SCOR Working Group Proposal

Title

Towards a Global Comparison of Zooplankton Production: Measurement, Methodologies and Applications

Acronym

ZooProd

Abstract

Knowledge of zooplankton production rates is key to our understanding how physical forcing such as climate change will impact the material and energy flux pathways which characterize the structure and function of marine ecosystems. Unfortunately, our understanding of the processes driving variation in zooplankton production is limited due to difficulties in identifying the most practical and relevant methodologies for measuring the production rates of natural zooplankton populations and communities across a wide range of phyla and trophic levels. A quantitative comparison, reevaluation and inter-comparison of methodologies are urgently needed.

The proposed Working Group (WG) will focus its attention on assessing the applicability of existing methodologies (i.e., traditional and biochemical methodologies) for measuring *in situ* rates of zooplankton production, and for developing new methodologies. The work will be conducted over a period of four years, culminating in a final report that will:

1. Review and summarize assumptions (in peer-reviewed articles), recent progress and limitations of traditional and biochemical methodologies for measuring the production of natural zooplankton populations and communities.
2. Develop recommendations for standardized protocols for both the traditional and biochemical methodologies available for measuring zooplankton production. These standardized protocols will be made available globally to users via a website.
3. Build a global network of the scientists and laboratories measuring zooplankton production rates.
4. Develop a rigorous inter-comparison/calibration methodology for production rates measured with different approaches.
5. Compile published rates of zooplankton production measured with both traditional and biochemical methodologies.
6. Promote international cooperation of zooplankton production researchers through international organizations such as ICES, PICES and IMBER.

Scientific Background

Zooplankton communities occupy a central position in the flow of matter and energy passing from primary producers to animals at higher trophic levels in marine ecosystems (e.g., Lalli and Parsons 1993). Over the past two decades, the need for quantitative evaluations of marine ecosystem function has been emphasized as necessary toward improving our understanding of how marine ecosystems respond to global climate change (e.g., Walther et al. 2002; Edwards and Richardson 2004; Boyce et al. 2010). Zooplankton production represents a quantitative proxy for the functional response of marine ecosystems since it corresponds to the zooplankton biomass accrued through consumption of lower food web levels.

Zooplankton production has long been estimated using a variety of methods which either: 1) follow the development of zooplankton populations or communities over the course of several weeks or months (e.g., Hirche et al. 2001; Ohman and Hirche 2001); or 2) employ *ex situ* fixed-period incubations (e.g., Burkill and Kendall 1982, Kimmerer and McKinnon 1987; Berggreen et al. 1988; Peterson et al. 1991). Incubation-based techniques with simultaneous sampling of natural communities are the most widely used

methods in the field. In 2000, Runge and Roff (2000) reviewed the field application of these traditional methods in a chapter of the ICES Zooplankton Methodology Manual (Harris et al. 2000). However, shortly after its publication, some studies documented limitations of the incubation-based methods, which required revision of the application and interpretation of these approaches and their derived production estimates (Hirst and McKinnon 2001; Hirst et al. 2005; Kimmerer et al. 2007). Meanwhile, advances in biochemical tools for measuring zooplankton growth and production, which were not covered by Runge and Roff (2000), were also developed (Wagner et al. 2001; Sastri and Roff 2000; Oosterhuis et al. 2000; Yebra and Hernández-León, 2004) and have been applied to a wide range of organisms and habitats (e.g., Yebra et al. 2004, 2009; Sastri et al. 2012).

Over the past half century, phytoplankton production rates have been measured using radio-isotope (Steeman-Nielsen 1952) and stable isotope-based approaches (Hama et al. 1983). In the early 1980's, similar measurement approaches were also developed for bacterial production rates (Fuhrman and Azam 1982). A major consequence of the long-term use of routinely applicable *in situ* methods for phytoplankton and bacterial productivities is that we can now generate their spatio-temporal patterns at relatively high resolution using satellite imagery. SCOR has sponsored several working groups covering related topics such as standardization for zooplankton sampling (WG3 and WG13), biomass measurements (WG23), and global comparisons of zooplankton time series (WG125). Despite support by SCOR and the availability of many measurement methods zooplankton production, the routine and universal application of these methodologies is limited because they can only be used under specified conditions and are not necessarily comparable. Moreover, the existing production estimates include some uncertainty because zooplankton communities span a wide range of phyla and trophic levels.

In October 2012, a workshop was convened to discuss the issues surrounding the most commonly applied zooplankton production measurement methodologies. The motivation for this workshop was the recognition that there is still little knowledge of, or confidence in, the existing zooplankton production methodologies relative to those used for estimating primary and bacterial productivity. The two major conclusions which emerged from the workshop are as follows:

1) We need to summarize assumptions, limitations and recent progress of existing methodologies which purport to measure zooplankton production.
2) We need methods which are routinely applicable to natural zooplankton populations and communities across a wide range of phyla and trophic levels.

In order to resolve these significant issues, an international WG on zooplankton production methodologies was proposed during the workshop.

Rationale

It is particularly timely to focus on zooplankton production because assumptions and limitations underlying the most commonly applied methods have now been reconsidered and other approaches have also been developed since the publication of the *ICES Zooplankton Methodology Manual* in 2000. A major consequence of these recent developments has been a general confusion about how these methods should be applied for natural zooplankton populations and communities, and how the various estimates can be compared. The latest IPCC report (IPCC 2013) has reaffirmed that global warming exerts widespread impacts on natural systems; a quantitative evaluation of secondary productivity is therefore both timely and critical for understanding how marine ecosystems adapt to continued global climate change. However, there is still little information on zooplankton production as a proxy for the integrated biological response of lower trophic levels in marine food webs. Indeed, the generation of global maps of primary productivity is now routine, but the ability to make similar spatial comparisons is lacking for zooplankton productivity. At this stage, a comprehensive review of zooplankton production methodologies (in the context of recent advances) would allow us to:

1) Elaborate on recommendations for the standardized application of traditional and biochemical zooplankton production measurement methodologies for worldwide users
2) Develop protocols for inter-comparison/calibration between different approaches
3) Compile existing zooplankton production estimates.

Since the WG objectives are global and fundamental to ocean science, it is reasonable that the WG activities are sponsored by an international scientific organization such as SCOR. The WG objectives can also be shared by the global scientific efforts and the science topics of marine ecosystems emphasized by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES) and the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project. If this WG is sponsored by SCOR and endorsed by PICES, ICES and IMBER, information exchanges and discussion on ocean science would be enhanced among members of these organizations, and would provide the basis for training in both developed and developing countries. For this purpose, the proposed WG has assembled scientific expertise from PICES/ICES and from several developing nations in order to fully represent the worldwide community of zooplankton researchers as well as to foster a global exchange of scientific information and discussion.

Terms of Reference

This WG will:
1. Summarize and review assumptions (in peer-reviewed articles) and recent progress and limitations of traditional and biochemical methodologies for measuring zooplankton production of natural populations and communities.
2. Develop recommendations for standardized protocols for both traditional and biochemical zooplankton production rate measurement methodologies and make these available worldwide for users on a website.
3. Build a global network of scientists and laboratories measuring zooplankton production.
4. Develop protocols for inter-comparison/calibration between different approaches.
5. Compile existing zooplankton production rates estimated by traditional and biochemical approaches.
6. Promote international cooperation between zooplankton production researchers through international organizations such as ICES, PICES and IMBER.

Working plan

Year 1 (2016)
- WG meetings will be held for discussing details of the working plan just before or after the Ocean Science Meeting and the ICES Working Group on Zooplankton Ecology (WGZE) annual meeting.
- The WG will host a workshop at the PICES/ICES 6th Zooplankton Production Symposium (ZPS) to discuss traditional and biochemical methodologies for measuring zooplankton production across a wide range of phyla and trophic levels, including gelatinous groups and other less studied taxa in addition to major crustacean groups. After this workshop, a WG meeting will be held for drafting review articles on traditional and biochemical methodologies for measuring zooplankton production.
- The WG will work on the review articles summarizing the assumptions, advantages and limitations of both traditional and biochemical methodologies for measuring zooplankton production of natural populations or communities.

Year 2 (2017)
- The WG will submit the articles to peer-reviewed journals.
- A WG meeting will be held to discuss standardized procedures and to develop recommendations for the traditional and biochemical zooplankton production measurement methodologies just before or after the Aquatic Sciences Meeting.

- The WG will produce and publish guidelines for standardized procedures with recommendations for worldwide users on the proposed website.
- The WG will build a global network of scientists and laboratories measuring zooplankton production in collaboration with former members of the SCOR WG on Global Zooplankton Time-series (WG125).
- The WG will compile existing zooplankton production rate estimates measured by traditional and biochemical methodologies in order to make comparisons and to quantify driving forces.
- The WG will post the lists of the network partners and the zooplankton production estimates on a website.

Year 3 (2018)
- A WG meeting will be held to discuss suitable protocols for inter-comparison/calibration between different approaches and the WG outreach activities (e.g., summer schools and promotion to international organizations).
- The WG will develop methodological protocols for inter-comparison/calibration of different approaches for measuring zooplankton production.
- The WG will disseminate the results produced (i.e., guidelines report, list of partners, compilation of production estimates) through workshops and sessions at international conferences such as Aquatic Sciences Meeting, Ocean Sciences Meeting, as well as at ICES WGZE and PICES annual meetings.

Year 4 (2019)
- The WG will promote global cooperation and collaboration on zooplankton production measurements in international programs endorsed by ICES, PICES and IMBER.
- The WG will submit a final report to SCOR.

Deliverables
1. The WG will publish peer-reviewed review articles summarizing the assumptions, recent advances and limitations of both traditional and biochemical methods to estimate production of zooplankton populations and communities.
2. The WG will post a guideline report with recommendations on standardized procedures for both traditional and biochemical methods on a website of an international organization such as PICES and/or ICES.
3. The WG will host summer schools teaching traditional and biochemical methodologies for measuring zooplankton production for students and early-career scientists.

Capacity Building
1. The WG will work to create a global network of collaborating zooplankton production researchers from ICES and PICES nations as well as developing countries.
2. The WG will post a list of the scientists and laboratories (and their contact information) forming the global network on a website.
3. The WG will convene an international and/or regional summer school on zooplankton production measurements for students and early-career scientists.
4. The WG will provide guidelines and assistance on the application of standardized experimental procedures of traditional methodologies and biochemical approaches to estimate zooplankton production for worldwide users on a website.
5. The WG will promote integrating zooplankton production rate measurements into ecological modelling and satellite imaging efforts.

Working Group composition

Full Members (*: Chairs, TM: Traditional method, BM: Biochemical method)

	Name	Gender	Place of work	Expertise/ Area	Roles
1	Toru Kobari*	Male	Japan	TM/BM expertise, Western North Pacific	Coordinating to PICES
2	Lidia Yebra*	Female	Spain	BM developer, BM/TM expertise Mediterranean Sea and North Atlantic	Coordinating to ICES
3	Akash Sastri	Male	Canada	BM developer, Freshwaters, Eastern North Pacific and Arctic Seas	Coordinating to PICES
4	Andrew G. Hirst	Male	UK	TM developer, Global oceans	Compiling zooplankton production data
5	Wim J. Kimmerer	Male	USA	TM developer, Coastal regions	Compiling zooplankton production data
6	Sigrún Jónasdóttir	Female	Denmark	TM/BM expertise, North Atlantic and North Sea	Coordinating to ICES
7	Felipe Gusmão	Male	Brazil	TM/BM expertise, South Atlantic	Networking with developing countries
8	Jenny Huggett	Female	South Africa	TM/BM expertise, Upwelling regions and Indian Ocean	Networking with developing countries
9	Rubao Ji	Male	USA	TM expertise, Production modeler, North Atlantic and Polar Regions	Coordinating to ICES, Incorporating WG products to ecological modelling
10	Takafumi Hirata	Male	Japan	Satellite imagery analysis, Global oceans	Incorporating WG products to satellite imagery

Associate Members (TM: traditional method, BM: biochemical method)

	Name	Gender	Place of work	Expertise/ Area	Roles
1	Ruben Escribano	Male	Chile	TM expertise, South Pacific	Coordinating to IMBER
2	Hyung-Ku Kang	Male	Korea	TM expertise, Continental shelf	Coordinating to PICES
3	Marina Sabatini	Female	Argentina	TM expertise, South Atlantic	Networking with developing countries
4	William T. Peterson	Male	USA	TM expertise, Upwelling regions	Coordinating to PICES
5	Sanae Chiba	Female	Japan	Long-term change, Western North Pacific	Coordinating to WG125
6	Elena	Female	Sweden	BM expertise,	Coordinating to ICES

	Gorokhova			Freshwaters and coastal regions	
7	May Gómez	Female	Spain	BM expertise, Upwelling regions, North Atlantic	Coordinating to ICES

Working Group contributions

Toru Kobari

    Develop methodology for comparison/calibration between different approaches.

    Produce a review paper and standardized manual on traditional methodologies.

    Build global network of researchers measuring zooplankton production.

    Produce WG report to SCOR committee.

Lidia Yebra

    Develop methodology for comparison/calibration of different approaches.

    Produce a review paper and standardized manual on biochemical methodologies.

    Build global network of researchers measuring zooplankton production.

    Produce WG report to SCOR committee.

Akash Sastri

    Promote WG activities and results to PICES.

    Contribute to review paper and standardized manual on biochemical methodologies.

    Build network of researchers measuring zooplankton production in North Pacific and freshwaters.

Andrew G. Hirst

    Compile existing zooplankton production estimates by traditional and biochemical methodologies.

    Contribute to review paper and standardized manual on traditional methodologies.

    Build network of researchers measuring zooplankton production in Southern Ocean.

Wim J. Kimmerer

    Contribute to review paper and standardized manual on traditional methodologies.

    Develop methods of estimating biomass per animal using image analysis.

    Build network of researchers measuring zooplankton production in upwelling regions.

Sigrún Jónasdóttir

    Promote WG activities and results to ICES.

    Convene international workshops, sessions and/or summer schools.

    Build network of researchers measuring zooplankton production in North Atlantic.

Felipe Gusmão

    Build network of researchers measuring zooplankton production in South Atlantic.

    Convene international and/or regional workshops, sessions and/or summer schools.

    Contribute to review paper and standardized manual on biochemical methodologies.

Jenny Huggett

    Build network of researchers measuring zooplankton production in South Atlantic and Indian Ocean.

    Convene international and/or regional workshops, sessions and/or summer schools.

    Contribute to review paper and standardized manual on traditional methodologies.

Rubao Ji

    Compile existing zooplankton production models.

    Promote incorporation of WG products to ecological modelling.

    Build network of researchers modeling zooplankton production.

Takafumi Hirata

    Produce global and/or regional map of zooplankton production estimates using satellite imagery.

Promote incorporation of WG products to satellite imaging technology.

Relationship to other international programs and SCOR Working groups
1. Contribute to the update of the Zooplankton Methodology Manual (2000) produced by the ICES Working Group on Zooplankton Ecology (WGZE) by publishing review papers.
2. Promote zooplankton production measurements to science plans in international organizations such as PICES, ICES and IMBER.
3. Propose sessions and workshops at international meetings and conferences co-sponsored by ASLO, PICES and ICES.
4. Creation of a global network for zooplankton production researchers based on the products of SCOR WG125.
5. Promote zooplankton production measurements and networking within the 2nd International Indian Ocean Expedition (IIOE-2), an IOC/SCOR/IOGOOS initiative from 2016 to 2020.

Appendix
Key references for each full member (up to 5 papers)

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