

EDITORIAL: Phytoplankton food quality determines time-windows for successful zooplankton reproductive pulses

By Cristian Vargas, Ruben Escribano and Serge Poulet

In the zooplankton, copepods are numerically dominant and are key organisms having a significant role in the control of the C budget of marine ecosystems. This recognition has motivated much research focused on the factors and mechanisms that control their growth and production in highly productive coastal zones. Copepods might govern the fate of C fixed by phytoplankton and thus greatly influence production at higher trophic levels. Studies have shown that at the population level copepod recruitment relies primarily on the reproductive success, which is known to be affected by quantity and nutritional quality of food resources. Estimates of copepod feeding selectivity and reproduction in response to seasonally changing phytoplankton characteristics were measured in the highly productive coastal upwelling area off Concepcion. The variable phytoplankton diversity and changing food quality had a significant effect on the feeding selectivity, reproduction and larval survival (Fig. 1) of three indigenous copepod species.

Seasonal changes in copepod feeding behaviour were related to the alternating protozoan-diatom diets, mostly based on dinoflagellates and ciliates during winter and autumn having low contents of polyunsaturated fatty acids (HUFA/PUFA), in contrast to the spring/summer period when copepods switched diet to centric and chain-forming diatoms (with high HUFA/PUFA contents). Ingestion of diatom cells induced a positive effect on egg production. However, a negative relationship was found between egg hatching success, naupliar survival and diatom ingestion (Fig. 2). Depending on the phytoplankton species, diets had different effects on copepod reproduction and recruitment. A major implication from these findings is the suggestion that the classical marine food web model, relying on a lineal relationship between phytoplankton and zooplankton, does not apply to this coastal upwelling systems. Similar biological interactions may be taking place in other important marine ecosystems as well.

At the COPAS Center, while having a Post-doctoral position (2004-05), Cristian Vargas funded by FONDECYT of Chile, carried out numerous experiments on copepod feeding during the four seasons in the coastal area off Concepción. Complementary data on

food quality and quantity allowed a precise assessment of the effect of changing diets on reproductive success and viability of early stages of dominant copepods feeding on natural food resources. Highly relevant results from these studies are being published in the scientific journal *Ecology* (Vargas et al., in press). A summary of major scientific findings from this research is presented below.

Estimates of copepod feeding selectivity and reproduction in response to seasonally changing phytoplankton characteristics were measured in the highly productive coastal upwelling area off Concepcion. The variable phytoplankton diversity and changing food quality had a significant effect on the feeding selectivity, reproduction and larval survival (Fig. 1) of three indigenous copepod species.

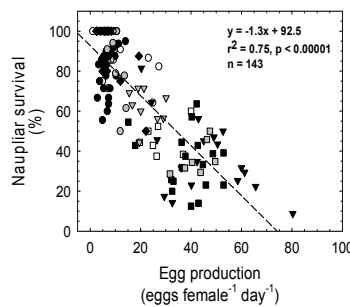


Fig.1. Relationship between egg production (EP) and naupliar survival (NS) in autumn (diamonds), winter (circles), spring (triangles) and summer (squares). Black, grey and white symbols correspond to *Acartia tonsa*, *Paracalanus parvus* and *Centropages brachiatus*, respectively (From Vargas et al. in press).

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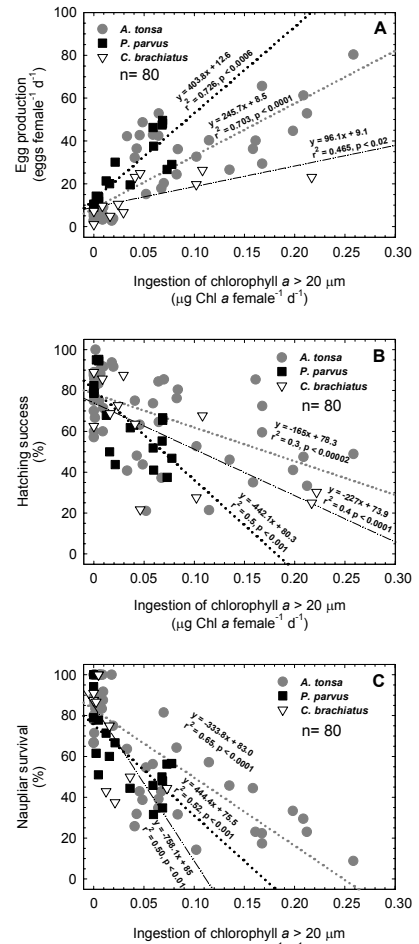


Fig.2. Relationship between ingestion rates of chlorophyll a > 20 µm by the copepods *Acartia tonsa*, *Paracalanus parvus*, *Centropages brachiatus* and [A] egg production, [B] hatching success and [C] naupliar survival. n = 80 is the total number of observations (From Vargas et al. in press).

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RESEARCH ACTIVITIES AND NEW PROJECTS

GENOME SEQUENCING OF *THIOPLOCA* FROM OFF CENTRAL CHILE. COPAS Research Program #5 is pleased to inform that one of its ‘flag-ship’ species of giant filamentous sediment bacteria under study since several decades, i.e., *Thioploca araucae* (Fig. 3) has been selected by the Gordon and Betty Moore Foundation’s Marine Microbial Gene Sequencing Program (www.moore.org/marinemicro). On July 11, 2006, Dr. Lita Proctor, Senior Program Officer of the Marine Microbiology Initiative conveyed the invitation to Dr. Victor A. Gallardo who discovered this form off northern Chile in 1962 and has confirmed its presence at several sites along the eastern Pacific, i.e., central Chile, off Peru and off Costa Rica. A similar species was also recorded by the same researcher in the ‘sister’ Benguela marine ecosystem off Namibia. The species appears to represent forms that may be considered relicts from the late Proterozoic era when oxygen had already reached appropriate levels but hydrogen sulfide was still important in the benthic environment, as it is today under some Oxygen Minimum Zones of the world.

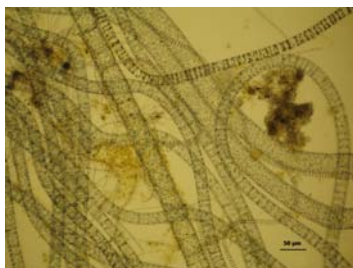


Fig. 3. The microphotograph shows the three forms of *Thioploca* described for off central Chile, i.e., *Th. araucae* (the thickest), *Th. chilense* (the intermediate sized), and *Th. 'marina'* (the thinner one). Photograph by Carola Espinoza.

According to the project, the J. Craig Venter Institute, Rockville, MD, USA is to perform the sequencing and scientists associated with Dr. Gallardo, both local and international, will analyze and publish the results.

CENSOR Project Activities. Winter 2006 Chipana upwelling site off northern Chile

Research activities of COPAS Oceanographic Center in collaboration with Universidad Arturo Prat (UNAP, Chile) and Instituto de Ciencias del Mar-CSIC (ICM-CSIC, Spain), in the framework of WP2 Benthic-pelagic processes of the CENSOR Project, involves seasonal oceanographic studies at the coastal upwelling site off Chipana, located in northern Chile. These are process-oriented studies through short-term, but intensive sampling and experiments in the water column. The same sampling strategy was applied in winter 2005 and summer 2006. In summer 2006 the location of Mejillones (23° S) was also studied in addition to Chipana (Fig. 4). Here we describe the studies corresponding to the winter of 2006, which were carried out between 01 and 10 July 2006.



Fig.4: The small Chipana village at northern Chile where CENSOR research activities take place

Participants

Bárbara Jacob (CENSOR Ph.D. Student), Víctor Aguilera (CENSOR Ph.D. Student), Pamela Hidalgo (COPAS Technician), Paula Mendoza (CENSOR Technician), Marcelo Fuentes (COPAS Technician), Alvaro Araneda (COPAS Technician), Rubén Escribano (COPAS Researcher, Chief scientist), Patricia Homs (CENSOR Ph.D. Student ICM-CSIC), Enrique Isla (CENSOR Post-Doc, ICM-CSIC), Gabriel Claramunt (UNAP Researcher), Liliana Herrera (UNAP Researcher)

Scientific Objectives

- To estimate fluxes of C and N in the water column at upwelling sites off northern Chile
- To determine C and N pools of the coastal upwelling system and the role of changing community structure on C fluxes

- To estimate the quality of settling particles throughout the water column
- To understand the key processes determining variability of productivity and functioning of the coastal upwelling system
- To construct the food web of the pelagic system in this upwelling zone and its potential changes upon ENSO variability

Field sampling

The general scheme for field sampling includes 7-9 days of intensive activities performed at a fixed station off Chipana bay onboard the L/C Rigel from UNAP (Fig. 5). This station is located at 21°19'560"S and 70°08'03"W with a depth of 94 m. CTDO profiling is carried out daily to measure temperature, salinity, dissolved oxygen, fluorescence and PAR from 85 m to surface (Fig. 6). Water samples with 10 L Niskin bottles are also obtained at 5 (0-10-20-45-85 m) depths for measurements of macronutrients, oxygen with Winkler method, DOC, POC, fractionated chlorophyll-a, picoplankton (flow cytometry), nanoplankton, microplankton, phytoplankton and metazooplankton biomass (C and N content) and composition for two strata: below oxycline and above oxycline. All samples are processed at a shore-based laboratory (Fig. 7). In addition, analysis on the protein, carbohydrate, lipid and biogenic silica contents are performed to estimate the nutritive quality of the particles settling throughout the water column and its relationship to the other measured variables.



Fig. 5: L/C Rigel from UNAP



Fig. 6: CTDO deployment off Chipana.

Process-studies

Primary production rates are estimated after 24h incubation of dark-light bottles to assess changes in dissolved oxygen. Two or three depths are incubated in according to the fluorescence profile and light attenuation pattern.

Bacterial secondary production is measured by incorporation of labeled isoleucine in conjunction with measurements of primary production.

Zooplankton Grazing experiments are performed for dominant species of copepods. Consumption rates and food selection are assessed by estimates of items removal and lipid markers for at least three size fractions of food.

Nanoplankton-grazing impact on bacterial production, are examined by fractioning and incubation. The fractions involved are 11-20 μm , 1.7-11 μm and <1.7 μm .

Growth rates of dominant zooplankton species are evaluated by estimating *in situ* molting rates, egg production rates and changes in C content through developmental stages of dominant species of copepods.

Predation impact of carnivorous zooplankton on copepods is also evaluated after incubation experiments.

Carbon export and sedimentation rates of organic matter are assessed by a moored sediment trap at a nearby location. The trap was set up in July 2005 at a depth of 90 m. during the first winter campaign. This mooring is also equipped with a current meter and an oxygen optode sensor.



Fig. 7: Shore-based laboratory at Chipana village

Complementary data: A sensor PAR was installed at a shore location to obtain continuous data of light during the study. Wind data are expected to be obtained from the meteorological station at the nearby airport. COPAS Center also has a current meter mooring and oxygen optodes sensors at the same latitude at 800 m depth for large scale variability studies.

FIP. New Fishery Research Fund Project.

The monitoring of oceanographic variability of the VIII Region of Chile is one of the projects linked to management of marine resources with which COPAS Center commits its research with issues that have more direct impact on the socio-economical components of the country. This project, funded by FIP

(Fishery Research Fund), constitutes a tool to maintain an observational system of oceanographic variability in the coastal upwelling region off Concepcion. The project began in 2004 and is being renewed on a yearly basis. Six COPAS Researchers participate in the project. Dr. L. Fariás, associate investigator of Research Program #2, is the 2006-2007 coordinator of this activity.

OUTREACH ACTIVITIES

By Dr. Luis Pinto

COPAS AND AQUASENDAS

1. Twenty-eight middle-school science teachers from the Concepción Province attended a workshop entitled "Introduction to highly-motivating aquatic-science activities to apply as part of the water curricula in school". This activity took place at the Lycée Charles de Gaulle of Concepción.

2. Two public schools of San Pedro de La Paz neighborhood have been selected to start a pilot program using available data of the *Argo International Program* to understand basic concepts in oceanography along the eastern coastal margins. The program entitled "Drifting within the ocean depths" will be using data produced by *buoys 4900512 & 513* deployed by the Chilean Navy Oceanographic Service.

3. Two educational posters have been produced as a result of project EXPLORA-Conicyt ED9/04/046. One poster displays and explains the most common oceanographic sampling devices; the other gives an explanation about Cretaceous Oceanic Anoxic Events. Eight hundred copies have been distributed among the schools of the Bio Bio Region.

4. The EXPLORA-Conicyt project ED9/04/046: "Urban lakes, bays and fjords: natural laboratories to experiment global change" ended with three mayor activities during the last two months: 1) Three members of AquaSendas traveled to Puerto Cisnes in the XI region to organize the local Youth Meeting about Global Change. Dr. Giovanni Daneri, COPAS researcher and Director of the new center in Patagonia CIEP, delivered a talk about "Potential effects of climatic change on Patagonian ecosystems". Educational posters about estuarine water analysis produced by AquaSendas with COPAS sponsorship were donated to elementary and high schools of Puerto Cisnes. 2) A similar activity also took place at the Marine Biology Station in Dichato, with 65 students and 18 science teachers attending the meeting to present results of their scientific work in two urban lakes and one coastal area. A public ceremony that included the participation of students and teachers, local governmental authorities, and Dr. Carina Lange, COPAS director, was the final act in Concepción.

3) Interactive learning modules about Global Change designed and produced by AquaSendas with COPAS sponsorship were exhibited at the Water student Olympics in San Pedro de La Paz and a Water Festival in the county of Concepción.

CAPACITY BUILDING

COPAS researcher Dr. Silvio Pantoja is the Co-Chair of the Committee on International Capacity Building for the Protection and Sustainable Use of Oceans and Coasts of the National Academies, US. The *ad hoc* committee will examine current and past efforts to build the scientific, technological and institutional capacities required for countries to develop and implement effective coastal and marine resource policies. This study will identify barriers to effective management of coastal and marine resources encountered in coastal nations.

Austral Summer Institute (ASI VII).

The Department of Oceanography and the COPAS Center are pleased to announce the Austral Summer Institute VII (ASI VII) to be held at the University of Concepción during 2-26 January 2007. It will be devoted to: "Methane Biogeochemistry and Geophysics & Remote Sensing and Ocean-Land Interaction".

METHANE BIOGEOCHEMISTRY AND GEOPHYSICS

Biomarkers & carbon cycle, January 2 – 5

Antje Boetius, Max Planck Institute for Marine Microbiology, Germany
Gerald R. Dickens, Department of Earth Science, Rice University, USA,
Kai-Uwe Hinrichs, RCOM, University of Bremen, Germany

Methane hydrates, January 8 –12

Richard J. Behl, California State University Long Beach, USA, Gerhard Borhmann, RCOM, University of Bremen, Germany

Sediment diagenesis & biology, January 15 –19
Jeffrey Chanton, Department of Oceanography, Florida State University, USA

Lisa Levin, Scripps Institution of Oceanography, USA

Methane turnover & seeps, January 22 –26

Guillermo Alfaro H., Instituto de Geología Económica Aplicada, University of Concepción, Chile,
Jean Whelan, Woods Hole Oceanographic Institution, USA

REMOTE SENSING AND OCEAN-LAND INTERACTION

Rivers: Connecting land and the ocean. Processes and problems, January 3-12.

John D. Milliman, The College of William & Mary, USA.

Use of remote sensing and bio-optics for coastal water quality monitoring, January 16-26.

Ajit Subramaniam, Lamont Doherty Earth Observatory at Columbia University, USA

Detailed information can be found at: <http://www.udec.cl/oceanoudec/oceanografia/>



Newsletter

Centro de Investigación Oceanográfica en el Pacífico Sur-Oriental

The Austral Summer Institute is part of the Capacity Building activities sponsored by UDEC, Fundación Andes and the IOC UNESCO Chair in Oceanography in the framework of the Program *Consolidating Advanced Research and Higher Education in Ocean Sciences at the University of Concepcion* under the Direction of Silvio Pantoja.

NEWS

COPAS scientists, technicians and staff are proud to announce that the Center has been positively evaluated for its First Phase achievements (2002-2007). We would like to thank our students, national and international collaborators, members of the External Advisory Panel, and especially the University of Concepción authorities for their support in reaching this milestone. Presently, we are preparing our continuation plan for the next 5 years which will be evaluated in December, including an *on-site* visit of international evaluators Drs. L. Mayer, L. Legendre and W.H. Berger, and members of the Council of CONICYT.

CENSOR Midterm Symposium. The Climate Variability and the El Niño Southern Oscillation (CENSOR) project has held its Midterm Symposium on 4-9 September. The event was organized by COPAS Center and AWI of Germany and took place at Bellavista Club in Concepción. Researchers, students and collaborators of CENSOR presented scientific results from ongoing studies in relation to El Niño impact and ENSO variability in the coastal zones of Peru and Chile. About 60 people from Germany, France, Spain, Peru, Argentina and Chile participated in this very successful meeting. The last two days of the meeting were devoted to the *Pasarela* project, also funded by the EU, through which active interaction with stakeholders took place. Stakeholders from Peru and Chile linked to marine resources and management were invited to the symposium.

The South America Census of Marine Life Steering Committee met in Mar del Plata, Argentina, on 27-29 September. The meeting was organized by Universidad de Mar del Plata and INIDEP (Argentinean Fishery Research Institute). COPAS researchers R. Escribano and V.A. Gallardo attended the meeting; the former as the Chilean National representative, the latter representing the International Steering Committee.

OBIS Pacific sub-node. The Ocean Biogeographic Information System (OBIS) project of Census of Marine Life is supporting the South American regional node (RON). This RON has been divided into three sub-nodes: one for the Atlantic administered by the University of Sao Paulo (Brazil), one for the

Austral region administered by CENPAT (Argentina), and one for the tropical and subtropical Pacific administered by the COPAS Center. This Pacific subnode is currently serving data bases of phytoplankton, zooplankton and benthos of Chile and Ecuador. New data bases are being processed from Peru, Ecuador and Chile and are expected to be available at the end of this year. The Pacific subnode has also created a web site and data portal (<http://ron.udec.cl>) available to the South American scientific community involved with taxonomic and marine biodiversity issues.

Upcoming cruise: Research Program #6 will participate in the upcoming **PACHIDERME (Pacifique-CHili-Dynamique des Eaux intermediaires)** cruise onboard RV Marion Dufresne. Long piston cores from a latitudinal transect extending from 39°S to 60°S along the Chilean Fjord region will be recovered. The main goals of this expedition are: 1) to determine the thermocline and intermediate water ventilation in the far southeastern Pacific; 2) to study the past latitudinal intensity variability of the westerly wind belt; 3) to establish the chronology for the retreat of the major Patagonian/Cordillera Darwin glaciers since the LGM to address questions concerning inter-hemispheric synchronicity of climate change; 4) To establish the climatic variability around the mean state at decadal periods. This represents a collaborative effort among French, Chilean, German and Norwegian scientists. Chief scientist is Dr. Catherine Kissel, Laboratoire des Sciences du Climat et de l'Environnement, France.

UPCOMING EVENTS

El Niño 2006-2007? A warm event seems to have developed in the tropical region of the Pacific and is likely to remain as an El Niño condition for the rest of 2006 and during early 2007. It is not known, however, if this El Niño will further develop and impact the eastern South Pacific region, where most research of the COPAS Center takes place. If it does, oceanographic observations and time series studies carried out by COPAS in the past 5 years will serve as a strong baseline.

SCOR General Assembly and Workshop on OMZ Systems. The University of Concepción and the COPAS Center welcomes the 2006 SCOR General Assembly, which will be held in Concepción on 23-26 October. Coinciding with the Assembly, COPAS together with the Faculty of Natural and Oceanographic Sciences and the Department of Oceanography has organized a Scientific Workshop on Oxygen Minimum Systems. The Workshop will be held on 24-26 October, and consists of invited lectures to be delivered during the first two days, and poster presentations during the last day. This event is coordinated by COPAS

Researcher V.A. Gallardo and J.W. Farrington of Woods Hole Oceanographic Institution.

Invited speakers to the Workshop are:

Yrene M. Astor (Venezuela)
Kennet W. Bruland (USA)
Tage Dalsgaard (Denmark)
Ruben Escribano (COPAS Center)
Victor A. Gallardo (COPAS Center)
Humberto Gonzalez (COPAS Center)
Dimitri Gutierrez (Peru)
Samuel Hormazabal (Univ. Concepcion)
Richard J. Matear (Australia)
Syed Wajih Ahmad Naqvi (India)
Temel Oguz (Turkey)
Silvio Pantoja (COPAS Center)
Renato Quinones (COPAS Center)
Nancy N. Rabalais (USA)
Wolfgang Schneider (COPAS Center)
Mary I. Scranton (USA)
Osvaldo Ulloa (COPAS Center)

Further information can be found at the following web sites: <http://www.copas.udec.cl> and <http://www.cona.cl/scor/oms.htm>

CmarZ Meeting. The Census of Marine Zooplankton (CmarZ) project of Census of Marine Life will hold a coordination meeting in Tokyo (Japan) on 6-8 November 2006. This worldwide initiative to compile data bases of marine zooplankton is coordinated by Dr. A. Bucklin. COPAS Researcher R. Escribano will attend the meeting representing the South American region.

RECENT COPAS PUBLICATIONS

Giraldo, A., **Escribano, R.**, and Marin, V. 2006. A field test of temperature effects on ecophysiological responses of copepodids *Calanus chilensis* during coastal upwelling in northern Chile. *Continental Shelf Research* 26, 1307-1315.

Hidalgo, P. and **Escribano, R.** 2006. Naupliar stages of *Eucalanus inermis* (Giesbrecht) (Copepoda: calanoidea) from the Humboldt Current System (northern Chile). *Crustaceana* 79, 513-523.

Herrera, L. and **Escribano, R.** 2006. Factors structuring the phytoplankton community in the upwelling site off El Loa River in northern Chile. *Journal of Marine Systems* 61, 13-38.

Kemp, A.E.S., Pearce, R.B., Grigorov, I., Rance, J., **Lange, C.**, Quilty, P. and Salter, I. 2006. The production of giant marine diatoms and their export at oceanic frontal zones: implications for Si and C flux in stratified oceans. *Global Biogeochem. Cycles* doi:10.1029/2006GB002698, in press.

Thamdrup, B., Dalsgaard, T., Jensen, M. M., **Ulloa, O.**, **Farias, L.** and **Escribano R.** 2006. Anaerobic ammonium oxidation in the oxygen-deficient waters off northern Chile. *Limnology and Oceanography* 51, 2145-2156.

Newsletter requests and information should be sent to:

COPAS Newsletter
COPAS, Universidad de
Concepción. P.O. Box 160-C,
Concepción, CHILE
Telephone: 56 (41) 2683247