

EDITORIAL

Mineralization of organic matter: The importance of pelagic bacterioplankton in the Humboldt Current system off Chile

By Giovanni Daneri^{1,2} & Silvio Pantoja²

¹ Center of Patagonian Ecosystem Research (CIEP), Bilbao 449, Coyhaique, Chile; ² Department of Oceanography & Center for Oceanographic Research in the eastern South Pacific (FONDAP COPAS Center), University of Concepción

The bulk of organic matter is synthesized in the photic ocean by the activity of microscopic marine algae. Marine photosynthesis is arguably one of the most important biogeochemical processes mediating the transformation of inorganic into organic molecules that fuel the majority of known marine food webs.

It has been shown that bacterioplankton (both bacteria and archaea) is one of the key groups controlling the fate of organic matter. Both the amount and utilization of organic matter in the upper ocean influences fundamental processes such as a) availability to different trophic compartments, b) air-sea exchange of CO₂, and c) downward export of organic matter (including its eventual burial in the ocean sediment). If the bulk of organic matter is rapidly mineralized within the photic layer, then trophic transfer to organisms higher in the food chain can be significantly reduced. This has been one of the main arguments to underplay the importance that bacterioplankton may have in highly productive marine environments such as the Humboldt Current System (HCS) off Chile. Furthermore, balancing primary and fish production has only been achieved by simple models that consider few trophic steps from primary producers to fish (Cubillos et al., 1998) thus reinforcing the notion that the high fish production in this system can only be sustained by short, thermodynamically efficient trophic food chains.

We have estimated bacterioplankton turnover of organic matter by directly measuring dissolved organic carbon (DOC) decay under different conditions (with both amended and unamended substrates) in seawater samples obtained from different areas of the HCS (Columo, Valparaiso and Mejillones). The importance of bacterial activity in the Humboldt Current System has also been assessed by examining the relationship between Gross Primary Production (GPP) and Bacterial Carbon Demand (BCD), and between GPP and community respiration (CR) from a comprehensive data set containing published (Daneri et al. 2000, Troncoso et al. 2003, Cuevas et al. 2004) and unpublished data. DOC degradation rates obtained with amended

water samples were exceptionally high (12.7-21.6 μM h⁻¹) while degradation rates in experiments conducted at ambient DOC concentrations were in the upper range, and higher (0.18-2.56 μM h⁻¹) than degradation rates published for other marine environments (0.019-1.46 μM h⁻¹). The exceptionally high organic matter degradation rates may largely explain the significant regression found between BCD and GPP (r² = 0.62; Fig. 1) and the unusually high proportion of organic matter that is currently being channeled through pelagic bacteria in the HCS (73%, if we consider the slope of the regression BCD-GPP of Figure 1 to be a valid average indicator of GPP consumed by bacteria). The close coupling between organic matter synthesis and rapid degradation within the photic layer is also reflected in a strong positive correlation between integrated gross primary productivity and community respiration (Fig. 2). The slope of this regression indicates that 83% of carbon is being respired within the photic layer. Although dark oxygen utilization represents respiration of the whole microplanktonic community, the fact that BCD and dark oxygen utilization are of similar magnitude, supports the notion that most of respiration (measured by the dark oxygen bottles) in the HCS can be attributed to marine bacterioplankton.

Our experimental and field sampling provide strong support to the notion that bacterioplankton plays an extremely important role in the cycling of organic carbon within the photic layer in the HCS. This observation has profound implications both to fisheries and biogeochemical models that to date have assumed that the main pathway of carbon utilization in upwelling ecosystems is through short thermodynamically efficient trophic pathways.

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Acknowledgments

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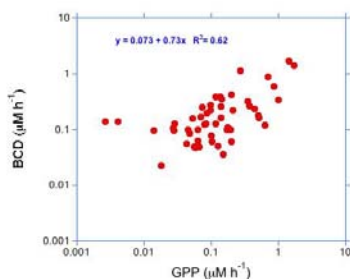


Fig. 1. The relationship between gross primary production (GPP) and bacterial carbon demand (BCD) in the Humboldt Current system.

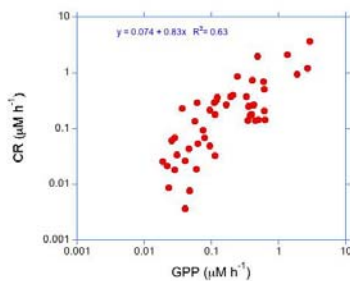


Fig. 2. The relationship between community respiration (CR) and gross primary production (GPP) in the Humboldt Current system.

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RESEARCH ACTIVITIES AND NEW PROJECTS

“SeepOx” cruise off Concepción: A multidisciplinary cruise was carried out off Concepción (August 30-September 4, 2006) onboard the Chilean Navy R/V AGOR Vidal Gormáz. Target areas of the cruise were the recently discovered Concepción Methane Seep Area (CMSA; Sellanes et al. 2004, Sellanes & Krylova 2006) and the nearby Oxygen Minimum Zone. This cruise was funded mainly by FONDECYT Project #1061217, PI: Javier Sellanes, Universidad Católica del Norte (UCN), Co-investigators: Víctor A. Gallardo (COPAS), Eduardo Quiroga (CIEP) and Guillermo Guzmán (UNAP); FONDECYT Project #1061214, PI: Práxedes Muñoz, UCN, and FONDAP-COPAS Project #15010007, Research Program #5 (PI: Renato Quiñones, Co-PI: Víctor A. Gallardo). Additional funding was provided by Scripps Institution of Oceanography with two participants, Dr. Carlos Neira and Jennifer González of Dr. Lisa Levin’s Lab. Besides the above mentioned institutions, researchers and students from the Universidad Arturo Prat, Iquique; Centro de Investigación del Ecosistema Patagónico (CIEP), Coyhaique and Université Montpellier II, France, also joined this initiative.

The activities on the SeepOx Expedition consisted in sediment sampling (gravity coring, multicoring and dredging; Fig. 3) and water column sampling at seven stations ranging from 64 to 850 m water depth. These stations were arranged to represent oxic bottoms, anoxic bottoms, and seep and non-seep conditions. Although part of the originally planned sampling was not possible to do due to unfavourable weather conditions, which persisted throughout the cruise, the main objectives of the cruise were reasonably fulfilled.

The aim of Dr. Práxedes Muñoz and collaborators’ of COPAS RP #6, is to understand the geochemistry of sensitive redox trace metals (Cd, Co, U, Mo) related to carbon fluxes to the sediments and/or authigenic enrichment at the seasonally hypoxic shelf area off Concepción. Other elements related to primary production fluxes, not sensitive to redox conditions, are also considered (Ba, opal). In addition, Fe, Mn and Al will be analyzed in order to establish the oxidative state of the sediments and detritus inputs to the shelf. Trace metals in anoxic sediments are enriched in different ways, and have been used widely to reconstruct ancient environments. Because some of them are biologically essential elements for primary producers, they can reach the sediments during organic matter sedimentation. Others elements, such as U and Mo are conservative in the water column but can be affected by the redox environmental conditions, reaching the sediments *via* authigenic precipitation or adsorbed to organic

or inorganic particles. In anoxic sediments, the sulfide concentration could determine the immobilization of trace metals within the sediments by incorporation into pyrite (e.g., Co); however, the kinetic reactions of other elements result in soluble metal sulfide formation prior to iron sulfide and subsequent pyrite formation (e.g., Cd). In this sense, the metal distribution in the sediments shows different geochemical pathways, and hence different environmental interpretations are plausible. Thus, in order to adequately interpret their distribution in the sediment through time, it is necessary to understand the recent processes in which they are involved. Sediments underlying the OMZ off Concepción offer an ideal scenario to study the geochemistry of trace metals sensitive to redox conditions. The establishment of the extension to which post-depositional processes affect the distribution of trace metals could be useful as a proxy to understand paleoceanographic processes. During the cruise sediment cores of up to 2.3 m long were taken at most of the planned stations. These samples will be analyzed both at the Marine Chemistry Laboratory of UCN, Coquimbo and at Université Montpellier II, France (in collaboration with Dr. Laurent Dezileau of UMP II, France).

The main activities of the biology group (Sellanes and collaborators) concentrated at the CMSA and at a nearby non-seep control area. The CMSA was discovered in 2003 during a COPAS cruise oriented to the study of Antarctic Intermediate Waters when shell fragments of two species of bivalves known to host chemosynthetic endosymbionts, (a vesicomid clam and *Acharax* sp.), were retrieved in a dredge haul from ca. 800 m water depth, in the vicinity of COPAS’ Time Series Station 40. Abundant carbonate breccia slabs were also retrieved, indicating microbial activity associated with the anaerobic oxidation of methane within the sediment. Subsequent to that first finding, further dredging in this area, on board L/C Kay Kay, of the University of Concepción, allowed the collection of gas-saturated sediment samples (H₂S and CH₄) and shell fragments of additional species of chemosymbiotic bivalves (e.g., *Archivesica*, *Lucinoma*, *Thyasira*). Articulated valves of a small new species of *Calyptogena*, resembling NE Pacific *C. pacifica*, were also collected. Living chemosymbiotic organisms were collected for the first time during October 2004, in a cruise oriented to study the distribution of gas hydrates off south-central Chile (COPAS Newsletter 8, May 2005). Since that time many new species of both chemosymbiotic (e.g., *Calyptogena gallardoi*, *Thyasira methanophila*, *Lucinoma anemiophila*) and non-chemosymbiotic (e.g., *Margarites huloti*, *Otukaia crustulum*, *Trophon concepcionensis*) mollusks have been described from material gathered in that opportunity.

Seepage areas are known to provide a suitable environment for the development of singular communities consisting of sulfide oxidizing bacteria, highly endemic endosymbiont-bearing clams and tubeworms. Besides, non-chemosynthetic fauna (e.g., crustaceans, gastropods, cephalopods, fishes) appears to be massively attracted to these deep-sea oases of biological activity. It is thus important to elucidate which is the role of chemosynthetically fuelled communities in providing an alternative food source for neighbouring heterotrophs, as well as the basic biology traits (e.g., fecundity, reproductive output) of the chemosymbiotic and the associated heterotrophic assemblages. This includes even commercially fished species, since it has been suggested that one of the ultimate fates of chemosynthetically-generated organic carbon could be large mobile predators. Moreover, authigenic carbonates at seep sites generate reefs that are also avidly colonized by a diverse benthic fauna. It is thus feasible to hypothesize that off Chile, large predatory fish like the Patagonian tooth-fish (*Dissostichus eleginoides*), an important fishing resource, thrives on methane seepage areas for feeding and/or breeding grounds. Evidence supporting these relationships was documented during the cruise.

It is also remarkable that living specimens of a tube-building syboglindid polychaete (previously known as pogonophorans), probably a new species of the genus *Lamellibrachia*, were collected for the first time off the Chilean margin. Many other new species were also collected and work to describe them has already started. Faunal samples for stable isotope based food-web analysis, size distribution and growth of asteroids and enzymatic activity levels were also withdrawn. For this last aspect, the lactate and opine pathways will be studied to estimate the contribution of the anaerobic metabolism to the energy production of selected species.

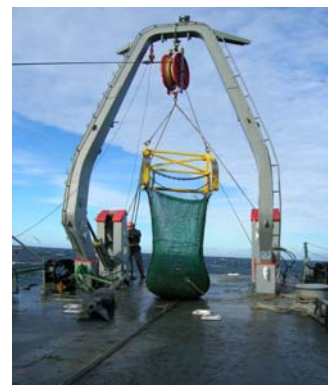


Fig. 3. Agassiz dredge with a good haul from 1000 m depth off Concepción seep area.

Long term activities, now extending to most of the Chilean margin, are being programmed

in the frame of a Census of Marine Life-associated Worldwide Universities Network proposal, i.e., INSPIRE initiative (International South-East Pacific Investigation into Reducing Environments) which points to the study of reducing systems in the Chilean margin. Three proposals are actually submitted to the NOAA-Ocean Exploration program in collaboration with: i) the University of Hawaii (study of chemosynthetic communities associated to large organic falls, PI: Dr. Craig Smith); ii) Scripps Institution of Oceanography (ROV exploration of the CMSA, PIs: Drs. Lisa Levin and Carlos Neira); and iii) Woods Hole Institution of Oceanography and Southampton Oceanographic Centre (AUV mapping of the Chile Triple Junction area to detect hydrothermal and cold seep activity, PI: Dr. Christopher German). In the meantime, COPAS will continue its Time Series deep-sea station #40 seasonal observations focusing on the benthos of the seep area off Concepción, under the direction of Dr. Victor A. Gallardo.



Fig. 4. Scientific group and some members of the R/V AGOR Vidal Gormaz at the end of the SeepOx Cruise.

CENSOR (Climate Variability and El Niño Southern Oscillation) Project. During January/February 2007 Work Package 2 "Benthic pelagic processes" of the CENSOR Project funded by EUC, carried out field work at two upwelling sites off northern Chile: Mejillones (23°S) and Chipana (21°S). Intensive studies allowed estimates of primary production, plankton feeding rates, studies on zooplankton-diatoms interactions, the pelagic carbon pools and high frequency variability of upwelling for a summer condition, under a potential influence of a 2006-2007 El Niño event. Despite international information describing the presence of a warming event in the Pacific region, oceanographic conditions at both study sites were dominated by strong coastal upwelling and high phytoplankton biomass, with no evidence for an "abnormal" warming episode in the coastal zone. Work Package 2 of CENSOR project is lead by COPAS researcher Dr. R. Escribano. Participants in these field studies were: Dr Serge Poulet (CNRS, Roscoff, France), Dr. Pamela Hidalgo (COPAS Postdoc), Dr. Ruben Escribano (COPAS Researcher), Victor

Aguilera (Fig. 5) and Barbara Jacob (both are Ph.D. Students of the CENSOR Project), Paula Mendoza (CENSOR Technician), Claudia Pérez and Marcelo Fuentes (Marine Biologists of COPAS Center), and Dr. Enrique Isla (CSIC-ICM Barcelona, Spain). The work was carried out in collaboration with the Universidad de Antofagasta and Universidad Arturo Prat of Iquique, both participant partners in the CENSOR Project.



Fig. 5. Victor Aguilera, CENSOR Ph.D. student examining zooplankton samples during feeding experiments in the laboratory at the Universidad de Antofagasta

RV Marion Dufresne Cruise PACHIDERME MD 159, February 6-28, 2007. On February 6, the RV Marion Dufresne left Punta Arenas on the collaborative cruise PACHIDERME (Pacífico-CHili-Dynamique des Eaux intermédiaires), including scientists from France, Germany, Norway and Chile. The purpose of the cruise was to recover long piston cores along a latitudinal transect from 48° to 55°S, including both the inland waterways of the Chilean Fjord region and off the bounding islands along the Chilean outer continental shelf and slope. Thirty-eight stations were visited, and a total of 55 cores were recovered (including CALYPSO and CASQ cores). In the northern fjord region, for example, several sites were cored to study the evolution of this fjord system since the retreat of the Northern Patagonian Ice sheet. Cores recovered from the southern fjord region, on the other hand, offer a unique opportunity to constrain the late glacial ice-retreat of glaciers from Cordillera Darwin. Within the oceanic realm, the sedimentary sequences recovered will provide constraints on intermediate water mass extent and property changes at various timescales. Chilean participants included: five members of COPAS Research Program 6 (graduate students Lorena Rebolledo, Magali Caunipán and Tania León; technician Alejandro Avila; and COPAS Director and Principal Investigator RP6 Carina Lange), Dr. Sandor Mulsow (Director of Geosciences and Senior Scientist FORECOS Millennium Nucleus, UACH) and his team; and Jean Pierre François (Department of Ecological Sciences, Universidad de Chile). Research Program 6 wishes to thank Dr. Catherine

Kissel, chief scientist of the PACHIDERME cruise, Capt. Hedrich and his crew of the Marion Dufresne, and all colleagues onboard for these three very successful weeks.

OUTREACH ACTIVITIES

For the first time, middle- and high school teachers participated on board the Marion Dufresne Cruise PACHIDERME MD 159, February 6-28, 2007, as part of a new educational program at sea, lead by Carlo Laj, Chairman of the Committee on Education of EGU. In a "Classroom at sea" fashion, one American teacher of Chatman HS and two Chilean teachers of Talcahuano schools, and COPAS Outreach coordinator Luis Pinto, participated in the scientific activities on board, kept in contact with their schools, sent regular reports on the cruise and answered questions from the students.

CAPACITY BUILDING

The Austral Summer Institute VII: 2 - 26 January 2007 (By Monica Sorondo, Carmen Gloria Leiva & Silvio Pantoja): Forty nine graduate and advanced undergraduate students from Scotland, Germany, Mexico, Brazil, Peru, Argentina and Chile participated in the Austral Summer Institute VII organized by the Department of Oceanography and the FONDAP-COPAS Center of the University of Concepción. This graduate activity is chaired by Silvio Pantoja and supported by the Graduate School at UDEC, UNESCO-IOC, Fundación Andes-Chile, Woods Hole Oceanographic Institution (WHOI) the Partnership for Observation of the Global Oceans (POGO), Integrated Marine Biogeochemistry and Ecosystem Research (IMBER), Centro de Investigación en Ecosistemas de la Patagonia (CIEP) and the Ministry of Education of Chile (MECESUP Program).

The Austral Summer Institute VII (ASI-VII) was devoted to the topics of Methane Biogeochemistry and Geophysics & Remote Sensing and Ocean-Land Interaction (www.udec.cl/oceanoudec/oceanografia/). The topic of Methane Biogeochemistry and Geophysics consisted of four courses held at the Marine Biology Station of UDEC in Dichato. Courses included regular lectures, class discussions and presentations by students. Laboratory work to examine sulfide oxidizing bacteria and infaunal invertebrates was also performed. A field trip to the Coliumo Tidal Flat to observe invertebrates and study redox zonation was part of the third course. A field trip to the Nahuelbuta Mountain region to observe upper mantle rocks and 280 million year-oceanic crust was organized as part of the activities of the fourth course.

The topic of Ocean-Land Interaction was organized in two courses held at the Main

Campus of UDEC. Dr. John Milliman lectured on the topic Rivers: Connecting land and the ocean. Regular lectures and class discussions were complemented with a field trip to the Bio-Bio River to examine the river bed. Dr. Ajit Subramanian lectured on Remote Sensing & bio optics. Regular lectures were complemented with computer activities to analyze satellite-derived data. Participants boarded the R/V Kay Kay to the Coliumo Bay to collect optical data.

On January 5th a reception offered by the Director of the FONDAP COPAS Center was held at the Casino Los Patos of UDEC. This occasion brought together the scientific community of the Center and UDEC collaborators as well as ASI VII lecturers and participants to celebrate the approval of the Center's five-year Continuity Plan and the success of the Austral Summer Institute, presently in its seventh version.

The Austral Summer Institute VII is a contribution of the Department of Oceanography and the FONDAP-COPAS Center at University of Concepción to capacity building in Latin America, allowing the development of networks among local and visiting scientists and students.

NEWS

COPAS Continuity Plan was evaluated as outstanding by a Committee comprised of international evaluators and members of the Chilean Council for Science and Technology (CONICYT). Due to this successful outcome funding is secured for the next five years (Mar 2007 - Feb 2012).

New COPAS Members. The Continuity Plan of the COPAS Center for the next 5 years projected the incorporation of new members to the Center, starting in March 2007. COPAS welcomes Dr. Leonardo Castro (UdeC biological oceanographer), Dr. Dante Figueroa (UdeC, physical oceanographer), and Dr. Javier Sellanes (UCN, biological oceanographer) to the COPAS Research team.

New FONDECYT Projects. Congratulations! Six FONDECYT grants were awarded to COPAS Researchers by the Chilean Council for Science and Technology (CONICYT), as follows:

Dr. Leonardo Castro (PI), *Effects of Egg Quality and Essential Fatty Acids Variations on the Anchoveta (*Engraulis Ringens*) Hatch Success in Different Spawning Areas*, with co-PI G. A. Claramunt (UNAP)

Dr. Giovanni Daneri (PI), *Bacterioplankton Response to Phytoplankton Blooms in an Enclosed Marine Area (Puyuhuapi Channel), and its Impact on Sedimentation, Mineralization of Organic Matter and Water Column PCO₂*, with co-PI P. A. Montero (CIEP)

Dr. Laura Fariás (PI), *Autotrophic Processes and Greenhouse Gases Cycling on the Continental Shelf off Central Chile (32-38°S)*, with co-PI C. Fernández (UDEC)

Dr. Victor Ariel Gallardo (PI), *Study on the Biodiversity, Function, and Temporal and Spatial Patterns off Distribution off Giant Benthic Filamentous Bacteria and their Relationship with the Prevailing Enso Regime Conditions in the Eastern South Pacific*, with co-PIs H. E. Urrutia and N. Ruiz-Tagle (CSBIOL UDEC), and C. S. Espinoza (COPAS)

Dr. Carmen E. Morales (PI), *Coastal-Ocean Exchanges in a High Eddy Kinetic Energy Region and Productive Upwelling System: Effects on Plankton Community Structure and Carbon Production*, with co-PI S. E. Hormazabal (DCEO UDEC)

Dr. Marcus Sobarzo (PI, UDEC), *The Dynamic of Waters on the Inner Shelf in an Upwelling Region: The Role of Winds, River Discharges and Coastline*, with co-PIs **Dante Figueroa** (DCEO & COPAS) and C. F. Moffat (WHOI)

These grants will substantially strengthen COPAS research.

New COPAS Post Doc: Dr. Pamela Hidalgo, a former COPAS Ph.D. student, has won a 2-years Post-Doc funding by FONDECYT. She will carry out research on zooplankton ecology under the supervision of COPAS Researcher Dr. H. González and supported by the SENSOR Project.

COPAS Researcher, Dr. Silvio Pantoja, has been appointed as a member of the SCOR-IOC-IGBP Planning Committee for the Second Symposium on the Ocean in a High-CO₂ World. The planning meeting for the Symposium took place at the International Atomic Energy Agency (IAEA) in Monaco on Feb. 26-27, 2007.

Handbook on methods for the study of marine planktonic systems (In Spanish: *Manual para el Estudio de los Sistemas Planctónicos Marinos*) co-edited by Dr. Viviana Alder (Instituto Antártico Argentino and CONICET) and Dr. **Carmen E. Morales** (Department of Oceanography and Center FONDAP-COPAS), will be published by the University of Buenos Aires Printing Office EUDEBA. Components of the global biodiversity program Census of Marine Life (CoML: www.coml.org), specifically the Census of Marine Zooplankton (CmarZ) project directed by Dr. Ann Bucklin and the South American Implementation CoML Committee, directed by Dr. Diego Rodríguez of the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata, Argentina, as well as the Instituto Antártico Argentino and the FONDAP-COPAS Center have agreed to co-finance this book.

UPCOMING EVENTS

On March 13th, in Washington DC the launching of the multi-authored publication, "The Sorcerer II Global Ocean Sampling Expedition: Northwest Atlantic through Eastern Tropical Pacific", to be published that day on PloS Biology (Public Library of

Science, an open access publishing system). Dr. V.A. Gallardo, as co-author of the publication and as vice-chair of the international SSC of CoML has been invited to the launching by the leader of the Expedition, J. Craig Venter. Thanks to the support of the Sloan Foundation, main financier of CoML, Dr. Gallardo will spend the week participating in the event and carrying out research both at the J. Craig Venter Institute and the Smithsonian Institution National Museum of Natural History. Other members and friends of CoML co-authoring the paper are Dr. Dave Karl, University of Hawaii, and Dr. Shubha Sathyendranath, Bedford Institute of Oceanography.

GLOBEC SSC Meeting will be held at Hiroshima on 24-28 May 2007. R. Escribano, a current member of the SSC, will attend this meeting.

4th International Zooplankton Production Symposium: sponsored by ICES, PICES and GLOBEC will take place in Hiroshima, Japan, on May 28-June 01. COPAS Researchers H. Gonzalez, L. Castro and R. Escribano will have presentations at the event. R. Escribano is also a member of the Scientific Committee of the meeting.

IMBER SSC meeting, Victoria, Canada. The next IMBER Scientific Steering Committee meeting will be held at Dunsmuir Lodge in Victoria, Canada, 12-14 June 2007. COPAS Director, Dr. Carina Lange is a member of the IMBER SSC and will participate in the event.

RECENT COPAS PUBLICATIONS

- Fariás, L., A. Paulmier, Gallegos, M.** (2007) Nitrous oxide and N-nutrient cycling in the oxygen minimum zone off northern Chile. *Deep-Sea Research* 54, 164-180.
- Olguin, H. F., Boltovskoy, D. Lange, C.B., Brandini, F.** (2006) Distribution of spring phytoplankton (mainly diatoms) in the upper 50 m of the Southwestern Atlantic Ocean (30–61°S) *Journal of Plankton Research* 28, 1107–1128.
- Vargas, C., Escribano, R., Poulet, S.** (2006) Phytoplankton diversity determines time-windows for successful zooplankton reproductive pulses. *Ecology* 87, 2992-2999.
- Venrick, E.L. C. B. Lange, F. M. H. Reid, A. Weinheimer and E. P. Dever** (2006) Temporal Patterns of Siliceous flux in the Santa Barbara Basin: the influence of North Pacific and local oceanographic processes. *CalCOFI Rep.*, vol 47: 156-173.

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COPAS Newsletter
COPAS, Universidad de Concepción.
P.O. Box 160-C, Concepción, CHILE

Telephone: 56 (41) 2683247
e-mail: rescribano@udec.cl
Web: www.copas.udec.cl