Proposal for a SCOR working group on
Patterns in global plankton biogeography

Acronym: MARBIOG

Abstract

Marine planktic ecosystems respond to changes in environmental conditions such as global warming and ocean acidification, but they also drive global biogeochemical cycles themselves. Thus, a major reorganization in plankton biogeography due to climate change will feed back onto climate and global biogeochemical cycling by modulating ocean CO_2 storage and emissions of climatically important trace gases. Recently, the MARine Ecosystem DATa (MAREDAT) initiative brought together over 500'000 abundance and biomass measurements. For the first time, it is now possible to investigate plankton biogeography at the global scale, and within the context of a diverse set of applications from marine ecosystem model validation to applications in theoretical ecology. However, the MAREDAT data set is inhomogeneous, and has strong biases due to inconsistent sampling and data recording strategies. In order to fully understand plankton biogeography, a pairing with physiological trait data is essential. Here, we propose a SCOR working group on the analysis of plankton biogeography. The SCOR group would develop new protocols for the reporting and collection of global-scale planktic ecosystem data relevant for ocean biogeochemical cycles and macroecology, and would extend the current MAREDAT collection. We propose to include geo-referenced abundance/biomass and plankton physiological traits as well as biological rates in the next version of MAREDAT, and to analyse global patterns of plankton and trait biogeography across multiple trophic levels. We will synthesize data on both zooplankton and phytoplankton, develop tools to extrapolate scarce biological data to global scales, and compare global patterns of trait and plankton biogeography and diversity.

1. Scientific Background and Rationale

Anthropogenic climate change has been shown to impact marine planktic ecosystems in several crucial ways: On a global scale, the ocean is simultaneously undergoing warming, deoxygenation and acidification (Doney, 2010); that is, the ocean is "warming up, losing breath, and turning sour" (Gruber, 2011). Increased stratification in subtropical and temperate latitudes may limit nutrient availability and decrease primary productivity over this century (Steinacher et al. 2010). These changes may already be underway: the oligotrophic regions of the oceans appear to be expanding (Polovina et al. 2008), Pacific species have been shown to migrate into the Atlantic (Reid et al. 2001), zooplankton species shifts have been recorded in the North Atlantic (Beaugrand et al. 2004, 2008), and regime shifts have occurred in the Black and Caspian seas (Oguz & Gilbert, 2007). These and many more studies show that anthropogenic impacts affect ecosystems across multiple trophic levels and in many different ways (Doney et al. 2012).

Marine planktic ecosystems play an important role in the global biogeochemical cycling of key elements such as carbon, nitrogen and sulfur. Marine plankton form the base of the food web, and are of crucial importance for everything from the marine biological pump and ocean CO_2 storage to global fisheries and food security. Specific plankton groups produce nitrogen, sulfur and organohalide trace gases that can affect climate and atmospheric chemistry. Marine biodiversity forms a resource that is exploited in many industrial ways from the use of genes that code for low-temperature enzymes in detergents, to food supplies and animal food stocks. However, many marine ecosystem services related to global biogeochemical cycling, food provision and genetic diversity are still poorly quantified (Worm et al. 2006), since few aspects of marine ecosystem structure and composition are routinely monitored on the global scale. Thus, changes in marine ecosystem structure and functioning may crucially impact global climate and the livelihood of millions of people relying on marine resources. The FAO estimates that about one billion people worldwide rely on fish as their primary source of animal protein (FAO, 2000).

Recent advances in remote sensing now allow the estimation of different plankton functional types (PFTs) and size structure from space using water-leaving reflectance (Alvain et al. 2005, Hirata et al. 2008, 2011) or backscattering (Kostadinov et al. 2009, 2010), with prospects for long-term monitoring. However, most remote sensing algorithms have been validated using only a few hundred data points in limited ocean regions (e.g. Hirata et al. 2011, Alvain et al. 2012). Extensive sets of validation data are essential in order to use the high-resolution products to monitor patterns of change on the synoptic global scale. In order to quantify potential future change, ecosystem model simulations are required (Bopp et al. 2001, Hashioka et al. 2009, Steinacher et al. 2010). Marine ecosystem models are becoming increasingly complex (Follows et al. 2007), and the availability of trait data for their parameterization, and biomass data for their evaluation, is an important determinant in the rate of progress (Le Quéré et al. 2005, Litchman et al. 2006).

Recent years have seen an exponential increase in the availability of plankton trait data. Published phytoplankton trait data comprise maximum growth rates and nutrient, light and temperature responses (Klausmeier et al. 2004; Litchman et al. 2007, Litchman and Klausmeier 2008; Edwards et al. 2012; Thomas et al. 2012). Zooplankton trait data on size distribution, feeding strategies and behavioral patterns are also abundantly available (Forster et al. 2011, Kiørboe, 2008, Kiørboe 2011). Yet, an understanding of marine ecosystem structure and functioning based on first principles of ecology remains elusive, as high observational coverage remains limited to a few regions. In their recent review, Barton et al. (2013) suggest that an initiative to collect trait data in a concerted manner similar to MAREDAT is essential for further progress on the understanding of marine planktic ecosystem structure and functioning.

The MAREDAT2012 atlas of PFT abundance and biomass, compiled by members of this group, published publically available databases and peer-reviewed documentation. The analysis of the datasets is under way (Brun et al. in prep.; Vogt et al. in prep.; O'Brien et al., in prep.), and initial results reveal exciting insights into plankton biodiversity and biogeography. Yet, methodological and sampling biases are present, which need to be addressed in order to understand plankton community structure and its vulnerability to global change: (1) inconsistency in the reporting of species information, (2) bias due to inconsistent sampling methods, (3) seasonal and regional bias, and (4) does not include all existing data. While these issues were unavoidable in a first round of data collection, some can be addressed in a second round, and global standards can be set in a joint international effort.

In terrestrial ecosystems, trait and abundance measures have been combined into multiple indices of, for example, functional diversity, which is shown to relate to the magnitude of ecosystem services (e.g. Randerson et al. 2009; Clark et al. 2012). In order to quantify marine ecosystem services, a similar effort is necessary to understand, model and predict present and future changes in marine planktic ecosystems, and their consequences for ecosystem service provision. The systematic data collection we propose opens the door for a variety of different applications:

1) predict spatio-temporal patterns in species characteristics (Edwards et al. 2012, Thomas et al. 2012),
2) elucidate biodiversity patterns (O'Brien et al., in prep., Worm et al. 2006, Irigoien et al. 2004, Rutherford et al. 1999),
3) study the flow of matter across different trophic levels (Buitenhuis et al. 2013b),
4) study ecological niches of plankton species (Brun et al., in prep., Irwin et al. 2012),
5) investigate species and biome shifts in marine planktic ecosystems (e.g. Beaugrand, 2004, Beaugrand et al. 2008, Alvain et al. 2013),
6) assess global patterns of elemental ratios that are crucial for global biogeochemical cycling (Martiny et al. 2013),
7) determine the drivers of plankton biogeography (Dutkiewicz et al. 2012, Luo et al., 2014),
8) quantify ecosystem services related to global biogeochemical cycling, such as primary production (Buitenhuis et al. 2013b) nitrogen fixation (Luo et al. 2014), DMS production (Schoemann et al. 2005), and opal production and export (Sarmiento and Gruber, 2006),
9) calibrate remote sensing algorithms of phytoplankton groups (Alvain et al. 2012, 2013, Hirata et al. 2011).

1.3 Timeliness and relevance of the activity

The proposed activity is timely, as global data sets have only recently become available, and standards for their formats, archiving and quality control have not yet been set. Defining standards and joint interpretation will provide added value and will speed up research on the impact of climate change on marine ecosystems.

1.4 Relevance for SCOR sponsorship

This proposal addresses a topic at the forefront of current marine ecosystem research, focusing on global patterns of marine biogeography and potential changes in marine ecosystem structure and functioning, and will solve essential methodological and ecological questions that would otherwise remain unanswered were it not for the synergy between MAREDAT, international data archives such as ICSU's World Data System, GBIF, EMODnet and others, and the physiological/ecological trait communities that a SCOR working group provides on an international level. It would allow the participants to address ecological questions across multiple trophic levels by specifically tailoring the new plankton atlas to the scientific questions it aims to address. The working group would allow the combination of global scale information on ecosystem function and trait biogeography with information on community structure and plankton distribution, for example to address the role of biodiversity and functional diversity for ecosystem functioning and ecosystem service provision.

2. Terms of Reference

The proposed working group would

(1) summarize and assess the current availability of experimental and field measurements of plankton abundance, biomass, pigments and traits

(2) collaborate with data archives such as PANGAEA, BCO-DMO, and COPEPOD, and with SeaDataNet, the ICSU World Data System, the IMBER data management group, EMODnet, GBIF and others in order to develop and publish a comprehensive *Guide of standard protocols and best practices for the compilation of plankton data*, including specifications about data citation, geolocation, collection methods, standard parameter vocabularies & units, and quality control

(3) publish a new open access atlas of marine plankton abundance and biomass data (MAREDAT2017) and a collection of geo-referenced and in situ life history and physiological trait data across multiple trophic levels in marine ecosystems.

(4) develop and disseminate new methods to interpolate scarce biological data to scales relevant to address important concepts of theoretical ecology and to quantify important ecosystem services provided by marine ecosystems, using statistical tools from terrestrial ecosystem research and important concepts of theoretical ecology, and the quantification of important ecosystem services.

(5) generate a knowledge base of taxon-specific and phylogenetic-specific traits for the full size spectrum of plankton, i.e. from viruses to large planktonic metazoans and inform the observational community of our data needs and current gaps in our understanding of marine ecosystem structure and functioning.

(6) joint analyses of global patterns in trait and plankton biogeography and diversity and their role for marine ecosystem functioning across multiple trophic levels.

3. Working Plan

The workflow is broken down into 3 work packages.

Work package 1. Synthesis of plankton biomass data and plankton biogeography: WP1 will produce an update of the MAREDAT2012 first global atlas of marine plankton functional type abundance and biomass data in 2017. MAREDAT2017 will contain at least 14 contributions: updates of the 12 databases in MAREDAT2012 for diatoms (Leblanc et al. 2012), coccolithophores (O'Brien et al. 2013), nitrogen fixers (Luo et al. 2012), *Phaeocystis* (Vogt et al. 2012), picophytoplankton (Buitenhuis et al. 2012a), bacteria (Buitenhuis et al. 2012b), micro- (Buitenhuis et al. 2010, 2013a), meso- (Moriarty and O'Brien, 2012) macrozooplankton (Moriarty et al. 2013), pteropods (Bednarsek et al. 2012) and planktic foraminifers (Schiebel and Movellan 2012), as well as HPLC pigments (Peloquin et al. 2013). In addition, an update of the World Ocean Atlas Chlorophyll *a* database (Conkright et al. 2002) will be included, as well as a new database on autotrophic/mixotrophic dinoflagellates. We will also solicit contributions on gelatinous plankton, virioplankton and planktic species in palaeoceanographic sediment records.

Work package 2. Synthesis of plankton life history traits: WP2 will generate a knowledge base of taxon-specific traits for the full size spectrum of plankton (MARETRAIT), which will be included in the taxonomic register WoRMS. WP2 will produce comparisons of phytoplankton and zooplankton traits across size classes, and of trait biogeography across multiple trophic levels. The zooplankton traits will include grazing rate and respiration rate as a function of temperature, assimilation and gross growth efficiency, and DOM exudation (Buitenhuis et al. 2006, 2010, Kiørboe and Hirst 2014). The phytoplankton traits will include intra- and inter-PFT changes in growth rate with cell size (Le Quere et al. in prep.), temperature dependence of growth rate (Buitenhuis et al. 2013b; Thomas et al. 2012) and nutrient uptake traits (Klausmeier et al. 2004; Litchman et al. 2007, Edwards et al. 2012). This WP will also address the issue of compatibility between geo-referenced and laboratory trait data, and develop recommendations for the collection, reporting and use of these different data types.

Work package 3 Understanding marine ecosystem structure and functioning: WP3 will combine trait and biomass data to further our understanding of marine ecosystem function. It will develop and test statistical techniques for the extrapolation of scarce biological data to larger scales, using methods common in species distribution modeling. It will build on the MAREDAT2017 and MARETRAIT datasets, and the EURO-BASIN special issue which includes key links between planktic systems and ecosystem services. WP3 will quantify fluxes between the different trophic levels, and assess links between different forms of diversity and the magnitude of ecosystem services related to biogeochemical cycling and food-web dynamics. WP3 will also identify gaps in our understanding of marine ecosystems and associated data needs, and publish a joint paper on this issue.

Pre-meeting: The members of the proposed SCOR working group will attend the IMBER Open Science Conference in Bergen in June 2014, but it will not rely on SCOR funding. A pre-meeting will take place after a common session between the trait and biomass community on: "Data synthesis and modeling of marine planktic ecosystems with plankton functional types and trait-based models". This session invites discussion between members of trait ecology and plankton biogeography on how to combine abundance and biomass data with trait and pigment data, and how to link them for a better quantification of ecosystem services.

Kick-Off Meeting: In order to provide international visibility and assure high attendance, the kick-off meeting would coincide with a relevant international conference, probably the ASLO Aquatic Sciences meeting in 2015 in Granada, Spain. We will organize a 2-day workshop after the meeting where data collection strategies will be coordinated.

Further meeting: A second business meeting would be organized in 2016 during the Ocean Sciences conference in New Orleans. During this meeting, the progress of data collection and publication would be reviewed, and the guidelines for data standards re-evaluated.

Workshop: In the beginning of 2017, the proposed SCOR working group would host a workshop at the University of East Anglia. WP1 will discuss ongoing and new scientific collaborations to exploit the MAREDAT2017 databases (e.g. ecological niche determination, gap filling algorithms, bottom-up / top-down interactions). WP2 will finalise the zooplankton trait intercomparison and discuss the phytoplankton trait intercomparison. Both groups together will discuss mathematical tools to constrain PFT traits using biogeochemical models evaluated against the MAREDAT2017 databases. Furthermore, the group will coordinate the analysis of the collected data, i.e. identify lead authors for the planned set of synthesis papers. During the workshop, the group would generate an outline for the community white paper on our current understanding of marine ecosystem structure and functioning.

Final meeting: In 2018, members of this SCOR working group would meet either at the Ocean Sciences 2018 or at the ASLO meeting, and coordinate further joint analysis of the data collected.

Timeline of Milestones

Year 1 (2015):
A) Synthesis of protocols specific for each data type, method and plankton group (WP1&2).
B) Identification of ecological, physiological and morphological traits with sufficient data coverage, in space and time, to be included in MARETRAIT2017 (WP2).
C) Development and dissemination of guidelines for quality control (WP1&2).
D) Data call for MAREDAT2017 (WP1).

Year 2 (2016):
A) Data collection for the different plankton groups to be included in MAREDAT2017 (WP1).
B) Submission of individual MAREDAT2017 datasets and papers. (WP1).
C) Inclusion of taxon-specific traits in the taxonomic register WoRMS (WP2).

Year 3 (2017):
A) Publication of a standard protocols and software (WP1&2)
B) Workshop at UEA (WP1&2&3)
C) Papers analyzing phyto- and zooplankton trait biogeography across different PFTs (WP2)
D) Open access publication of final MAREDAT2017 papers and databases (WP1).

Year 4 (2018):
A) Submission of methods paper to interpolate scarce and highly variable biological data sets to larger scales (WP3).
B) Submission of a paper analyzing and comparing MAREDAT2017 biomass data across different taxonomic groups and trophic levels (WP1&3).
C) Submission of a paper analyzing links between phyto- and zooplankton biogeography and their respective patterns in trait distribution across different PFTs (WP3)

4. Deliverables

The main final products of the SCOR working group are the updated MAREDAT2017 atlas of global plankton biogeography by the end of 2016, consisting of a set of at least 14 papers on plankton abundance, biomass and pigment data; and a new MARETRAIT2017 atlas, with at least two papers on geo-referenced/laboratory trait data for zooplankton and phytoplankton and three synthesis papers that analyse the MAREDAT and MARETRAIT databases across all groups and links between plankton biogeography and global patterns in trait distribution. A guide will be published with data format and quality control recommendations, including taxonomic specification, and standard units for abundance, biomass, pigment and trait data to make them suitable for a wide set of applications in biological oceanography and marine ecosystem modeling. Common software will be created and published on the MAREDAT website (www.maredat.info) that handles (1) the quality control procedure, (2) the generation of gridded products, and (3) routines for the interpolation of data to larger scales using novel techniques (e.g., Lana et al. 2011; Landschützer et al., 2013). A white paper will be written by the end of year 3 that identifies gaps in our current understanding of marine ecosystem structure and functioning, and details the data needed to address these. A joint interpretation of the data and recommendations will also be highlighted in a high-profile publication written by the group in year 4.

5. Capacity building

From a socioeconomic perspective, many issues in current marine ecosystem research, such as the quantification of potential impacts of global change on marine ecosystem service provision is highly important for developing countries and economies in transition. The results of the proposed activity will inform policy makers and the public on potential hotspots of ecological change, and on locations with a high degree of diversity. The proposed SCOR working group would bring together the MAREDAT community with other marine ecologists, data archives, marine ecosystem modelers (e.g. MAREMIP initiative), and members of the remote sensing community. These communities have a common goal – the understanding of present and future marine ecosystem structure and functioning – but are currently not linked through an international working group. The SCOR working group would thus facilitate the important exchange of ecosystem data between different ecosystem researchers working toward a common goal. For example, the remote sensing community may require data for the evaluation of their algorithms, while marine ecosystem modelers will need physiological rates/trait data to implement further complexity into their models. A SCOR working group would also lead to the identification of data requirements and needs by these different communities, and how MAREDAT could accommodate a maximal set of such needs through sensible and simple data standards. Bringing these diverse communities together around a table would also increase the international visibility of marine ecosystem research, and will lead to future collaboration, ideas and findings. The SCOR working group would also increase efficiency in the expansion and establishment of global plankton data sets. The MAREDAT community already has experience with the generation of a global plankton atlas, and this know-how can be exploited by the trait community to collect and archive data more effectively. In addition, close contacts will be established with members of the terrestrial ecosystem community through the use of statistical tools and concepts that are common in terrestrial ecosystem research. Building necessary capacities in developing countries can be fostered by providing access to open-source data, best practice manuals and standard protocols that will augment access by members from countries with limited financial and infrastructural means to generate their own data. Additional funding would be requested from SCOR's travel grant program to finance the attendance of at least one additional young scientist from a developing country to attend international meetings, whenever the proposed SCOR group members meet. Thus, young scientists would be trained in essential networking and technical skills while being introduced to leading international members in the field.

6. Working Group Composition

Full members, chairs in bold

Name		Place of work	Expertise
Meike Vogt	F	ETH Zürich, Switzerland	Phytoplankton ecological niches and biogeochemistry, global plankton biogeography
Erik Buitenhuis	M	University of East Anglia, UK	Plankton ecology, global biogeochemical modelling, macroecology
Simon Claus	M	Flanders Marine Institute	Biodiversity patterns. Contact with EMODnet and WoRMS
Forough Fendereski	F	Gorgan University, Iran	Plankton biogeography and marine biomes
Takafumi Hirata	M	Hokkaido University, Japan	Detection of plankton functional groups from space
Xabier Irigoien	M	King Abdullah University of Science and Technology, Saudi-Arabia	Marine ecology, biodiversity
Thomas Kiørboe	M	DTU-Aqua, Denmark	Zooplankton ecology and traits
Elena Litchman	F	Michigan State University, USA	Phytoplankton ecology and traits
Yawei Luo	M	Xiamen University, China	Nitrogen cycling, traits of nitrogen fixers
Maria Deng Palomares	F	World Fish Centre, Philippines and University of British Columbia, Canada	Fish population dynamics

Associate members

Andrew Barton	M	Duke University, USA	Lower trophic level trait ecology, ecological modelling
Karine Leblanc	F	MIO CNRS, France	Diatom biology and silicon cycling
Stephane Pesant	M	Bremen University, Germany	Biological data collection, integration and publishing
Ralf Schiebel	M	University of Angers, France	foraminifera and palaeoceanography

7. Working Group Contributions

7.1 Full Members

1. **Meike Vogt**: Co-coordinator of MAREDAT2012 & 17. Collection of standardized plankton data for use in biological oceanography and ecosystem modeling. Standard protocols and data collection for use in model validation and marine ecology. Species distribution modelling and phytoplankton macroecology. Member of MAREMIP SSC.

2. **Erik Buitenhuis**: Co-coordinator of MAREDAT2012 & 17. Marine ecologist. Ecosystem model development and evaluation. Macroecology, interactions between biogeochemical cycles and both autotrophs and heterotrophs.
3. **Simon Claus**: Coordinates the biology project of EMODnet. Data management in the Belgian NODC, trait and abundance cross-referencing.
4. **Forough Fendereski**: Marine ecologist working on plankton biogeography and on neural networking methods for the definition of marine biomes. Intelligent clustering and interpolation of marine ecosystem data.
5. **Takafumi Hirata**: Detection of plankton functional groups from space / remote sensing. Member of the MAREMIP SSC.
6. **Xabier Irigoien**: Plankton ecology, trophic relations in plankton, climate effects and biodiversity patterns.
7. **Thomas Kiørboe**: Zooplankton traits, quantification of ecosystem services.
8. **Elena Litchman**: Phytoplankton community ecologist, plankton trait data. Interpretation of patterns from first principles and the combination of trait and abundance data.
9. **Yawei Luo**: Ocean nitrogen cycling. Traits and global biogeochemistry of nitrogen fixers. Member of MAREDAT
10. **Maria Deng Palomares**: Fish population dynamics and fish data. Coordinator of SeaLifeBase, which aims to provide a 'FishBase-like' database for all other marine organisms that are not included in fish databases.

7.2. Associate Members

1. **Andrew Barton**: Ecosystem modeler and trait ecologist. Global marine lower trophic level trait data, combination of abundance and trait data.
2. **Karine Leblanc**: Marine biology with a focus on diatoms and biogeochemical flux measurements.
3. **Stephane Pesant**: Plankton ecology, editor for biological data at PANGAEA, and advocate for citation, open access and reuse of scientific data. Stephane is a member of Tara Oceans, SeaDataNet, and EMODNet Biology, and was guest editor for MAREDAT 2012 Atlas.
4. **Ralf Schiebel**: Foraminifera and palaeoceanography. Long-term changes in marine ecosystem structure and functioning, with a focus on calcifying organisms.

8. Relationship to other international programs and SCOR Working groups

The proposed working group would allow knowledge transfer from SCOR working groups 125 (Global Comparisons of Zooplankton Time Series) and 137 (Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation), but it would focus on open ocean and global scale patterns of both autotrophic and heterotrophic constituents of lower trophic level ecosystems, and the combination of different data types. We will work closely with the World Register of Marine Species (WoRMS), in particular for the review of ecological and biological trait information that is being coordinated in the European Marine Observation and Data Network (EMODnet). We will work closely with ICSU's World Data System, in particular with its thematic data center PANGAEA, where the MAREDAT atlases are published. Biogeographic data published at PANGAEA are cross-linked with registers for taxonomy (WoRMS) and are served/disseminated to SeaDataNet, GBIF, OBIS and EMODNet. The working group would facilitate data exchange on marine planktonic traits, presence/absence data, and methodologies to interrogate the databases to define biogeographies ecological niches and to quantify functional diversity.

9. References (Full member references in Appendix)

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