also submitted an article to *EOS*, discussing all of the activities of our group and highlighting this JMR piece. That article is currently in review, and I expect would be published some time this summer/fall of 2007. This piece is called

"Estimating upper ocean particle fluxes using sediment traps: Current Status"

and will have the same authors/WG members.

So while we are no longer an active WG in context of new meetings or publications, we continue to interact via email and other correspondence for the publication of these WG products. We appreciate your continued support of the publication of these pieces, and we anticipate no further activities after publication of the JMR and *EOS* articles.

Cheers, Ken

2.2.4 WG 119: Quantitative Indicators of Marine Ecosystem Change Induced By Fisheries
Joint with IOC (2000)

Terms of Reference:

- To review the current state of knowledge in different marine and terrestrial disciplines relevant to the development of indicators for marine ecosystems (environmental, ecological and fisheries).
- To review theories (hierarchy, cascade…) and indicators that have been developed in terrestrial ecology and to assess their utility for marine ecosystems.
- To develop new indicators to study the functional role of species in ecosystems, exploitation and environment using output of multi-species models or available time series (e.g., fish catch statistics….), and using satellites, GIS (Geographic Information System).
- To apply these indicators in a comparative way to characterize ecosystem states, changes and functioning.
- To assess the utility of these indicators for management purposes and for the sustainable utilization of renewable resources**.**

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S. Cousins	UK	A.D.M. Smith	AUSTRALIA
H. Gislason	DENMARK	J. Steele	USA

(Continued on next page)

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A. Jarre	GREENLAND	K. Sainsbury	AUSTRALIA
K. Korateng	GHANA	Y. Shin	FRANCE
R. Lae	SENEGAL	P. Sunye	BRAZIL
S. Murawski	USA	K. Zwanaenburg	CANADA

Executive Committee Reporter: Peter Burkill

This working group was carried over from last year because they requested that their remaining funds from registration fees be used for a related meeting to be planned by one of the WG co-chairs. In the end, the co-chair asked permission to devote the funds to another workshop, on "Coping with global change in marine social-ecological systems". This workshop will contribute to the objectives of both GLOBEC and IMBER. The Executive Committee approved this reprogramming of the leftover registration fees in May 2007.

2.2.5 WG 120: Marine Phytoplankton and Global Climate Regulation: The *Phaeocystis spp.* Cluster as a Model (2000)

Terms of Reference:

- Establish a website to facilitate coordination of ongoing research worldwide, and to create cohesion of efforts
- Make an inventory of aspects that relate to cycling of biogeochemically relevant elements. These aspects are:
  - Factors regulating bloom inception
  - The grazing issue: bottom-up or top-down control
  - Cellular response to environmental factors
  - Distribution patterns: molecular-biological approaches
  - Genetics: pathways of distribution and biodiversity in the cluster
  - Emission of climate-relevant biogenic gases, and relevance for climate regulation
  - Cloud inception and characterisation of condensation nuclei over blooms
  - Sensitivity of climate models for presence of plankton, *in casu* the *Phaeocystis* cluster
- Meet once a year to discuss progress, and divide tasks to arrive at a series of chapters produced under the responsibility of members of the Working Group.
- In the last year writing of a series of reviews covering the subjects mentioned under 2, which will be the chapters of a book that will be produced as the product of the Working Group. At least 2 of the WG members are responsible for each chapter.

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Gillian Malin	UNITED KINGDOM	Peter Verity	USA
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Albert Gabric	AUSTRALIA	Marcel J.W. Veldhuis	NETHERLANDS
Ronald Kiene	USA	Maria Vernet	USA
M. Madhupratap	INDIA	Ingrid Zondervan	GERMANY

Executive Committee Reporter: Jorma Kuparinen

From: Winfried [mailto:gieskess@xs4all.nl]
Sent: Thursday, June 21, 2007 4:47 AM
To: ed.urban@scor-int.org
Subject: RE: Correction

Our 'Phaeocystis' book (2007 spring/summer issue of the journal 'Biogeochemistry') will be in print soon (the editors promise this already for weeks !!!!). As you know, it's available online already since 3 months (see http://www.springerlink.com/content/g12x20148815/?p=1d1789a4d9e24f9aa783b65b5dbea74e&pi=3).

Kindest regards !

Winfried (e-mail address: gieskes@xs4all.nl)

2.2.6 WG 121: Ocean Mixing (with IAPSO) (2002)

Terms of Reference:

- Summarize past results, including analyses of historical field data, concerning the sources for, and geographical distribution of, mixing in the deep-ocean basins. In light of recent results, tidally driven mixing mechanisms will be emphasized.
- Assess, within the established observational and theoretical context, those difficulties involved with parameterization of mixing in numerical ocean GCMs.
- Assess what more should be done by further observational programs or improved observational techniques to fill gaps in understanding essential to provide useful information for modeling the effects of deep-ocean mixing, including the potential to detect deep-ocean mixing through remote sensing and tracer techniques.
- Produce a comprehensive, published final report incorporating appropriate results from the above topics.

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Anders Stigebrandt	SWEDEN	Fangli Qiao	CHINA-Beijing
Louis St. Laurent	USA	Barry Ruddick	CANADA
		Anne Marie Treguier	FRANCE

Executive Committee Reporter: Victor Akulichev

IAPSO/SCOR WG 121 on Ocean Mixing
Progress as of 31 May 2007

This working group was formally approved by SCOR in October 2002. The present working group membership reflects interim changes, following recommendations made to SCOR by the original members, to the associate memberships. The group is currently at full strength as follows:

Full Members	**Associate Members**
Hans Burchard (Germany)	*Sybren Drijfhout* (Netherlands)
Chris Garrett (Canada)	*Ann Gargett* (USA)
Toshiyuki Hibiya (Japan)	*Theo Gerkema* (Netherlands)
Peter Killworth (UK)	*Sonya Legg* (USA)
Trevor J. McDougall (Australia)	*Jennifer Mackinnon* (USA)
Eugene Morozov (Russia)	*Mark Merrifield* (USA)
Robin Muench, Chair (USA)	*Rob Pinkel* (USA)
David Salas de Leon (Mexico)	*Fangli Qiao* (China)
Louis St. Laurent (USA)	*Barry Ruddick* (Canada)
Anders Stigebrandt (Sweden)	*Anne Marie Treguier* (France)

The group has focused on assessing the role of mixing in the large-scale ocean circulation. The scientific consensus needed to accomplish this task has relied on networking, through conferences and email communications, of specialists in field and theoretical studies of turbulent mixing and of those seeking to incorporate mixing into large-scale ocean circulation models. Toward this end, one highly successful dedicated conference and several dedicated sessions at other conferences have been convened. A tentative set of recommendations for ongoing and future action has been published, along with a number of pertinent papers, in the open literature. Similar activities are planned to continue, with active participation by working group members, following formal disbandment of the group. Details are provided below.

1. Working Group Meetings

The most recent meeting was held during October 2004 in conjunction with the IAPSO/SCOR Ocean Mixing Conference in Victoria, Canada. There has been no compelling need for a meeting since that time. The membership has been involved in pursuing goals identified at that meeting and has communicated as needed via email and through informal smaller gatherings of group members at the international conferences noted below and in previous annual working group reports.

2. Requests to SCOR concerning membership or terms of reference
The working group has no requests concerning membership or terms of reference.

3. Activities other than working group meetings

Activities completed over the past year:

- A session on ocean mixing was organized and chaired, primarily by working group members, at the Fall 2006 Meeting of the American Geophysical Union in San Francisco, California.
- A symposium on ocean mixing, organized by working group members, will be convened at the XXIV General Assembly of the International Union of Geodesy and Geophysics in Perugia, Italy on 2-4 July 2007. This symposium promises to be well attended, as the number of submitted abstracts was second largest of any of the IAPSO oceanographic symposia being held at the IUGG.
- A proposal for establishment of a Gordon Research Conference series on Ocean Mixing was submitted by a subset of Working Group 121 members, on behalf of the entire working group, on 31 May 2007. The inaugural conference, assuming a successful proposal, is anticipated to be held in early 2009. A continuing series of these conferences, which are typically popular and provide an excellent venue for exchange and discussion of new concepts, is intended as a legacy of the working group. General information on the Gordon Research Conferences can be found at http://www.grc.org/.

Ongoing activities:

- Work has been initiated on an article, to be submitted to *Oceanography* magazine, that will summarize the cumulative recommendations from the working group.

Future plans:

- Following disbandment of this working group following its next meeting, former members and colleagues plan to continue those activities that have characterized the working group during its tenure. These activities focus on fostering communication among the ocean mixing community and are planned to include an ongoing series of Gordon Research Conferences on Ocean Mixing.

4. Next working group meeting
The next and final meeting takes place in conjunction with the IAPSO Ocean Mixing symposium at the IUGG General Assembly in Perugia, Italy during July 2007. The primary goal of this final meeting will be to discuss and outline an article to be submitted for publication in *Oceanography* magazine. Estimated costs for member travel to Perugia, already requested in last year's annual working group report to SCOR, are US$3,000.

5. Assessment of progress
The group has been consistently ahead of schedule, having held its major conference in late 2004

and seen the proceedings volume published in early 2006. It has convened, during its existence, a number of highly successful and well-attended symposia at major national and international conferences including AGU meetings, and IAPSO and IUGG Assemblies. Its final action before its dissolution was submittal of a proposal for a Gordon Research Conference series on Ocean Mixing, and it plans over the coming year to submit an article to *Oceanography* magazine.

Working Group 121 has effectively enhanced communication among researchers of ocean mixing, has fostered new and fruitful new collaborations, and has, we believe, generally contributed to the health of the field. The timeliness of this group's tenure is made clear by the appended news item, dated 31 May 2007, from *Nature* magazine. The group, and its role, is cited briefly toward the end of the news item.

Robin Muench
Chair, IAPSO/SCOR Working Group 121

2.2.7 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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Marek Zajaczkowski	POLAND

Executive Committee Reporter: Bjørn Sundby

SCIENTIFIC COMMITTEE FOR OCEAN RESEARCH (SCOR)
LAND-OCEAN INTERACTION IN THE COASTAL ZONE (LOICZ)
INTERNATIONAL ASSOCIATION FOR THE PHYSICAL SCIENCES OF THE OCEANS (IAPSO)

FOURTH REPORT - JUNE 2007
WG 122
MECHANISMS OF SEDIMENT RETENTION IN ESTUARIES

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James Syvitski (USA)

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Yoshiki Saito (Japan)
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John Milliman (USA)
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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 the formation of 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 are 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 geomorphology change 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, the 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 that should be asked is 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

- overall and local geomorphology;
- overall sediment load and local sediment storage/erosion processes;
- within-estuary tidal range, water level, and current variability;
- tidal pumping;
- formation of turbidity maxima;
- vertical and longitudinal salinity (density) gradients;
- nearshore coastal dynamic processes;
- climate dynamics;
- relative sea level change;

- sediment-biological interactions; and
- 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 not completed until 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 with meeting room facilities and lunch for the participants. At this meeting, the 10 Full Members and 2 Associate Members participated.

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, we will attempt 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 23-25 June, 2005. This meeting was only supported by SCOR and LOICZ. At this meeting participated 6 full members, 3 corresponding members and one invited participant, Dr Han Winterwerp (Delft University) who covered his own expenses.

The meeting was mostly devoted to round-table discussions regarding the TORs and how best to provide answers by the end of WG time limit. A decision was made to elaborate a position paper to be submitted to *EOS*, with the provisional title "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. Both tasks are in process the publications are expected to be submitted by October 2007. Paper titles and authors for the ECSS special issue is as follows

- Perillo - Syvitski. Introduction
- Milliman and Syvitski. Land-derived inputs to estuaries - climatic and anthropogenic change.
- Saito, Depetris, Stallard, and Snoussi. Sediment processes in tidal river basins, flood plains, and wetlands and anthropogenic effects.
- Perillo, Gao, Syvitski, Zajaczkowski. Morphodynamics and evolution of estuaries, lagoons, fjords in response to climatic and anthropogenic change.
- Vinzon, Amos, Gao, Winterwerp, Caceres. Physical sediment-trapping mechanisms in estuaries.
- Pejrup, Perillo, Amos, Andersen. Biological factors responsible for sediment trapping in estuaries.
- Amos, Syvitski, Pejrup, Wolanski, Capabilities of models in assessing sediment

accumulation, transport, and erosion in estuaries on different time and space scales.
- Cranston, Kjerfve, Kuehl. Anthropogenic impacts on changing sediment budgets in estuaries.
- Wolanski, Dennison. Socioeconomic impact of anthropogenic change in estuarine sedimentation.

2.2.3.- Proposed Third and Final Meeting

The final meeting will take place in Boulder (Colorado, US), 22-25 September 2007. INSTAAR will look after meeting logistics. The meeting will be restricted to the members of the WG and the general structure of the workshop will be of three days dedicated to the TOR. The topics will be

- Sediment Input to Estuaries under human influence
- Morphodynamics and Evolution of Estuaries
- The Physics and Models of Sediment Budgets in Estuaries
- Socioeconomic Impact of Changes in Estuarine Sedimentation

Plenary sessions will be based on full group discussions on the topics. Presentations by the lead authors of the papers being prepared will be made on the first day.

Reasons for delaying this meeting are to: 1) better integrate between the specific TORs of the WG: and 2) provide enough time for members to have drafts of their review papers ready for the final meeting (final manuscripts would include any new insights/information presented at the meeting). The meeting will also finalize contributed papers to the special issue to *Coastal and Estuarine, and Shelf Science.*

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, 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. The link to the web page is http://www.criba.edu.ar/scorwg122.

3.- Publications

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

2-24

3.1.- Published

Andersen, T. J., Lund-Hansen, L., Pejrup, M., Jensen, K. T. and Mouritzen, K. N., 2005. Biologically induced differences in erodibility and aggregation of subtidal and intertidal sediments: A possible cause for seasonal changes in sediment deposition. Journal of Marine Systems 55:123-138.

Andersen, T.J , Pejrup, M. and Nielsen, A.A., 2006. Long-term and high-resolution measurements of bed level changes in a temperate, microtidal coastal lagoon. Marine Geology 226:115-125.

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Lumborg, U., Andersen, T. J., and Pejrup, M., 2006. Modelling the effect of macrozoobenthos and microphytobenthos on cohesive sediment transport on an intertidal mudflat. Estuarine, Coastal and Shelf Science 68:208- 220.

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

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3.2.- In press or submitted

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5.- Budget 2007

For the year 2007 the WG is planing its third meeting in USA to be held on 23-25 September. This meeting will follow a workshop type of organization based on round-table discussions to complete the terms of reference.

To organize the meeting we request $7,500 + $500 (left from the previous year) from SCOR that will be matched by LOICZ ($7,500).

2.2.8 WG 123: Reconstruction of Past Ocean Circulation (PACE) (with IMAGES) (2003)

Terms of Reference:

- Assess the existing paleoceanographic methods for reconstructing the history of ocean circulation over the past 120,000 years. Are the existing methods sufficient for a robust reconstruction of past ocean circulation? Are existing chronological tools sufficient to reconstruct distinct ocean circulation states? If not, what developments are necessary?
- Assess the available paleoceanographic data for reconstructing the history of ocean circulation over the past 120,000 years. Can robust conclusions on past ocean circulation be drawn from existing data? For what time periods and locations?
- Develop recommendations for future approaches to quantitatively assess the hypothesised changes in ocean circulation over the same time scale.
- Identify a minimum array of global locations and data types that would help to constrain uncertainties concerning changes in ocean circulation linked to major climate changes, bearing in mind the potential for collecting appropriate geological material as well as the size of the expected circulation signal relative to uncertainties in the methods. Through international co-operation within the IMAGES and ODP, existing cores would be identified and plans for new coring to meet these objectives would be discussed.

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WG 123 on Reconstruction of Past Ocean Circulation
2007 Report to SCOR

WG 123 (joint with IMAGES) yielded three products:

1. A final report from the working group (following)
2. A special theme section of the online journal *Geochemistry Geophysics Geosystems* (see http://www.agu.org/contents/sc/ViewCollection.do?collectionCode=POCIRC1&journalCode=GC)
3. An article in the journal *Science*: Jean Lynch-Stieglitz, Jess F. Adkins, William B. Curry, Trond Dokken, Ian R. Hall, Juan Carlos Herguera, Joël J.-M. Hirschi, Elena V. Ivanova, Catherine Kissel, Olivier Marchal, Thomas M. Marchitto, I. Nicholas McCave, Jerry F. McManus, Stefan Mulitza, Ulysses Ninnemann, Frank Peeters, Ein-Fen Yu, and Rainer Zahn. 2007. Atlantic Meridional Overturning Circulation During the Last Glacial Maximum *Science* 316: 66-69.

2.2.9 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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Fourth Report on the SCOR/IMAGES Working Group **LINKS**

"Analysing the links between present oceanic processes and paleorecords"

2006-2007

Overview:
The LINKS working group reached the end of its funding period in December 2006. During three meetings (September 2004, ICP-8 in Biarritz, France; December 2005, AGU Conference in San Francisco, USA; November 2006, Hanse Wissenschaftskolleg in Delmenhorst, Germany) topics that are relevant for the link between surface ocean productivity and the paleorecord were discussed. The outlines of five papers were developed jointly between members of the working group and further invited authors during the last meeting (see below and Appendix 1).

Meeting November 2006:
The meeting of the working group LINKS during 21-24 November 2006 at the Hanse Wissenschaftskolleg in Delmenhorst, Germany, was the main activity in 2006 and the last (official) meeting of the group. Advance outlines of papers were developed and their content was further discussed additional the 3.5 days of the meeting.

The participants of the meeting included Full Members, Associate Members and invited guests that are relevant for the topics of the manuscripts: Avan N. Antia, Jelle Bijma, Hans-Jürgen Brumsack, Maureen Conte, Christina De La Rocha, Colomban de Vargas, Frank Dehairs, Roger Francois, Marion Gehlen, Alan E.S. Kemp, Christine Klaas, Karin Lochte, Paul Loubere, Bernard Queguiner, Renate Scharek, Sabine Schmidt, Marie-Alexandrine Sicre, and Dieter Wolf-Gladrow.

Each topic was introduced by the lead author and it was discussed whether there are presently controversial hypotheses or fast-developing new ideas. Authors responsible for writing certain aspects were identified and it was the aim to have joint authorships of paleo-scientists with biologists or biogeochemists. In cases where the topics cannot be adequately covered by the members of the working group, additional colleagues have been asked to contribute as co-authors.

At the end of the meeting, tasks were distributed among the participants and we agreed upon a time schedule leading up to the submission of the manuscripts in spring 2007.

Publications:
Although it was initially envisaged to write overarching review papers, it became obvious that it would be more interesting to focus on controversial or topical issues within the chosen themes that are relevant for the link between surface ocean productivity and the paleorecord. We aim to produce challenging discussion papers that address a current topical aspect. The focus is on

controls of ocean productivity and export as far as we understand it from the "present ocean" and the "paleo-ocean" point of view. The five topics comprise

- the opportunities and problems of the rain ratio,
- the role of trace metals in the Southern Ocean,
- consideration of key areas and species for highest export,
- effects of hypoxia on large-scale nutrient budgets, and
- windows of opportunity in new technologies to detect changes in paleoproductivity.

(Please see Appendix 1 for more detail)

The detailed time plan devised during the meeting at the Hanse Wissenschaftskolleg proved too optimistic. One manuscript is nearly finished and will be submitted soon, others are presently in different stages of completion. The participants were not able to deliver the promised manuscripts on time due to their severe time constraints. As a consequence, it was not yet possible to circulate and review all the manuscripts within the group. LINKS will therefore continue to work on the topics and the discussion continues via e-mail. We still plan to submit the manuscripts in 2007.

The manuscripts will either be submitted to *Biogeosciences*, which has the advantage of being an open access journal, or in *Global Biogeochemical Cycles*. The contribution of SCOR and IMAGES will be duly acknowledged. We will inform SCOR and IMAGES when the papers are ready.

Appendix 1:

Workshop 21- 24 November 2006
Hanse Wissenschaftskolleg (HWK), Delmenhorst, Germany

Analysing the links between present oceanic processes and paleo-records
"LINKS"

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Dieter Wolf-Gladrow	dwolf@awi-bremerhaven.de

Schedule of Workshop:

November 21, 2006

11h30 – 12h00	**Introduction** from K. Lochte, **Practical info** D. Wolf-Gladrow
12h00 – 13h00	*Lunch*

Presentation of the groups:

13h00 – 13h45	Ballast and Rain Ratios *(Group 1)* *Authors: Roger François, Christine Klaas, Dieter Wolf-Gladrow*
13h45 – 14h30	Role of dust-born trace metals (Fe) on stimulation of primary production and nitrogen fixation *(Group 2)* *Author: NN*
14h30 – 15h15	What generate most export in key areas *(Group 3)* *Authors: Alan Kemp, Renate Scharek*
15h45 – 16h30	Effects of changes in hypoxic zones on large scale nutrient cycles *(Group 4) Authors: Raja Ganeshram, Karin Lochte*

16h30 – 17h15	Windows of opportunity for paleorecords *(Group 5)* *Author: Marie-Alexandrine Sicre, Carina Lange*
17h15 – 17h45	Discussion of potential New Themes *(Group F)*

18h30 Dinner (Buffet)

November 22, 2006

09h30 – 11h00	Meeting of Group 1
11h15 – 13h15	Meeting of Group 3
13h15 – 14h30	*Lunch*
14h30 – 15h30	Meeting Group 4
16h00 – 17h30	Change: Time for writing (MS 1, 3, 4)
18h00	*Dinner*

November 23, 2006

09h00 – 10h30	Meeting of Group 2
11h00 – 12h30	Meeting of Group 5
12h30 – 13h30	*Lunch*
13h30 – 15h00	Links to international programmes or writing
16h00 – 18h00	Plenary: Presentation of Progress of Groups
18h30	*Dinner*

November 24, 2006; Conclusions of the meeting

09h00 – 11h00	Plenary discussion: Draft of recommendations for the international programs (IMBER, GLOBEC, LOICZ, SOLAS)
11h15 – 13h30	How to proceed: - deadlines for writing groups - who is responsible
13h30	Closure of the meeting
13h00	*Snack*

<u>Outline of Manuscripts:</u>

Theme 1: Is the Rain Ratio hypothesis still alive???

- What are the main functional groups in the carbonaceous plankton that are instrumental in export production?
- How do changes in the rain ratio affect export?

- How is this flux being changed during sedimentation and how is it preserved at the sea floor?
- Is there evidence from the past that ballasting increases export?
- What is the effect of dust on the rain ratio (high dust increases diatom productivity)?
- Is there a bias due to the restriction of the sampling of carbonaceous sediments at certain sites?
- How can the functional groups be included in models, how many groups do we need for modelling?

Authors: Roger Francois, Christine Klaas, Dieter Wolf-Gladrow, F. Dehairs, B. Queguiner, S. Schmidt, P.Loubere, C. de la Rocha, C. de Vargas, M. Conte, M. Gehlen, A. Antia

Theme 2: Role of trace metals (Fe) in the Southern Ocean

- What is the "novel" aspect -> contradiction of N isotopes and Si isotopes re production; explain the contradiction by new observations of phytoplankton physiology and Si leakage hypothesis
- Fe limitation effects Si and Nitrate uptake, large diatoms benefit mainly from iron fertilisation experiments, light adaptation
- What are the consequences for export and nutrient regimes
- What are the source of Fe now and in the past (dust, Kerguelen,
- Iron in sea ice (concentrated from seawater) as an iron source
- What do we know from paleo-records in respect to the effects of Fe on the plankton, e.g. shifts in phytoplankton assemblages and productivity in relation to dust input

Authors: Christoph Völker, Peter Croot, Dieter-Wolf Gladrow, Philip Assmy, Renate Scharek, Bernard Queguiner, Christina de la Rocha, Linn Hoffmann, Delphine Lannuzel, Karin Lochte

Theme 3: What generates the highest export in key areas

- -Which areas are supporting highest export: Upwelling areas, SO fronts, and blooms, deep chl maximum?
- The most productive species may not be the best exporters and may not be best recorded in the sediments
- -What is the link between the surface production and the record in the sediments?
- -Which are the most important species for export (compare evidence from plankton, traps and sediment)
- Importance of large diatoms (also from deep Chl Max.) and of species with endo-symbionts for the fossil records
- Which role do radiolaria and silicoflagellates play?
- Which functional groups should be included in models?

Authors: Alan Kemp, Renate Scharek, Carina Lange, C. de la Rocha, A. Antia

Theme 4: The "nitrogen swing"

- Changes in ventilation are predicted to lead to spreading of low oxygen zones in the ocean
- What is the role of the newly discovered anammox process in comparison to denitrification?

- What are the effects of spreading low oxygen zones on N/P/Fe ratios, how does plankton species composition respond to such changes?
- Which lessons can be learnt from past low oxygen regimes?
- Which paleo-evidence is available to assess the effect of low oxygen on N2 fixation and on changes in the N- and P-cycle?

Authors: Raja Ganeshram, Karin Lochte, M. Gehlen, M. Kuypers.

Theme 5: "Windows of opportunity" for paleorecords

- How can we identify most 'reliable' proxies that are less subject to alterations?
- Which environmental conditions are conducive to preservation of which proxies?
- Which chances are provided by biomarkers, stable isotopes, molecular techniques?
- inorganic proxies and isotopes in …
- Using proxies in modern ocean process studies
- Indicators for seasonal signals

Authors: Marie-Alexandrine Sicre, P. Loubere, S. Schmidt, J. Bijma, C. de Vargas, M. Conte, C. de al Rocha, D. Wolf-Gladrow, H. Brumsack

2.2.10 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.

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Todd O'Brien	USA	Harold Bachelder	USA – Sponsored by PICES
Mark Ohman	USA	Juha Flinkman	FINLAND
Chris Reason	SOUTH	A. Lopez-Urrutia	SPAIN
Anthony	AFRICA	Welbjørn Melle	NORWAY – Sponsored by ICES
Richardson	AUSTRALIA		
Andy Solow	USA	Luis Valdes	SPAIN

Executive Committee Reporter: Annelies Pierrot-Bults

SCOR Working Group 125
"Global Comparisons of Zooplankton Time Series"
June 2007 Updated Status Report

Most members attended the second WG 125 meeting, held 4-7 December 2006 in Miraflores Peru, prior to the Humboldt Current Symposium (summary report submitted to SCOR in February 2007). Many were also able to participate in a brief supplementary WG meeting, held 26-27 May 2007 in Hiroshima Japan, prior to the 4th International Zooplankton Production Symposium. The Hiroshima Symposium also saw 14 papers authored/coauthored by WG125 members presented in the first of 10 topic sessions ("Global comparison of zooplankton time series"; conveners Mackas and Valdes).

There were two main discussion topics during the May 2007 WG meeting. The first was development and testing of "tool kit" software and statistical methodologies for calculating seasonal climatologies (and anomalies relative to these) for our variety of spatial and temporal sampling designs (single location time series vs. line transects vs. irregular grids within statistical regions). We now have access to three long zooplankton data sets with very high temporal resolution (Plymouth L4, Helgoland Roads, and Bay of Naples). By comparing complete vs. decimated versions of these time series, we expect to be able to evaluate which averaging methods are most robust to data gaps.

The second topic was where and how to present and publish our final working group results. We confirmed that the date and venue will be May 2008 in Gijon, Spain, to coincide with the upcoming Symposium on "Effects of Climate Change on the World's Oceans", co-sponsored by SCOR, IOC, WCRP, ICES, PICES, and GLOBEC. Prior to the Symposium, we plan a 2-3 day final WG meeting at the Instituto Espanol de Oceanografia (home institution for WG members Valdes and Lopes-Urrutia). During the symposium, we will present one jointly authored summary paper in the symposium plenary session on "Impacts on Marine Ecosystems," and also request a half-day workshop session on zooplankton time series. Papers on this topic will be collected for a special issue of *Progress in Oceanography* (editor-in-chief Cisco Werner has given us pre-approval for a special issue to appear in late 2008, and Pierre Pepin has agreed to serve as "arms-length" guest editor for the issue).

2.2.11 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

Scientific Committee on Oceanic Research Annual report of Working Group 126 – *The role of viruses in marine systems*

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

Ongoing progress for working group and a report on the May 2007 meeting.
The second meeting of the group was held in Bergen, Norway from May 8 to 12, 2007 and organized by Professor Gunnar Bratbak. The meeting dovetailed with the EurOceans group meeting on virus ecology; the meetings differed in that the EurOceans group focused on questions in virus ecology, while the SCOR WG focused on methods. More than 25 attendees spent four days discussing the charge of this group as well as undertaking an inter-laboratory comparison of techniques in virus ecology.

The focus of the meeting was the inter-lab comparison. Approaches to examining virus abundance, production rates, and diversity were tested by multiple laboratories on mesocosm samples established and maintained by Professor Bratbak and colleagues at the marine lab. Results are anticipated to be ready for comparison among groups sometime in August 2007.

The event also included discussions concerning one of the proposed outcomes of this working group: the development of a definitive manual on methods in marine virus ecology. As reported last year, the plan is to publish an electronic version and make it freely available to people whom are interested, though the *American Society for Limnology and Oceanography's* website for their journal *Limnology and Oceanography: Methods*. A draft outline of the proposed chapters has been approved and specific contributors identified for most of the chapters. The product itself will be financially supported by the generous support of the Gordon and Betty Moore Foundation.

Another outcome arising from the meeting was the reaffirmation of a commitment from the investigators to work towards having a "virus-centric" research project, where investigators from all labs are invited to participate and compare methods. Locations for this program, to most likely be carried out in 2008 or 2009, are still being discussed, as is the potential funding.

One final outcome of note was an invitation to submit a Perspectives paper to *Nature Reviews Microbiology*. This effort, arising during the workshop from communications with the journal's editor, is currently underway.

Plans for the next working group meeting.
Currently, we are planning to hold a meeting in 2009, most likely somewhere central to most of the members. This is a slight departure from the planned final meeting in 2008, but we feel it is prudent as it will allow us to see the book through to its completion.

Overall progress of working group in completing its terms of reference, in reference to the initial time schedule for the group.
In general the group is making significant progress in all of its goals. We anticipate that charges to authors for our publication will be made in July, with a submission date of sometime in late 2007. We hope to have drafts of the manuscripts completely ready for review by the core members in early 2008, with mid-late 2008 representing a target publication date.

Appendix I:

SCOR's Practical Workshop on Methods in Marine Virus Ecology

Organizers: Gunnar Bratbak, Markus Weinbauer, Steven Wilhelm

Goals: The goal of the practical workshop is to have groups from different marine virus ecology labs compare their approaches to understanding parameters which are commonly measured during field studies. An inter-comparison at this level should help alleviate discrepancies between different data sets that may arise. We anticipate that the results of this study will be useful in the preparation of the ***Practical guide to marine virus ecology*** which core members and other participants will be preparing. We also anticipate that these comparisons may be documented separately and ultimately lead to new collaborations amongst participants.

Contact information for participants:

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*these researchers want to participate in the discussions and to potentially receive samples but are unable to make the meeting. A cut and paste email list will also be appended to this document.

† Attendance has been confirmed for these researchers.

Samples for this project will be collected from mesocosms established at the Espeland Marine Biological Station. Details of the mesocosm will follow. As well, lysates of model cultures (a bacterium, cyanobacterium and eukaryotic alga) will also be made available to all PIs as

standards for comparison (a fourth "mixture" sample will also be made). This later sample set will be of primary interest to researchers comparing enumeration and diversity metrics.

SCOR WG126 Meeting – Bergen Norway, May 2007

The overall schedule will thus be something like this

For those attending - Sunday evening until Tuesday morning - EurOceans meeting organized by Corina
http://www.eur-oceans.eu/document/index.php?num_information=476

Tue afternoon	Briefing / update on the mesocosms, setup and coordination of labs Pre-nutrient addition sampling
Wed	Sampling
Thu	Sampling
Fri	Sampling / pack up / leave
Sat / Sunday	pack up / leave

This will not keep everybody busy all the time so we should in addition have some discussions and working on the method book.

Gunnar's suggested experimental design.
Two mesocosms will be filled *ca* 1 week before the workshop starts. One mesocosm (High NP) is fertilized with N and P to start a succession and bloom (all nutrients at once or a little every day) the other is kept unchanged until we start measuring viral activity and then we add N and P also to this mesocosm (*Shift-up*). We will make a few counts of alga, bacteria and virus to follow the development so we have an idea of what is going on in the mesocosms when we start.

Based on experience, the High NP mesocosm should give us a quite diverse phytoplankton community and a microbial community (algae + bacteria) that is increasing in abundance. In the *Shift-up* mesocosm I hope we will see a shift in the community with decreased abundance in bacteria and picoplankton within a couple of days after the nutrient addition (induction of viral activity??). In any case, this setup should give us different microbial communities to measure on, and in addition we have the fjord outside. It will allow us to compare methods and protocols and to possibly to observe a change over time.

Measurements to be compared. Below are the methods people have suggested that would like to try out. Please note that there are areas where we still need to *beef up* our sampling.

The enumeration of virus like particles

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed	Comments
Brussaard	**Martinez**	**Flow cytometry**	
Sime-Ngando	**Ram**	**SYBR Green I and epifluorescence**	
Bratbak	Thyrhaug/Larsen	Flow Cytometry	

The production rate of viruses

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed	Comments
Wommack		**Virus production**	**Dilution and reoccurrence with TFF**
Wilson	**Kimmance**	**Landry / Hassett style dilutions**	**SWW – I think this is planned**
Sime-Ngando	**Ram**	**TEM for FVIC / Burst Size**	**Can be used to infer production rates**
Bratbak	Thyrhaug/Bratbak	Viral decay	
Bratbak	Heldal/ Bratbak	**TEM for FVIC / Burst Size**	
Weinbauer / Vaqué / Wilhelm	Weinbauer / Boras	Virus reduction approach	**Direct counts as well as qPCR of cyanophage and phycodnaviridae**

Lysogeny in natural samples

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed (please specify system, etc.)	Comments
Paul		**Titzenbacker method**	**Induction with mitomycin c ?? Are there other DNA damaging agents we could add?**
Weinbauer		**He just looks at the samples and knows !!!!**	
Vaqué	**Boras**	**Reduction method**	

Concentration / ultrafiltration approaches

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed (please specify system, etc.)	Comments
Sime-Ngando	Ram		

The diversity of viruses / viral assemblages

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed	Comments
Middelboe		**Track of specific assemblages by plaque assay**	**Will we spike the mesocosm or isolate hosts from it?**
Sime-Ngando	**Ram**	**PFGE**	**Fingerprintin g approach**
Wilson	**Kimmance**	**Diversity of *E. huxleyi* viruses**	
Wommack		**Diversity of viruses (*G20, psbA, psbD, etc.*)**	

Wilhelm	**Wilhelm**	**Diversity and abundance of cyanophage (*G20, psbA, psbD*)**	**Will PCR amplify and then high through-put sequence**
Brussaard	**Brussaard / Martinez**	**PFGE**	**Fingerprinting approach**
Wommack		**RAPD-PCR and PFGE**	
Bratbak	Sandaa	PFGE	
Schroeder	**Schroeder and Hall**	**Community diversity**	**Preserved and fresh samples**

Other areas to be considered

Laboratory (list PI's name)	Person responsible for sample collection	Technique to be employed	Comments
Fuhrman	**Wilhelm**	**ARISA**	**Comparison of bacterial host diversity**
Sime-Ngando	**Ram**	**TEM for morphology**	
Jiao	**Liu**	**TUNEL Staining, TEM, caspase and DNA fragments**	**Apoptosis parameters**
Schroeder	**Schroeder and Hall**	**Community diversity**	**Preserved and fresh samples**

Appendix II: Finalized contents of publication.
METHODS IN AQUATIC VIRUS ECOLOGY

Organizing Editors: Curtis A. Suttle, Markus G. Weinbauer and Steven W. Wilhelm

Section I. Introduction

Section II. Sampling:
1. Concentration of free viruses from water samples
2. Separation of free virus particles from sediments in aquatic systems

Section III. Enumeration:
4. Counts of viruses by epifluorescence microscopy
5. Determining virus abundance by flow cytometry
6. Estimation of infectious virus titre by plaque assay or MPN assay

Section VI. Isolation and purification of viruses:
7. Isolation of viruses infecting photosynthetic and nonphotosynthetic protists
8. Isolation of viruses infecting heterotrophic bacteria and cyanobacteria
9. Temperate phages and lysogens
10. The isolation of viruses infecting Archaea
11. Purification of virus particles with centrifugal gradients

Section IV. Characterization:
12. Transmission electron microscopy of viruses and viral communities
13. Characterization of virus life cycles (incl. adsorption kinetics)
14. Preparation and application of fluorescently labeled virus particles

Section V. Virus production and mortality estimates:
15. Estimating viral-mediated mortality rates of prokaryotes method
16. Estimation of autotrophic mortality by the virus dilution method

Section VII. Molecular methods:
17. Isolation of nucleic acids from virus particles and communities
18. Sequencing and characterization of viral genomes
19. Construction and analysis of marker gene libraries
20. Fingerprinting virus communities by DGGE and PFGE
21. Construction of microarrays and applications to virus analysis
22. Metagenomics with virus communities
23. Characterization of RNA virus communities

2.2.12 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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Rainer Feistel	GERMANY	Frank Millero	USA
Valentina Gramm-Osipova	RUSSIA	Petra Spitzer	GERMANY
David Jackett	AUSTRALIA	Dan Wright	CANADA
Brian King	UK		

Executive Committee Reporter: Lawrence Mysak

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

Progress as at 27th June 2007

This working group was approved in 2005, it had its first meeting in May 2006, and its second meeting at Reggio, Italy in May 2007. The present membership is as follows

Full Members

Trevor J. McDougall, Chair (Australia)
Rainer Feistel (Germany)
Chen-Tung Arthur Chen (Taiwan)
Valentina N. Gramm-Osipova (Russia)
David R. Jackett (Australia)
Brian A. King (UK)
Giles M. Marion (USA)
Frank J. Millero (USA)
Petra Spitzer (Germany)
Dan Wright (Canada)

Associate Members
Peter Tremaine (Canada)

The second meeting in May 2007 was attended by all Full Members except Valentina Gramm-Osipova.

1. Working Group Meetings

The progress to date of Working Group 127 can be summarized as follows.

- We reaffirm that the primary standard for fresh water will be that defined by the International Association for the Properties of Water and Steam (IAPWS) and known officially as the "Release on the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use", briefly "IAPWS-95" (Wagner and Pruß, 2002, *Journal of Physical and Chemical Reference Data*, **31**, 387-535).
- The properties of seawater will be defined relative to those of fresh water described by IAPWS-95. This new description of seawater will be in form of a single thermodynamic potential function (Gibbs function) as a primary standard, rather than by a set of equations like the current EOS-80 formulation. From this primary standard, practical approximate equations for specific quantities or purposes will be derived, for example, equations that are valid in restricted parameter ranges or are designed for improved computational speed.
- All new algorithms will be in terms of the 1990 international temperature scale.
- We have carried out a hierarchy of procedures by which we have checked that the Gibbs

function of Feistel (2003, *Progress in Oceanography*, **58**, 43-114) does indeed represent the raw data of the original published papers of the various thermodynamics quantities from which it was derived. This work has being carried out between the first and second meetings of WG127 by several subcommittees and has included the checking of various computer algorithms (in Fortran and Matlab) that produce the thermodynamic quantities of interest from the Gibbs function of seawater.

- The Gibbs function of Feistel (2003) is currently being extended to improve its accuracy (especially freezing temperature, enthalpy and specific heat capacity) for very salty water (from approximately 50 to 110 g/kg) for temperatures up to 40°C and pressures up to 100 MPa = 10,000 dbar. There is a new draft manuscript Feistel (2008?) that represents this new work and this will undergo the same rigorous testing by WG127 before its next meeting.
- Over the past year we have settled on a definition of The Reference Composition of seawater. This is actually a necessary first step in order to define the Gibbs function at very low salinities. This Reference Composition, consisting of the major components of Standard Seawater, is determined from the results of earlier analytical measurements.
- Having defined the Reference Composition, this enables the determination of the Absolute Salinity of seawater that has this Reference Composition. This leads naturally to the need for a new salinity variable called the "reference salinity" S_R, which is quantitatively identical with "absolute salinity" S_A within practically reasonable limits. The reason for this formal distinction is that the exact chemical composition of real sea salt is unknown (and will be unknown in the foreseeable future), but the stoichiometry of the reference sea salt can suitably be specified, based upon the latest standard atomic weights. There are three main reasons for introducing an extra salinity variable. First, freshwater content of seawater is $(1 - 0.001S_A)$ not $(1 - 0.001S)$, and S_A and S are known to differ by about 0.5%. There seems no good reason for continuing to ignore this known difference in ocean models. Second, salinity expressed in the PSS-78 scale is outside the system of SI units. Reference salinity is expressed in units of g/kg, as absolute salinity. This approach could terminate the ongoing controversies in the oceanographic literature about the use of "psu" or "pss" and makes research papers readable to the outside scientific community. Third, the next largest improvement in the equation of state of seawater (with respect to that derived from Feistel (2003) will come from incorporating the variation in the composition of seawater. It is known that the ratio of various constituents of seawater vary throughout the world ocean. This variation impacts (i) the determination of S_A from measurements of conductivity ratio, and (ii) the dependence of density on both S and on S_A.
- A new Reference Salinity S_R is defined to provide the best available estimate of the Absolute Salinity of both Reference Seawater and Standard Seawater. From a practical point of view, the value of S_R can be related to the Practical Salinity S that is now commonly used by $S_R = (35.164\ 86/35)\ \mathrm{g\ kg^{-1}} \times S$. The error in using this variable to approximate the absolute salinity of Standard Seawater is approximately one-eightieth of the error associated with using Practical Salinity for this purpose.
- We have written and submitted a manuscript on the Reference Composition of Seawater and on the definition of Reference Salinity. (Millero, F. J., R. Feistel, D. G. Wright and

T. J. McDougall, 2007: The composition of standard seawater and the definition of the reference-composition salinity scale. submitted to Deep-Sea Research). The new independent salinity variable, Reference Salinity, is intended to be used as the concentration variable for future thermodynamic functions of seawater, as an SI-based extension of Practical Salinity, as a reference for natural seawater composition anomalies, as the currently best estimate for Absolute Salinity of IAPSO Standard Seawater, and as a theoretical model for the electrolyte "seawater".

- A major next step for the working group will be to determine salinity corrections to account for anomalous properties, including spatially varying concentrations of alkalinity, total carbon dioxide, calcium and silica. Such anomalies are now the single largest source of uncertainty in the determination of salinity and related thermodynamic properties of seawater. We are investigating methods of using additional information (such as nutrient measurements) together with conductivity ratio to estimate the Absolute Salinity of a seawater sample. We are also investigating whether the various thermodynamic properties of interest can then be determined to sufficient accuracy from knowledge of S_A alone (that is, without having to know the concentrations of all the individual constituents). This work requires measurements of absolute density to be made on samples taken from different ocean basins where the nutrient data is also taken. Cruises have been identified for this purpose and initial results on the feasibility of this method of estimating Absolute Salinity are expected at our next meeting in Berlin in September 2008.
- We are also finalizing a list of preferred nomenclature and symbols for thermodynamic quantities.

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 choice is so we can have a joint session with the International Association of the Properties of Water and Steam (IAPWS). This body is having a major bi-annual symposium in Berlin at that time. The thermodynamic properties of fresh water are defined by IAPWS and they have an interest in the properties of seawater (w.g., for seawater cooling of power plants). Dr. Petra Spitzer of our Working Group will act as local host for our meeting in Berlin.

5. Assessment of Progress

The members of WG127 feel that we are making good progress towards our main goals. There is certainly much work being done between meetings, with several of us spending many months

of full-time work on these activities between meetings. During our meetings we produce detailed minutes with actions items and deadlines for all of the tasks that arise.

A draft form of the final Gibbs functions exists (Feistel (2008?)) and much of our work between now and September 2008 will be involved in checking this Gibbs function and submitting it also to the IAPWS approval process. Our aim is to be in a position to approve this Gibbs function at our meeting in September 2008. This approval process will include checking that the Gibbs function does in fact reproduce the data from which it is derived (within their error limits) as well as checking that the various algorithms do what they are advertised to do. Secondary algorithms (e.g., algorithms that are of reduced accuracy but are computationally faster) will also be checked. At that time we hope to have a draft manuscript that compares the thermodynamic quantities derived from this Gibbs function with those of the International Equation of State of 1980 and to be able to discuss the source of the errors in each.

By September 2008 we also aim to be able to assess the viability of the envisaged method of estimating the Absolute Salinity of seawater samples based on combining the conductivity measurements with supplementary data.

Trevor J McDougall
Chair, SCOR/IAPSO Working Group 127

2.2.13 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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Temel Oguz	TURKEY
Nancy Rabalais	USA
Osvaldo Ulloa	CHILE

Associate Members:

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Werner Ekau	GERMANY
Ragnar Elmgren	SWEDEN
Elva Escobar	MEXICO
Andy Gooday	UK
Mike Kemp	USA
Silvio Pantoja	CHILE
Mary Scranton	USA
Anja van der Plas	NAMIBIA

Executive Committee Reporter: Robert Duce

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

Annual Report – 2006/2007

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.

2. Activities since April 2006

Activities of WG#128 were mostly undertaken by email among WG members, long-distance phone calls, and occasional simultaneous participation of several WG members to international conferences. The outcomes of the first WG#128 Meeting include

- tentative list of synthesis papers to summarize the group's work,
- making contact with LOICZ IPO to create a Web site for the group,
- contribution to other organizations (e.g., meetings and other activities) from members of WG#128, and
- preliminary planning for the second WG meeting in conjunction with one of the international conferences in 2007.

With regard to the second meeting of this Working Group, we made a suggestion to the IPOs of IMBER and LOICZ to hold the meeting as part of the LOICZ/IMBER Open Science Conference, which will be held at Shanghai on 17-21 September 2007. The co-chairs of WG#128 have successfully proposed a session on "low oxygen on continental shelves" (i.e., Session 6) for the LOICZ/IMBER OSM (Annex 1).

3. Final results of WG#128

The major activity for this Working Group after its first meeting was to produce a list of the synthesis papers, with volunteer leading authors and co-authors. The preliminary list is made up of 14 synthesis papers (Annex 2), but is still under revision. At this time, the plan is still to publish the group's work in an internationally peer-reviewed journal, for example, an EGU open-access journal such as *Biogeosciences*, although the final decision will depend on the funding availability to cover the publication cost, for which the possibility of obtaining extra funding should be explored. At the same time, the Working Group welcomes and makes efforts to invite scientists from outside the group to contribute their results to the special issue. We also invite scientists from the broader scientific community to participate in the synthesis work of the group and to contribute as co-authors of synthesis papers led by members of WG#128.

As for the progress of manuscript preparations, the up-to-date information (i.e., June 2007) about the status of synthesis papers is given in the table below:

No.	Manuscript Title	Proposed leading author (November 2006)	Status
1	Natural and human causes of hypoxia	Unknown	To be discussed at the second WG meeting
2	Geographical coverage of hypoxia occurrence	Nancy Rabalais	Manuscript in preparation
3	Worldwide oxygen trend patterns	Denis Gilbert	Manuscript in preparation
4	Historical record of hypoxia from sediment proxies	Andy Gooday	Draft manuscript is done
5	Future research avenues and knowledge gaps (including genomics, economics, model inter-comparisons)	No volunteer	To be discussed at the second WG meeting
6	Recovery following remediation efforts (including unanticipated side effects)	Michael Kemp	Manuscript in preparation
7	Report or paper on designing observation systems for studying coastal hypoxia	No volunteer	To be discussed at the second WG meeting
8	hypoxia effects on the benthic-pelagic coupling – biogeochemical and ecological perspective – integrated view of organic matter fluxes, bioturbation, nutrient cycling within the sediment	Jack Middelburg	Manuscript in preparation
9	Upwelling-dominated hypoxic systems	Pedro Monteiro	Manuscript in preparation
10	Hypoxia/anoxia as a source of greenhouse gases (N_2O and CH_4)	Wajih Naqvi	Manuscript in preparation
11	Future changes in hypoxia frequency and intensity with global warming	Richard Matear	Manuscript in preparation
12	Effects of hypoxia on nekton and plankton	Werner Ekau	Draft manuscript is done
13	Microbial communities within hypoxic zones	Osvaldo Ulloa	Manuscript in preparation
14	Overall SUMMARY linking all papers	Jing Zhang	Manuscript in preparation

We have suggested that the leading authors of synthesis papers post their draft manuscripts on the WG Web site in the first week of September 2007, which would allow Working Group members to contribute and revise the manuscripts before the second Working Group meeting. Posting the draft manuscripts on the Web site will also help the internal review process that needs to be performed prior to final submission. It is expected that leading authors of synthesis papers will give an oral presentation of their papers on Day One of the Shanghai meeting of the working group.

4. Web site of WG#128

Soon after the Vienna Meeting in April 2006, we started to work with colleagues from LOICZ IPO on the possibility to have a window for SCOR WG#128 on the LOICZ Web site. A proposal was made to LOICZ by Nancy Rabalais (LOICZ SSC member) to help establish the cross-link between the two organizations (Annex 3). The idea is to have a joint facility for sharing the references of WG#128 and to have a Web site that WG members can use for circulation of manuscripts and open discussion on WG-related activities. At the same time, LOICZ IPO will help to maintain the Web site, which is highly appreciated from this WG. This is also considered as an active, dynamic link between SCOR WG#128 and IGBP-LOICZ. By the end of 2006, a Web site was created by LOICZ IPO at http://kopc01.gkss.de:8080/LOICZWG128Wiki/Wiki.jsp for this WG, with ID and passwords for every WG member to use. We take this opportunity to acknowledge LOICZ for the support we benefited from them in establishing this Web site.

5. Shanghai meeting in September 2007

At the first meeting of this WG in Vienna, there was a suggestion to have the second meeting of WG#128 as part of another international conference to bring in the contribution from colleagues of the broader scientific community. A number of choices were proposed, but the group settled on the LOICZ – IMBER Continental Margins Open Science Conference in 2007, suggested venue of Shanghai. Besides the relevance of topics of the LOICZ/IMBER Continental Margins Open Science Conference to the Terms of Reference of WG#128, two full members, that is, Nancy Rabalais and Jack Middelburg, were co-conveners for this open science conference. The co-chairs made a proposal to the IMBER IPO and the International Organizing Committee to have our second meeting together with this OSM, which was approved by the end of 2006. At the LOICZ – IMBER Continental Margins OSM, this WG will chair session (6): "low oxygen on continental shelves", which is the major activity of Day One for the WG#128 Meeting and taken as a window to invite scientists from outside the WG to participate in our activities. In the following two days (22-23 September 2007), there will be time exclusively reserved for this Working Group to present the draft synthesis papers and discuss the revision of these papers, although we will keep the policy that we adopted in Vienna of inviting other scientists to join our meeting.

6. Other activities of WG#128

(a) Conference on Oxygen Minimum Zone in November, 2006 (Concepcion, Chile)

Eight members of SCOR WG 128 took part in this OMZ symposium (Boris Dewitte, Denis Gilbert, Mary Scranton, Nancy Rabalais, Osvaldo Ulloa, Sylvio Pantoja, Temel Oguz, Wajih Naqvi), which occurred in parallel with the SCOR General Meeting. The paper on microbial communities (#13) was proposed by Osvaldo Ulloa at the Concepcion meeting.

(b) Contribution to PACKMEDS: Rapid Assessment of Semi-Enclosed Marine Systems

The PACKMEDS project was launched in March 2006 and was coordinated by IUGG, SCOPE and SCOR. The project is focused on the dynamics of semi-enclosed marine systems, especially the integrated effects of changes in sediment and nutrient inputs from land, in the context of ocean physics and biogeochemistry, to synthesise and review the current understanding in an assessment activity that focuses on the world's largest semi-enclosed seas. About 40-50 experts were invited to join the second workshop of PACKMEDS at Delmenhorst, Germany on 1-5 April 2007. The experiences and knowledge from studies on marine systems and their

surrounding lands were shared at the PACKMEDS Workshop in sufficient depth to provide a firm foundation for a set of examples from which general principles could be drawn. The final product of PACKMEDS will be a report aimed at providing a scientific synthesis and review of the current understanding of semi-enclosed marine systems in a timely manner to meet the needs both of research planners and of policy makers and practitioners with the publication of a scientific book targeted to the environmental science community, and of a policy brief, jointly with UNESCO.

Members of WG#128 were actively involved in the PACKMEDS workshop and made unique contributions to the success and final product of this international project. For example, 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. As for the steering committee of PACKMEDS, Venu Ittekkot, Jack Middelburg, Temel Oguz, Wajih Naqvi and Jing Zhang from WG #128 are 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 well relevant to the TOR of this Working Group.

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)	GEOTRACES (Silvio Pantoja)

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

It is hoped that at the second meeting of WG#128 at Shanghai in 22-23 September 2007, draft manuscripts of Hypoxia Special Issue will be revised, as this is the major final product of this Working Group. In addition, more papers are welcome from scientists outside this Working Group. Another topic of this second meeting is to discuss the activities of WG#128 after the second meeting and on the time and venue for the final meeting of this Working Group. As can be seen from Annex 2, leading authors for three out of fourteen proposed manuscripts have not yet been identified, which means that the final list of synthesis papers is subject to change made at Shanghai in September 2007.

Annex 1.

First announcement for the IMBER/LOICZ Continental Margins Open Science Conference
Impacts of global, local and human forcings on biogeochemical cycles and ecosystems.
September 17-21, 2007 Shanghai (P.R. China)

Dear Colleagues ,

Please allow us to draw your attention to the next IMBER/LOICZ Continental Margins Open Science Conference that will be held on, September 17 – 21, 2007 in Shanghai (P.R. China).

The goal of the conference is to estimate the relative importance of the changing forcings - global, local, and human - and determine how changes in shelf ecosystems can be attributed to the respective forcings.

The conference will be organized around nine themes including (1) ocean-shelf exchanges, (2) continental shelf interactions with coastal systems and the atmosphere, (3) the role of sediments in ecosystem functioning and particle dynamics on the continental shelf, (4) continental shelf ecosystems: commonalities and particularities of high-latitude, temperate and low-latitude systems, (5) eutrophication and oligotrophication in coastal systems, and influences on outer shelf ecosystems, (6) low oxygen on continental shelves, (7) air-sea exchanges and climate-active gases on the continental shelf, (8) sustainable use of continental shelf resources and (9) long time series, remote sensing, observation systems and integrative modeling.

The Conference poster is downloadable in high or low resolution on both the IMBER and LOICZ web sites at http://www.imber.info/ and http://www.loicz.org/.
For further information regarding this conference, sent your enquiries to: shanghai.osc@univ-brest.fr.

This Meeting is co-convened by Nancy Rabalais (nrabalais@lumcon.edu) and Jack Middelburg (j.middelburg@nioo.knaw.nl).


First Announcement
Joint IMBER / LOICZ
Continental Margins
Open Science Conference
上海
2007年9月
17-21日
Shanghai
September 17-21st
2007
Impacts of global, local and human forcings on biogeochemical cycles and ecosystems
Co- conveners :
Nancy Rabalais (USA): nrabalais@lumcon.edu
and Jack Middelburg (Netherlands): j.middelburg@nioo.knaw.nl
International organizing committee :
Katja Fennel (Canada), Burke Hales (USA), K.K. Liu (Taiwan),
Isabelle Niang Diop (Senegal), Helmuth Thomas (Canada),
Paul Wassman (Norway), Kai Wirtz (Germany)
and Jing Zhang (P.R. China)
Contact:
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International Council for Science
Scientific Committee on Oceanic Research
IMBER
LOICZ
SKLEC

Annex 2

Proposed list of papers - SCOR WG 128 on Natural and Human-Induced Hypoxia and Consequences for Coastal Areas (November 30, 2006)

Note: The names of lead authors who volunteered are indicated in red. Other lead author names (in blue) were suggested by individual working group members or the two co-chairs. Comments appear in green.

Natural and human causes of hypoxia
Lead: Unknown
Co-authors: D. Gilbert, M. Kemp, J. Middelburg, P. Monteiro, T. Oguz, N. Rabalais, M. Scranton, A. van der Plas, J. Zhang (alphabetical)
Scientific Questions:
What are the major forcings/causes for natural and human related hypoxia problems in the coastal ocean? How do these forcing/causes change as a function of temporal and spatial scales? For natural hypoxia events, are they regulated by changing climate? For human related hypoxia, are they behaving differently in response to different human activities, and how? How do long-term trends (decadal) and short-term variations (inter-annual) in climatic conditions affect anthropogenic hypoxia?

Geographical coverage of hypoxia occurrence
Lead: Nancy Rabalais
Co-authors: R. Diaz, R. Elmgren, E. Escobar, D. Gilbert, L. Levin, W. Naqvi, T. Oguz, R. Rosenberg, A. van der Plas, J. Zhang (alphabetical)
Scientific Questions:
Can we define hypoxia typologies? What kind of "comparison" and/or "comparative work" can be thought out by looking at the geographic coverage of hypoxia? How can hypoxia occurring in tropical and high latitudes be compared in terms of geographical coverage?

Worldwide oxygen trend patterns
Lead: Denis Gilbert
Co-authors:R. Diaz, J. Middelburg, P. Monteiro, W. Naqvi, N. Rabalais, M. Scranton, A. van der Plas, J. Zhang (alphabetical)
Scientific Questions:
Is there a global, statistically meaningful downward oxygen trend in estuarine and coastal waters around the world? Perform a meta-analysis of oxygen trends in estuaries and coastal areas around the world using time series spanning at least two decades, and taking into account the effects of serial correlation on the effective number of degrees of freedom. From individual oxygen time series, produce a global map showing sites where oxygen is significantly decreasing (or increasing) over the 20+ year oxygen time series. How and to what extent do open ocean DO trends and patterns affect the formation and evolution of hypoxia in the coastal seas? Are open ocean oxygen trends different from coastal and estuarine oxygen trends?

Historical record of hypoxia from sediment proxies
Lead: Andy Gooday
Co-authors: F. Jorissen, L. Levin, J. Middelburg, W. Naqvi, N. Rabalais, M. Scranton (alphabetical)
Scientific Questions:
What kind of "proxies" can we use in paleo-studies of coastal hypoxia (e.g. foraminifera, diatoms and cysts of dinoflagellates, etc.) and how to extract the information to understand the history? What problems do we have to solve to link the records and/or information by proxy with climate change and human perturbations in the past with acceptable uncertainties? How to make comparisons between different regions using paleo-records for hypoxia? What is the greatest challenge we meet in paleo-records of hypoxia (e.g. ambiguities)?

Future research avenues and knowledge gaps (including genomics, economics, model inter-comparisons)?
Lead: No volunteer (Jack Middelburg made this comment: I see this more as an EOS article by the whole working group rather than a peer-reviewed article. What do others think of this suggestion?)
Co-authors: M. Kemp, L. Levin, J. Middelburg, N. Rabalais, M. Scranton (alphabetical)
Scientific Questions:
What existing knowledge gaps do we identify as a WG? What are the innovations that we should push forward for the study of coastal hypoxia (e.g. techniques and models). What do we foresee as new research avenues in the future? What observing system configurations and cyberinfrastructures are needed to address current vexing questions?

Recovery following remediation efforts (including unanticipated side effects)
Lead: Michael Kemp
Co-authors: R. Elmgren, L. Mee, J. Middelburg (alphabetical)
Scientific Questions:
Do we have good examples of remediation of hypoxia in coastal ocean and what can we learn from their experiences? What are the benefits and pay-offs for the remediation efforts? What are the by-products and side effects of remediation? Can we adopt the remediation efforts from one region and apply to another region, and what kind of problems may we have in this case? What non-linear (e.g., hysteretic) trajectories should we anticipate (have been observed) in system recovery following remediation of anthropogenic hypoxia, and what are the ecological processes and mechanisms that control these dynamics?

Report or paper on designing observation systems for studying coastal hypoxia
Lead: No volunteer. Jack Middelburg expressed this opinion: this is more a white-paper than a review/research article
Co-authors: Most WG members could contribute to this paper
Scientific Questions:

- What observations techniques do we require for characterizing the scales of forcings and responses?
- Automated versus ship-based observation systems

- Sustainability of the observation system: long-term monitoring versus short-lived research program?
- Minimal versus ideal observation system
- Identification of key indicator species

Paper on hypoxia effects on the benthic-pelagic coupling – biogeochemical and ecological perspective – integrated view of organic matter fluxes, bioturbation, nutrient cycling within the sediment
Lead: Jack Middelburg
Co-authors: E. Escobar, M. Kemp, L. Levin, W. Naqvi (alphabetical)
Scientific Questions:
What are the real effects of hypoxia besides the DO reduction to the benthic ecosystem, e.g. side effects? How much do we know about hypoxia effects on the benthos and the influence that can be propagated to whole system, e.g. food web from end to end? What is the effect of coupling and de-coupling of pelagic and benthic systems in terms of hypoxia? What do we know about the sedimentary records of benthic systems affected by hypoxia? What are the key feedback processes between pelagic processes generating hypoxia and redox-sensitive benthic processes?

Upwelling-dominated hypoxic systems
Lead: Pedro Monteiro
Co-authors: B. Dewitte, W. Ekau, V. Ittekkot, W. Naqvi, T. Oguz, M. Scranton, O. Ulloa, A. van der Plas (alphabetical)
Scientific Questions:
What kind of boundary effect and/or forcing do we know on the development, evolution and disappearance of coastal hypoxia? What is the difference between eastern and western boundaries in terms of the physics and biogeochemistry of hypoxia? How can we identify the role of offshore water advection in the development of coastal hypoxia? What are different roles played by eastern and western boundary currents (e.g. Gulf and Kuroshio) on the hypoxia of coastal waters?

Hypoxia/anoxia as a source of greenhouse gases (N_2O and CH_4)
Lead: Wajih Naqvi
Co-authors: J. Middelburg, J. Zhang (alphabetical)
Scientific Questions:
What is the significance of hypoxia on the feedback from the ocean to the atmosphere in terms of trace gas species (e.g. N2O and CH4). How can changes in ocean-atmosphere fluxes of greenhouse gases be specified and compared with normal/DO depleted situations? What is the effect of hypoxia on the cycles of nitrogen, carbon and probably sulfur as well and their flux at inter-faces? What is our knowledge gap on the budgets of trace gas species taking into account the existence of hypoxia?

Future changes in hypoxia frequency and intensity with global warming
Lead: Richard Matear
S. Doney, D. Gilbert, D. Justic, P. Monteiro, W. Naqvi, N. Rabalais (alphabetical)

Scientific Questions:

- How will different hypoxic regions behave under global warming?
- How will open-ocean oxygen conditions change with global warming? Models predict lower oxygen concentrations (and lower saturations) with global warming, thus increasing the likelihood of coastal hypoxia in some regions.
- Within the context of global warming what do we foresee in terms of future prevalence and damage caused by hypoxia?
- What trends in N-P-Si riverine inputs can we expect in the future?
- How can we evaluate the damages caused by changes in the frequency and duration/spatial extent of hypoxia?

Effects of hypoxia on nekton and plankton
Lead: Werner Ekau
How do the nekton and zooplankton react to hypoxia? Document lethal thresholds. Discuss sublethal effects on growth rate, locomotion, reproduction. Discuss succession of species dominance, issues of biodiversity.

Microbial communities within hypoxic zones
Lead: Osvaldo Ulloa

- Nitrifying bacteria
- Denitrifying bacteria
- Anammox bacteria
- Archaea

Overall SUMMARY linking all papers
Lead: Jing Zhang
Co-authors: D. Gilbert, J. Middelburg, P. Monteiro and others? (alphabetical)
Scientific Questions:
Based on the work of this WG, what do we foresee that can be summarized, e.g. knowledge, techniques, models, human vision, and others? This should be a very condensed paper based on the soul, ability and wisdom of whole Working Group.

Annex 3

Proposed Linkages of SCOR WG 128 with LOICZ

The reasons for the linkage between LOICZ and the now approved SCOR Working Group 128 on "Natural and Human-Induced Hypoxia and Consequences for Coastal Areas" are:

(1) SCOR Working Group 128: Terms of References 2 & 3 – "Identify gaps in our understanding of hypoxia and make recommendations for future research", and "Determine the requirements for observing hypoxia events and their impacts in coastal systems, and for modeling coastal hypoxia and its impacts"
Coastal ocean hypoxia/anoxia is a major focus of the SCOR WG 128 because this is the area where the more obvious and dramatic changes of hypoxia occurrence, severity and persistence have occurred within the last half of the 20th century. The coastal regions are also better sampled and controlled at their boundaries (i.e. continental contribution), which allows us to gain knowledge in the near-shore biogeochemical mechanisms involved in hypoxia events.
The intensity, duration and frequency of recent marine hypoxia are changing due to human-induced alteration of coastal ecosystems (e.g., enhanced delivery of nutrients and/or organic matter). The LOICZ program (http://www.loicz.org/) is centered at the interface of land and the coastal zone. It accounts for the flux of materials from the land to the coastal ocean as well as the biogeochemical cycles. The term of "ecosystem" that is addressed in LOICZ is therefore from the head of a watershed, through the coastal zone and into the adjacent continental shelf area. The processes of cultural eutrophication and subsequent hypoxia/anoxia with several adverse impacts are located in these coastal areas, as well as the consequences of oxygen deficiency.

(2) LOICZ Science Plan and Implementation Strategy: Theme 3 – "Anthropogenic influences on river basin and coastal zone interactions"
LOICZ can help realize complementary knowledge products that highlight the land-based fluxes. These would include nutrients, sediments and quantity of fresh water. Changes in each of these categories and among categories to varying degrees dictate the physical structure of the water column and gradients within estuary and coastal ocean, the light field, the water residence time, and the relationship between nutrient loads, changes in nutrient ratios, and biological response of the receiving water body. The compilation of the coastal typologies and the synthesis of information on nutrient budgets from around the world form a good background in which to consider areas of higher vulnerability to hypoxia based on relative fluxes of materials from the watershed.

(3) LOICZ Science Plan and Implementation Strategy: Theme 4 - "Fate and transformation of materials in coastal and shelf waters"
The change in the oxygen budget of coastal areas, both in estuaries and the adjacent continental shelf, has a dominant effect on the biogeochemical cycling of nitrogen, phosphorus, carbon, metals, trace elements, and contaminants. These processes occur within the lower water column, at the sediment-water interface, and at the interface of oxic and anoxic layers within the seabed.

The biogeochemical processes occurring within these zones shift as the oxygen gradient changes among these interfaces.

(4) Human Dimensions

River basin/coast interactions reflect a coupled human and natural system. The LOICZ II SPIS has an explicit inclusion of human society as a part of the coastal ecosystem. Human activities that cause coastal water quality problems and that mitigate or repair damages to aquatic ecosystems are a component of all aspects of the LOICZ program. There are implications of these fluxes and subsequent hypoxia on human uses of coastal waters and coastal functioning, which is the major concern of SCOR WG 128 as well.

(5) Modeling

Several well-established or planned modeling activities integrate with aspects of coastal hypoxia. Coastal nutrient budgeting was approached with box numerical models of freshwater and salt balances and dissolved nutrients to compute internal source/sink rates and fluxes. Refinement of these models to include inputs and processes (e.g. parameterization) will improve the ability to estimate the impacts of landscape change, flux of materials from the open ocean, and coastal activities on biogeochemical cycles. Advances in the science of observing and modeling estuaries and coastal regions are to be reviewed, synthesized and integrated into a rigorous conceptual, statistical, and modeling framework for biogeochemical data analysis and interpretation.

(6) Relevance to Global Change Studies

LOICZ and IMBER are expected to be closely linked in order to properly establish an interface with the ocean and river catchment boundaries of the continental shelf, which is relevant to the terms of references for SCOR WG 128.

LOICZ and GLP (Global Land Project) are collaborating on coastal typologies of land-based drivers of coastal change (i.e. land use and cover change interacting with material fluxes); collaboration between LOICZ and the Integrated Global Observing Strategy Coastal Theme has also been made on remote and in situ-based monitoring and observation systems for integrated coastal management (e.g. turbidity, salinity, temperature and wind regimes in the coastal ocean), targeting the areas of expansion of human coastal populations. SCOR WG 128 wishes to collaborate with LOICZ on the above mentioned activities within the frame of global change studies, particularly in the region where coastal hypoxia is concerned.

2.2.14 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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Wajih Naqvi	INDIA
Alex Orsi	USA
Gordon Swaters	CANADA
Olga Trusenkova	RUSSIA

Associate Members

Kenneth Brink	USA
Xavier Durrieu de Madron	FRANCE
John Middleton	AUSTRALIA
Pedro Monteiro	SOUTH AFRICA
Jonathan Sharples	UK

Executive Committee Reporter: Mike MacCracken

SCOR/IAPSO WG 129

Working Group 129 on Deep Ocean Exchange with the Shelf (DOES) has been set up with the following members:

John Johnson (UK,chair), Piers Chapman (USA, vice-chair),
Other Full Members: Isabel Ambar (Portugal), Jan Backhaus (Germany), Hu Dunxin (China), Takeshi Matsuno (Japan), Wajih Naqvi (India), Alex Orsi (USA), Gordon Swaters (Canada), Olga Trusenkova (Russia),
Associate Members: Kenneth Brink (USA), Xavier Durrieu de Madronj (France), John Middleton (Australia), Pedro Monteiro (South Africa), Jonathan Sharples (UK).

John Middleton and Pedro Monteiro are supported by IAPSO.

The first meeting of the Working Group will take place at the IUGG meeting in Perugia on 10-11 July 2007. It is expected that 13 members will attend. IMBER, iAnZone and LOICZ will be represented by members of the WG. Representatives of GEOTRACES and CLIVAR will attend.

Compilation of an extensive bibliography of papers relevant to DOES is underway, and already contains 550 references.

Major items for discussion at the meeting in Perugia include refinement of the bibliography, interaction with other projects and the planning of the workshop in 2008, as shown in the following agenda. Timings are approximate and will vary according to necessity. Tea and coffee may be taken while we are in session.

AGENDA SCOR WG129 (DOES)

Tuesday 10th July, Palazzo dei Priori, sala Rossa, Perugia

09.00 Welcome:	Chairs -John Johnson, Piers Chapman SCOR- Mile McCracken IAPSO- Paola Malanotte-Rizzoli
09.15 -11.45	Talks by individual WG members (about 10 minutes each), saying what they would like to see come out of the DOES WG: Isabel Ambar, Xavier Durrieu de Madron, Hu Dunxin, Takeshi Matsuno, John Middleton, Pedro Monteiro, Wajih Naqvi, Alex Orsi, Jonathan Sharples, Gordon Swaters, Olga Trusenkova (including a coffee break)

11.45- 12.15	Talks by invited representatives of GEOTRACES - Chris Measures IMBER - Wajid Naqvi
12.15-13.45	Lunch (opportunity for informal discussion)
13.45-14.30	Bibliography (do we have the right topics covered - how to split it up - how to disseminate it, etc.)
14.30-15.15	2008 Workshop (venue - date - discussion topics - invited keynote speakers - funding - resulting publications)
15.15-15.30	tea break
15.30-17.00	split into working groups to look at details for Bibliography and 2008 Workshop

Wednesday 11th July

09.00-10.00	Talks by invited representatives of CLIVAR - Roberto Boscolo iAnZone - Alex Orsi LOICZ - Hu Dunxin ICOM, NEMO - David Stevens
10.00-10.45	working groups report back
10.45-11.00	coffee break
11.00-12.15	further discussion
12.15-13.45	Lunch (informal discussion)
13.45-15.15	Check to cover our terms of reference, and matters arising
15.15-15.30	tea break
15.30-17.00	next steps and timelines - publications - any other business - responsibilities of individual members for the next 12 months.

2.2.13 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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Rubens M. Lopes	BRAZIL
Angel Lopez-Urrutia	SPAIN
Maria Grazia Mazzocchi	ITALY
Michael Edward Sieracki	USA
Hans M. Verheye	SOUTH AFRICA

Associate Members

Carin J. Ashjian	USA
J.M.H. du Buf	PORTUGAL
Gabriel Gorsky	FRANCE
Xabier Irigoien	SPAIN
Norm McLeod	UK
Song Sun	CHINA-Beijing
Bob Williams	UK

Executive Committee Reporter: Peter Burkill

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SCOR WG 130: Automatic Visual Identification of Plankton
2006 – 2007 Annual Report

1. Report of the first working group meeting held at the Hiroshima City Plaza for Town Development through Citizen Exchange, Hiroshima, Japan, 2–3 June 2007

1.1 Executive summary

Discussion of open-source software platform development

Our membership feels that we need to focus on standards such as quality assurance and dataset construction, and operate at essentially a higher level than just the development of software. We support the development of an open platform and we have carefully considered the recommendation of standards, and encourage all software developers to adopt those standards. Agreement on these issues will foster growth in this area faster than individual groups working in isolation.

Our group was unanimously supportive of development of common, open-source software platform designed to provide a framework for a complete solution (image import through to production of ecological data) for automatic or semi-automatic analysis of plankton samples.

Actions arising:

i. Define the capabilities and standards for open-source plankton identification software; identify the capabilities that are currently present in existing software; and determine which capabilities need to be added or improved. This would include discussion of the need for, and recommendations for establishment of, standards for file import and export and a determination of the degree to which the software would be open. Lead: Michael Sieracki, Philippe Grosjean, Gaby Gorsky, Phil Culverhouse, Rubens Lopes, Sun Song, Josué Alvarez-Borrego, and Mark Benfield.

ii. Write a paper that describes the group's vision for what is necessary for development of an open-source image classification software package and the status of the various component modules. This will be led by Philippe Grosjean and will likely be conducted in conjunction with the previous action item.

iii. A related action item is to write a proposal to secure funding to move the development of an open-source software platform. Lead: Philippe Grosjean.

Development of taxonomically validated image datasets

There is a critical need for leadership from the taxonomic community to secure funding for programs that integrate voucher specimen imaging and both traditional and molecular taxonomy. There are programs that have been funded by NSF to support museums to organize areas of expertise. NSF has mature programs to support the archiving of samples and collections. Fewer examples exist in other regions. In the UK, Steve Hay's NERC-

funded program to create an image-based taxonomic training and reference program is one example. While such efforts may not have a sufficient number of representative images of each taxon or images collected with the appropriate sensors to be useful for automated identification, they are a step in the right direction and could be adapted to meet the needs of automated techniques. There is also a wealth of validated image data at many different marine laboratories and on websites. We need to mine these data into a central image database. This SCOR WG will advocate, and take steps to secure the start of such programs in the United States, Europe and elsewhere, and promote links among existing programs.

A valuable contribution by our Working Group would be to establish recommendations for standards for image datasets. To that end we proposed to pursue the following action items:

i. Form a subcommittee that will make recommendations for standards for taxonomically validated image datasets: Maria Grazia Mazzocchi will chair this subcommittee with Hans Verheye (rapporteur), Alena Arashkevich, Gaby Gorsky and Priscilla Licandro.
ii. Encourage the creation of expert taxonomic networks. This will provide a means of virtually linking taxonomic experts who can assist with the identification of organisms in reference images. Lead: Phil Culverhouse with Maria Grazia Mazzocchi et al.
iii. Establish a linkage with the DNA barcoding initiative within CMarZ to explore the development of high-resolution image datasets from specimens that will subsequently be barcoded. This may include confocal microscopy images. This initiative should be linked to the previously mentioned expert network. Lead: Benfield, Song, Verheye, Culverhouse, Licandro et al.
iv. Propose a list of target species/taxa/functional groups for the automatic identification of plankton. This list would be open to discussion in the expert taxonomic networks. Considering the great variety of morphology and material characterizing marine organisms this will help the improvement of hardware and software in order to successfully identify species/taxa/functional groups relevant to the end users.

<u>Workshop needs</u>
It was agreed that training new scientists was a crucial aspect of encouraging adoption of automatic plankton identification technologies. However, many members of the working group felt that it would be instructive for those members of the group who have not used such approaches to gain experience in these systems soon, through a practical workshop that should also be addressed to the definition of standards. Another planned workshop will invite a range of experts from pattern recognition fields to summarize advances in their particular disciplines. Phil Culverhouse and Norm McLeod agreed to provide an introductory paper on relevant image analysis techniques as an initial step toward organization of this workshop.

Funding requirements
It is clear that an important role for SCOR WG130 is the promotion of its objectives to funding agencies. It is expected that a set of proposals will arise from some of the above actions, which will benefit from overt support of the SCOR framework. It was agreed that SCOR WG130 would provide letters of support to proposals that fulfill its terms of reference.

Mechanisms to advance the state of image identification/RAPID
The working group agreed that a global network of excellence would support cooperation and collaboration across what are currently disparate domains of artificial intelligence, engineering, ecology, oceanography and systematics. European FP7, U.S. NSF and the Sloan Foundation were all suggested as potentially appropriate funding sources.

Actions arising:

i. Encourage the creation of expert taxonomic networks. This will provide a means of virtually linking taxonomic experts who can assist with the identification of organisms in reference images. Phil Culverhouse and Mark Benfield will both investigate opportunities with EU FP7, NSF and Sloan.

Date and location of next meeting
Shortly after the inception of this working group, Rubens Lopes wrote a proposal to Petrobras (the Brazilian state oil company) to hold a scientific meeting in Brazil. He was funded and anticipates being able to support travel to Säo Paulo for the majority of the working group. He will inform the group of likely dates for the meeting in late 2007 or early 2008.

WG Website
The group felt that a secure website was important for effective collaboration. Phil Culverhouse offered to support a secure website at Plymouth to allow working group members to communicate, upload data and reports, share and edit reports. Some funds would be needed to create the site. The University of Plymouth has since offered the resources for web hosting. Culverhouse is exploring website design and costs. Philippe Grosjean offered WiKi concurrent editing tools for the site.

Timelines for deliverables
It was agreed that the draft report arising from the meeting would be tabled to the group within two weeks of the meeting. Drafts of all three working documents on (a) open-source software; (b) datasets, quality assurance and standards; (c) workshops for training; and (d) a brief review of current machine methods in natural object categorization would be made

available within three months of the meeting. Final versions to be sent to working group members before the next meeting.

Working Group Products to Date
A white paper summarizing the importance of, challenges associated with, and need for automated image analysis of plankton has been recently published in the *Oceanography* magazine in the 2007 June issue (Benfield et al. 2007).

Arising from an earlier publication (Culverhouse *et al*. 2006) authored by five members of WG130, the need for a web-based shared image database was espoused. From this specification a distributed web-based database called Pleione has been created (web link). It is capable of offering images drawn from *in situ* and laboratory samples of plankton to scientists across the globe. Scientists identify specimens through a web interface, and hence contribute to a consensus of opinion that validates the specific or generic identification of the specimen. Validated datasets can be used for machine and human training. All members of the working group are encouraged to visit the site and participate in the classification experiments. Phil Culverhouse and Mark Benfield have agreed to mirror this database at University of Plymouth and at LSU, which will enable experiments to be conducted in image validation with global access.

1.2 Background

The oceanographic community has long been capable of collecting and accumulating plankton samples at a rate that far exceeds our ability to process and extract meaningful ecological information from their contents. As a consequence, large archives of plankton samples are accumulating at laboratories throughout the world. The potential information contained in these samples is enormous and could contribute fundamental insights into the responses of planktonic communities to natural and anthropogenically induced environmental change. Regrettably, our inability to process the majority of these samples means that over time, desiccation, acidification, and catastrophic events are constantly destroying preserved organisms before they can be examined, counted, measured, and identified.

Nets, pumps, and water-bottles represent core-sampling techniques for plankton and are the basis for many long time series and oceanographic programs such as GLOBEC. While these methods have the advantages of providing a physical record of planktonic organisms from [frequently] large volumes of water, one of the central challenges confronting plankton researchers is the relatively low spatial and temporal resolution that these approaches provide. It is widely recognized that many important ecological interactions and processes involving plankton, occur on time and space scales that are typically much finer than those normally sampled using traditional samplers such as nets. Moreover, the invasive nature of net tows causes disruption of relevant plankton features (e.g., patchiness, thin layers), which

are important to be explored for a better understanding of community structure and distribution and can be maintained only by *in situ* observatory systems. The other challenge is that ecologically important but fragile species (e.g., ctenophores, siphonophores, larvaceans) are under-represented when studying plankton collected with conventional nets. The past decade has seen a rapid evolution in development of innovative *in situ* and benchtop imaging systems designed to quantify the contents of water at fine temporal and spatial scales (Benfield *et al*. 2007). These instruments typically collect images at high rates (up to 60Hz) resulting in the rapid accumulation of very large numbers of digital images (e.g., 108,000 images hr^{-1} @ 30 Hz). Another recent development in the plankton imaging field has been the emergence of highly modified flatbed scanners that create a high-resolution digital record of the contents of preserved plankton samples (Grosjean *et al*., 2004; http://www.obs-vlfr.fr/LOV/ZooPart/ZooScan). This instrument produces large image files that can contain many hundreds of zooplankton and other particles. While all of these imaging systems represent a welcome addition to our plankton sampling/sensing toolbox, they also present a new challenge: the manual analysis of images from such systems is impractical; due to the huge amount of information and quantities of images they produce. New image analysis systems offer a potentially advantageous solution compared to manual methods of counting and sizing. With the aid of image analysis and classification software and hardware, the planktonic targets within images can be located, isolated, and identified to at least major groups. Many sophisticated automatic recognition algorithms exist, and research in this area is very active. Thus, there is now a real potential of using image analysis techniques to obtain more refined taxonomic classification in the near term.

To assess and maintain biological diversity is a major concern in marine science. If we want to achieve any progress in addressing plankton diversity in the ocean then the development of new technology needs to be sponsored for rapidly imaging and identifying specimens in plankton samples. The new technology will notably shorten the time of sample analysis, and it will support existing (and increasingly scarce) taxonomists and marine ecologists (Culverhouse *et al*. 2006). Looking at this (near) future perspective, this working group focuses on the automation of identification. Drawing from recent progress in object recognition in the wider machine vision community, marine scientists and engineers have made significant progress in demonstrating the feasibility of automated recognition of planktonic taxa.

A call for collaboration by both software developers and end-users arose from a meeting at the 3rd Zooplankton Productivity Symposium held in Gijon, Spain in 2003. Further discussions led to this working group as a direct response to a recent 2005 GLOBEC/SPACC-sponsored workshop held at San Sebastian, Spain (Irigoien *et al*. 2006). That workshop, which brought together software and hardware developers, machine vision and pattern recognition computer scientists, taxonomists, and end user planktologists, concluded that it was imperative to co-operate and not compete in the development of

machine vision solutions for automatic identification of plankton. The Research on Automated Plankton Identification (RAPID) initiative arose from this workshop (Benfield *et al*. 2007). RAPID is designed to advance the development of open-source, community-based plankton identification software and WG130 will act as a steering group for RAPID.

GLOBEC, IMBER, Census of Marine Life, and Census of Marine Zooplankton are some of the global initiatives that will benefit from the outputs of this working group. This is reason enough for an international approach to this work. However, it is also important from several other perspectives: plankton identification is an international problem, and a global approach will increase the visibility of local solutions to identification and perhaps also adoption of solutions from outside marine science. A common platform will make it quicker to integrate new software into applications that are immediately useable by marine scientists.

1.3 WG130 Membership

WG130 was formed in November 2006 and consists of the following persons:

Co-Chairs:

Phil Culverhouse
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Mark Benfield
Department of Oceanography and Coastal Sciences
Louisiana State University
Baton Rouge, LA 70803 USA

Members:

- Elena Arashkevich, Shirshov Institute of Oceanology, Russian Academy of Sciences, Russia
- Josué Alvarez-Borrego, Optics Department, Division of Applied Physics, CICESE, Mexico
- Philippe Grosjean, Numerical Ecology of Aquatic Systems, Mons-Hainaut University, Belgium
- Rubens Lopes, Instituto Oceanográfico, Universidade de São Paulo, Brazil
- Maria Grazia Mazzocchi, Stazione Zoologica ‘Anton Dohrn’ Napoli, Italy
- Michael Sieracki, Bigelow Laboratory for Ocean Sciences, USA
- Angel Lopez-Urrutia, Centro Oceanográfico de Gijón, Instituto Español de Oceanografía, Spain

- Hans Verheye, Biological Oceanography, Marine & Coastal Management (Research and Antarctica & Islands), Dept of Environmental Affairs & Tourism), South Africa

Associate Members:

- Carin Ashjian, Department of Biology, Woods Hole Oceanographic Institute, USA
- 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

All Full and Associate members of WG130 except Drs. Ashjian, DuBuf, and Irigoien were able to attend the first meeting of the group. In addition, Dr. Priscilla Licandro (Sir Alister Hardy Foundation for Ocean Sciences) attended and is now an Associate Member of the group.

1.4 Meeting Agenda

- Review of WG130 terms of reference
- Introductions and brief position statements by the membership
- Overviews of some existing plankton identification software
- Discussion of open-source software platform development
- Discussion of development of taxonomically-validated image datasets
- Workshop needs
- Funding requirements
- Mechanisms to advance the state of image-identification/RAPID
- Date and location of next meeting
- WG Website
- Timelines for deliverables.
- Working group products to date.

1.4.1 Review of WG130 terms of reference

- *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.*
- *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.*
- *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 recognized, peer-reviewed journal or a book by a major publisher.*

1.4.2 Introductions and brief position statements by the membership

Each member introduced him/herself and outlined his/her interest in the issue of automated plankton identification and relevant expertise.

Phil Culverhouse: In 1989 Bob Williams and I began by looking at the problems of recognition of small sets of closely related species of phytoplankton, as a way of exploring machine vision algorithms. I'm an engineer but have an interest in cognitive processes. For almost every year since then we have been telling people that this is a difficult problem, but we can make progress. Initially, we started with systems that can give us 60 percent performance. Now we're going up to 70-80% with the latest variant of our recognition software (DiCANN) tested on species and genera of phytoplankton and zooplankton. The people who reviewed that work were highly critical of what they perceived as poor performance. Why should they be interested in supporting this? The answer is that machines can be as good as people, and in fact people may not be reliable categorizers. I became interested in what level of accuracy humans are capable of achieving. We were able to demonstrate that humans can be quite poor in certain cases. It is possible to be better than 90% accurate when there is inter-calibration among groups. In groups that don't inter-calibrate, the performance can be very poor and as low as 50%. There are errors and biases in the analyses and they haven't been assessed in any systematic way. There is now an understanding that while machine analysis has difficulties, so do humans. Recently Bob and I made the Harmful Algal Bloom (HAB) Buoy system for high-volume 24/7 monitoring of plankton *in situ* and we've been interested in making it more compact and low power. We're also moving forward to extract more information using machines, as we make them behave more like experts using hybrid generative models and expert systems.

Mark Benfield: I have had a lot of experience working with imaging hardware. I started out working with the video plankton recorder (VPR) while at Woods Hole and later at LSU I began to construct my own imaging systems. I've built several different in situ instruments. I'm not a software programmer and I can't write the software necessary to process the vast numbers of images that these systems collect. I have rows of videotapes from the VPR sitting in my lab and hard drives full of images from ZOOVIS. There is a lot of great information in those tapes and drives, but I can't get at

it. Recently I've been involved in an NSF-funded project with Mike [Sieracki] at the Bigelow Laboratory and the University of Massachusetts computer science department to develop public-domain image processing and classification software. I've been following image classification software used with other systems around the world and there a common problem. There just isn't widely available, user-friendly software out there to extract useful information from these large image datasets. We're not going to realize the full potential of these imaging instruments until we have useful software to turn them into user-friendly systems. Another area that I'm interested in is in phytoplankton and microzooplankton imaging. My wife is a zooplankton ecologist and has just been funded to purchase a FlowCam so that's another image dataset we'll be working with at LSU. We still use nets in my lab and would like to be able to process our net samples using systems like ZOOSCAN. There are over 4000 oil platforms in the Gulf of Mexico. These platforms have high-bandwidth connections to shore and would make an outstanding oceanographic observation system that could be equipped with imaging systems. There is no point in doing so until we have software that can handle the vast numbers of images that such an observatory would produce. We need software to be open-source and user friendly, and we need it soon. The Gulf of Mexico has a large plankton time series that started in 1987 covering many stations over the shelf collected at least twice a year. These samples were sorted for fish eggs and ichthyoplankton, but had not been worked up for zooplankton. The samples were stored at the Gulf Coast Research Laboratory and the building housing the collection collapsed during Hurricane Katrina. A large fraction of this time series was lost. I firmly believe in the importance of using systems like ZOOSCAN to create a digital archive of these data. These archives need to be backed up and distributed so that we don't have the equivalent of a building collapse when a hard drive fails. I feel very strongly that we have a very important opportunity here today. We can change the way these imaging systems are used. There is a very large, potential user base for imaging systems out there, but nobody is going to adopt these instruments unless those systems are capable of providing useful information. I'm encouraged by what I've heard so far in this meeting, and we've got the right people here. I hope that in a few years we're going to revolutionize how imaging systems operate.

Alena Arashkevich: I am a classical taxonomist, working with plankton ecology and physiology. In the past I've used submersibles to investigate the vertical distributions of plankton and found new information on thin vertical layers. New approaches are potentially very important. In terms of laboratory analyses, automated sample processing can speed things up, but unless it adds new information, it isn't very useful. In terms of field instrumentation, imaging systems can add a great deal of new instrumentation. I bring taxonomic analysis and expertise to the group. My primary taxonomic group of interest are the copepods, particularly from Arctic regions and the Black Sea. I would like to see automated analysis of abundance and biomass.

Josué Alvarez-Borrego: I work at the Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) in Mexico. I received my B.S. in physical oceanography and M.S. and Ph.D in optics. I'm interested in recognizing complex patterns in plankton and bacteria. The challenge is to resolve the different shapes, morphologies and patterns associated with the different orientations of organisms. In my lab we have an automated microscope and have developed some autofocus and fusion algorithms for that system. My field is the Image Processing. We have some experience in to develop invariant correlation algorithms applied to recognize some microorganisms like copepods, phytoplankton and some bacterias like tuberculosis or *Vibrio cholerae* 01.

Philippe Grosjean: I am relatively new to plankton. I started to work on the population dynamics and modeling of sea urchins and then I moved to start working with plankton with the Villefranche group. I joined Gaby Gorsky's team to develop the ZOOSCAN and then moved to Belgium to start a new lab. One of those things I chose to work on was to develop software for biological oceanography and in particular, image analyses of plankton. In terms of my feelings about this working group and image analysis in general, I realize that not everyone is convinced that image analysis can replace a taxonomist. I don't think that a computer should mimic or replace a taxonomist. What we really need is something that can provide new information. Systematic bias from computer analysis can be further modeled and corrected. With taxonomists, the bias is more random. From one taxonomist to another the bias is different. This produces an error that is hard to detect and correct. It also raises the question of whether it is possible to get results that are comparable from one group to another, and the computer could help here. There are many different plankton time series in existence. The challenge may be putting all of them together. It depends a lot on practical aspects. How are the data stored? How easily can the different software be used? For all these reasons, we need a common platform. Next what can we get from it? Well, we have to be imaginative…

Rubens Lopes: We also have a large [zooplankton] sample collection, perhaps not as long as some of you, but our oldest collections date back to the 1970s. We have the same challenges. We need people to run the samples. Most of our surveys were dedicated originally for fish eggs and larvae. Most of the samples have been processed for ichthyoplankton, but not for other taxonomic groups. When I first heard about the imaging systems and hardware, I was excited and gradually I have learned that the amount of work still required for image recognition remains very large. In that sense I started to get involved in the field and learn a bit about it. I feel I'm just scratching the surface. I purchased a ZOOSCAN a couple of years ago and have just started to really use it. The ZooProcess software seems to work well. We don't just work with

macrozooplankton, but also with microzooplankton and are interested in working with other instruments as well. We also are involved in challenging biomonitoring activities. We have one of the largest harbors in Brazil and there is very strong demand to look at biodiversity in the sea. My feeling is that we have been able to get very little information using traditional techniques, compared to the physical oceanographers. This field of image analysis is the future. It takes us to other interests: ballast water sampling where there are potentially a lot of resources available to support the research. You cannot make a commercial vessel wait in a port, so there is a need for a rapid, automated recognition system for the organisms in ballast water. When you compare the biological information to the physical information in ballast water, the salinity doesn't give you an idea of the origin of the water. In Brazil we have a very strong petroleum industry and the oil companies are very interested in monitoring programs. There is a great deal of application for software, also in mariculture. I have these two major interests in participating in the working group. There is a key role for the working group. To try and encourage development of common platforms and to make those platforms reliable. There is an issue of confidence here. Many people that have considered using this technology, were frustrated because they couldn't use them effectively. We should try to interact here to make an effort to build confidence in those systems. We should try to learn more lessons from other fields.

Maria Grazia Mazzocchi: I work in the field of marine zooplankton ecology and taxonomy using traditional methods such as nets, microscopic observations and counts at the dissecting microscope. My taxonomic expertise is mainly in copepods (and a few other groups) and I work mainly in the Mediterranean Sea and other subtropical areas. While I have no experience in automated instruments, I recognize that this is the future for zooplankton field studies, and for this reason I am very pleased to be part of this WG. The *in situ* observatory systems are non-invasive and depict the real distribution and behavior of the organisms in the sea. Automated recognition is important for my lab and we have bought a ZOOSCAN. A Ph.D student, who is funded by the NoE EUR-OCEANS and is shared between SZN in Naples and LOV in Villefranche, is using the ZOOSCAN to harmonize and compare the two long-term time series from the Gulf of Naples and the Bay of Villefranche. To the best of our knowledge, this is the first effort to compare a time-series data set using the ZOOSCAN with the traditional processing. It is clear to me that from most of the scanned images we are able to identify copepods to genus and sometimes to the species level, as well as to distinguish juveniles from adults. Now we need good software to process the samples and identify things to this level. Another important aspect of automatic recognition is the inter-calibration among the available systems. I think that the interdisciplinary nature of this WG is a strength. I can contribute to the biological aspects of zooplankton taxonomy.

Michael Sieracki: I have a background in microbial ecology and have been involved in visual analyses of microscope images. The FlowCam was developed in my lab and we quickly came to the realization that we had to do something with all these images. We have a collaborative project to develop automated tools to classify images. That project is working with both phytoplankton and microzooplankton. I was also aware of what was going on with the VPR and recognized that there needed to be common tools. Our project involves Mark Benfield and Cindy Pilskaln to develop software tools. At the same time we became aware of the work that Philippe was doing and his vision for a common framework. There are a lot of people who would potentially be involved in this initiative as end users. There are things we can do to make the whole thing simpler that should result in useable tools. In the future these instruments will have to be simpler to use.

Angel Lopez-Urrutia: I have two main lines of research: application of the metabolic theory of ecology and time series. I can program in R and have worked with Philippe Grosjean on a precursor to ZooImage. My ambition is to get a system for zooplankton that is somewhat similar to what a flow cytometer is for the microbial community. We need to put some realistic milestones on our work. First: am I able to get size structure from an image. Second: can I identify different functional groups? This is a realistic milestone that is achievable in a few years. The final one goal is: can we use automated systems to measure biodiversity?

Hans Verheye: I work for Marine and Coastal Management in Cape Town, South Africa since 1982. This government agency deals with management of fisheries and the coastal environment. I am a biological oceanographer with an interest in zooplankton. Part of my job is monitoring the food environment of fish stocks and in particular pelagic fisheries. I have interests in long-term changes in zooplankton, both off South Africa (southern Benguela Current region) and Namibia (northern Benguela Current region), via retrospective analyses of substantial sample archives that date back to the 1950s. This is one area where emerging technologies can have a great deal of utility. We are still engaged in the monitoring of zooplankton populations. At the moment analyses of both the historical archives and ongoing are using classical microscopy, which is very labor intensive and time consuming, but I would like to use automated systems in order to speed up the analyses. A colleague has purchased a ZOOSCAN that (once it is working – it has been sent back to be replaced by the newer model) will be used to investigate the spawning habitat of pelagic fishes. Their initial focus is on fish eggs and larvae collected using the continuous underway fish egg sampler (CUFES), but they recognize the importance of zooplankton (collected using conventional net samplers). I also represent the BENEFIT program: a regional research and capacity building program (involving Angola, South Africa, and Namibia) that focuses on the Benguela Current (1997-2007). Three to four years ago it

was augmented by the Benguela Current Large Marine Ecosystem (BCLME) program. We have established an enormous plankton archive that has been partially analyzed. I sit on the steering group of the Census of Marine Zooplankton (CMarZ) and it would be important to tie this barcoding project with SCOR WG 130. I am also working on the establishment of a continuous plankton recorder (CPR) survey program in southern Africa. Will image analyses and barcoding be a useful or practical tool to examine CPR samples? We are about to launch an LME on the east coast of southern Africa, viz. the Agulhas-Somali Currents program (ASCLME), which will generate even more plankton samples. We therefore have an urgent need for technology that will enable us to keep up to date with sample analysis and also handle retrospective analyses of existing sample archives. I'm not sure if I will be able to contribute to development of software. From our perspective and speaking perhaps as a representative of developing/transitional countries, there is certainly a need for applying automated analysis technologies. From the perspective of SCOR WG125, our brief is *inter alia* to make comparisons among and within basins of available time series of zooplankton with respect to different 'modes'. For instance, the mode that I'm concerned with is to examine how size-spectra of zooplankton communities have changed over time and whether there is any synchrony between ocean basins in that respect.

Gabriel Gorsky: I started working on the taxonomy of euphausiids and shifted to appendicularians. While observing appendicularians from submersibles, I recognized the importance of marine snow. Knowing the importance of appendicularians in producing houses and their incredible abundance, I looked for data. Nothing was in the literature because of the difficulties in sampling. I built the Underwater Video Profiler (UVP) to address this issue. It was built at the onset of JGOFS. Zooplankton were not a favored topic of JGOFS. Many zooplanktologists were collecting samples, but few were actually processed. Consequently, many [samples] were lost to acidification and desiccation. In hindsight, the value of these collections can really be recognized. We have also seen a loss of taxonomic expertise. Moreover, it has become more difficult to work with formalin-preserved samples because of environmental and toxicological issues. Preservation of samples via digitization is important and this led to the development of the ZOOSCAN. It is important to have useable, user-friendly instruments that can be put into the hands of a novice and still provide useful information. In my lab the ZOOSCAN is now doing 14 samples per day.

As for imaging versus genetics, you have to consider where many samples for genetics are coming from. The CPR is only giving information in the first 10m. We know little about what is happening deeper. In deeper layers, the community is dominated by fragile and gelatinous forms. I agree that we need very high resolution images at a level that is not yet available. There is also a real need for moored optical devices that provide real-time data on zooplankton. We should take advantage of deepwater

geological observatories and nutrient observatories. They have the high-bandwidth links to the shore that could carry image data.

Imaging is a very promising tool to discover new things. At present, it is probably better suited to address ecological questions rather than taxonomic ones. We are still a long way from automated taxonomic information. However, for size classes of 400 microns and larger, we can go to species level for many species of appendicularians. We have processed ten years of samples in five days and used it to study one particular species. Intercalibration is very important because when a training set is being built in real time by two individuals that were 800km apart, the quality of vignettes (regions of interest) must be the same. Interactions will be more and more virtual, but without intercalibration two different systems will not be able to get the same answer. Prototype instruments and small companies are also a problem. They may not have the budget or experience to develop and market the instrument properly. At the moment we are working with a large firm (BIOTOM) to develop the ZOOSCAN. Finally, the reliability of archived data is highly variable. By scanning archived data, we may still be able to get functional groups. Both in situ and laboratory imaging, along with genetics, are the future. The information from these techniques is highly useful for society.

Norm McLeod: I come from two areas. I conduct research on the palaeontology of foraminiferans and radiolarians and also work in the area of morphometrics (both techniques development and applications research). There are many resonances with what WG 130 is trying to do and what we have been doing in morphometrics over the past 15 years or so. Five years ago I became interested in neural nets. My program in this area is now one of the strongest research areas in the NHM and probably in any UK systematics institution. I am also finishing off the final edits on a book on automated object recognition which is very much along the lines of a book that RAPID wants to produce in the future. I am going to gently disagree with a lot of what I've heard about the nature of the problem and the work WG 130 wants to do. This [automated specimen identification] is a generic problem not a zooplankton community problem. The techniques the zooplankton community is working on in this area are of general utility, far beyond the zooplankton community *sensu stricto*. One of the groups I work with is the petroleum industry. The forams come up in drilling operations. When you are trying to drill a well, there is a biostratigrapher/systematist working on the specimens coming up in the drilling mud. Million dollar decisions are being made on the identification of the forams in those samples. The identification decisions you are trying to make are the same ones that palaeontologists and many others are trying to grapple with. But you have a headstart. You already have the machines to collect the images. I think you are a bit behind the curve in terms of the software to do the identifications. That's fine, you'll catch up. Most importantly, you

have a three-year program, broad support from your user community, and money to spend to get more money. I see this group as being able to take a strong leadership role and to capitalize on what other groups have done. This is not just about zooplankton and we need to recognize that.

Sun Song: I am interested in the output of imaging systems to answer questions in marine science and zooplankton ecology. Local and central governments are always asking my institute: what is going on in the ocean (with respect to zooplankton and fisheries)? While it's known that zooplankton play an important role in the ecosystem, how can one obtain that information? They are looking for something simple, analogous to tools used by physical oceanographers, that can be measured to classify zooplankton. About five years ago we purchased two optical plankton counters (OPCs). They haven't worked well. We really want to use a telemetered OPC. In the continental shelf area, there are a lot of phytoplankton and jellies that complicate their use. I would like to use image analysis systems and microscopy to identify sample contents. Another group (CMarZ) is using barcoding to identify zooplankton. What we need is a technique that integrates information and provides species composition and biomass data. We have a large plankton sample archive (more than 100,000 from over the past 50 years of benthos, fish and zooplankton). Samples are catalogued and there are pictures of the samples. We really want to use image analysis to process the samples. Only ⅓ to ¼ of samples taken in the past 30 years have been processed.

Bob Williams: For the last forty years I have worked and published data on plankton from ocean, shelf and estuarine habitats. Twenty of those years I have been spent as a bench scientist identifying zooplankton. I have been an Honorary PML Fellow for the last 14 years As well as collecting and identifying plankton I have spent a great deal of time in developing instrumentation for plankton net systems such as the Longhurst-Hardy Plankton Recorder (LHPR), the CPR, and the Undulating Oceanographic Recorder (UOR). My interest in automatic identification of plankton goes back many years, realized through my work with Phil Culverhouse. I have always considered that it would be possible to automatically identify plankton from digital images. I firmly believe that if a taxonomist can identify an image, then a machine can as well. I believe that it is a goal that will be realized in the not-too-distant future.

Priscilla Licandro: Automated identification is a new technology that can provide very useful information. At SAHFOS we run the longest and geographically the most extensive marine biological survey in the world. Merchant ships routinely tow the Continuous Plankton Recorder (CPR) along their normal routes of passage throughout the majority of the North Atlantic together with, more recently, the North Pacific and the Atlantic sector of the Antarctic. We are therefore able to provide taxonomic, plankton expertise for different regions of the oceans. In general, we identify up to

species level for copepods and to genus or a higher taxonomic level for other groups. Taxonomy and biogeography are what we deal with every day, and at SAHFOS there is regular training for younger taxonomists. I do not think that in the short term automated techniques are useful for the routine analysis of CPR samples. This is mainly due to the peculiarity of our sampling method. The CPR filters the plankton, which is then retained on a moving band of silk progressively rolls up inside the CPR as the ship progresses along its route. For this reason, some of the obvious morphological characteristics of many planktonic organisms are often damaged or missing. Identification of the plankton sample is carried out on the silk by a CPR analyst. The CPR analyst uses a wide range of morphological features, together with distributional/ecological knowledge to achieve taxonomic identification of a specimen. Confocal microscopy, has however been successfully applied to plankton specimens collected by the CPR.

There is a great potential in imaging technologies for the spatio-temporal study of plankton distribution *in situ* Although this is something that is still lacking, I don't see why in the future in a framework of a research project, the CPR couldn't be provided by a Video Plankton Recorder or another optical imaging system to study for instance gelatinous plankton in situ. The applications of plankton imaging for processing preserved plankton are interesting as well. Many people want new tools to speed up taxonomic identification. In this respect it is important to give clear information about what can already be done, what we would like to achieve and what may be realistically done in the near future. For instance, for any system of automatic visual identification to provide information on plankton biodiversity, it would be necessary for the system to recognize and identify all species. Taxonomic expertise is being lost because experts are retiring. It is important to provide funding for training the new generations. Taxonomy is one of our main skill and interest at SAHFOS; because of this our website will host a manual for the identification of zooplankton around UK, based on an initiative led by Steve Hay (FRS, Aberdeen).

1.4.3. Overviews of some existing plankton identification software

1.4.3.1 ZOOSCAN Software (Gaby Gorsky)

The ZOOSCAN system consists of the hardware plus software. Software consists of ZooProcess (macros written in ImageJ) and Plankton Identifier (written in Delphi with the Tanagra package). The software is freely available from http://www.zooscan.com). Raw images from the ZOOSCAN are imported into ZooProcess. ZooProcess has a metadata file that always follows the image data throughout the processing sequence. Raw images are converted to an 8-bit normalized image (256 gray levels). The method of normalization allows full inter-calibration among different ZOOSCANs and ensures inter-compatibility of different training sets. After normalization, the regions of

interest (vignettes or ROIs) are automatically isolated and features are extracted from each. These are summarized in a file (.pid).

ZooProcess contains a series of tools. These allow production of basic statistics, object separation, manual measurements, and semi-automatic identification (for production of training sets). Thumbnails are used for training set production, manual identification, and semi-automated identification. Plankton Identifier was written by a programmer who is also a zooplankton specialist (Dr. Stephane Gasparini). It is a general software that can handle any kind of image. After images have been extracted in ZooProcess they are frequently put into different taxonomic categories by a human for production of a training set or for manual classification. When an image is placed in a category, it is indexed. This is important because when students or inexperienced people are working with images, this feature prevents duplication of objects in two or more categories due to human error. The .pid text files from ZooProcess are also brought into Plankton Identifier.

Data analysis is done using Tanagra, which is embedded in Plankton Identifier. Tanagra is a complete statistical package. Tanagra uses features extracted from the image. There are currently 30 single features and 13 combined features available for classification. Currently available classification methods include K-nearest neighbor, two support vector machine (SVM), random forest, decision tree, multinomial logistic regression with ridge estimation, and multi-layer perceptual neural network. The results are presented in a statistical report (html format) that includes methods used, classification accuracy and performance, and a summary of results.

An example of the application of the software for a difficult classification problem from the North Atlantic was given.

1.4.3.2 Visual Plankton (Mark Benfield with post-meeting information from Cabell Davis)

This software was briefly described with the caveat that the developer and users of the software could not be present. Cabell Davis from Woods Hole had kindly provided a PowerPoint presentation summarizing the software. Philippe Grosjean had discussed the software with Cabell Davis and was able to include additional information on its capabilities.

Visual Plankton is written in Matlab and is the software that, along with other software, is designed to work with the VPR. Visual Plankton (VP) has five steps: (1) calibration, (2) focus detection, (3) training, (4) automated

classification, and (5) viewing results. The method is described in Davis et al. (2004, 2005) and Hu and Davis (2005, 2006). Calibration is done using a calibration target, and the VP interface for this step is used to record the dimensions and compute the image volume for subsequent abundance estimates. The focus detection step in VP simply tells the user to run a separate program to extract ROIs (vignettes) from raw VPR images. This program (called "deck.exe" for the real-time VPR or "autodeck.exe" for the autonomous system) does a running average (500 frame) background brightness correction, a segmentation (binarization) based on user-selected brightness threshold setting, BLOB detection and size thresholding using a user-specified size threshold, and focus thresholding (Sobel gradient based and other routines used) using a user-specified focus threshold. The resulting in-focus ROIs are written into automatically generated subdirectories for year-day and hour, each ROI being named as millisecond time of day. Using settings determined during calibration, this program discriminates between targets within the image volume and those outside of it. If conservative focus threshold settings are used, many unwanted out-of-focus images will be obtained, so it is important to be careful in selecting the focus threshold settings during calibration. The ROI extraction program (deck or autodeck) also writes files containing navigation and VPR sensor data.

Once a set of in-focus ROIs has been obtained, a subset of these ROIs is copied to a parallel directory (named 'trrois') for training. Visual Plankton uses the freely available IrfanView software (http://www.irfanview.com). A human goes through the ROIs and puts them into different folders of taxonomic categories, including an "other" category that includes unidentifiable and rare taxa. For building (training) the classifier, the software first finds all trrois folders for a specified cruise and assembles the training set. The user then selects which tows and taxa to use in the training and specifies the minimum and maximum numbers of objects to be used in each category of the training set, then presses the Build Classifier button. VP then extracts shape-based and texture-based features from the training ROIs and builds both a neural network (NN) classifier using the shape-based features and a support vector machine (SVM) classifier using texture-based features (co-occurrence features). After building the classifiers, VP automatically builds a confusion matrix using a cross-validation method which involves a leave-N-out approach, where N is the number of taxa in the classifier.

Once the classifiers are built, the next step is classification. The user can choose single classifiers, SVM or NN, or a dual classifier consisting of both, the dual classifier is the default. In the dual classification mode, if both

classifiers agree on the identity of an object, then it is classified as that object. If they disagree, then the object is classified as unknown. The dual classifier greatly reduces the number of false positives and increases the specificity. The automatic classification creates autoid (aid) files for each taxon, each file containing a list of ROIs belonging to that taxon. The classifier also creates corresponding measurement files for each taxon, with measurements corresponding to the list the aid files. The final step is data visualization, which plots abundance of selected taxa. The plotting routine reads the autoid results and creates a list of times (in decimal yearday) when the selected taxon was observed. This list then is time-matched to navigational (GPS) and VPR sensor data (depth, C, T, fluorescence etc). The program creates processed data files containing individual-based and binned data. For individual data, navigation and sensor data are interpolated, based on time, to the time of each identified organism. For the binned data, the observation times of individual ROIs are binned into the time bins of the navigation and sensor data (typically 1-s) and the number of individuals per time bin is divided by the volume imaged during the sampling period to give the abundance in number per liter. The abundances of each taxon are automatically corrected for classification errors using the proportion of true and false positives in the confusion matrix. The abundance data then are used to visualize the spatial distributions of the taxa in relation to the corresponding hydrographic properties. This can be done in real time for the towed system and off-line for the autonomous system. The software can be freely downloaded from a website: http://www.whoi.edu/page.do?pid=11348.

1.4.3.3 NSF-ITR Project Software (Michael Sieracki)

A group from the Bigelow Laboratories, University of Massachusetts and Louisiana State University have been developing software that is prototyped in Matlab, but the goal is to produce them in open source languages such as Java and Weka. At the Zooplankton Production Symposium, most of you saw an example of one product that we're using, which is an interactive thumbnail browser called PICT. PICT is designed to facilitate production of training sets. It has a classifier running in the background watching what the user is doing and assisting with the classification. We're also working on a package that is an interactive confusion matrix where you can interrogate the confusion matrix and find the instances in the features that are causing the inaccuracies.

1.4.3.4 ZooImage/PhytoImage (Philippe Grosjean)

ZooImage and PhytoImage *are essentially* the same program with different names. The objective of ZooImage is to build a framework that allows the analysis of a variety of plankton images. The plugins that have already been

developed for use with particular types of images or different classifiers are just examples of how the system can be used, expanded or customized.

ZooImage is based on Java (with ImageJ libraries) and R (a GNU public license, open-source language). We decided to start with those because they were complimentary and both are completely free and available for all three platforms (Windows, Linux, Mac-OS). There are three ways to access the functions in this software: all functions can be accessed by writing a few lines of code; access through a graphical user interface containing customizable menus; and assistant dialog boxes eases direct use of the various functions contained in the toolbox.

The ZooImage toolbar contains an icon to acquire images, which allows acquisition from an instrument. In the case of a scanner, it starts the VueScan driver to scan a sample. It's just a convenient way to start another program. The import icon allows datasets of images to be brought into the software. Next you process the data. In the processing, you switch to another language (Java using ImageJ). There are specific plugins for particular types of images. Again, the ZooImage software is a flexible framework that allows the user to customize the system for their particular application. The plugin allows modification to the software without the need to recompile it.

The creation of the manual training set is similar to other packages. One creates a series of directories containing ROIs/vignettes of different categories. You can create as many different taxonomic categories as you require. Once you have a manual training set, you are able to build a classifier. The output from the classifier is a confusion matrix and identification of the unknown particles, size distributions, biomass, and abundance. One can quickly graph the results using the built-in graphical functions in R. Then you can export the data to another package should you wish to do so.

A few summary points. The software is free using a GPL (gnu public license) and open. At the moment it is a flexible skeleton that readily allows for flexible modification via authoring of different plugins. All the software in it could be compiled in the future for other platforms. At the moment it is just for Windows, but adaptation to Mac OS and Linux/Unix is rather straightforward. The software is available from: http://www.sciviews.org/zooimage.

1.4.4 Discussion of open-source software platform development

The group undertook an extensive discussion of the pros and cons of supporting the development of a common open-source image classification software platform[1]. We recognize that we cannot and should not attempt to prevent individuals or groups from pursuing and supporting their own architecture. Commercial instruments such as the VPR and ZOOSCAN have an immediate need for operational software to classify their images and any attempt to discourage development of their associated software would adversely affect their commercial success. Moreover, the parallel development of some image classification software specifically designed to work with commercial instruments fosters a healthy environment of innovation, which will ultimately benefit both commercial and open-source packages. It is our hope that the best features of these other software packages, such as Visual Plankton or ZooProcess, could be incorporated into the open-source software platform.

There is a potentially large user base of scientists who would like to adopt *in situ* or laboratory-based imaging systems. Until flexible and user-friendly software is available for these instruments, their widespread adoption will be limited. As a SCOR Working Group, we should encourage international cooperation among software developers to use and enhance the capabilities of open-source software platform for plankton identification. Such software would ideally be flexible enough to provide a common solution for the ever increasing numbers of imaging systems being developed.

There is a need for a subset of our group along with others to identify the core requirements of an open-source software system and to determine which of the existing packages perform those various tasks most effectively. Then a proposal needs to be written to fund the implementation of the best of the existing packages into an open-source platform.

In terms of extant software, ZooProcess is nearly complete. Gaby and his team are not interested at this point in switching to another package such as ZooImage because they are close to having a system that meets their requirements and the successful development of their software is dependent upon the close proximity of their programmers and hardware developers. Nevertheless, their software may become easily compatible with the ZooImage software. Ultimately, they feel that their software development activities will enrich the future open-source platform through incorporation of useful features from ZooProcess/Plankton Identifier. Visual Plankton is based on Matlab and therefore is at a disadvantage due to licensing issues.

[1] The term platform refers to a collection of software that embodies a range of tools, which all can communicate through common interfaces as required.

ZooImage represents a useful model for the open-source platform. The primary advantage of ZooImage is that it is written in R – a language that is rich in features. Although it has a relatively steep learning curve, once mastered, a developer is able to write complex programs with more powerful graphing and analysis features than other packages such as Matlab of Delphi. One criticism of packages like Matlab is that with new releases, there are legacy issues that lead to incompatibilities. R does not suffer from this issue to the same extent as its development is incremental, with built-in test routines for each new procedure that automatically generate reports regarding the incompatibilities that may occur.

Why not use a simpler language? Execution times are issues as well as memory management. The willingness of groups to work in R is limited to some extent by the reluctance to commit to open-source initiatives that may not have longevity. A strong statement by our group would likely sway them.

There is also a potential risk to using ImageJ because it is written by one person. If that individual stops supporting it, and there are architecture changes, then it might not work any more. This is a risk, but realistically not a great one, because the code is available and others will likely step up to continue to support it. There are other options. Intel has published libraries of image processing functions that require code to implement. Again, the utility of such libraries depend upon the willingness of the company to continue to support them.

How will the development of ZooImage be furthered? It will require money. A subset of the group, and others, will need to write proposals and get funding to develop the common software. If it is fruitful, then the community and funding agencies will be likely to continue to support the initiative.

Our membership would like to suggest that as a SCOR WG, we need to focus on standards, quality assurance, dataset construction and operate at essentially a higher level than just the development of software. We support the development of an open platform and we have carefully considered the recommendation of standards, and encourage all software developers to adopt those standards. Agreement on these issues will foster growth in this area faster than individual groups working in isolation.

After much discussion, our group was unanimously supportive of development of a common, open-source software platform designed to provide a complete solution (image import through to production of ecological data) for automatic or semi-automatic analysis of plankton samples.

Action Items:

i. Define the capabilities and standards for an open-source plankton identification software platform; identify the capabilities that are currently present in existing software; and determine which capabilities need to be added or improved. This would include discussion of the need for, and recommendations for establishment of standards for file import and export and a determination of the degree to which the software would be open. Lead: Michael Sieracki, Philippe Grosjean, Gaby Gorsky, Phil Culverhouse, Rubens Lopes, Sun Song, Josué Alvarez-Borrego, and Mark Benfield.
ii. To write a paper that describes the group's vision for what is necessary for development of an open-source image classification software platform and the status of the various component modules. This will be led by Philippe Grosjean and will likely be conducted in conjunction with the previous action item.
iii. A related action item is to write a proposal to secure funding to move the development of an open-source software package Lead: Philippe Grosjean.

1.4.5 Discussion of development of taxonomically validated image datasets

The discussion began with definitions of what was meant by a dataset. We are describing a collection of zooplankton or phytoplankton images that were collected (imaged) with a particular instrument for which there is a taxonomic identification that accompanies each image. The dataset would include many examples of each taxonomic group and potentially a range of likely orientations that they might be imaged in.

These datasets would facilitate several advances: (1) they would permit rapid development of training sets for samples collected in the same region using the same instrument as the validated dataset; (2) they would permit evaluation of the performance of new or existing classifiers; (3) they could be used to measure errors and biases associated with classification by human taxonomic experts; (4) the images would be of value to others interested in learning to identify organisms in a particular region.

Some of these datasets already exist. For example, there is currently a dataset for the ZOOSCAN that contains a wide range of taxa in various orientations Examples of such datasets can be seen at http://www.obs-vlfr.fr/LOV/ZooPart/Gallery/Zooscan-Zoopk-Images. The UVP also has a large reference image library that could be used to develop a dataset (http://www.obs-vlfr.fr/LOV/ZooPart/Gallery/Underwater-Video-Profiler-Images).

For most instruments, we need images that are representative of the typical image quality obtainable from the system and containing the full range of orientations of the

organisms (relative to the camera) normally present. One consideration in this area is that if you take the same individual and put it in different orientations, you don't get the same information as if you take different individuals at different orientations (pseudo-replication). The exact impact of these pseudo-replicates, or artificial training sets on the performances of an automatic classifier remain to be determined. That said, two views of the same organisms may well provide additional classification features that result in reduced classification error compared to single orientation features. A second equally important requirement is to have an unambiguous taxonomic classification that accompanies each image. Both requirements are achievable for preserved samples that are imaged with benchtop instruments. For *in situ* images the issue of high-quality validated datasets is going to be difficult. Although it is possible to collect organisms in a cod end after they have been imaged (e.g. Broughton and Lough, 2006), it is virtually impossible to determine the correspondence between the individuals in the cod end and those in the images. Most current camera systems image a subset of the total volume of water passing into a collection device. Consequently there are more individuals in the cod-end than in the image record. This means that even when cameras are mounted on nets, determining the correspondence between the imaged organisms and the contents of the cod end is usually impossible. Furthermore, the *in situ* instruments often use lower resolution sensors than benchtop instruments. Without a chance to examine the organism carefully to locate taxonomically important features, the level of taxonomic resolution that can be achieved from a relatively low resolution image can be limited. In some cases, sufficient taxonomic information does exist in the images from *in situ* systems to identify organisms to genus or species.

No matter what the source of the datasets, there is need of funding to allow taxonomists to produce them. The CMarZ project provides a unique opportunity to collect images of species for which definitive taxonomic identifications can be obtained via traditional taxonomic expertise and DNA barcoding. DNA barcoding uses a short gene sequence from a standard position in the genome as a diagnostic tool for species identification (Bucklin *et al*. 2006). Scanning at sea may not be feasible but there are attempts to provide stabilized platforms from which to scan. A more practical approach would be to take ethanol preserved specimens and scan them prior to conducting barcoding. This may be problematic because zooplankton preserved in alcohol can become brittle and more fragile. Other preservative such as RNAlater (www.ambion.com) may provide a means of preserving specimens for imaging. For larger or fragile gelatinous forms, preservation may not be an option and scanning immediately following collection remains the only way to obtain a useful image. Establishing standards for how organisms are imaged is important because if organisms could be imaged properly prior to being barcoded, it would yield definitively identified image datasets. In the future, *in situ* confocal, holographic or tomographic sensors may yield good quality images for such reference datasets.

Unfortunately, we are behind on this project. Ann Bucklin's CMarZ team are collecting and requesting specimens from all oceans (20-30 individuals per vial are requested to be sent). If all these specimens could have been imaged prior to dispatch we would already have amassed a large image base. Similarly, on their cruises where taxonomists are separating specimens for DNA analysis these specimens could have been imaged. The organisms that have been barcoded represent a lost opportunity; however, we need to establish close contact with Ann Bucklin to ask for her help and involvement of our task

Another issue is what taxa are individuals most interested in classifying. This will have a bearing on the composition of reference datasets. Do we attempt to start with a very simple set made up of functional groups that pools many different species into higher taxonomic categories (e.g., chaetognaths, copepods, filter feeders, fish larvae, jellyfish)? This option may appear to be simple, but the combination of many different taxa, each with different recognition features, into a single class would likely degrade the ability of a classifier to distinguish among the classes. Another possibility would be to focus on indicator species. This might also be problematic if the indicator species had very similar morphologies.

Copepods dominate mesozooplankton communities in terms of number and frequently in terms of ecological importance. For some species there are very fine morphological features that may not be possible to capture as features for recognition. Under such circumstances, you may not be able to distinguish the species using an image. In other taxa, there are visual cues that can be used to classify to genus and species (e.g., pigmentation patterns). The absence of taxonomically relevant features that a systematist might use for identification does not preclude the existence of image-based features (e.g., texture, specularity, greyscale distribution, Fourier transforms of brightness levels, etc.), which might have taxonomic utility.

The choice of the target plankton taxa is subordinate to the type of study undertaken. For example, in-situ studies that identify high taxonomic categories (e.g., copepods, chaetognaths, etc.) are already very valuable. They allow the description of real spatio-temporal information and behaviour of plankton, at different scales than those resolved by conventional sampling (e.g., nets). However, when plankton imaging is used to process preserved plankton, the use of more interesting targets would be indicator species, functional groups (e.g., copepod filter-feeders vs. copepod predators, gelatinous filter feeders vs. gelatinous predators) and size classes.

How will the evolution of imaging systems affect the utility of reference datasets? If image systems constantly improve in resolution, won't older images captured at lower resolutions become obsolete? The answer is probably not. The reality is that benchtop

instruments such as scanners evolve in response to market forces. Most scanners currently can image at 4800 dpi and there are no economic or market force forces that are driving a requirement for higher resolution scans in the consumer marketplace. Scanning resolution is therefore likely to remain near its current maximum. Experiments with higher resolution scans to (9600 dpi) on ZOOSCAN indicated that the higher resolution scans did not provide much additional information. For other instruments, such as microscopes, there are fundamental optical principles that limit the resolution of the images. During the Zooplankton Symposium we heard a presentation on the potential use of confocal microscope reference images. Such images have the potential to provide 3D high-resolution information that may have utility for identifying organisms imaged by *in situ* systems where the organism appears at a variety of orientations relative to the camera.

There is a need for leadership from the taxonomic community to secure funding for programs that integrate imaging and traditional or molecular taxonomy. There are programs that have been funded by NSF to support museums to organize areas of expertise. NSF has mature programs to support archiving of samples and collections. Fewer examples exist in other regions. In the UK, Steve Hay's NERC-funded program to create an image-based taxonomic training and reference program is one example. This SCOR WG could provide an impetus to start such programs and promote links among the existing ones in the United States, Europe and elsewhere. There are also quite a few different image datasets housed at various marine laboratories and on websites. Examples of the latter include the Image Quest 3D dataset (http://www.imagequest3d.com/stock/index.htm) and the CMarZ images (http://www.cmarz.org/). We need to mine these resources and incorporate them where possible into a central image database.

It was decided that a valuable contribution by our Working Group would be to establish recommendations for standards for image datasets.

Action Items:

i. Form a subcommittee that will make recommendations for standards for taxonomically validated image datasets: Maria Grazia Mazzocchi will chair the subcommittee with Hans Verheye (rapporteur), Alena Arashkevich, Gaby Gorsky and Priscilla Licandro.
ii. Encourage the creation of expert taxonomic networks. This will provide a means of virtually linking taxonomic experts who can assist with the identification of organisms in reference images. It was recognized that funding to assure taxonomist participation was probably an issue that needs further investigation and proposal preparation.
iii. Establish a linkage with the DNA barcoding initiative within CMarZ to explore the

development of high-resolution image datasets from specimens that will subsequently be barcoded. This could include confocal microscopy images. Benfield, Song, Verheye, Culverhouse Licandro et al.

iv. Propose a list of target species/taxa/functional groups for the automatic identification of plankton. This list would be open to discussion in the expert taxonomic networks. Considering the great variety of morphology and material characterizing marine organisms this will help the improvement of hardware and software in order to successfully identify species/taxa/functional groups relevant to the end users.

1.4.6 Workshop needs

Our working group is composed of scientists with a wide range of research interests, ranging from taxonomy to machine vision. Some members of the group expressed an interest in holding a workshop for the taxonomists and other members who have not had direct experience using plankton classification software. The purpose of this workshop would be to familiarize them with the complete sequence of events necessary to classify images of plankton beginning with construction of a training set, building a classifier, and classifying unidentified test sets of images. This workshop could also be addressed to the definition of standards. It was decided that one venue for such an exercise could be at our next meeting. Examples of the process could be conducted using image datasets from a ZOOSCAN and the FlowCam.

A second workshop that would be of great value to the group and the community would be to bring experts in machine vision, pattern recognition, and classification together. The objective would be to summarize the state of the art in other disciplines. By learning from others who are using this approach to identify items in other disciplines, we will be better able to assess whether the approaches we are using are taking maximum advantage of current advances in the field. This is a very large amount of literature on this topic. It would be a very large effort for a few individuals to distill this literature down for our group. An alternative approach would be to hold a small symposium and bring in invited experts who are representative of other disciplines to describe their state-of-the-art. As a precursor to convening such a workshop Phil Culverhouse assisted by Norm McLeod and Mike Sieracki will summarize the state of the art in object and pattern recognition from other disciplines in a very general way.

On a related topic, it would be interesting to see whether others working in the field of machine vision and pattern recognition could make progress with our datasets. We can put out a challenge to the machine learning community via the Pascal Challenge (http://www.pascal-network.org). By providing a high-quality validated dataset that can be put out to these groups as a challenge, we can determine whether our current

best accuracy (about 78%) can be improved upon. This will have the additional benefit of fostering interest in the field of marine science and zooplankton ecology.

1.4.7 Funding requirements

It is clear that an important role for SCOR WG130 is the promotion of its terms of reference to funding agencies. It is expected that a set of proposals will arise from some of the above actions, which will benefit from overt support of the SCOR framework. It was agreed that SCOR WG130 would provide letters of support to proposals that fulfill its terms of reference.

The first of a series of papers that publicize the work being conducted by this group has been written and it appears in the June 2007 issue of Oceanography (Benfield *et al*. 2007). That was a very general overview of RAPID. Additional papers that describe specifics such as standardization of datasets, quality assurance, and intercalibration need to be published in peer-reviewed journals.

A proposal to fund the development of the open-source software needs to be written. ZooImage would be a logical candidate for this proposal. This could be submitted through the EU Framework7 Initiative (http://ec.europa.eu/research/future/index_en.cfm) as part of a larger proposal to develop a network of excellence for taxonomists, end-users, and machine vision hardware and software developers. This network of excellence is a large undertaking but will provide an effective tool for advancing the field. Within the EU there are probably less than 60 sites that could be linked. Of these, a practical number that could be managed would be 10–20. The collaborations that we would be interested in would be both face-to-face and virtual via the Internet. Existing networks that are relevant are the Marine Biodiversity and Ecosystem Functioning (MARBEF) Network of Excellence (www.marbef.org), and the European Network of Excellence for Ocean Ecosystems Analysis (EurOceans: http://www.eur-oceans.eu). Such a network is crucial for the growth in interest and research in automated plankton identification. It is possible that a joint bid to EU FP7 and U.S. NSF will be most appropriate.

1.4.8 Mechanisms to advance the state of image-identification/RAPID

For the moment we are still in the very early stages of using the computer for taxonomy. We use the information given by the taxonomist as the gold standard and the computer has to use that information to assess its error. There is a way of inverting this. It would be interesting to take a dataset that has some confusing organisms and see what the computer could do with them. This could be a learning tool for the taxonomist.

The working group agreed that a global network of excellence would support cooperation and collaboration across what are currently disparate domains of artificial intelligence, engineering, ecology, oceanography and taxonomy. European FP7, U.S. NSF and the Sloan Foundation were suggested as appropriate funding sources to be approached.

It is proposed that initially the network would have the following aims and objectives:

i. To establish a standard of taxonomic-quality images of specimens from live and preserved plankton. These images, which would be associated with voucher specimens, will be validated for use in automatic categorization machines and for other scientific endeavors.
ii. To adapt the software in order to use features like color and behavior for the automatic identification of plankton in situ.
iii. To identify 'holes' in taxonomic expertise in basic technology developers. For example, it has been estimated that there are only five or six competent experts worldwide on appendicularia (larvaceans) identification, three of whom have already reached retirement age.
iv. To disseminate images of unknown species to experts across the world, through the World Wide Web. This would provide the widest possible access to expert taxonomic opinions.

Action Item:

i. Encourage the creation of expert taxonomic networks. Encourage the creation of expert taxonomic networks. This will provide a means of virtually linking taxonomic experts who can assist with the identification of organisms in reference images. Phil Culverhouse and Mark Benfield will both investigate opportunities with EU FP7, NSF and the Sloan Foundation.

1.4.9 Date and location of next meeting

The Brazilian oil industry has a very strong interest in marine science. Shortly after the inception of this working group, Rubens Lopez wrote a proposal to Petrobras (the Brazilian state oil company) to hold a scientific meeting in Brazil. He was funded and anticipates being able to support travel to Säo Paulo for the majority of the working group. The costs of accommodation and meals will be quite low and hopefully could be borne by individuals from other funds. He will inform the group of likely dates for the meeting in late 2007 or early 2008.

1.4.10 Website and communication

The group felt that a secure website was important for effective collaboration. Phil Culverhouse offered to support a secure website at Plymouth to allow the working

group members to communicate, upload data and reports, share and edit reports. Some funds would be needed to create the site. The University of Plymouth has since offered the resources for web hosting. Culverhouse is exploring website design and costs. Philippe Grosjean offered WiKi concurrent editing tools for the site.

All members of the Working Group are encouraged to obtain a Skype (http://www.skype.com) account. This free video-conferencing service will facilitate face-to-face meetings over the Internet. Current Skype addresses are: Mark Benfield (mark.benfield); Phil Culverhouse (philculverhouse); Rubens Lopes (rubens-iousp). Until our website has been established, large documents can be uploaded to Web-based ftp sites such as sendthisfile (http://www.sendthisfile.com) or xdrive (www.xdrive.com).

1.4.11 Timelines for deliverables

It was agreed that the draft report arising from the meeting would be tabled to the group within two weeks of the meeting. Drafts of all four working documents on (a) open-source software; (b) datasets, quality assurance and standards; (c) workshops for training and (d) a brief review of current machine methods in natural object categorization would be made available within three months of the meeting. Final versions will be sent to working group members before the next meeting.

1.4.12 Working Group Products to Date

A white paper summarizing the importance of, challenges associated with, and need for automated image analysis of plankton has been recently published in *Oceanography m*agazine in the 2007 June issue (Benfield *et al*. 2007).

Arising from an earlier publication (Culverhouse *et al*. 2006) authored by five members of WG130, the need for a Web-based shared image database was espoused. From this specification a distributed Web-based database called Pleione has been created (web link). It is capable of offering images drawn from *in situ* and laboratory samples of plankton to scientists across the globe. Scientists identify specimens through a web interface, and hence contribute to a consensus of opinion that validates the specific or generic identification of the specimen. Validated datasets can be used for machine and human training. All members of the working group are encouraged to visit the site and participate in the classification experiments.

Phil Culverhouse and Mark Benfield are already agreed to mirror this database at University of Plymouth and at LSU, which will enable experiments to be conducted in image validation with global access.

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2. Requests from the group to SCOR in relation to changes in membership and/or terms of reference or other issues.

We have requested the addition of Dr. Priscilla Licandro as an Associate Member. Dr. Licandro represents the Sir Alister Hardy Foundation for Ocean Science (SAHFOS). [The SCOR Executive Committee Reporter for WG 130 approved this request.]

3. **Plans for work between meetings.**
   Work will begin to address all action items agreed upon at the first meeting of the WG.

4. **Plans for the next working group meeting. If the time of the next meeting is significantly longer or shorter than one year from the previous meeting, please provide justification. The group should provide a budget to show how they will be able to stay within the SCOR allotment (normally US$15,000 per meeting) for their upcoming meeting.**
   As per section 1.4.10: Rubens Lopez wrote a proposal to Petrobras (the Brazilian state oil company) to hold a scientific meeting in Brazil. He was funded and anticipates being able to support travel to Säo Paulo for the majority of the working group. The costs of accommodation and meals will be quite low and hopefully could be borne by individuals from other funds. He will inform the group of likely dates for the meeting in late 2007 or early 2008. This next meeting will likely require minimal financial support from SCOR.

5. **Overall progress of working group in completing its terms of reference, in reference to the initial time schedule for the group.**
   Based on our first meeting and the level of enthusiasm and energy in this group, we are making excellent progress towards addressing all the goals of our terms of reference.

2.3 Working Group Proposals

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

Proposal for SCOR Working Group on Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems

Abstract
Nutrient over-enrichment (*eutrophication*) from land-based sources has degraded estuarine and coastal marine waters worldwide. Eutrophication has been linked to the increased prevalence of harmful algal blooms (HABs) that cause serious ecological, economic, and human health impacts. Yet, the linkage between nutrient loading and HABs currently lacks a firm, quantitative foundation. This working group will assess and compare *spatial* relationships between changing global nutrient exports and loads and the proliferation of major HAB species around the world. However, nutrient loads alone are likely not sufficient to predict where certain HABs may occur. Therefore, the patterns in nutrient loads and HABS will be further evaluated in the context of physical characteristics of the receiving waters (the typology) as well as the type of HAB (functional group) and their physiological characteristics. We will use a range of global databases and models in these analyses, including spatially explicit watershed nutrient export models, ecosystem and physiological models, and statistical approaches. This project will advance predictive capability of the extent of blooms, the dominant harmful taxa involved, and our ability to manage these HABs by an improved understanding of the impacts of nutrients on HABs. Products will be an atlas of maps of global HABs and nutrient export, as well as future predicted scenarios, which will be published in newsletters, peer-reviewed articles and graphic-rich reports which will be produced and made available in print and on the web.

Rationale
Nutrient over-enrichment (*eutrophication*) is one of the most serious aquatic pollution problems throughout the world (National Research Council 2000, Smil 2001, Cloern 2001, Howarth et al. 2002, Seitzinger et al. 2002, 2005, Wassmann 2005). Nutrient pollution arises from human activities such as use of synthetic fertilizers, energy production, and expansion of industrialized agriculture and aquaculture operations. An important adverse consequence of eutrophication is the increased prevalence of harmful algal blooms (HABs) that can cause oxygen depletion and fish kills, seafood poisoning, and undesirable shifts in food webs (Smayda 1990, Hallegraeff 1993, Anderson et al. 2002, Glibert et al. 2005a,b). Although eutrophication is generally known to stimulate many harmful estuarine and marine algal species (Anderson et al. 2002), the relationship is complex (Glibert et al. 2005a,b, Glibert and Burkholder 2006). *Through improved global, spatially explicit models of nutrient loading from watersheds to coastal*

systems, and the development of new spatially referenced global databases of HAB occurrences, we are now in the position to begin to link patterns of eutrophication with HAB occurrence around the world in a more rigorous and quantitative way.

A SCOR working group is the ideal mechanism to address this issue. The questions are international in scope, build on existing SCOR and Intergovernmental Oceanographic Commission (IOC) activities, and will provide the kind of global synthesis that is only possible when individuals who have developed these databases and models come together to integrate their knowledge. Knowledge of these relationships is also important for developing countries, as these areas are experiencing rapid changes in nutrient export and HABs as the use of fertilizers and large-scale aquaculture grows in those regions.

The activities of this working group are relevant to several SCOR and IOC international research programs. They are directly relevant to the Global Ecology and Oceanography of Harmful Algal Blooms Programme (GEOHAB 2006; http://www.geohab.info) which has specifically identified the following questions as priorities in the Core Research Project on HABs and Eutrophication, chaired by P. Glibert, "What HAB species or species clusters are indicators for nutrient over-enrichment at global and regional levels?" and "How are long-term trends in nutrient loading changing HAB bloom patterns and dynamics?" (GEOHAB 2006). The working group can address these questions in a fundamentally different way from the activities of GEOHAB, however, since GEOHAB is focused on ecology, physiological adaptive strategies of species, and oceanography (GEOHAB 2001), but does not have expertise on watershed nutrient loading or the development of coastal typology databases. However, the Global Nutrient Export from Watersheds Program (Global NEWS), chaired by S. Seitzinger, has developed and applied spatially explicit models that predict nutrient (nitrogen, phosphorus, carbon) loading from watersheds to coastal systems globally. Global NEWS has been an ad hoc workgroup of IOC (http://www.marine.rutgers.edu/globalnews/).

Questions of nutrient export and its effects in the coastal zone are relevant to many global change programs. Nutrient fluxes and their key impacts are relevant to the mission of LOICZ, IMBER, and the International Nitrogen Initiative (INI), which is cosponsored by IGBP and SCOPE. Global NEWS has received endorsement from LOICZ, and we will seek endorsement from LOICZ, GEOHAB and IMBER for this SCOR working group. Co-sponsorship for this working group by IOC is also under consideration at this time. The working group will build on existing data sets and models, synthesize relationships and lay the groundwork for new research which can, and likely will, be proposed under the auspices of these global programmes. Our working group will be composed of biologists, chemists, hydrologists and modelers, as well as those who have experience in large-scale data and GIS analysis.

Scientific Background

The questions related to understanding the linkages between HABs and eutrophication are many. Our goal is to determine if there are patterns in the relationships between nutrient loading and HABs, by building on existing global nutrient loading models and HAB databases.

There are literally hundreds, if not thousands, of reports of HAB occurrences around the world. Historically, the data on HAB occurrence were scattered in government reports, websites, and scientific journals, and often data on nutrients and coastal typology were not included in those reports. Therefore, to date, our attempts to relate the occurrence of particular HAB species with nutrient loading have largely been based on using a limited amount of data from the literature on HAB occurrences where nutrient loading and other parameters could also be found. However, a major effort has been underway by the IOC-HAB program to develop a global database that documents the occurrence of species, along with many site characteristics (http://ioc.unesco.org/hab/data.htm). Maps based on frequency of occurrence are also available for ICES nations for the past ten years (http://www.ices.dk/marineworld/hab.asp). 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 IOC-HAB database is a critical component of any attempt to relate the global patterns of HAB occurrence with coastal eutrophication. However, most of the studies in that database do not contain specific information on nutrient loading rates, and in many cases details of the coastal typology. The Global NEWS efforts make available those needed data and expertise. The Global NEWS group maintains a global database of measured and modeled river nutrient loads and watershed nutrient sources (including IOC-UNESCO, LOICZ, U.S. Geological Survey and others (http://www.marine.rutgers.edu/globalnews/).

Estimating nutrient export to the coastal zone has been a challenge, but enormous advances have been made with respect to global models over the past several years. The first global model of nitrogen loading to coastal systems was published less than 10 years ago (Seitzinger and Kroeze 1998). Our 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 (Fig. 1; Glibert and Burkholder 2006). While these results are interesting, these initial efforts represent only a small portion of HAB species groups and the data were not geo-referenced (they were derived from literature reviews). Also, the data in Fig. 1 are only for nitrogen export models and comparable relationships for other nutrients or nutrient forms are not yet available. Through the work of the Global NEWS workgroup, global models of nitrogen, phosphorus and carbon exports, by form, have been developed based on watershed characteristics such as river discharge, land use, human population, fertilizer nitrogen and phosphorus use, manure from animal production, atmospheric nitrogen deposition and biological N_2 fixation (e.g., Beusen et

al. 2005; Bouwman et al. 2005a,b; Dumont et. al. 2005; Harrison et al. 2005a,b; Seitzinger et al. 2005) and are available for use. These models demonstrate that the ***amount*** of nutrient discharge is unevenly distributed, the ***nutrient forms and their ratios*** vary with land use, and the ***composition*** of the nutrient discharge is changing due to land-use patterns. These new models need to be compared to HAB distributions.

Development of these models also allows us to now ask questions about whether different nutrient elements, forms and ratios are related to different functional groups of HABs. A gradient of habitats has been characterized which tend to foster distinct types of dinoflagellate HABs (Reynolds and Smayda 1998; Smayda and Reynolds 2001). Some types of HABs, such as the high-biomass bloom former *Prorocentrum minimum*, seems to mirror the global export of nitrogen as shown in Figure 1, with hot spots along the U.S. east coast, European and Asian coasts, and appears to be increasing, along with its deleterious effects (Heil et al. 2005). However, other species groups, such as *Karenia mikimotoi*, on the other hand, are dinoflagellate species that bloom in open coastal waters, aggregate in fronts and are transported by coastal currents (Dahl and Tangen 1993; Vargo et al. in press). They proliferate in oligotrophic waters (Heil et al. 2001), but appear to be maintained in nearshore waters. We aim to compare the global nutrient export models with the available global data of these HAB types. There are several classification schemes of estuarine and coastal typology that are now available that have been related to algal composition, but not necessarily HABs (e.g., Ferreira et al. 2005). We aim to build on these efforts and to use that information to develop relationships that predict the probability of occurrence of different HAB groups. We aim to focus on the dinoflagellates, as most data are available for this class of HABs, but may explore relationships for other HAB groups, including raphidophytes or cyanobacteria, if sufficient data are available.

Note: best viewed in color

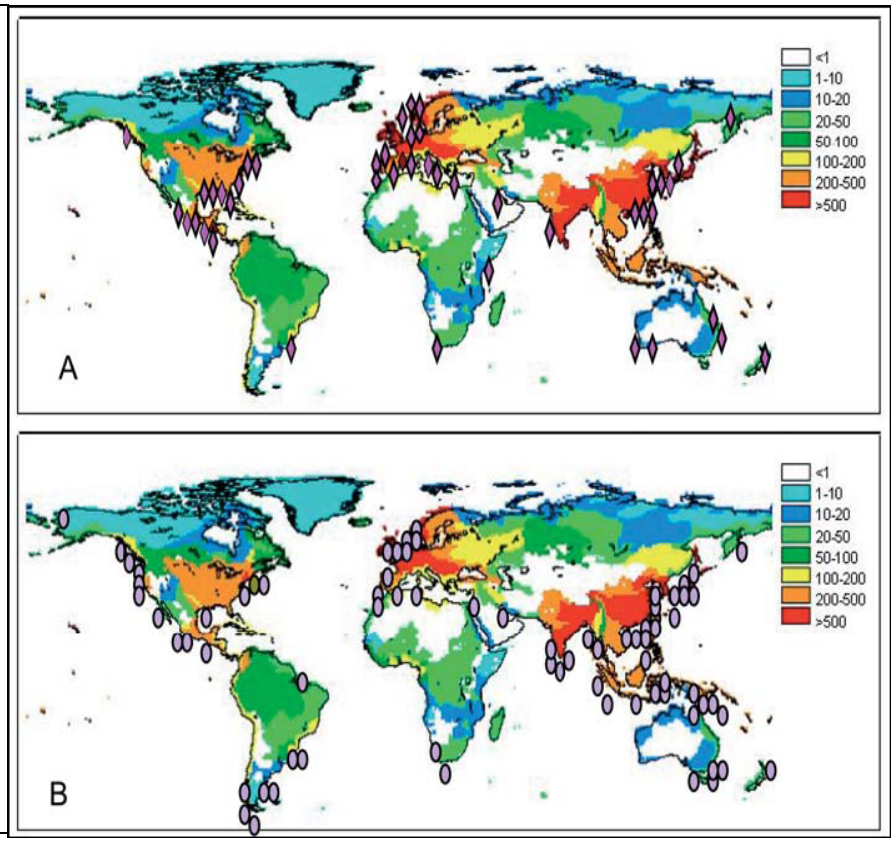

Figure 1. Global distribution of recorded incidences of major toxic HAB species superimposed on a global map of modeled nitrogen export (base map from Seitzinger and Kroeze 1998). Nitrogen export is calculated as kg N · km^{-2} watershed · year^{-1}.
A) Documented occurrences of dinoflagellates *Prorocentrum minimum*, based on the review by Heil et al. (2005).
B) Documented occurrences of a species cluster that causes paralytic shellfish poisoning (dinoflagellates *Alexandrium tamarense, A. minutum, Gymnodinium catenatum, Pyrodinium bahamense* var. *compressum*), modified from GEOHAB (2001).

The results of this analysis will also be used to link the future predicted magnitude of sources to the anticipated future occurrences of HABs. Previous modeling explored the effect of a number of global change scenarios on nitrogen export, including changes in population, and food and energy production (Kroeze and Seitzinger 1998; Kroeze et al. 2001; Seitzinger et al. 2002a; Bouwman et al. 2005b). Model forecasts predict that large increases in dissolved inorganic nitrogen export to coastal ecosystems will occur by 2050 for many world regions, due to predicted large increases in the global population and in associated food and energy production. The Global NEWS workgroup is currently developing input databases for their nutrient export models that are consistent with the

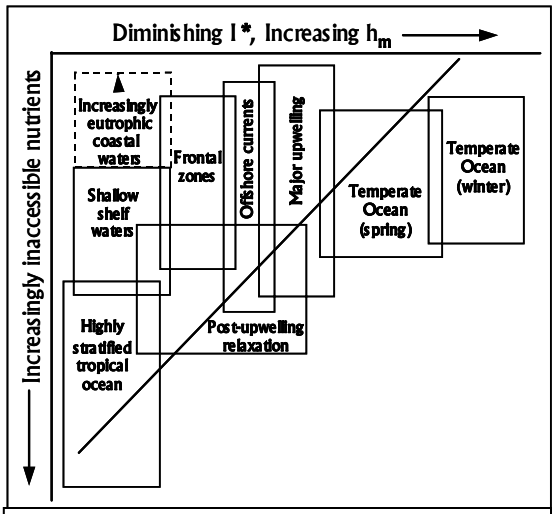

Figure 2. Habitats in marine coastal waters as a function of light and nutrient regimes (Smayda and Reynolds 2001). These habitats select for certain HAB species, species clusters, or species functional groups. The model incorporates parameters describing the abilities of the species to grow in these hydrographic regimes as physical/chemical factors or behavior alter vertical distributions and growth potential.

four scenarios for the year 2030 outlined in the Millennium Assessment (http://www.maweb.org/documents/ document.332.aspx.pdf). The Global NEWS models will be run with these input databases to explore the changes in nutrient loading to coastal systems around the world under these four development scenarios. In this proposed SCOR working group we will use these Global NEWS model predictions in concert with the relationships we develop between nutrient loading and HAB occurrence to explore future scenarios of HAB occurrence. *Thus, this effort also will begin to link human dimensions with coastal ecosystem effects.*

Neither GEOHAB nor Global NEWs has the mandate or the resources to conduct the kind of analysis that is proposed for this working group.

Terms of Reference
The working group will integrate existing data on HABs and eutrophication by conducting the tasks listed below:

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.
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 and develop newsletters/outreach reports for managers and the public summarizing the findings.

Approach and Products
The groundwork for the working group effort will be laid by accomplishing the first term of reference. This will be done through volunteer efforts by several of the working group members in advance of the first group meeting by examining each data record in the HAB database and formatting it for GIS application using the same grid format employed for the NEWS model. GIS expertise is represented on the working group. We will also work to develop a detailed global coastal typology using high resolution GIS coastal delineations to define open coastal environments, enclosed estuaries, shallow lagoons, and fjords, including their size, freshwater flow, retention time, and depth.

Through the working group process, we will then combine and develop/explore the databases for relationships between HAB species, nutrient loading/forms/ratios, and coastal typology. The first product will be series of maps in which various HAB groups are compared to the global maps of nutrient by form (e.g. nitrogen as nitrate, organic nitrogen, phosphorus by phosphate

and organic phosphate), by ratio (e.g. N:P, N:Si, C:N), by season, or by physical factors such as flow or retention time. Regional maps will be made by working group members for the regions in which they have expertise. Estimates of forecasts of nitrogen and phosphorus export (by form) under future scenarios will be developed by using the land use changes as predicted in the Millennium Assessment under their four global change scenarios. These forecasts will then be related to future estimated HAB occurrences based on the relationships established for existing data (by nutrient form, ratio, etc.). The synthesis products expected include a series of maps which then will be interpreted in interdisciplinary, concept-driven, peer-reviewed papers. The expertise of the working group will guide the emphasis on particular regions and HAB types. Progress reports, maps and conceptual syntheses will be made broadly available through the global publication *Harmful Algal News*, similar regional/national publications, websites (such as http://www.geohab.info (GEOHAB), http://www.whoi.edu/redtide, http://www.marine.rutgers.edu/globalnews/, and the institutional and laboratory websites of the working group members. We will also publish several outreach newsletters and reports on the web and in print, through GEOHAB, LOICZ and other outlets.

Proposed Activities/Timeline
A series of 3- to 5-day workshops will be conducted over 3 years:

1. Spring 2008 in the Netherlands— The first meeting will be to advance the database as much as possible, to introduce the Global NEWS models to the HAB community and the complexities of HABs to the Global NEWS members. A list of the desired relationships and maps will be developed, and explored at the meeting and in post-meeting efforts.
2. Spring 2009 in Hong Kong or Japan— The second meeting will be to critique and interpret the maps and relationships developed, and to outline the projections of future scenarios required; and

3. Fall 2010, in conjunction with the 14th International HAB meeting in Greece—The third and final workshop will be to assess the scenarios developed from applying the Millenium Assessment projections; to critique, interpret and discuss all the findings of the working group; and to prepare the final manuscripts and report.

A newsletter will be prepared at the end of each workshop and made available through GEOHAB, *Harmful Algal News* or other outlets.

Participants –The working group will be chaired by the current chair of the GEOHAB Core Research Project on HABs and Eutrophication (**Glibert**) and Co-Chair of the IOC ad hoc working group on Global NEWS (**Bouwman**). These chairs bring together knowledge and experience on HABs and global nutrient use and land-use changes.

The following individuals have the expertise required for the working group, and to date, 8 of the 10 have agreed to participate in this working group (awaiting responses on the other 2), if approved by SCOR:

Name	***Country***	***Expertise***
Patricia Glibert* CO-CHAIR	USA	HABs and Eutrophication, GEOHAB Core Research Project Chair
Lex Bouwman CO-CHAIR	Netherlands	Land Use and Nutrient Export, Global database development; GIS modeling, Global NEWS Co-chair
Sybil Seitzinger	USA	Global nutrient export, biogeochemistry, GIS modeling, Global NEWS Chair
Paul Harrison	Hong Kong	Nutrient Export, Biogeochemistry, HABs
J. Icarus Allen	United Kingdom	Numerical modeling of marine systems, coupling of ecosystem and physical models, ecosystem forecast
Edna Graneli	Sweden	HABs and Eutrophication
Adnan Al-Azri	Oman	Time series of HABs; HABs in Arabian Gulf and Arabian Sea
Sandor Mulsow	Chile	Nutrient input to the coastal zone; Global NEWS; GIS modeling, effects of land-use change and aquaculture on coastal ecosystems
Paul Wassmann	Norway	Nutrient export to the coastal zone; impacts and effects including HABs
Ichiro Imai	Japan	Ecology of HABs in North Pacific; HAB database for North Pacific

* cv available at: http://www.hpl.umces.edu/faculty/glibert.html

We anticipate that there will be associate members of this working group who will participate in some or all the workshops. We will work with SCOR to identify additional associate members from developing countries. The preliminary list of associates will include the following people:

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Name	*Country*	*Expertise*
Charlie Vörosmarty	USA and Italy	Hydrology
K. Padmakumar	India	HABs in India
Jorge A. Herrera-Silveira	Mexico	Nutrient export, HABs, Global NEWS, GIS modeling
Hak-Gyoon Kim	Korea	Asian HABs; eutrophication
Gustaf Hallegraeff	Australia	Australia and New Zealand HABs; eutrophication
Vera Trainer	USA	North Pacific HABs; time series databases
Grant Pitcher	South Africa	African HABs, nutrient relationships, GEOHAB Core Research Project chair
David Dickey	USA	Statistics, time series analysis, nutrient trends with time

Anticipated Results and Beneficiaries

Impacts of HABs on human health, ecological health and coastal economies are increasing worldwide (e.g., Glibert and Pitcher 2001, Ramsdell et al. 2005), and many of these blooms have been linked to eutrophication (Smayda 1990, National Research Council 2000, Anderson et al. 2002, Glibert et al. 2005a,b). At present, however, scientists, public health officials, federal and global agencies concerned with managing and protecting marine resources lack a firm, quantitative foundation on which to manage and mitigate this global epidemic. In this workshop series, we will assess the importance of eutrophication in stimulating various HAB species by applying quantitative and comparative analysis to global nutrient export/HAB data. Through this analysis an increased understanding of the potential to manage these threats by nutrient reductions will also be attained.

The work of this group will contribute to GEOHAB Core Research Project on HABs and Eutrophication by providing an in-depth analysis of the relationship of HAB occurrences to land-based factors, which GEOHAB is not addressing. The results should also contribute to LOICZ and IMBER. The work of the group will add value to, and leverage, the results of Global NEWS.

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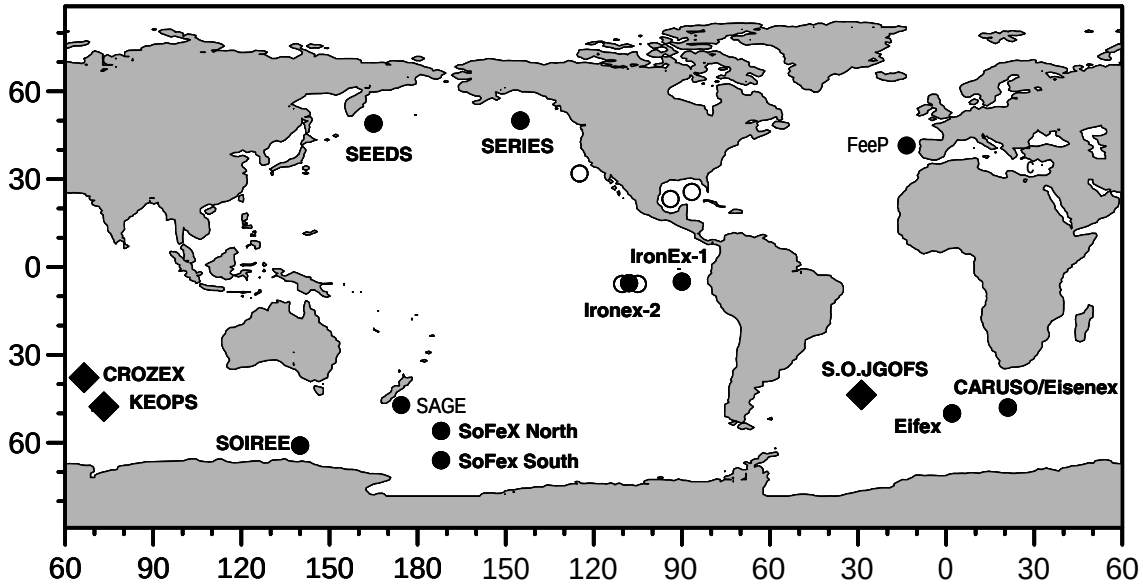
2.3.2 Working Group on The Legacy of in situ Iron Enrichment: Data Compilation and Modeling

Proposal for a SCOR Working Group
The Legacy of *in situ* Iron Enrichments: Data Compilation and Modeling

Introduction

From 1993 onwards there have been 10 *in situ* iron fertilization experiments, from Ironex-1 (1993) to SEEDS-2 (2004), as well as 3 natural fertilization studies (1992 Southern Ocean JGOFS, 2004-2005 Crozex, 2005 KEOPS). Primary results of individual experiments have been reported in *Nature* and *Science* as well as in oceanography journals, sometimes in special issues of journals like *Deep-Sea Research II* and *Progress in Oceanography*. For the most recent experiments (e.g. Eifex 2004, SEEDS-2, CROZEX, KEOPS) several articles have either been published or are accepted for publication.

Synthesis of the combined experiments has only just now started with one first semi-quantitative effort by multiple authors (*de Baar et al., 2005*) focusing on only the most basic variables (i.e., primary production, major nutrients, CO_2 system variables) of the then-available 8 experiments. This is seen as the modest first step towards more rigorous quantitative assessment by ecosystem simulation modeling of these unique time-series experiments. Nevertheless, several remarkable trends are becoming apparent from the combination of experiments. For example, light limitation due to depth of the wind-mixed layer was highly significant, and the major floristic response was always by larger size class diatoms, with almost universal flourishing of *Pseudonitzschia* sp. Unfortunately, during this first synthesis effort it was found that integrated datasets of even the earlier single experiments of the 1993-2000 period hardly existed, with one laudable exception (SOIREE, data CD in 2001 *DSR-II* special issue). At most, the individual scientists had their own data files which were kindly and generously made available. Sometimes fundamental data (e.g., hydrography, incoming sunlight or PAR) could hardly be traced; some other data of interest could not be located in time vis-à-vis the publication time frame of the synthesis article.



The *in situ* fertilization experiments (filled dots) and natural fertilization studies (filled diamonds) thus far: S.O.JGOFS (1992), IronEx-1 (1993), IronEx-2 (1995), SOIREE (1999), CARUSO/EisenEx (2000), SEEDS-1 (2001), SOFeX-North (2002), SOFeX-South (2002), SERIES (2002), EIFEX (2004), SAGE (2004), FEEP (2004), SEEDS-2 (2004), CROZEX (2004/2005), KEOPS (2005). Cyclops (C in East Mediterranean) P fertilization, FeCycle (not shown) and various pilot experiments (open circles) are beyond scope of this WG proposal (map after *deBaar etal., 2005*)

In addition to this synthesis of basic variables of the first 8 experiments, there have been some recent articles combining 2-3 experiments for specific topics, that is, CO_2 budgeting (*Bakker et al. 2005*) and DMS(P) processes (*Turner et al., 2004*).

A special synthesis workshop (FeAX) was held in Wellington (New Zealand) in November 2005 under the aegis of SOLAS. The insights gained during that workshop have been reported in a recent multi-authored article in *Nature* (*Boyd et al., 2007*). At this meeting it was unanimously agreed by all participants that a special effort should be developed towards establishing a common open-access database of the *in situ* iron enrichment experiments. From this unanimous agreement follows this proposal for a SCOR WG. Success of this group could provide a model for data synthesis within SOLAS, IMBER, and other projects.

Rationale

The iron enrichment experiments have been done at great expenditure of scientists' time, research vessel time, and other costs. Thus overall, taxpayers of various nations worldwide have

invested heavily in these experiments. Yet apart from the typical first round of articles on any single experiment, this investment has not led to an international resource or heritage. The already collected but thus far widely scattered data, once brought together, would be extremely valuable for various reasons:

- the ocean science community needs to fully exploit the results of preceding *in situ* experiments before proposing and implementing the next generation of experiments. In other words, there is no credibility to continue asking taxpayers to subsidize one experiment after another in the future, unless the ocean science community first fully exploits the investments of the past decade. Full use of existing data may yield insights to help design future experiments.
- properly compiled datasets of both natural and *in situ* iron fertilizations will allow the application of 'generic' simulation modeling, thus yielding insights and model robustness far beyond what is feasible by simulating just one experiment.
- the value of the experiments is far beyond the 'iron issue'. For example, the experiences and findings of labeling (SF_6 and sometimes ^3H as well) and following a patch of water are most valuable for designing future 'lagrangian' experiments for a wide variety of purposes. If nothing else, the dispersion of the added tracer(s) is a powerful tool for quantifying lateral and vertical mixing in the surface oceans. Moreover, the practical ability to follow a surface water mass or 'patch' over periods of weeks to months allows a wide range of topical biogeochemistry studies.

Objectives

The objectives of the proposed working group are twofold:

1. Data compilation. Assembling a common open-access database of the *in situ* iron experiments, beginning with the first period (1993-2002; Ironex-1, Ironex-2, SOIREE, EisenEx, SEEDS-1; SOFeX, SERIES) where primary articles have already been published, to be followed by the 2004 experiments where primary articles are now in progress (EIFEX, SEEDS-2; SAGE, FeeP). Similarly for the natural fertilizations S.O. JGOFS (1992), CROZEX (2004/2005) and KEOPS (2005).

2. Modeling and data synthesis of specific aspects of two or more such experiments for various topics, such as physical mixing, phytoplankton productivity, overall ecosystem functioning, iron chemistry, CO_2 budgeting, nutrient uptake ratios, DMS(P) processes, and combinations of these variables and processes.

1. Data compilation

An international Working Group under the aegis of SCOR and with full endorsements by SCAR, SOLAS, IMBER is deemed essential for success in compiling all the appropriate databases. At the planning stages of each experiment, mutual access of data is commonly agreed

and most funding agencies require the data to enter the public domain within 24-36 months after completion of the granted project. Nevertheless, in practice, compilations beyond individual investigators rarely occur, for a variety of reasons:

- Projects tend to be under-funded, often subject to budget cuts before granting, and the originally intended data management often is quietly sacrificed.
- At the level of the individual scientist only the most essential data are rapidly picked out for publication of articles, and an individual dataset often is not even compiled. Scientists are under considerable time pressure for publishing scientific articles and applying for future research funding. As a result the data management and submission to a central database too often is neglected.
- Some types of data can be produced relatively rapidly, and are sometimes already available at the end of the cruise, while other types of data require much painstaking labor afterwards in the home laboratory. Physical oceanography data tend to become available for the community at large within 2-3 months, but marine chemists and biologists seem to be far slower in data dissemination.

In summary, our marine science community at the onset of each new project has been intending data management and eventual open access, yet for various reasons in the end this has rarely been accomplished. This proposal aims to remedy this situation for the *in situ* iron enrichment experiments and natural fertilization studies, which may also serve to improve data practice of other, future ocean experiments.

An international Working Group will be able to set the example (i) for readily making available data, first to colleagues of the given experiment and next to the open access database, (ii) for proper recognition of the original scientist, (iii) for spreading the good practice of fast data dissemination in one discipline to other disciplines with a slower culture for data dissemination, and (iv) for re-assuring hesitant scientists about protection of their interests as the original data producer.

2. Modeling and data synthesis

Simulation models pivoting around phytoplankton ecology have thus far been performed independently for SOIREE (Hannon et al., 2001), IronEx (Chai et al., 2002), SEEDS-1 (Yoshie et al., 2005), SERIES (Takeda et al., 2005; Denman et al., in press), and comparison of Ironex-SOIREE-SEEDS (Fujii et al., 2005; Fujii and Chai, submitted). Moreover, there exists a refined simulation model on DMS(P) of SERIES (LeClainche et al., 2006). For physical mixing versus dispersion of SF_6 tracer, efforts are being made by Goldson, Law and others. Implications for Ocean Biogeochemical Climate Models (OBCMs) including full ocean circulation and cycling of trace element iron are being pursued by Follows, Sarmiento and others. In general within each class of models, that is, plankton models, mixing models, OBCMs, the individual models

vary widely in design and objectives, and much can be learned by comparison between such models.

The Working Group will in a suite of 2-3 workshops bring together these modelers and key experimentalists to encourage data synthesis, compare models, define common standard scenarios for validation and, in general, make available the compiled datasets (objective 1) to the wider scientific community.

Terms of Reference

Within the proposed 4-year period of existence, the WG plans to achieve the below objectives. Work on the first objective is already underway for several of the experiments, yet on the other hand this first objective is also essential before the next objectives 2, 3, and 4. can be realized. Therefore, we propose approval and implementation of the WG in two steps. In the first step, the WG would be formed and would be funded to work on only the first Term of Reference. Once this is realized and approved by SCOR, the remaining second part of the usual WG funding would be approved by SCOR and allocated towards realization of the remaining objectives 2. and 3. and 4. Thus, the corresponding four Terms of Reference would be as follows:

1. Compilation of a database for open access (via the Internet) of the following experiments:
    1.1. the 1999-2001 era (IronEx-1, IronEx-2, SOIREE, EisenEx, SEEDS-1), plus 1992 S.O. JGOFS
    1.2. the 2002 experiments (SOFeX-North, SOFeX-South, SERIES)
    1.3. 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.

2. Organization of 2-3 workshops where simulation modelers and key scientists of the experiments will meet. These workshops will be publicized in advance (SCOR website, other websites and newsletters) to allow colleagues beyond the actual WG membership to express interest in participation. Colleagues from developing nations will actively be encouraged to attend.

3. Organization of 2-3 special sessions at international marine science conferences will encourage a broad participation from scientists not yet involved in the activity.

4. Publication of new synthesis papers based on data comparison, a suite of simulation modeling articles, as well as the common database (i.e., its brief description) in a special issue of an oceanographic journal, as well as a multi-authored paper with recommendations for the next generation of *in situ* experiments and other types of process studies. The latter will include guidelines and advice on standardization of measurement protocols, as well as best procedures to ascertain timely submission of experimental data to a common database.

Optional. Beyond the above 4 terms of reference to be accomplished, the WG may organize or contribute to a training and education activity, for example, a summer school.

Data Management

The EUR-OCEANS Network of Excellence comprises a Data Integration and Networked Database task force with major objectives: (1) to rescue relevant historical datasets, (2) to organise long-term archiving of scientific information, (3) to develop an electronic portal for online access and dissemination. Dr. Nicolas Dittert, as head of this task force, will also be Full Member of the proposed SCOR WG, and relies on the permanent data centres World Data Centre-MARE (Bremen) and PANGAEA (AWI, Bremerhaven) for implementation of the above Terms of Reference number 1. The WDC-MARE is within the WDC Network linked with the relevant data centres in North America (e.g., CDIAC at Oak Ridge), Asia and other regions. The World Data Centres will also ensure long-term data storage.

Working Group Membership

Full and associate membership aims for a good mix of junior and senior scientists in both categories, where senior colleagues are urged to pursue own funds for workshop participation, thus allowing optimal allocation of the WG budget to participation of junior scientists.

Membership includes a mixture of pivotal leaders of the experiments, as well as scientists from the range of disciplines, as well as various modelers. In accordance with SCOR requirements, the Working Group consists of 10 Full Members. An extensive group of Associate Members will be sought in order to ensure the necessary additional expertise, as well as representation from the various *in situ* experiments, natural experiments, and simulation modeling. Both for Full Members and Associate Members, appropriate representation of both gender and

developing country scientists is achieved. Several more excellent scientists are envisioned to contribute datasets and/or modeling expertise via liaison with the Full and Associate Members, and workshops will be open to draw in a broad involvement. Below is a suite of names of Liaison Scientists, to which more names will be added in due course.

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	Eur. Union
Minhan Dai	ocean cycling of carbon and metals	GEOTRACES	China
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 OBCMs		USA
Fujii, Masahiko	simulation modeling	SEEDS-1&2, SERIES	Japan
Hong, Huasheng	ocean biogeochemistry		China
Kozyr, Alex	ocean CO_2 data management	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	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

<u>Endorsements and Financial Support and Budget</u>
This SCOR Working Group proposal has been endorsed by SCAR in its July 2006 meeting at Hobart, and by the Scientific Steering Committees of SCOR-IGBP-SOLAS, SCOR-IGBP-IMBER, and SCOR-GEOTRACES. These endorsements are of primary importance for fostering the constructive, collaborative spirit essential to meet the terms of reference. Copies of endorsement letters/documents are available on request. Nevertheless, SCOR is envisioned to take primary responsibility and accountability for the proposed working group.

The standard budget for a SCOR WG would allow organization of 3 workshops for 10-12 Full Members at a cost of US $ 15000 per workshop, i.e. in the order of US $ 45000 in total. The first installment of the subsidy would be allocated for the first workshop aiming primarily at the first Term of Reference.

Other participants would finance their travel costs from their own sources. Nevertheless additional finances may well be realized towards supporting Associate members, as well as financing other costs such as data management expenses or publication costs. We envision considering video-conferencing as another approach in order to save travel time and expenses as well as to avoid CO_2 emissions. Once this initiative is approved and established as a SCOR Working Group, we hope that national agencies (and the European Union) will be more convinced that their contributions are justified. These may range from a travel grant of one scientist of such nation, to hosting one of the workshops. For example Dr. Minhan Dai (China) and Prof. De Baar (The Netherlands) are confident in being able to raise national support for hosting one workshop in their country.

<u>References of overview articles each containing many more references</u>

Boyd,P., T.Jickells, C.Law, S.Blain, E.Boyle, K.Buesseler, K.Coale, J.Cullen, H.deBaar, M.Follows, M.Harvey, C.Lancelot, M.Levasseur, R.Pollard, R.Rivkin, J.Sarmiento, V.Schoemann, V.Smetacek, S.Takeda, A.Tsuda, S.Turner, A.Watson (2007) Mesoscale iron-enrichment experiments 1993-2005: synthesis and future directions. Science,315,612-617.

De Baar, H.J.W., P.W. Boyd, Kenneth H. Coale, Michael R. Landry, Atsuhsi Tsuda, Philip Assmy, D.C.E. Bakker, Y. Bozec, R.T. Barber, M.A. Brzezinski, K.O. Buesseler, M. Boyé, P. L. Croot, F. Gervais, M.Y. Gorbunov, P. J. Harrison, W.T. Hiscock, P. Laan, C. Lancelot, C. Law, M. Levasseur, A. Marchetti, F. J. Millero, J. Nishioka, Y. Nojiri, T. van Oijen, U. Riebesell, M.J.A. Rijkenberg, H. Saito, S. Takeda, K.R. Timmermans, M. J.W. Veldhuis, A. Waite and C.S. Wong (2005) Synthesis of Iron Fertilization Experiments: From the Iron Age in the Age of Enlightenment. In: Orr, J. C., S. Pantoja, and H.-O. Pörtner (eds.) The Oceans in High CO_2 World, Special Issue of *J. Geophys. Res. (Oceans)*, *110*, C09S16, doi:10.1029/2004JC002601, pp 1-24.

Jickells, T.D., Z. S. An, K. K. Andersen, A. R. Baker, G. Bergametti, N. Brooks, J. J. Cao, P. W. Boyd, R. A. Duce, K. A. Hunter, H. Kawahata, N. Kubilay, J. laRoche, P. S. Liss, N. Mahowald, J. M. Prospero, A. J. Ridgwell, I. Tegen, R. Torres (2005) Global Iron Connections Between Desert Dust, Ocean Biogeochemistry, and Climate, *Science*, 308, 67-71.

Recent relevant article on the natural Fe fertilization study KEOPS:

Blain,S., B.Queguiner, L.Armand, S.Belviso, B.Bombled, L.Bopp, A.Bowie, C.Brunet, C.Brussaard, F.Carlotti, U.Christaki, A.Corbiere, I.Durand, F.Ebersbach, J-

L.Fuda,N.Garcia, L.Gerringa, B.Griffiths, C.Guigue, C.Guillerm, S.Jacquet, C.Jeandel, P.Laan, D.Lefevre, C.LoMonaco, A.Malits, J.Mosseri, I.Obernosterer, Y-H.Park, M.Picheral, P.Pondaven, T.Remenyi, V.Sandroni, G.Sarthou, N.Savoye, L.Scouarnec, M.Souhaut, D.Thuiller, K.Timmermans, T.Trull, J.Uitz, P.vanBeek, M.Veldhuis, D.Vincent, E.Viollier, L.Vong, T.Wagener (2007) Effect of natural iron fertilization on carbon sequestration in the Southern Ocean, *Nature*, 446, 1070-1075.

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

Proposal for a **SCOR Working group on the Coral Triangle**: the centre of maximum marine biodiversity

Background.
Tropical marine ecosystems are well known for their high biodiversity. Coastal ecosystems (mangroves, seagrass beds, coral reefs) and near-shore oceanic ecosystems in the tropics 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 important sources of income for 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). However, their exploitation appears unsustainable and destructive, especially regarding coral reefs and mangroves.

Corals as main reef-builders, have increasingly endured various kinds of illnesses and plagues, such as by the coral predator Crown-of-Thorns starfish. Large reef areas have suffered from coral bleaching since 1983, which has been associated with patterns of elevated seawater temperatures. Governments, nature conservation organizations and scientists are aware that tropical marine ecosystems need to be protected to conserve global marine biodiversity.

Coral reefs are the world's most species-rich marine biotopes, as fringing reefs and barrier reef systems along continental shorelines and as atolls in the wide open ocean. One key to this success is formed by the complex of species interdependencies. Most reef corals and many other reef organisms harbor algal symbionts, which causes their rapid growth, lime stone accumulation and subsequent reef formation with the help of sunlight in transparent warm seawater. The corals and many other sedentary organisms, such as invertebrates and algae serve as food and hiding place to other organisms. Host-symbiont relationships appear very specific. This implies that in order to study the evolutionary history of species associations for a better understanding of species-rich ecosystems, a good knowledge of both host and symbiont species groups is required. Such studies usually require the application of molecular (DNA) techniques in order to reveal sibling species (look-alikes) and to indicate evolutionary inter-relationships (Gittenberger & Gittenberger 2005, Schiaparelli *et al*. 2005, Fransen 2007).

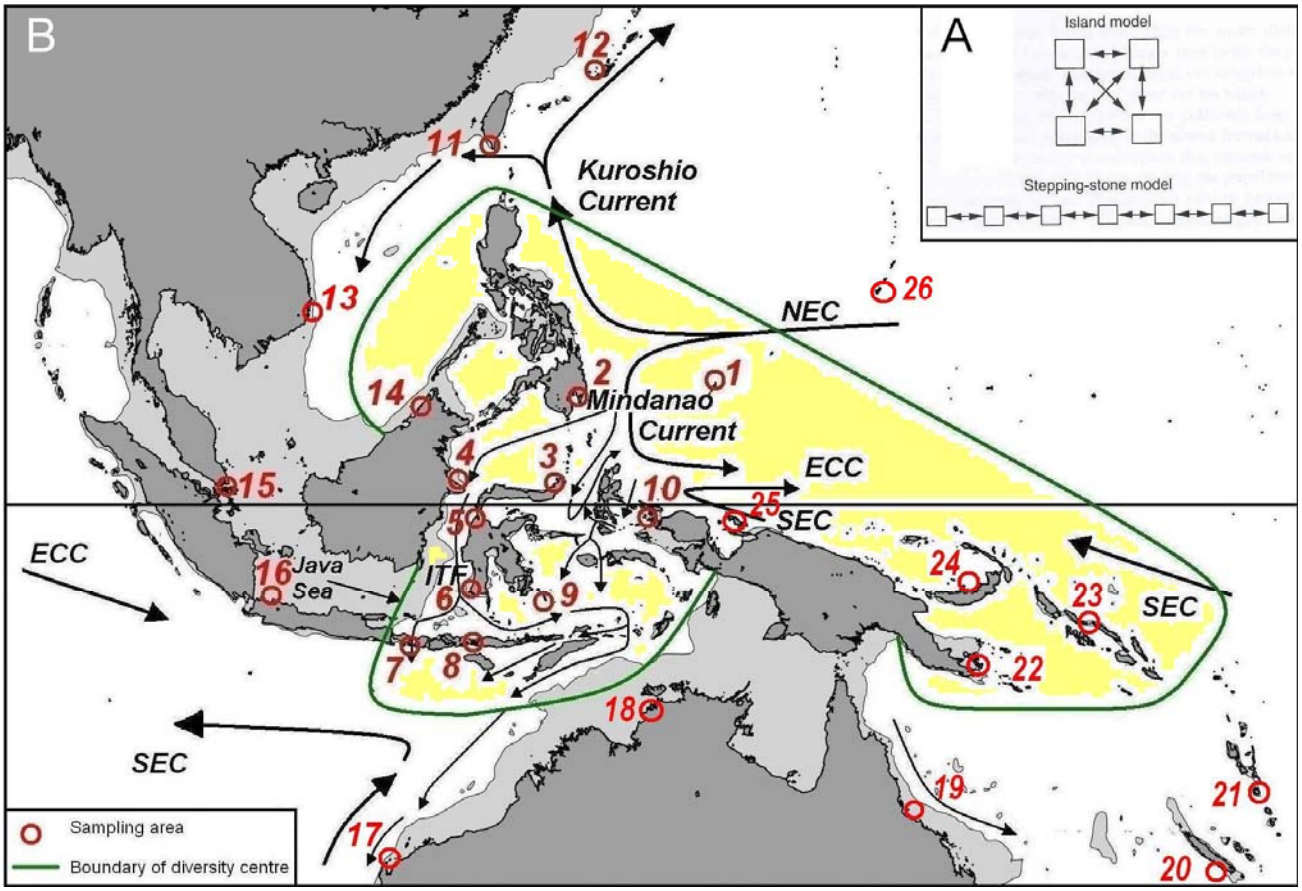


Fig. 1. The Coral Triangle: a search for patterns and processes. A. Possible mechanisms of connectivity between populations (Palumbi 2003). B. The Southeast Asian - West Pacific centre of maximum marine biodiversity with its hypothetical boundaries (Hoeksema 2007). Vanuatu may have to be included as well (Hoeksema unpublished). Oceanic currents are indicated to show most likely major pathways of gene flow. Numbers indicate suggested areas in and outside the Coral Triangle for data sampling.

Coral reefs of the Indo-Pacific are richer in species and more densely populated that those of the Atlantic, particularly the coral reefs in the Southeast Asian – West Pacific (SEA-WP) region. The world's highest concentration of marine species occurs in this region. Due to its dependence on corals, it has been dubbed "The Coral Triangle". Knowledge about its species richness and about endemic and endangered species is important for the design of marine protected areas (MPAs). However, due to a lack of data from enough localities it is not yet clear where the most likely 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. Such records are based on observations of sessile or demersal individuals but 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 would benefit from cooperation of specialists who work on different marine taxa. At present, different localities and 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 animal species show large geographical distribution ranges that may be the result of a high dispersal capacity linked to a long-lived larval stage, while other species show very restricted ranges due to a short larval stage or its absence in the case of brooders. In the latter category, much endemism can be expected and the distribution ranges of closely related endemics may reflect their speciation pattern. Most reef-dwelling species show wide-spread (Indo-West Pacific = IWP) ranges. This indicates that they are relatively long-lived (occasionally confirmed by their fossil record) and that their present range may have been shaped during long periods of dispersal that were interrupted during low sea level stands.

In order to get a better insight in marine species richness patterns in the Southeast Asian – West Pacific region, specialists of Indo-West Pacific reef organisms should integrate their efforts. By evaluating biodiversity patterns of various reef taxa, their respective biodiversity assessments should be comparable. This does not necessarily mean that all specialists need to adopt the same methods, but for a few taxa different assessments should be used to enable calibrations. Methods that imply large taxa usually have as disadvantage that they are less reliable and nearly irreproducible due to unresolved taxonomies. This problem can eventually be solved if specimens of sampled taxa are deposited in reference collections housed by museums. This is the most time consuming method. Another reliable method is the use of presence / absence data, which is mostly applied to smaller taxa (at genus or family level) that can be assessed in a relatively short time. Because of small taxon sizes, more taxa need to be compared in order to get reliable indications of species richness patterns.

Since present species range boundaries are largely determined by gene flow, it is important to find species suitable for phylogeographic studies that indicate connectivity among populations within species ranges. Such connectivity studies support the design of potential 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 organisms become extinct in one MPA and need to be replaced by larval recruits from an upstream MPA.

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, 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).

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 better fit 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. The different assessment methods that need to be discussed and combined for marine biogeographic and phylogeographic studies are:

ATBI (= All Taxon Biodiversity Inventory) aims at giving an overview of as many species as possible for an area with maximum effort, including the use of many collectors and collecting methods. In theory, this method will approach the real number of species present in an area. Although common species are likely to be identified, not all species need to be identified directly since their numbers as morpho-species count (Bouchet *et al.* 2002). Material is usually deposited in a scientific reference collection for further investigation. New species are very likely to be found in the IWP.

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 (more than 500), no estimate of the real species number can be found in the available time limit. Records of new species remain unclear unless material has been sampled for study by a specialist. If no specimens are available, the claims remain untested. There usually also is a high

risk of the occurrence synonymies in the species lists produced. The reliability of the results depends heavily on the experience of the observers.

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).

LIT (= Line Intercept Transect). This method can be used to record the occurrence of species (fish, corals, etc) along 10, 20, or 50 m lines at fixed depths (e.g. 5 m). Since LITs do not cover complete reef profiles and depth gradients, no representative species lists are made for each reef site. This method is currently used by the Research Centre for Oceanography in Jakarta to compare regions within the Coral Triangle. It is therefore useful as a relative measuring method.

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). The sampling should be based on the direction of ocean currents and the position of continental shelves (Fig. 1). 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). The results are very useful for designing network of MPAs. In total, the design of MPA networks would benefit from knowledge on species diversity, endemism and gene flow (Ablan *et al.* 2000, 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 agreement on

- methods for coral reef biodiversity assessment or ways to combine different methods
- integration of coral reef biodiversity research and conservation
- groups of reef organisms that may act as model taxa for coral reef biodiversity assessments
- areas suitable for biodiversity assessments and DNA sampling for connectivity studies

- reef organisms that are suitable for connectivity studies within the SEA-WP region, inside and around the Coral Triangle
- genetic markers for organisms in phylogeographic connectivity studies

Organisation of three meetings in the SEA-WP region in collaboration with regional branches of nature conservation organizations working on coral reef biodiversity management and its outreach. Objectives are

- to find agreements on the issues mentioned above
- to present results on marine biodiversity and phylogeography
- 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 of the results in a peer-reviewed volume on the Delination of the Coral Triangle using examples of various model taxa.

Time line

The meetings will be organized in conjunction with already planned symposiums and workshops. For example

2008. Coral Reef Biodiversity, Conservation and Ecotourism, a pre-meeting of the World Ocean Summit, Manado, North Sulawesi, Indonesia. In combination with reef surveys at Bunaken Marine Park and Selat Lembeh.

2009. Tun Mustapha Marine Park - Pulau Banggi Reef Survey, Sabah, Malaysia

2010. Second Asia-Pacific Coral reef Symposium, Phuket, Thailand.

The SCOR working group

Because the SEA-WP is large and specialists on IWP reef organisms are predominantly 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 on scientific results and identification workshops should preferably occur in the SEA-WP region in order to make information optimally 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 in order to discuss ideas and plans regarding the Coral Triangle. TNC has established a Coral Triangle Center (http://www.coraltrianglecenter.org/) at Bali (Indonesia) 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 by TNC, WWF and CI 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 NOAA's coral.aoml.noaa.gov e-mail list. Local scientists and marine conservation specialists (non-members) who are expected to be interested will be contacted personally.

Name	M/F	Expertise	Institute/Country
Co-chairs:			
Dr. Bert W. Hoeksema	m	Stony corals	National Museum of Natural History, Naturalis, Leiden The Netherlands
Dr. Annadel Cabanban	f	Reef fish/connectivity	WWF-Malaysia, Kota Kinabalu, Malaysia
Full members:			
Ir. Yosephine Tuti	f	Soft corals	Research Centre for Oceanography, Indonesian Institute of Science, Jakarta, Indonesia
Dr. Michael Dawson	m	Coelenterates	University of California, Merced, USA
Dr. Philippe Bouchet	m	Molluscs	National Museum of Natural History, Paris, France
Dr. Terry Gosliner	m	Molluscs	California Academy of Sciences, San Francisco, USA
Dr. Dwi Listyo Rahayu	f	Crustaceans	Timika Environmental Laboratory, RCO-LIPI, Timika, Indonesia
Dr. Paul Barber	M	Crustaceans/connect.	Boston University, Boston, USA
Dr. David Lane	M	Echinoderms	University of Brunei, Darussalam, Brunei
Dr. Sara Lourie	f	Reef fish / connect.	McGill University, Montreal, Canada
Associate Members:			
Dr. Sheila A. McKenna	f	Marine RAPs	Conservation International, Washington, DC, USA

Dr. Gerry Allen	m	Reef fish	Conservation International, Perth, Australia
Dr. Mark Erdmann	m	Crustaceans	Conservation International, Sorong, Indonesia
Dr. Alison Green	f	MPAs, Coral Triangle	The Nature Conservancy, Brisbane, Australia
Dr. Wilfredo Licuanan	m	Stony corals	De La Salle University / University of the Philippines, Manila, Philippines
Dr. Charlie Veron	m	Stony corals	Australian Institute of Marine Science, Townsville, Australia
Dr. Peter Ng	m	Crustaceans	Raffles Museum of Biodiversity, National University of Singapore, Singapore
Dr. Bertrand Richer de Forges	m	Crustaceans	Research Institute for Development (IRD), New Caledonia
Dr. Lida Pet-Soede.	f	Reef fish, Coral Triangle	WWF-Indonesia, Bali, Indonesia
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. Chris Meyer	m	Molluscs	Florida Museum of Natural History, University of Florida, Gainesville, USA
Dr. Gustav Paulay	m	Molluscs, invertebrates	Florida Museum of Natural History, University of Florida, Gainesville, USA
Dr. Chris Glasby	m	Bristle worms	Northern Territory Museum, Darwin, Australia
Dr. Nancy Knowlton	f	CReef, CoML	Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, La Jolla, USA
Dr. Jim Thomas	m	Crustaceans	Nova Southeastern University, Fort Lauderdale, USA

Dr. Charles H.J.M. Fransen	m	Crustaceans	National Museum of Natural History (NNM) Naturalis, Leiden The Netherlands
Dr. Adriaan Gittenberger	m	Molluscs, Tunicates	Naturalis, Leiden, The Netherlands
Dr. Leendert P. van Ofwegen	m	Octocorals	Naturalis, Leiden, The Netherlands
Dr. Willem Renema	m	Benthic foraminifera	Naturalis, Leiden, The Netherlands
Dr. Nicole J. de Voogd	f	Sponges	Naturalis, Leiden, The Netherlands
Dr. Gerard van der Velde	m	Flat worms	Naturalis, Leiden, The Netherlands
Dr. Harry ten Hove	m	Bristle worms	Zoological Museum of Amsterdam, The Netherlands
Dr. Annelies Pierrot-Bults	f	Arrow worms, Plankton	Zoological Museum of Amsterdam, The Netherlands
Dr. Rob W. van Soest	m	Sponges	Zoological Museum of Amsterdam, The Netherlands
Dr. John Hooper	m	Sponges	Queensland Museum, Brisbane, Australia

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SCOR SCIENTIFIC SUBSIDIARY BODIES - as of July 30, 2007

		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 116	Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination	Buesseler	Labeyrie
WG 119	Quantitative Ecosystem Indicators for Fisheries Management	Cury/Christensen	Burkill
WG 120	Marine Phytoplankton and Global Climate Regulation: The *Phaeocystis spp.* Cluster as a Model	Gieskes/Belviso	Kuparinen
WG 121	Ocean Mixing	Muench	Akulichev
WG 122	Mechanisms of Sediment Retention in Estuaries	Perillo/Syvitski	Sundby
WG 123	Reconstruction of Past Ocean Circulation (PACE)	Lynch-Stieglitz/Kissel	Labeyrie
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	MacCracken
WG 130	Automatic Plankton Visual Identification	Benfield/Culverhouse	Burkill
SCIENTIFIC STEERING COMMITTEES, PANELS, etc			
GLOBEC	Global Ocean Ecosystem Dynamics SSC	Werner	Burkill
GEOHAB	Global Ecology and Oceanography of Harmful Algal Blooms SSC	Raine/Babin	Hong
SOLAS	Surface Ocean - Lower Atmosphere Study SSC	Liss/Matrai	Hong
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research TT/SSC	Hall/Hansell/ Monfray	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	Elgar Desa	Pierrot-Bults
	SOLAS/INI Review of Anthropogenic Nitrogen Impacts on the Open Ocean	Duce/La Roche	MacCracken
	IGBP/SCOR Fast-Track Initiative on Atmospheric CO_2 and Ocean Biogeochemistry: Modern Observations and	Elderfield/ Caldeira/ Kleypas/	Labeyrie
PACKMEDS	Physics and Chemistry as the Key to Marine Ecosystem Dynamics and Structure	Mellilo/Rizzoli	Sundby
	Committee on Capacity Building	Ittekkot	

AFFILIATED PROGRAMS

CoML	Census of Marine Life	Grassle	Burkill
iAnZone	International Antarctic Zone	Orsi/Bergamasco	Kuparinen
IMAGES	International Marine Global Changes	Rohling	Labeyrie
InterRIDGE	International RIDGE Studies	German/Lin	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	Rapley	Hall/Labeyrie
SCOPE	Scientific Committee on Problems of the Environment	Sala	Pierrot-Bults
IOC	Intergovernmental Oceanographic Commission	Pugh	Sundby
WCRP	World Climate Research Programme	Church	MacCracken
PICES	North Pacific Marine Sciences Organization	Wada	Akulichev