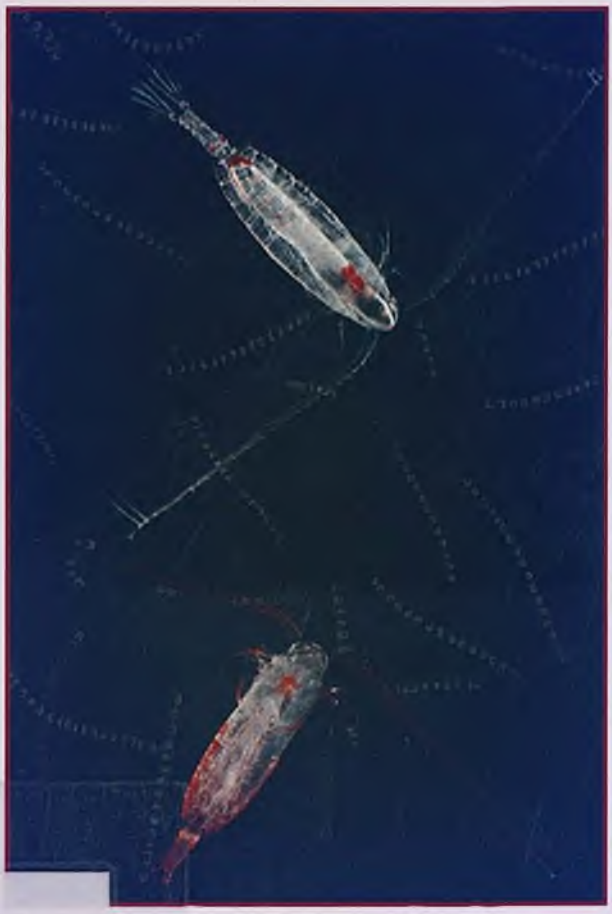
Copepods in *Skeletonema*-dominated food webs

Toxicity and nutritional quality as factors controlling copepod-diatom interactions



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Umeå, 2011

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Title
Copepoder i *Skeletonema*-dominerade födovävar. Betydelse av toxitet och näringskvalitet för interaktioner mellan copepoder och diatoméer.

Abstract
My thesis focuses on copepod-diatom interactions, specifically on the effects of food quality and toxicity on copepod feeding, reproductive success and behavior but as a frame, also includes a quantitative evaluation of copepod carbon requirements compared to other trophic plankton groups. My aim was to evaluate the function of copepods in diatom-dominated spring blooms. I thereby used a series of mesocosm and laboratory experiments. For a realistic extrapolation of the results to natural environments I used different strains of a diatom species, *Skeletonema marinoi*, which is a common spring blooming species in the Baltic Sea. This species is known to produce polyunsaturated aldehydes (PUA; mainly heptadienal, octadienal and decadienal), which have previously been identified as the potential reasons for the detrimental effects of diatoms on copepod reproduction. All strains varied in size, mineral and biochemical content, and PUA production. I tested the effects on different dominant copepod species from northern temperate waters; *Acartia* sp. (*A. clausi* and *A. tonsa*), *Calanus finmarchicus*, *Pseudocalanus elongatus*, and *Temora longicornis*, as well as the dominant species in the northern Baltic Sea, *Eurytemora affinis*.

The specific contributions of respiratory carbon requiment of mesozooplankton and lower size fractions to carbon cycling during PUA-producing diatom blooms are poorly documented. My results show that nanoplankton and microzooplankton dominated the carbon cycling (> 50% of primary production) whereas the contribution of bacterioplankton varied. Mesozooplankton was always of minor importance with contribution of <6% of primary production. This illustrates the importance of lower size fractions during a phytoplankton spring bloom.

Irrespective of their small contribution to the total community carbon cycling, copepods displayed non-selective and typically high feeding rate on different PUA-producing *S. marinoi* strains, indicating that there was no feeding deterrence. The effect of feeding on copepod reproductive success, however, varied between different strains, and depending on copepod species. In experiments with monospecific diatom diets reduced egg production rate and hatching success were mainly related to food quality measured as fatty acids and sterols, or algae growth rate, low assimilation efficiency or PUA production / ingestion. On the other hand, copepod reproduction and population development in the diverse diet, including a high concentration of *S. marinoi* and PUA (both particulate and dissolved), increased with increasing food concentration and was unaffected by the presence of toxic diatoms. I conclude that although a negative correlation between different reproductive variables and PUA production / ingestion may sometimes be observed in laboratory incubations, this is highly dependent on the strain / species used, and the effect of the algal strain can be stronger than the effect of the e.g., growth-stage dependent PUA production. Although copepod grazing might not be very important during a diatom spring bloom, even a highly PUA-producing *S. marinoi* can be considered an appropriate food source for copepods when occurring among the natural food assemblage, inducing a high reproductive output.

Keywords: Copepod-diatom interaction, *Skeletonema marinoi*, toxicity, nutritional deficiency

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Copepods in *Skeletonema*-dominated food webs

Toxicity and nutritional quality as factors controlling copepod-diatom interactions

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Natural Science Building (N420)
måndagen den 5 Dec, kl. 10:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Dr Sigrun Jónasdóttir
Technical University of Denmark, Denmark

Department of Ecology & Environmental Science
Umeå University
Umeå 2011

To Abang & Zara

List of papers

This thesis is based on the following papers, which will be referred in the text by their Roman numerals.

I. **Md Amin R**, Båmstedt U, Nejstgaard JC, Di Capua I . Partition of planktonic respiratory carbon requirements during a phytoplankton spring bloom. *In revision*. Marine Ecology Progress series

II. **Md Amin R**, Koski M, Båmstedt U, Vidoudez C (2011) Strain-related physiological and behavioral effects of *Skeletonema marinoi* on three common planktonic copepods. Mar Biol 158:1965-1980

III. **Md Amin R**, Koski M, Dutz J. Feeding and reproductive success of copepod *Acartia clausi* in different densities and growth rates of diatom *Skeletonema marinoi*. Manuscript.

IV. **Md Amin R**, Båmstedt U, Paul C, Samchyshyna L, Lindehoff E, Pohnert G. Reproduction and succession of *Eurytemora affinis* is unaffected during a diatom-dominatedspring bloom. Manuscript.

Corrections

Thesis summary
Page 15: Respiratory carbon requirement (2nd paragraph; line 5)
'lower clearance and ingestion rates than...' should be written as 'lower clearance rates than..'

Manuscript 1
Sould be written as:
Figure 4: Respiratory carbon requirement of different planktonic group; mesozooplankton (*solid diamonds*), microzooplankton (*solid squares*), nanoplankton (*open triangles*) and bacterioplankton (*cross symbols*) as a function of A) 22:6(n-3) fatty acid , B) *Phaeocystis* sp and C) *Skeletonema marinoi*. The figure show individual relationship with highly correlated variable on each PC. *Left axis*: smaller size fraction; *Right axis*: mesozooplankton

Paper 2
Table 4: Pseudocalanus elongatus
Egg production: '-' should be written as '='
Hatching success: '-' should be written as '='

Manuscript 3
Page 6: Algal culture (line 9)
'ca 6 times higher ' should be written 'as ca 10 times higher'

Page 7: left column before Clearance and ingestion
'EPA:DHA ratio > 10 in 1G and > 5 in all 9B strain' should be written as 'EPA:DHA ratio > 5 in 1G and > 10 in 9B strain'

Contributions

Contribution/Paper	I	II	III	IV
Original idea	FP6, JCN,UB,EUR-O	MK,RMA,UB	RMA,MK	MESO-A
Study design and methods	UB	RMA,MK	RMA,MK,JD	UB,GP,RMA,EL
Data collection	RMA,UB,JCN	RMA,MK	RMA,MK	UB,RMA,EL,LS,CP
Data analysis	RMA,UB,ID	RMA,MK,CV	RMA,MK	RMA
Contribution to interpretation of the result and manuscript preparation	RMA,UB,JNC,ID	RMA,MK,UB,CV	RMA,MK,JD	RMA,UB,EL, LS,CP,GP
Responsible for interpretation of the results and manuscript preparation	RMA,UB,JCN	RMA,MK	RMA,MK	RMA,UB,CP

CP: Carsten Paul, **CV**: Charles Vidoudez, **ID**: Iole Di Capua, **EL**: Elin Lindehoff, **GP**: Georg Pohnert, **EUR-O**: European FP6 Project "EUR-OCEANS", **JCN**: Jens C Nejstgaard, **JD**: Jörg Dutz, **LS**: Larysa Samchyshyna, **MESO-A**: MESOAQUA Transnational Access 2010, **MK**: Marja Koski, **RMA**: Roswati Md Amin, **UB**: Ulf Båmstedt

Table of Contents

Abstract

My thesis focuses on copepod-diatom interactions, specifically on the effects of food quality and toxicity on copepod feeding, reproductive success and behavior but as a frame, also includes a quantitative evaluation of copepod carbon requirements compared to other trophic plankton groups. My aim was to evaluate the function of copepods in diatom-dominated spring blooms. I thereby used a series of mesocosm and laboratory experiments. For a realistic extrapolation of the results to natural environments I used different strains of a diatom species, *Skeletonema marinoi*, which is a common spring blooming species in the Baltic Sea. This species is known to produce polyunsaturated aldehydes (PUA; mainly heptadienal, octadienal and decadienal), which have previously been identified as the potential reasons for the detrimental effects of diatoms on copepod reproduction. All strains varied in size, mineral and biochemical content, and PUA production. I tested the effects on different dominant copepod species from northern temperate waters; *Acartia* sp. (*A. clausi* and *A. tonsa*), *Calanus finmarchicus*, *Pseudocalanus elongatus*, and *Temora longicornis*, as well as the dominant species in the northern Baltic Sea, *Eurytemora affinis*.

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