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Parameterizing and operationalizing zooplankton population dynamic and trophic interaction models

Introduction

Stéphane Plourde[1]* and Howard I. Browman[2]

[1]*Department of Fisheries and Oceans Canada, Maurice-Lamontagne Institute, 850 Route de la Mer, PO Box 1000, Mont-Joli, QC, Canada G5H 3Z4*
[2]*Institute of Marine Research, Austevoll Research Station, Storebø 5392, Norway*

**Corresponding author: tel: 1-418-775-0676; fax: 1-418-775-0546; e-mail: stephane.plourde@dfo-mpo.gc.ca*

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This themed set (TS) of articles was motivated by the need for modellers and biologists–ecologists to work more closely together to produce more realistic simulation models of zooplankton population dynamics and trophic interactions. The TS was intended to cover a broad range of subjects and potential approaches, including identifying crucial gaps in our knowledge and parameterization of biological/physiological processes, experimental/fieldwork aimed at quantifying the response of key physiological and behavioural processes to variations in the environment, identifying novel modelling approaches that would enable the development of simulation models that would minimize the need for species-specific (and stage-specific) model parameterization, etc. Five articles were accepted for inclusion in the TS. They cover the majority of these themes. TSs are intended to be instrumental in focusing attention, triggering opinions, and stimulating ideas, discussion and activity in specific research fields. We hope that this TS has achieved that.

Keywords: ecosystem models, habitat modelling, predator–prey interaction models, simulation modelling, zooplankton population dynamics, zooplankton biodiversity.

This themed set (TS) of articles was motivated by the need for modellers and biologists–ecologists to work more closely together to produce more realistic simulation models of zooplankton population dynamics and trophic interactions. The TS was intended to cover a broad range of subjects and potential approaches. Among the topics that we considered should be addressed were

(i) identify crucial gaps in our knowledge and parameterization of biological/physiological processes at the individual or population levels to optimize coupled biophysical models;
(ii) describe experimental/fieldwork aimed at quantifying the response of key physiological and behavioural processes to variations in the environment, a problem that depends on the temporal/spatial scale of model application (i.e. the finer the scale is, the greater the limitation);
(iii) identify novel modelling approaches that would enable the development of simulation models that would minimize the need for species-specific (and stage-specific) model parameterization and that would support the development of community-level models;
(iv) develop new approaches aimed at increasing our capacity to model zooplankton habitat to forecast potential changes in zooplankton spatial distribution in response to future climate change.

Five articles were accepted for inclusion in the TS. In addition, one of the articles (Record *et al*., 2014a) provoked a COMMENT (Cropp and Norbury, 2014) to which Record *et al*. REPLY (Record *et al*., 2014b)—both of these are included in the TS. As a whole, these contributions cover the majority of the themes in which we were interested.

Daewel *et al*. (2014) assessed to what level zooplankton dynamics in different marine ecosystems of the Atlantic Ocean are driven by predation mortality and how the latter is considered in existing modelling approaches. They conclude that predation mortality generally plays an important role in controlling zooplankton population dynamics, but its impact varied among the six ecosystems examined. The authors describe several methods of parameterizing zooplankton mortality in models, ranging from fixed mortality rates to complex coupled multispecies models. They conclude that modelling constraints must be balanced with the ecosystem-specific demand for a consistent and spatio-temporally dynamic implementation of predation mortality in any model's zooplankton compartment.

A pair of companion articles demonstrates the need to better describe species-specific patterns of zooplankton diel vertical migration in response to variations in environmental conditions and the impact that these patterns have in three-dimensional transport models. Plourde *et al.* (2014) describe the species-specific response of daytime weighted mean depth (WMD) of two species of krill, *Thysanoessa raschii* and *Meganyctiphanes norvegica*, to variations in surface salinity and concomitant light attenuation. The WMD of *T. raschii* and *M. norvegica* were significantly and positively related to surface salinity (light), with *M. norvegica* observed deeper and in warmer water than *T. raschii*. Using these results as mechanistic functions regulating krill vertical position, Maps *et al.* (2014) used a three-dimensional coupled regional circulation model to quantify the differences in upstream advection resulting from the interaction between the circulation and the specific DVM of *T. raschii* and *M. norvegica*. They identified spatio-temporal patterns in krill upstream transport that differed in relation to the DVM behaviour exhibited by the different species of krill. These two articles illustrate the need to accurately parameterize first-order physiological/behavioural processes, such as DVM, to optimize modelling of species-specific transport and responses to environmental forcing.

Record *et al.* (2014a) present a novel approach to incorporate coexistence/biodiversity of zooplankton into ecosystem models. They suggest approaching the problem from the perspective of community-level patterns. The model allows for diverse assemblages of phytoplankton or zooplankton groups to persist and produces accurate community-level patterns. The approach is simple, adding only one additional parameter to existing models, and allows scientists to test the effects of trait distributions and environmental variables on diversity. The Record *et al.* (2014a) article prompted a COMMENT by Cropp and Norbury (2014). They discuss specific aspects of the mathematical mechanisms for coexistence proposed by Record *et al.* (2014a) and argue for the use of nonlinear mortality terms to produce coexistence. Record *et al.* (2014b) respond, promoting a community-level approach to the problem that they say can offer valuable simplifications and insights.

Chust *et al.* (2014) present a new approach to verify the poleward shift of *Calanus* species and to assess how much of this shift was triggered by ocean warming. To achieve this objective, they compared the observed species-specific population gravity centre with that estimated from a series of generalized additive models using: (i) only climate factors to simulate species-habitat suitability, (ii) only temporal and spatial terms to reconstruct the population distribution, and (iii) both factors combined. They found that only *C. finmarchicus* consistently shifted poleward in response to sea warming, but at a lower rate than previously estimated in other work. The authors found that *C. helgolandicus* was expanding in all directions, although its distribution limit in the North Sea has shifted further north. This approach, supported by high model accuracy, demonstrated its usefulness in detecting species latitudinal shifts, and identifying its causes.

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