BASAL FINANCING PROGRAM
FOR SCIENTIFIC AND TECHNOLOGICAL CENTERS OF EXCELLENCE

ANNUAL PROGRESS REPORT

OCEANOGRAPHIC APPLICATIONS FOR THE SUSTAINABLE ECONOMIC DEVELOPMENT OF THE SOUTHERN REGION OF CHILE

- Concepción, April 15, 2014 -
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REPORT PERIOD : 6th Year X  7th Year □  8th Year □  9th Year □  
PERIOD COVERED : From 1 April 2013 to 31 March 2014

I. PRESENTATION

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<th>NAME OF THE CENTER</th>
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<td>Center for Oceanographic Research in the eastern South Pacific (COPAS)</td>
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<tr>
<th>DIRECTOR OF THE CENTER</th>
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<tr>
<td>Silvio Pantoja Gutiérrez</td>
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<tr>
<th>EXECUTIVE / DEPUTY / CO-DIRECTOR</th>
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<tr>
<td>Carina Lange Mahn</td>
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<th>COORDINATOR</th>
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<td>María Angélica Carmona M.</td>
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<td>Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA)</td>
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<td>Centro de Investigación en Ecosistemas de la Patagonia (CIEP)</td>
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<th>CENTER WEBSITE ADDRESS¹</th>
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### Research Lines

<table>
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<tr>
<th>N°</th>
<th>Title</th>
<th>Objective</th>
<th>Principal Researcher</th>
<th>Other Researchers (participating in the line)</th>
</tr>
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</table>
| 1  | Oceanographic observation for the sustainable development of aquaculture | 1. Generate relevant oceanographic know-how for the sustainable development of aquaculture in Patagonian fjord ecosystems  
2. Evaluate the impact of aquaculture on the main state variables associated with productive processes  
3. Incorporate oceanographic modelling tools to current productive practices within the salmon farming industry  
4. Determine how cultivated organisms may respond to marine toxins | Giovanni Daneri     | • A. Astuya  
• C. Fernández  
• M. Gutiérrez  
• P. Mata  
• P. Montero  
• O. Pizarro |
| 2  | Environmental variability and ecosystem patterns associated with changing freshwater inputs in Patagonian fjords | 1. Time series of physical-chemical conditions and productivity in contrasting Patagonian fjords  
2. Identification of key physical components for freshwater budget of the Baker Channel and seasonal variability of freshwater inputs  
3. Interaction of freshwater and oceanic forcing  
4. Primary production and vertical carbon fluxes associated with nutrient and light gradients  
5. Role of macronutrients and Fe-DOM in productivity and phytoplankton composition  
6. Proxies of export production and freshwater input through sediment studies | Fabián Tapia       | • H. González  
• J. Luis Iriarte  
• C. Lange  
• C. Moffat  
• S. Pantoja  
• E. Quiroga  
• L. Rebolledo |
| 3  | Ecosystem Variability and Demersal and Pelagic Fisheries              | 1. Food web models supporting the main fisheries in the southern region  
2. Effects of environmental variability on fisheries resources  
3. Fishery management strategies: tools, procedures and comparative scenarios | Leonardo Castro      | • L. Cubillos  
• I. Pérez  
• W. Schneider |
| 4 | An ecosystem approach to Patagonian Fisheries | 1. Ecosystem analysis for the main benthic, pelagic and demersal fisheries in Los Lagos and Aysén Regions  
2. Develop ecosystem model for Patagonian Areas for the management of benthic resources  
3. Identify ecosystem effects of fishing in southern Chile using ecological indicators and models  
4. Ecological and trophic interactions of target and important non-target species  
5. Identify potential interactions between artisanal/industrial fisheries and proposed marine protected areas, and the conservation of emblematic species, relevant to ecotourism  
6. Diversification strategies for the small-scale fisheries | Sergio Neira  
• P. Gomez-Canchong  
• R. Montes  
• R. Wiff |
|---|---|---|
| 5 | Marine Biosafety and Biotechnology | 1. Molecular biogeography based in the genetic variability of toxic plankton  
2. Molecular epidemiology in the water column, sediments and organisms based on the genetic variability of the three pathogens (ISAV, *Piscirickettsia salmonis* and *Caligus* spp.), that are responsible for the major economic losses in aquaculture in Patagonia  
3. Human and animal fecal pollution  
4. Experimental bioreactor of *Thraustochytrids* with genetically-characterized strains able to produce DHA and/or carotenoids that grow in commercial and alternative culture media  
5. Detection and molecular quantification of Cyanobacteria as a component of microbial carbon fluxes in the Baker Channel  
6. Culturing marine bioluminescent bacteria with potential use as biological sensors for aquatic pollution and plankton toxins | Rodrigo González  
• F. Cruzat |
|   | Technological and Knowledge Transfer | 1. Design and implement a system of permanent identification and selection of transferable information and knowledge  
2. Monitor and diagnose the type of information and oceanographic knowledge demanded by public and private sectors  
3. Apply communication strategies for transfer or dissemination of information, services, products and knowledge to different stakeholders of fisheries and aquaculture in the Patagonia | Ricardo Norambuena | M. Carmona  
M. Sorondo  
A journalist |
Changes in research personnel

Indicate any changes in the Staff of Principal Investigators and other Investigators as compared to the Development Plan of Continuity. Use this section to introduce information on profiles and roles of newly hired personnel.

Changes in personnel during Year 6 are as follows:

Dr. Silvio Pantoja became the Director of the COPAS Center and its associated Program COPAS Sur-Austral (45 hr/week), replacing Dr. Carina Lange who had been in this position since 2004. Dr. Lange is now the Deputy Director and, as informed in the Continuity Plan, she has joined R+D Line 2 as an Associate Investigator contributing to the paleoclimate/paleoceanography efforts (15 hr/week).

Dr. Sergio Neira is now the Principal Investigator of R+D Line 4 (26hr/week) in replacement of Dr. Renato Quiñones who in 2013 became the Director of the new FONDAP Interdisciplinary Center for Aquaculture Research (INCAR). Due to his new responsibilities, Dr. Quiñones could not continue as PI of Line 4. Additionally, Dr. Cristian Gallardo is now the Deputy Director of the FONDAP-INCAR Center and due to incompatibility of working hours could not continue as Associate Investigator of R+D Line 1. However, Dr. Gallardo continues collaboration with Dr. Alisson Astuya (R+D Line 1) investigating the cellular and molecular interaction between marine toxins and aquatic organisms, and developing biomarkers that allow the accurate detection of marine toxins in commercially important marine species (e.g., projects FONDECYT 1120397, FONDEF #D1111140). Dr. Gallardo also collaborates with Dr. Fabián Tapia (R+D Line 2) in assessing spatial-temporal patterns in the expression of several stress-related genes in benthic invertebrates that span the ecological break observed at 30-31°S (FONDECYT 1120896).

The creation of the FONDAP-INCAR Center has also led to the resignation of Dr. Marcus Sobarzo (R+D Line 3) in March 2013. In addition, Dr. Sobarzo was elected Dean of the Faculty of Natural Sciences and Oceanography in 2013. Due to incompatibility of working hours he had to leave our program.

Starting in June 2013, Dr. Iván Perez (formerly postdoc during Phase I) joins R+D Line 3 as an Associate Investigator (6hr/week), mainly in charge of the buoy and meteorological/oceanographic stations in the Puyuhuapi and Jacaf channels. These activities were previously carried out by Dr. Wolfgang Schneider.

Dr. Wolfgang Schneider (R+D Line 1) presented his resignation to COPAS Sur-Austral in March 2014 due to his new responsibilities as an Investigator in the newly funded Millennium Institute of Oceanography. However, Dr. Schneider will continue to contribute to COPAS Sur-Austral with manuscripts already committed and the participation in the planned cruises onboard the Japanese vessel Mirai in 2016 and the German vessel Polarstern in 2015.

Dr. Eduardo Quiroga, Assistant Professor at the Universidad Católica de Valparaiso, returns to COPAS Sur-Austral as Associate Investigator of R+D Line 2 (10hr/week) collaborating with the Baker/Martinez/Tortel monitoring stations, estimates on organic carbon flux, benthic-pelagic coupling, and preparation of manuscripts.
Advisory Committee
Name its members and date of constitution, include new additions and/or drop-offs, describe its task(s), frequency of meetings, decisions taken and/or recommendations made over the period. Attach reports, if applicable.

COPAS Sur-Austral has two advisory entities, the Board of Directors which facilitates the relationships of the COPAS Sur-Austral Program with public and private stakeholders; and the External Advisory Committee (EAC) which makes recommendations with respect to the results, products, and services feasible to be transferred to the private and public sectors.

Board of Directors
The highest hierarchical body of the COPAS Sur-Austral Program is the Board of Directors. The Board met on 22 April 2013, with the participation of:

1) Rector Universidad de Concepción (UdeC): Mr. Sergio Lavanchy Merino
2) Vice-Rector Universidad de Concepción (UdeC): Mr. Ernesto Figueroa Huidobro
3) Dean of the Faculty of Natural and Oceanographic Sciences, Mr. Franklin Carrasco Vásquez
4) Head of the Oceanography Department of the Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA), Captain Miguel Vásquez
5) Executive Director of the Centro de Investigación en Ecosistemas de la Patagonia (CIEP), Mr. Giovanni Daneri Hermosilla
6) General Manager for Salmon Chile, Mr. Matias Medina
7) Director COPAS Center and COPAS Sur-Austral Program, Mr. Silvio Pantoja
8) COPAS Sur-Austral Coordinator, Ms. Ma Angélica Carmona M.

The meeting started with a detailed presentation by the Director of the COPAS Center, including the new structure of the Program for Phase II, the most important results in Research, Technological and Knowledge Transfer and Education, and an update on new infrastructure and equipment. A round of comments by the participants followed, and finally, the Rector of UdeC summarized i) the ideas that have been raised in terms of socializing the results to the community, ii) stressed the importance of oceanographic monitoring systems as early warning systems for important themes such as the ISA virus and red tides, and iii) noted the collaborative role that can be developed with the newly funded FONDAP INCAR Center regarding research for sustainable aquaculture.

Regarding changes in the Board, Mr. Matias Medina is now the General Manager for Salmon Chile in replacement of Mr. Carlos Odebrecht and Dr. Silvio Pantoja is now the Director of the COPAS Center in replacement of Ms. Carina Lange. Mr. Ian Famer, former member of the Board during Phase I, was unable to continue as a member of the Board due to other commitments.

External Advisory Committee
The EAC is now composed of two members, Mr. Gustavo San Martín Catalán, coordinator of protected marine areas and climate change of the Unidad de Biodiversidad y Patrimonio Acuático, División de Administración Pesquera of Subsecretaria de Pesca y Acuicultura (SUBPESCA); and Mr. Daniel Nieto Díaz-Muñoz, general manager of Aquaterra EIRL and Director of Agroaqu Ltda. Mr. Atilio Morgado, former member of the EAC, during Phase I, was unable to continue due to other commitments.

On December 6, 2013 we held a workshop with the EAC members to review the progress in scientific and technological transfer undertaken by the COPAS Sur-Austral program. The meeting started with a welcome and a brief presentation by Mr. Ricardo Norambuena, in charge of Line 6 (Technological and Knowledge Transfer line) summarizing the new structure of the COPAS Sur-Austral program and the challenges of Phase II. This was followed by presentations by the two members of the EAC as well as the PI s of each line, and a round of discussion.
II. EXECUTIVE SUMMARY OF THE PROGRESS MADE

This section should be written in no more than two pages and must be in relation to the progress made in the reporting period. This information is public and may be published on CONICYT's web site.

The Continuity Plan of the COPAS Sur-Austral Program introduced slight modifications to the original research lines with the goal of promoting closer integration among physical, biological, and biogeochemical kinds of expertise leading to integrative interpretation within the three strategic areas: Oceanographic observation, Fisheries, and Aquaculture. We have now five research lines: R+D Line 1: Oceanographic observation for the sustainable development of aquaculture; R+D Line 2: Environmental variability and ecosystem patterns associated with changing freshwater inputs in Patagonian fjords; R+D Line 3: Ecosystem Variability and Demersal and Pelagic Fisheries; R+D Line 4: An ecosystem approach to Patagonian Fisheries; and R+D Line 5: Marine Biosafety and Biotechnology. Each line is led by a principal investigator and accompanied by associate investigators, also hosting postdoctoral fellows, graduate and undergraduate students, and technicians. In addition, R+D Line 6 is in charge of Outreach and Transfer, and links COPAS Sur-Austral with the productive sector and public services.

Research: During Year 6 we have put emphasis on: i) sustainable aquaculture research, including studies on environmental carrying capacity and toxic plankton and pathogens that may seriously affect aquaculture activity (R+D lines 1, 5, 2 and 6); ii) regional management of pelagic, demersal and benthic fisheries (R+D lines 3 and 4); and iii) the effects of freshwater inputs at the ecosystem-level (R+D lines 1, 2 and 3), including sediment studies for understanding decadal/centennial variability (R+D Line 2).

Sustainable aquaculture in the Chilean fjords can only be achieved when there is knowledge on the structure and basic functioning of ecosystems. During Year 6, new information was generated on the synthesis of organic matter and microbial degradation of DOM; microorganisms and irradiance (light attenuation as one of the key factors determining latitudinal patterns of production); the influence of variable freshwater inputs; the release of nitrogen compounds from salmon food and their impact on nitrogen cycles; as well as on toxic organisms inhabiting the water column and sediments (e.g., molecular biogeography, molecular epidemiology). Research on physical processes focused on understanding hydrography, salt flux exchanges and the dynamics of low oxygen water penetration into de fjord areas, including the Reloncavi Fjord, the Inner Sea of Chiloé, the Boca del Guafo and the Puyuhuapi-Jacaf area. These studies are providing important knowledge on fundamental processes associated with the overall productivity, water quality and renewal of fjord ecosystems. In view of an increased number of salmon fish farms operating in the Aysén Region that may be driving fjord oxygen consumption to critical levels (especially in deep waters), we have made special efforts to continuously monitor “real time” basic oceanographic and climatic parameters in the Puyuhuapi-Jacaf area. This particular area has been chosen due to the severe hypoxic conditions that we have detected in the Puyuhuapi Channel. Continuous monitoring has been achieved through the installation of an array of 3 automatic stations and one oceanographic buoy with the active cooperation of the Aysén salmon farm industry. We also deployed an array of physical-chemical and oceanographic sensors (LOBO buoy plus a weather station) near the head of the Reloncavi Fjord which collects hourly data from both the surface ocean and the atmosphere (data are accessible over the Internet at reloncavi.loboviz.com), providing a detailed view of the evolution of ocean properties relative to atmospheric forcing over time scales spanning hours to seasons. Reloncavi is another fjord heavily used in salmon farming. Based on an extensive set of current-meter data collected in this fjord we tested the adequacy of present-day technical standards required by Chilean law to grant salmon aquaculture concessions (minimum record lengths of 15–25 days are needed and not the currently required 24-hour records), and made recommendations to improve procedures and requirements to grant aquaculture concessions in Chile.

The sustained time series observations are complemented by numerous oceanographic surveys in Patagonian fjords. COPAS Sur-Austral is making an important contribution to our understanding of how fjord ecosystems work. Most of the base line information being generated in the fjords is also contributing to the objective of developing physical and biological modelling tools to current productive practices within the salmon farming industry. However, our multiple efforts for interaction with the private sector (offering projects, partnerships and agreements; demonstrating the use of the fuzzy logic model; and the request for qualitative
information directly related to the management of farms) have not been as successful as expected.

In terms of regional management of pelagic and demersal fisheries, we have moved from a single-species analysis of the main fisheries in southern Chile towards a more holistic ecosystem approach that is more likely to reach sustainability. For the small pelagic fisheries, our studies provide new basic biological and ecological information on the Falkland sprat (Sprattus fueguensis), one of the main pelagic resources in inner seas of southern Chile, and new estimates for the acoustic target strength this species. The latter were used to update the stock assessment (carried out by Instituto de Fomento Pesquero IFOP) and allowed the Subsecretaría de Pesca y Acuicultura (Undersecretariat for Fisheries and Aquaculture) to estimate a Total Allowable Catch (TAC) for the pilchard fishery. For demersal fisheries, we also produced information for fisheries management purposes such as sensitivity of biological reference points, evaluation of the time necessary for biological recovery (e.g., for Patagonian grenadier Macruronus magellanicus), and compensatory responses of fish populations to fishing (e.g., for southern hake Merluccius australis and demersal hake Merluccius gayi). Modelling exercises at the ecosystem level show that fishing impacts the community structure well beyond target species and that long-term sustainability is strongly linked to multispecies interactions that need to be considered in fisheries management. Two COPAS Sur-Austral researchers have been selected as members of the recently created Scientific and Technical Fishing Committees that, according to the new Fishing Act, have decisional power in setting the range for the Biological Acceptable Catch for each fishery which must be taken into account by the fishing authority when setting the TACs.

Major efforts have been devoted to the understanding of land-ocean gradients in salinity and stratification in various fjords (e.g., Reloncavi, Comau, Puyuhuapi, Baker) due to input of freshwater (from rivers, meltwater and rainfall). We studied for example, its seasonality and mixing processes with intrusion of oceanic water; freshwater input effects on nutrient and plankton/microbial community dynamics (including the release of Fe from riverine sources); river-borne POM as a major source of organic matter available for marine species that occupy estuarine environments during early stages of their life cycle; primary productivity and trophic carbon fluxes; and potential changes in composition of microphytoplankton that would be expected if concentrations or ratios of nutrients are altered by changes in the input of freshwater to fjords. The analysis of a long instrumental record (1944–2007) of Puelo river outflow into the Reloncavi Fjord showed a decreasing trend in freshwater discharge since the late 1970s, whereas sediment studies encompassing the past 800 years revealed a clear decrease in allochthonus material since ~1850 AD which can be associated with the reduction in the Puelo River streamflow and rainfall reconstructed from tree rings. We have now completed 5 years of continuous measurements of temperature and sea level from instruments deployed near the Baker river mouth and 3 years from similar instruments deployed near the Jorge Montt Glacier. Together with offshore wind variability derived from the ASCAT scatterometer we are trying to understand the roles that wind and river influence play in determining seasonal and synoptic-scale changes in the location of the transition from river-dominated conditions in the water column to predominantly marine conditions which is key to comprehending patterns of productivity and vertical carbon fluxes along this and other fjords. On the other hand, Jorge Montt Glacier has experienced the fastest frontal retreat observed in Patagonia during the past century, and studies are underway to assess the response of microbes to the accelerated input of freshwater due to glacier melting. Our new small oceanographic vessel which is finally based in Caleta Tortel (Aysén Region) will start operations in the next few months. This new platform will provide us – and other researchers interested in this region – with the safety conditions, autonomy and necessary equipment to sample water, plankton and sediments over much greater ranges of depths and distances to port than we have been able to span thus far.

The scientific knowledge gained by the COPAS Center during Year 6 was communicated in the form of 48 presentations at national and international congresses, and workshops, of which >30 presentations involved results of our studies in Patagonia. In addition, we published 40 ISI articles (total average impact factor of 2.1); of these, 14 were entirely dedicated to the Patagonian fjord region.

COPAS Sur-Austral maintained the extensive collaborative network with national and international colleagues which is key for scientific and educational initiatives as well as for successful attraction of extramural funding; and its strong position in major network and international programs (e.g., POGO, IMBER). New alliances were made with the Leibniz-Institute for Baltic Sea Research, IO-Warnemuende (Germany), and others were maintained (International Associated Laboratory LIA-MORFUN, France; Japan Agency for Marine-Earth Science...
and Technology (JAMSTEC); Alfred Wegener Institut, AWI-Bremerhaven, Germany.

**Education:** COPAS researchers are strongly involved in university-based graduate and undergraduate education. At present, the Center hosts a total of 75 students (21 PhDs, 35 MSc, and 19 undergraduates). Of these, 1 PhD, 9 MSc and 10 undergraduate students have successfully defended their theses and obtained their degree in 2013/2014. Although most of our graduate students are of Chilean nationality, COPAS also hosts students from other countries (mainly from Latin America); they represent 16% of the graduate student pool. The Austral Summer Institute XIV (ASI XIV “Coastal and Open Ocean Studies through Multiple Approaches”) held in January 2014 involved the participation of 80 students (41 Chileans and 39 from various other countries). Seven postdoctoral fellows engaged in COPAS research themes during Year 6; 5 of them are directly associated to the COPAS Sur-Austral objectives. Extramural funding from FONDECYT is the most important source for including postdocs into the scientific activities of the Center.

**Outreach and Transfer:** Knowledge transfer to academic, public and private sectors as well as the community at large (Line 6 “Technological and Knowledge Transfer”) was also made through the organization of scientific events and workshops in the Concepción area, Valparaíso, Coyhaique and Puerto Cisnes, conferences by national and international colleagues, and training courses. The transfer project SUBPESCA 2013-12-FAP-2 (“Implementation of productive projects of seaweed farming on a pilot basis in areas of management and exploitation of benthic resources (AMERBs) in the Aysén region”) motivated a formal Collaboration Agreement between COPAS and the company ALGORG Ltda.

Our Outreach program continued in Patagonia and Biobio regions. During Year 6 more than 3,000 people were involved in 36 outreach activities including fairs, camps, lectures, seminars, and workshops. Also, 2 Club EXPLORA Projects in the Aysén Region and the EXPLORA Project “Chile MIO” were awarded in Year 6. We expect that the agreement of collaboration between COPAS Sur-Austral and the Municipality of Tortel in conjunction with the new vessel harboured in Tortel will open new possibilities for outreach/educational activities and a closer interaction with the local elementary school.

**Extramural funding:** Our members continue to be successful in bringing in outside grants beyond the PFB funding; 28 new projects have been awarded to us in Year 6.
III. OBJECTIVES AND RESULTS ACHIEVED

Considering the objectives established in the Continuity Plan for this period, in no more than 20 pages describe the results achieved during the period. Refer also to those objectives that have not been accomplished indicating the reasons.

1.- Scientific and technological research of excellence with national and international scope and collaboration

As stated in the Continuity Plan, based on the knowledge acquired during Phase I, we have re-arranged the original research lines into five research lines that converge in addressing the three strategic areas (Oceanographic observation, Fisheries, and Aquaculture) from a more integrated and multidisciplinary point of view: R+D Line 1: Oceanographic observation for the sustainable development of aquaculture; R+D Line 2: Environmental variability and ecosystem patterns associated with changing freshwater inputs in Patagonian fjords; R+D Line 3: Ecosystem Variability and Demersal and Pelagic Fisheries; R+D Line 4: An ecosystem approach to Patagonian Fisheries; and R+D Line 5: Marine Biosafety and Biotechnology.

The rearrangement aimed at promoting closer integration among physical, biological, and biogeochemical kinds of expertise leading to integrative interpretation of results. It included the incorporation of our physical oceanographers into the research lines instead of being a line by itself as before; a more ecosystem approach to aquaculture; creating an oceanographic baseline for the implementation of predictive models of natural variability of key elements for aquaculture; moving from a single-species analysis of the main fisheries in southern Chile towards a more holistic ecosystem approach that is more likely to reach sustainability; developing ecosystem-based stock recovery strategies for the more depleted demersal and pelagic stocks; developing molecular tools for the detection of toxic/harmful microalgae species; and a better understanding of contrasting regimes of freshwater input into the fjords. In addition during Year 6, we continued with our continuous oceanographic observation platforms with state-of-the-art technology in the various fjords (e.g., Puyuhuapi, Martinez/Baker) as well as the study of physical processes which is providing important knowledge associated with overall productivity (e.g., vertical water mixing processes) and water quality (e.g., low oxygen water intrusion and flushing times).

During Phase II we are putting strong emphasis on: i) sustainable aquaculture research, including studies on toxic plankton and pathogens that may seriously affect aquaculture activity (R+D lines 1, 5, 2 and 6); ii) regional management of pelagic, demersal and benthic fisheries (R+D lines 3 and 4); and iii) the effects of freshwater inputs at the ecosystem-level (R+D lines 1, 2 and 3), including sediment studies for understanding decadal/centennial variability (R+D Line 2). Here we summarize the most relevant scientific results achieved during Year 6.

Sustainable aquaculture research

In the field of aquaculture in fjords, the main gaps in knowledge are those related to the structure and basic functioning of ecosystems. As stated in our Continuity Plan, society needs new insight into ecosystems, including information on circulation, ventilation processes, inputs of freshwater, natural variability of key elements for aquaculture such as oxygen, inorganic nutrients and dissolved organic matter (DOM). In addition, gaps still persist in the knowledge of key health management at the scale of farms, as well as epidemiological aspects at the scale of fjord basin. Finally, oceanographic modeling tools need to be incorporated to current productive practices within the salmon farming industry.

The Puyuhuapi Channel stretches from the Puyuhuapi village in the north to the Moraleda Channel in the south which connects it to open seas. Also, the channel is united with open seas via the Jacaaf Channel in the north. This area hosts a large number of salmon farms and receives a large contribution of particulate and dissolved organic matter from both autochthonous (phytoplankton productivity) and allochthonous sources (from freshwater input and aquaculture). Hypoxic conditions throughout the Puyuhuapi Channel were first measured in 1995 and cannot be attributed to aquaculture activities which initiated in this channel during the
mid 1990s. The results by Schneider et al. (2014; accepted in Progress in Oceanography, “On the hydrography of Puyuhuapi channel (Chilean Patagonia)”) suggest that over the years the combination of high primary production, biological degrading, and sluggish ventilation of deeper waters impeded by bathymetry, is responsible for the observed hypoxic, although not anoxic, conditions in this channel. The authors also analyzed dissolved oxygen measurements available from fjords and channels of northern, central and southern Chilean Patagonia, and this analysis revealed that the Puyuhuapi Channel is the only place in Chilean Patagonia where severe hypoxic conditions were detected (R+D Line 3). In view of an increased number of salmon fish farms operating in Puyuhuapi Channel nowadays and thus driving oxygen consumption, a constant monitoring of the channel’s dissolved oxygen state is needed.

An important aspect has been the deployment and the maintenance of an oceanographic buoy anchored in the Puyuhuapi-Jacaf channel ecosystem (northern Patagonia) which transmits “real time” basic oceanographic and climatic parameters (R+D Lines 1 and 3, and collaborator Dr. Paolo Povero, expert on Open Source technology, www.gisweb.it). Additionally, one UV and one PAR sensors were installed in Magdalena island (1000m distance from the buoy). Six sampling stations are being sampled monthly by R+D Line 1 (three in the Cisnes river and three on the fjord). In the fjord, the sampling stations were selected according to influence of river (Station DESEMBOCADURA) and salmon farms influence (Stations ACHICO and PGANSO). Additionally a control station in the middle of channel is also sampled (Station BOYA). Emphasis on the synthesis of organic matter and microbial degradation of DOM is coincident with the specific objectives of the concurrent FONDECYT 1131063 (G. Danci PI) research project.

At each river sampling station the following variables are being measured: inorganic nutrients (NO3, NO2, NH4, PO4, Si), dissolved organic carbon (DOC) and microorganisms (community bacterial assemblages). In the fjord stations water samples are regularly obtained to estimate: chlorophyll-a, inorganic nutrients, DOC, microorganism counts (bacteria, phytoplankton, nanoflagellates, microzooplankton, mesozooplankton) and rates of gross primary production, community respiration, bacterial secondary production and bacterial respiration. Additionally in each fjord station vertical profiles of temperature, salinity and irradiance (PAR) are being recorded. Two day monthly sampling campaigns are being complemented with 10–15 days intensive process study campaigns. In Patagonian fjords one of the main forcing factors is light. Spatial changes in surface light attenuation along Patagonian region are largely driven by glacier-derived freshwater inputs and suggest that light attenuation is one of the key factors behind the latitudinal pattern in size-fractioned primary productivity and phytoplankton biomass (Jacob et al., in review in Progress in Oceanography, “Size fractionated primary production across hydrographic and PAR-light gradients in Chilean Patagonia (41–50° S)” (R+D Lines 1 and 2).

**Bacteria:** Spatial variability in bacterial diversity was analyzed at different depths throughout a river-fjord gradient in waters collected during intensive campaigns in August 2013 and March 2014. Similitude analysis showed three different clusters characterizing bacterial community in riverine waters (> 50% similitude) and in surface and subsurface waters from the fjord (>70% similitude). Among sampling sites located in the fjord basin no major differences were observed, suggesting that water column stratification is the main factor determining the bacterial community structure in the water column.

In addition, monthly variability in bacterial community composition is being studied in a time series station (BOYA) since June 2013. Similitude analysis of the bacterial diversity over the five months sampling at BOYA station evidenced temporal variability in bacterial OTUs composition. Our results suggest season changes in bacterial community composition and differences in the dynamics of bacteria inhabiting surface and subsurface waters of the Puyuhuapi Channel.

**Phytoplankton primary production (GPP) and community respiration (CR):** Seasonal variability were also analyzed at different sites and depths during intensive (August 2013) and monthly (June 2013-January 2014) campaigns. During most of the experiments carried out in the column water, CR rates were higher than those of GPP. The integrated GPP rates (down to 20 m) showed seasonality, with he highest value recorded in August 2013 (3 g C m^-2 d^-1) while values <1 g C m^-2 d^-1 were observed during winter (June-July 2013) and spring-summer period (from September 2013 to January 2014). Community respiration rates showed differences between seasons, especially during winter, where CR rates were consistently higher than those
registered in spring-summer season. From a spatial perspective, the lower integrated rates of GPP and CR were recorded at the DESEMBOCADURA station, while the highest values were observed in ACHICO/PGANSO and BOYA. The GPP/CR ratios, used as an index for the trophic status of the system, ranged from 0.003 to 2, with most experiments indicating a heterotrophic metabolism (GPP/CR <1).

Microplankton community: Seasonal variability of bacteria, nanoflagellates autotrophic (NFA), nanoflagellates heterotrophic (NFH) and phytoplankton was recorded monthly. Phytoplankton community showed a seasonal pattern that highlights the highest values in August-September 2013 (>8000 cel mL-1) and the lowest values in June-July (<500 cel mL-1). Abundances of NFA and NFH did not show a clear seasonal pattern.

Zooplankton/ichthyoplankton: Two cruises oriented to study the fine structure of the water column and zooplankton/ichthyoplankton microlayers of aggregation were conducted in the Puyuhuapi Fjord in May 2013 and January 2014. These cruises counted with the participation of investigators from the University of Miami in May (Dr. A Valle-Levinson and PhD. Student L Ross), research group that actively collaborates with R+D Line 3, and also with scientists from CIEP. Data are being processed and results will be reported in Year 7.

Most of the baseline information being generated on the Jacaf-Puyuhuapi area is also contributing to the objective of developing physical and biological modelling tools to current productive practices within the salmon farming industry (R+D Line 1 in collaboration with Dr. Pablo Mata of CIEP Center). Dr. Mata that has already developed a hydrodynamic circulation model for the Puyuhuapi channel and will begin work on a coupled biological model for the same area. Recently, R+D Line 1 submitted a manuscript on modelling the hydrodynamic effect of a salmon farm on a fjord environment (Cornejo et al., submitted to Aquaculture, “Numerical studies on the hydrodynamic effects of a salmon farm in an idealized environment”).

The extensive physical and biological datasets collected during 2008–2012 in other fjords also served to tackle questions relevant for the sustainable development of aquaculture activities. For example, we used an extensive set of current-meter data collected from 3 sites along the Reloncavi Fjord to test the adequacy of present-day technical standards required by Chilean law to grant salmon aquaculture concessions. Simulations of increasingly longer current-meter surveys, from 12 hours to 30 days, indicated that minimum record lengths of 15–25 days, and not the currently required 24-hour records, are needed to adequately characterize the current speed and velocity components, as well as the prevailing direction of the current. A contribution, recently submitted to Aquaculture by Tapi et al. (submitted to Aquaculture, “Measuring currents at potential aquaculture sites: recommendations to improve procedures and requirements to grant aquaculture concessions in Chile”) discusses the adequacy of existing regulation pertaining the gathering, analysis and reporting of current-meter records, and provides recommendations aimed at contributing to the sustainability of aquaculture in southern Chile (R + Lines 2, 4, 1 and 6). Moreover, in a contribution published by Quiroga et al. (2013 in Marine Pollution Bulletin 68, 117–26), data on benthic fauna from two fjords with contrasting histories in terms of salmon aquaculture were used to test a quantitative index of ecological quality. The marine biotic index known as AMBI was applied to data from the Baker Fjord, as yet a pristine system, and the Aysén Fjord which harbors salmon farms. Based on the soft-bottom macrobenthic communities and sediment properties, the ecological status of these fjords was classified as “good” for Aysén and “high and unbalanced” for Baker. The latter is probably related to a strong influence of variable freshwater inputs. The paper discusses the caveats, applicability, and usefulness of this type of index to provide baselines for the monitoring of aquaculture impacts on Chilean coastal ecosystems.

With respect to studies on toxic plankton and pathogens that may seriously affect aquaculture activity, we have worked on the molecular biogeography based in the genetic variability of species of toxic plankton in southern Chile. A new qPCR protocol for specific detection and quantification of the North American clade of *Alexandrium catenella* (which is present in the southern austral ecosystem of Chile) was standardized (R+D Line 5). This protocol can detect the genetic material of a single cell in a sample; it was validated in cultured conditions of this organism and it has been used in samples of water column from Puyuhuapi Channel to
estimate the cells number of this dinoflagellate present in this area to validate its potential use in a monitoring program. The results of detection and molecular characterization of A. catenella using 18s rRNA gene shows the presence of this dinoflagellate between 10 and 50m water depth in 58% of the stations analyzed. Five new genotypes were identified in the area which differ 6.8% with respect to the North American clade.

Research Line 5 has also continued with the effort of determining the molecular epidemiology in the water column, sediments and organisms based on the genetic variability of the three pathogens that are responsible for major economic losses in aquaculture in Patagonia. As for monitoring the presence of ISAV in native ichthyofauna, we analyzed (Patagonia Associative Project 213.114.001-1AP) a total of 192 samples from 10 species: Róbalo (Eleginops maclovinus), Chancharro (Helicolenus lengerichi), Cabrilla (Paralabrax humeralis), Lenguado (Paralichthys adspersus), Colde (Patagonotothen ramsayi), Pejerrey (Basilichthys australis), Trucha café (Salmotrutta fario), Trucha Arcoins (Onchorhynchus mykiss), Pez Toro (Cottoperca gobio), and Rollizo (Pingüipes chilensis). In addition to ISAV detection, we also analyzed for the presence of Pisicirickettssia salmonis, as another important pathogen in Chilean aquaculture. All the samples analyzed resulted negative for both pathogens. Nevertheless, the presence of endoparasites in liver tissue of Róbalo was evaluated by transmission electron microscopy and molecular tools. At the molecular level, the presence of Diphyllobothrium pacificum and Anisakis pegreffii was confirmed.

Using single nucleotide polymorphisms (SNPs) analysis of a partial sequence of the 18S rRNA gene, five populations of Caligus rogercresseyi from 41 to 45°S in southern Chile were characterized during 2013. The results show a total of 24 haplotypes with two main haplotypes (A = 36.7% and B = 16.3%), which were also present in sequences of this parasite stored in the GenBank database in 2003. The populations studied of C. rogercresseyi obtained from the farmed salmon, showed a low genetic flow and high genetic drift suggesting the presence of a possible bottleneck effect caused by a drug-selective pressure mechanism which could have artificially selected the A and B haplotypes due to the use of treatments with pesticides during more than a decade in this area. A manuscript entitled “The populations of Caligus rogercresseyi in the southern austral ecosystem of Chile and more than a decade of drug-selective pressure of resistant genotypes through pesticide treatments” is in preparation to be submitted to Aquaculture (R+D Line 5).

Research work related to the response of cultivated organisms to marine toxins and on salmon farm impacts and environmental risks is being coordinated by R+D Line 1 on two fronts: a) on the release of nitrogen compounds from salmon food dissolution and their impact on nitrogen cycles associated processes; and b) on the determination of potential harmful mechanisms associated with ichthyotoxic microalgae, in particular, the possible relationship between reactive oxygen species (ROS) production and the toxic potential of two strains of Heterosigma akashiwo is being evaluated by implementing NBT technique that allows to evaluate the liberation of the superoxide anion through the cytochrome c technique. The results so far have shown significant differences in the production of intra and extracellular ROS between different strains and growth phases. This work supports the hypothesis that liberation of ROS by H. akashiwo is an important factor that could be at least partially responsible for massive fish mortalities during this type of algal proliferation.

With respect to pollution in the area of the town of Tortel, R+D Line 5 advanced in the use of molecular marker mDNA to trace fecal pollution in the water column. Samples analyzed from a summer campaign in the Tortel area show the presence of human mDNA in the stations closer to the town of Tortel (E1 and E2), and a remarkable reduction in the more distant stations.

All the above information generated by COPAS Sur-Austral could reduce socio-economic impacts by toxic algae and pathogens in the Patagonian aquatic ecosystem and in its associated ecosystem services.

Research Line 5 is setting up an experimental batch bioreactor of 5L with a biomass production of 42g (dry weight), corresponding to a 23% of docosahexaenoic acid (DHA, and omega-3 fatty acid) and 12% of carotenoids. Based on the 18s rRNA gene sequence, the microorganism used correspond to a marine fungus with an 83% of similitude to Rhodosporidium sp (GenBank KJ530976) and 72% of similitude to a Thraustochytriidae sp. Although strains highly producers of DHA have been previously described for Thraustochytrids, for Rhodosporidium (Basidiomycetes) there are no reports of strains highly producers of DHA as the informed in here. We are preparing a manuscript titled “A marine fungoid highly producer of DHA, EPA
and carotenoids isolated from southern austral marine ecosystem in Chile” to be submitted to Marine Biotechnology. Last year we reported that this work has served as a baseline for the project FONDEF-VIU 120023 “Soft capsules of DHA from marine fungoids” with the main objective of encapsulating a marine fungoid strain to be used as nutritional supplement. In September of 2013 R+D Line 5 started the second part of this project by setting up an experimental bioreactor of 10L and experiments will be conducted to determine the innocuity of marine fungoids as nutritional supplement.

Another new developed area of marine fungoid research is the proteolytic capacity of these microorganisms that can be used in the industry of food for salmonids. Proteases are utilized as a supplement to increase the digestibility of the new formulas of food which incorporate vegetal materials indigestible for carnivore fishes. The results of R+D Line 5 show that four strains with high proteolytic activity exist inside the collection of marine fungoids. The results have been used for Innova Project 13.3395-EM.TES “Proteolytic activity of thrauschochytrids for fish food”.

Advances have also been made with respect to marine bioluminescent bacteria. R+D Line 5 has 15 positive isolations from the Puyuhuapi Channel and 11 from the Bio-Bio region. The characterization of ribosomal gene 16s RNA shows between 96 and 98% of similarity with Vibrio fischeri and Photobacterium phosphorum, both marine bacteria described as bioluminescent microorganisms. Assays of the effects of potassium dichromate used as referent toxic substance have shown a dose-response curve which suggests their potential use as biological sensors for aquatic pollution and plankton toxins.

Regional management of pelagic, demersal and benthic fisheries

The main fisheries in Patagonia are severely depleted. It is evident that there is need for information on the stocks/food webs, environmental variability impacts (R+D Lines 3 and 2), and a different management approach aimed at stock recovery strategies rather than maximum constant quotas (R+D Lines 3 and 4). The overall aim is to better understand the whole ecosystems and their management under an ecosystem approach.

With respect to trophic relationships and environment, we determined the ecotrophic and ecosystem-level similarities and differences between two basins (Inner Sea of Chiloé with high connectivity to the adjacent ocean, and Moraleda Channel which is relatively shallow), and built two static and mass-balanced trophic models using the software Ecopath with Ecosim 6.0 (EwE). EwE proved to be a useful tool for estimating changes in the properties of the plankton community in fjord systems triggered by changes in the biomass and/or production of producers and consumers. A collaborative paper (R+D Lines 2 and 3) has recently been accepted for publication in the journal Estuaries and Coasts, in which the differences in trophic webs between the X and XI inner seas are documented and explained in part on the base of the different amount of nutrients supplied into the basins exerted by the seasonal input of subsurface seawater from the ocean (Pavés et al. 2014, DOI: 10.1007/s12237-014-9780-y) (Fig. 1).

The differences in the components of the trophic webs between inshore and offshore waters were also used to study population connectivity through the use of biomarkers (fatty acids). They enabled us to determine that southern hake eggs (Meluccius australis) collected from the plankton in inshore waters of the X region were spawned from adult females residing for months in that zone and not from recent immigrant females from the offshore spawning areas (G. Medina Master of Fisheries thesis; Medina et al. in press in Fisheries Research, http://dx.doi.org/10.1016/j.fishres.2013.11.005) (R+D Lines 3 and 2). Additionally, a master thesis on the role of Sprattus fueguensis in the trophic web is now under way (Montecinos, thesis “Alimentación y utilización de isótopos estables de 13C y 15N para determinar nivel trófico de Sprattus fueguensis en la zona sur austral de Chile”).
Figure 1. Trophic pathways between functional groups in the classical and microbial food webs in the basins of (a) Inner Sea of Chiloé (41–43 °S) and (b) Moraleda Channel (43–46 °S). The thickness of the lines shows the level of energy flow between functional groups. The figure presents flows of >0.5%, and the size of the nodes represent biomass (B) of the different groups (flows entering a box do so in the lower half, whereas flows exiting do so in the upper half of the box). From Pavés et al. (2014).

Regarding resources management, efforts on the small pelagic fisheries in Patagonia were oriented to: i) improve the biology and ecology of key species in marine food webs of the Chilean Patagonia; ii) evaluate the total biomass present in May and June of 2013 for the X and XI Regions; and iii) provide new estimates for the acoustic target strength for *Sprattus fuegensis*.

One of the main pelagic resources in the study area is the Falkland sprat (*Sprattus fueguensis*), a species that was identified only in 2005 and, therefore, basic biological and ecological information is lacking. An important aspect in this fishery is the identification of the species in the catch, since at first sight it looks quite similar to the common sardine (*Strangomera bentincki*). Aranis et al. (“Identificación de rasgos morfológicos para una rápida diferenciación de sardina austral y sardina común”, accepted in Latin American Journal of Aquatic Research) developed a system based on morphological features that allows a rapid identification of these two species and hence better data collection. This will improve the management of austral sardine as well as the modelling of the ecosystem effects of this species in the food web. As shown by Neira et al. (2013; “Rol ecosistémico de sardina austral e impacto de su explotación en la sustentabilidad de otras especies de interés comercial”, Informe de Avance Proyecto FIP 2012-15), the species plays a key role as prey species in the food webs occurring in the inner seas of southern Chile (R+D Lines 4 and 3).

With respect to biomass evaluation and new estimates for the acoustic target strength of *Sprattus fuegensis*, R+D Line 3 conducted government funded projects which results were used to update the stock assessment.
carried out by investigators of the Instituto de Fomento Pesquero (IFOP). This allowed the Subsecretaría de Pesca y Acuicultura (Undersecretariat for Fisheries and Aquaculture) to estimate a Total Allowable Catch for the pilchard fishery. A similar study was conducted for the small pelagic fisheries off central-southern Chile for anchoveta (*Engraulis ringens*) and common sardine (*Strangomera bentincki*) in which we observed some recovery of the spawning females compared with 2013. Regarding these resources, two important issues were determined and published from our studies through collaborative research: 1) by means of a new analytical method developed to assess reproductive periods in small pelagic fishes, a delay in the initiation of the reproductive season was determined in these stocks during the last years (Claramunt et al. 2013, in press in Fisheries Research, http://dx.doi.org/10.1016/j.fishres.2013.09.010); and 2) our study confirmed that the removal of the fast growing juveniles could induce a delay in the reproductive cycle of the common sardine, a new clear example of fishery-induced changes on the reproductive dynamics that affects the overall population demography of fishes (Cubillos et al. 2013, in press in Fisheries Research, http://dx.doi.org/10.1016/j.fishres.2013.12.003).

In terms of demersal fisheries, emphasis during 2013 was to obtain stock assessment data for the main demersal fisheries operating in Patagonian waters (R+D Line 3). For the Patagonian grenadier (*Macruronus magellanicus*) fishery, an evaluation of the time necessary for biological recovery was investigated by considering interdecadal change in the recruitment (Cubillos et al. 2013, in press in New Zealand Journal of Marine and Freshwater Research, DOI: 10.1080/00288330.2013.846920). The main conclusion is that the Patagonian grenadier was able to recover within 8–15 years only when favorable regimen for recruitment tend to occur again. This research is part of the Master Thesis of Sandra Curin, and results were also presented at the Gadoid Fisheries ICES/NAFO symposium, 15–18 October 2013, St Andrews, New Brunswick, Canada. For the southern hake (*Merluccius australis*) fishery, the main research focused on: a) changes in the growth rates and length-at-age of the southern hake as compensatory responses of this population to fishing (a contribution of Pedraza-García et al. to the same Gadoid Fisheries ICES/NAFO symposium; and b) the sensitivity of biological reference points for southern hake with random participation of fishing fleets, a contribution of Yáñez et al. to the Gadoid Fisheries ICES/NAFO symposium. For the demersal hake (*Merluccius gayi*) fishery, changes in the growth rate were studied by considering that compensatory responses to fishing exploitation must be associated to faster growth rate (Cerna et al. 2013, published in Latin American Journal of Aquatic Research 41, 558–569). In addition, R+D Line 3 is investigating if the actual period of low abundance of hake determined changes in the predation mortality of their main prey species, particularly squat-lobsters and small pelagic fish. For the case of Patagonian toothfish (*Dissostichus eleginoides*), an operative model was conditioned to evaluate the performance of the stock assessment tools currently used to determine the status and total allowable catch. Partial results (4 presentations) were presented at the VI Foro Iberoamericano de los Recursos Marinos y la Acuicultura (FIRMA), Valparaiso 25–28 November, 2013.

Among demersal fish species, the pink cusk-eel (*Genypterus blacodes*) has been much less studied compared to other demersal species such as the southern hake (*Merluccius australis*) and Patagonian grenadier (*Macruronus magellanicus*). Baker et al. (in press in Environmental Biology of Fishes, DOI 10.1007/s10641-013-0199-2) studied the reproductive ecology of the pink cusk-eel and evaluated differences between fishery management zones in the Chilean austral zone. The status of pink cusk-eel in the austral demersal zone is critical and results presented by Baker et al. (in press) support the hypothesis that two separate stocks exist, and suggest that females from the northern zone have early maturation and a proportionally greater investment in reproduction than females from the southern zone (R+D Line 4).

Although marine mammals are important ecosystem components and iconic species for conservation, ecological and ethological studies on big cetaceans in the Chilean Patagonia have not been conducted on a regular basis. For example, the study of the Antarctic blue whales (*Balaenoptera musculus*), an endangered species, is recent. In 2012/2013 we started to characterize the song sequences of blue whales that use the Corcovado Gulf based on dipping hydrophone recordings. Our PhD student Susannah Buchan identified two distinct songs (SEP1 and SEP2) from the analysis of acoustic data (Buchan et al., 2014 in Endangered Species Research, vol 23, 241–252). Although SEP1 was the first song recorded in the Corcovado Gulf area in 1970, the authors found SEP2 to be the more common song, despite never having been reported previously in...
this area. The recording of SEP2 establishes a new acoustic link for this song between Chile and the Eastern Tropical Pacific. These findings provide the basis for future passive acoustic studies on the temporal and spatial distributions of endangered Southeast Pacific blue whales and for understanding how these songs relate to the population structure. This topic is being addressed in a new manuscript (Buchan et al., submitted to Marine Mammal Science, “Temporal variation of southeast Pacific blue whale songs in southern Chile and the eastern tropical Pacific”) (R+D Line 4).

When scaling up to the community, food web and ecosystem levels, R+D Line 4 has approached the system using a series of modelling approaches that are novel in terms of that they have never being applied in Chile. For example, Gomez-Canchong et al. (in review in Fisheries Management and Ecology, “The effect of the increase in fishing effort on the fisheries of the Central Chile upwelling system: a virtual network approach”) built an ecological model (including large mammals) based on allometric relationships useful to analyze a series of ecological and management scenarios relevant to the Sur-Austral fisheries. On the other hand, Gatica et al. (submitted to Fishery Bulletin, “A multispecies virtual population analysis for the southern Chilean demersal fishery”) built a multispecies virtual population analysis for the southern Chilean demersal fishery. The results of these modelling exercises can be summarized in that fishing impacts the community structure well beyond target species and that long-term sustainability is strongly linked to multispecies interactions that need to be considered in fisheries management. Neira & Arancibia (2013 in Deep Sea Research II), Neira et al. (2014a, b, both in Ecological Modelling) and Barros et al. (in review in Latin American Journal of Aquatic Research, “Trophic interactions in the upwelling system of northern Chile, year 1997”) developed food web models in northern and central-south Chile useful for future intersystem comparisons with models from the Patagonian system.

**Understanding physical processes and the effects of freshwater inputs at the ecosystem-level**

In fjord areas, strong land-ocean gradients in haline stratification are due to input of freshwater from the continent (rivers and meltwater) and rainfall. Because this input may have a marked effect on plankton dynamics that in turn influences the trophic carbon fluxes, physically orientated studies focused on understanding hydrography, salt fluxes exchanges and the dynamics of low oxygen water penetration into the Chilean Patagonian fjords.

**Northern Patagonia (Reloncavi Fjord and Sound, Comau Fjord)**

We analyzed (R+D Line 1) the seasonality of salinity, temperature, dissolved oxygen and Chlorophyll along the Reloncavi Fjord; changes in the vertical pattern of these parameters are related to changes locally and remotely forced (Castillo et al., in review in Estuarine, Coastal and Shelf Science, “Seasonal variability of the hydrography and salt fluxes exchanges in the Reloncavi fjord, Chile”). In the study, isohaline coordinates are used to estimate the exchange of waters between the fjord and the outer basin. The freshwater supply has two maxima along the year, the principal being in winter (1400 ± 400 m³ s⁻¹) due to the pluvial season while the secondary corresponds to the spring (1300 ± 300 m³ s⁻¹) produced by the snow melting of that season. The lower freshwater supply is in summer. The freshwater input inside the fjord generates an upper layer (~4 m depth) that is highly stratified year-round. The outflow (~2350 m³ s⁻¹) implies an exchange of about 30 tons of salt per second with the Reloncavi Sound. The upper layer has a flushing time of ~3 days. Additionally, our study indicates that the deeper layer is able to sustain that salt output. Estimation based on high resolution current measurements and hydrography made in cross-fjord transects during winter and summer complement previous results. These last observations showed that the flushing times of the upper layer were of 5 days and 7 days during winter and summer, respectively; these estimations will contribute to a better management of the aquaculture of this region. Our results also show the convenience for using isohaline coordinates to analyze the dynamics of the exchanges in well stratified fjords from the Chilean Patagonia.

A paper by León-Muñoz et al. (2013 published in New Zealand Journal of Marine and Freshwater Research, DOI: 10.1080/00288330.2013.802700) used a long record (1944-2007) of Puelo river outflow to document its variability regime (seasonal and inter-annual), as well as its influence on surface salinity, temperature and dissolved oxygen in the Reloncavi Fjord (R+D Line 2). The results showed a decreasing trend in freshwater discharge since the late 1970s, and frequent episodes of prolonged periods with low outflow in autumn and...
winter months. The influence of the Puelo river on the fjord’s hydrographic structure varied greatly among years. Years with mixed regimes (rainfall/snowmelt) and high outflow values (>1000 m³/s) in autumn and spring resulted in significantly cooler, fresher, and more oxygenated conditions in the fjord. A constrasting pattern was observed for 2007, with low freshwater discharge (250 m³/s) in autumn and winter that did not affect temperature or salinity in the fjord.

Work conducted by R+D Line 2 centered on the changes in composition of microphytoplankton that would be expected if concentrations or ratios of nutrients are altered by changes in the input of freshwater to fjords. Mesocosm experiments were conducted, starting with assemblages from Reloncavi Fjord in winter and from Comau Fjord in spring. The results indicated that phytoplankton responded to the addition of nutrients by increasing cell abundance and cell biomass, and that composition shifted to assemblages dominated by diatoms from pennate to chain-forming centric species. Besides providing information on controlling factors that determine natural microalgal composition, these results shed light on probable future scenarios that might undergo Patagonian marine environments. A manuscript authored by Master student Pamela Labbé-Ibáñez et al. (“Respuesta del microfitoplancton a la adición de nitrato y ácido silílico en fioros de la Patagonia, Chile”) is currently under review in Latin American Journal of Aquatic Research.

In temperate coastal regions, in addition to the typical spring–summer conditions such as high solar radiation and macronutrients availability, the release of Fe from strong riverine sources should also be considered as another element that may influence the seasonal cycle and magnitude of primary productivity (PP) and phytoplankton growth. During the past three years, R+D Line 2 studied the dynamics of dissolved inorganic macro-nutrients (N, Si) in the Comau and Reloncavi fjords, as well as the role of Fe and DOM in the microbial communities (in the context of a FONDECYT grant 1110614, Iriarte & Gonzalez). Two DOM types, marine polysaccharide and siderophore (DFB), have been used as models to understand how DOM affects the bioavailability of Fe to phytoplankton and bacteria, and to assess their ecological role in fjord systems. A 10-day microcosm study was performed in the Comau Fjord during summer conditions. Our main results show increased abundances of *Synechococcus*, picoeukaryotes, and autotrophic nanoflagellates during the first 4 days of the experiment. This could be at least partially attributed to biological utilization of Fe (2 to 3 nM) by <20 µm phytoplankton and bacteria through the interaction with organic ligands released by bacteria, which could increase solubility of the Fe dissolved fraction and positively affect the small-sized phytoplankton community (Iriarte et al. 2014, in press in Phycological Research, “Size-spectrum based differential response of phytoplankton to nutrient and iron-organic matter combinations in microcosm experiments in a Chilean Patagonian Fjord”).

**Puyuhuapi Channel**

The Puyuhuapi Channel receives freshwater discharges from the Cisnes River (218 m³ s⁻¹ annual mean river flow), which empties into Puerto Cisnes Bay (located in the middle of the channel) from the south after 160 km of run-off length; the Ventisquero River (~40 m³ s⁻¹ annual mean river flow), numerous creeks, and rainfall (≥ 2000 mm per year) constitute other sources of freshwater. With the data generated from seasonal cruises (between 2008 and 2012, and historical data from 1995 to 2007) and the oceanographic buoy anchored in the Puyuhuapi Channel, the variability of mixing processes were studied (R+D Line 3) (Schneider et al., 2014; accepted in Progress in Oceanography, “On the hydography of Puyuhuapi channel (Chilean Patagonia)”). Puyuhuapi Channel’s surface characteristics highlight a fresher northern and a more haline southern part except during winter when the pattern can reverse due to the intrusion of oceanic water via Jacaf Channel which has more favorable conditions for fish farms in its northern section. Thus, stratification of the water column divides the channel into a highly stratified northern part (north of Puerto Cisnes) and a less stratified and partially mixed southern part during spring and summer. This strong stratification favors the accumulation of plankton, including potentially harmful phytoplankton species, at the upper/lower layer interface.

**Baker/Martinez area**

The fjords in central Patagonia (47°S) receive freshwater from both precipitation and the Baker river. This buoyancy input generates a two-layer hydrographic system characterized by strong salinity stratification which favors baroclinic conditions in the fjord, ADCP data and CTD profiles analyzed by Ross et al. (accepted in
Progress in Oceanography, "Semidiurnal internal tides in a Patagonian fjord") allowed the detection of semidiurnal internal waves for the first time in this region (R+D Line 3). The semidiurnal internal waves were found as fluctuations near the pycnocline in sporadic packets correlated to high discharge pulses of the Baker River suggesting that they were modulated by pulses in high discharge rather than the interaction of barotropic tide with bathymetry. An implication of these internal waves would be to increase vertical mixing of nutrients toward the surface, through shear instabilities, which would favor primary production.

Instruments deployed near the Baker river mouth since late 2008 completed their 5th year of continuous measurements of temperature and sea level (Fig. 2), whereas similar instruments deployed near the Jorge Montt glacier (Fig. 3b) have completed their 3rd year of continuous record. Furthermore, continuous measurements of surface conductivity, temperature and sea level at 10 sites spanning the Baker and Martinez channels (Fig. 3b) were initiated in October 2012 and have produced valuable information on the hourly to seasonal fluctuations in the extent of freshwater influence along the Baker/Martinez fjord complex (Fig. 3c). Preliminary analyses of these data, together with offshore wind variability derived from the ASCAT scatterometer (Fig. 3a), suggest that synoptic-scale displacements of the conductivity front along the fjord are mainly driven by fluctuations in the intensity of zonal oceanic winds off the Gulf of Penas (Fig. 3d), rather than by changes in freshwater discharge from rivers (data not shown). The array of surface conductivity sensors was last serviced in November 2013; hence a 1-year time series is now available. It is expected that such dataset will make it possible to tease apart the effect that synoptic wind variability and seasonal changes in river outflow have on the along-fjord position of the conductivity front. Understanding the roles that wind and river influence play in determining seasonal and synoptic-scale changes in the location of this transition, from river-dominated conditions in the water column to predominantly marine conditions, is key to understanding patterns of productivity and vertical carbon fluxes along this and other fjords (R+D Line 2).

Figure 2. Record of water-column temperature variability at a site near the Baker river mouth, from moored instruments first deployed in September 2008. Black contours correspond to the 10°C isotherm.

Focusing on understanding glacier-ocean interactions (R+D Line 2, FONDECYT grant 11100362, and collaboration with Center CECS and University of Washington, USA), a large field campaign was conducted in the Jorge Montt pro-glacial fjord during March 2013. Glacier Jorge Montt has experienced the fastest frontal retreat observed in Patagonia during the past century. Results on recent calving dynamics during 2012 were presented at the AGU Fall Meeting 2013 (Bown et al. 2013, abstract #OS11A-1637). Together with the recovery of moored instruments, hydrographic and current velocity data, as well as sediment cores, were collected during shipboard surveys. Analysis of data retrieved from moored instruments revealed a significant influence of the glacier’s freshwater discharge on the hydrographic structure of the fjord and a strong wind modulation of the supply of warm, sub-surface oceanic water. This inflow of oceanic waters, forced by down-fjord winds originating at the glacier would contribute to the glacier’s retreat. These results are presented in the manuscript titled "Wind-modulated supply of warm water to a proglacial fjord, Jorge Montt Glacier, Patagonia" authored by Dr. Carlos Moffat and submitted to Geophysical Research Letters.
To assess the response of microbes to the accelerated input of freshwater due to glacier melting in Patagonian fjords, during Year 6 we conducted:

1) Studies on seasonal and spatial variability in microbial community composition by analyzing sequences of Bacteria, Archaea and Fungi in the fjord adjacent to the glacier Jorge Montt. Our results showed high diversity of operational taxonomic units (OTUs) in bacteria followed by the fungal community whereas Archaea was characterized by low OTU abundance in most of the sampling sites and depth. Our results indicate that hydrodynamic and water column characteristics play a main role in structuring microbial community and suggest that the progressive input of meltwater can strongly impact the microbial composition and therefore the heterotrophic activity in the Chilean Patagonia fjord ecosystem (R+D Lines 1 and 2, y FONDECYT grant 11110515, and international collaboration LiA-MORFUN) (Gutiérrez et al. 2014, “Melting glacier impacts the community structure of Bacteria, Fungi and Archaea in Chilean Patagonia fjord system”; EGU General Assembly 2014, abstract EGU2014-15007).

2) Seasonal sampling campaigns (summer and winter) along the Martinez and Baker channels, including a transect from the Jorge Montt glacier to the Baker Channel (R+D Line 2). Concentration of DOC varied between 0.1 and 5 mg/L (9-400 μM) with most values above 60 mg/L, which is comparable to what is found in well-known productive environments such as the coastal upwelling ecosystem of the Humboldt Current.
Stable-isotope composition of this DOC pool suggests that depleted carbon is predominant in surface waters during winter. Additional work is needed to test whether this is a glacial signature, and why it is not detected in summer.

With respect to productivity in relation to salinity/freshwater gradients, the study published by Gonzalez et al. (2013 in Progress in Oceanography 119, 32–47) focused on spatial variability in the rates and size composition of primary production along a salinity gradient in the Martinez/Baker fjord complex – as well as other channels in the 47–50°S region – during springtime conditions (R+D Lines 2, 3 and 1). Together with the expected land-ocean gradient in salinity and stratification, this paper documents a seaward increase in the concentration of inorganic nutrients (nitrate and silicic-acid) and a drop in POC:chl-a ratios, due to a seaward increase in diatom dominance and concurrent drop in river-borne POC. Estimates of depth-integrated net primary production (NPP) obtained near the Baker river mouth were almost 3 times lower than at stations closer to open-ocean waters (360 vs 1063 mg C m⁻² d⁻¹), and were numerically dominated by small-size phytoplankton groups (picoplankton and nanoplankton). Estimates of vertical carbon flux (234 mg C m⁻² d⁻¹) and export production (65% of NPP) suggest that this and similar Patagonian fjords may constitute net sinks for CO₂ during the productive (spring) season.

A related topic is the importance of rivers as sources of Particulate Organic Matter (POM) for marine species that occupy estuarine environments during early stages of their life cycle. One such species is the squat lobster *Munida gregaria*, a deposit-feeding marine crustacean whose early larval stages are most abundant in the Baker river estuary during winter months, with minimum river outflow. Juveniles, on the other hand, are found in the plankton only during summer months when river outflow reaches its annual maximum (Meerhoff et al. 2013 in Cont. Shelf Res. 61-62, 1–11). Given the low rates of primary production estimated for this area (Gonzalez et al. 2013), it has been hypothesized that river-borne POM may constitute a major source of organic matter for *M. gregaria* juveniles, thus playing a key role in their seasonal migration into the fjord. Work to test this hypothesis is underway, based mostly on analyses of isotopic composition in juvenile tissue, phytoplankton, and POM sampled during a 10-day survey conducted in early February 2014 (R+D Lines 2 and 3).

As for the effect of terrestrial-derived organic matter on sustaining secondary production in fjord ecosystems, previous work by Sepulveda et al. (2011, Continental Shelf Research 31, 315–329) over an extended area in Northern Patagonia indicated that an average of 40% of terrestrial-derived organic matter was found in surface sediments, suggesting that a high capability of microbes to degrade the presumably refractory terrestrial organic carbon. Work conducted during Year 6 (as part of Ms. Marine Blanchet’s Ph. D. thesis, R+D Line 2 in conjunction with LIA-MORFUN) addresses this issue by testing whether labile organic matter may modify mineralization rates of recalcitrant organic matter in fjord ecosystems. Laboratory experiments that use water from the Baker Channel area followed the degradation of riverine DOM and subsequent response on marine bacterial growth are underway. Pyrosequencing has been used to determine the changes in the composition of the bacterial community in response to labile DOM additions.

**Physical-chemical and biological data, an overall picture**

We pooled physical-chemical and biological data together from five spring CIMAR cruises (2006–2010) which jointly span ca. 14 degrees of latitude (41.5 to 56.0°S). We found that phytoplankton biomass varies in association with freshwater discharges, mineral nutrient load and light availability. However, the sign of these correlations, and the spatial domain over which they hold, changes depending on which size fraction is analyzed. Total chlorophyll-a (chl-a) and the large-cell fraction are mostly controlled by freshwater discharges and their influence on density stratification, silicon and light availability (represented by PC1 in Fig. 4), with the exception of the Reloncavi Fjord and the northern section of the Chiloé Inner Sea. Dominance of picoplankton, on the other hand, seems to respond positively to this factor in southern Patagonia and in the Gulf of Corcovado. Macro-nutrients from ocean waters (represented by PC2 in Fig. 4) controlled total chl-a north of 48°S and appeared to favor the dominance of nanoplankton south of this latitude. These results indicate that the relative success of different phytoplankton size classes along this extensive region may be sensitive to
changes in nutrient inputs and hydrological cycles, modifying important ecological processes and the fate of organic matter (Cuevas et al., submitted to Estuaries and Coasts; “Control mechanisms on phytoplankton size structure: A bottom-up control analysis in the Chilean Patagonia”) (R+D Line 2 in collaboration with the EULA Center at UdeC).

![Figure 4. Spatial variability of Spearman correlation between chlorophyll-a (total and size-fractionated), and the first two principal components obtained from a PCA of hydrographic and chemical variables in the water column (PC1 and PC2 explained 36% and 27% of total variance). Red and blue symbols indicate positive and negative correlations, respectively. Only significant correlations are shown. Modified from Cuevas et al. (submitted).](image)

**Past variability in export production and freshwater input**

Paleoceanographic studies of sediment cores began in 2013 with the goal of describing past and present connection between export production and freshwater input regimes. During Year 6, R+D Line 2 focused on the Reloncavi Fjord mainly and initiated surface sediment studies of the Baker/Martínez area. Our studies focused on assessing the response of fjord environments to changes in precipitation and river discharge, and on finding the best proxies for river discharge, which we can then use to reconstruct past precipitation.

Our studies in the Reloncavi fjord showed the following:

- Surface sediments revealed a spatial pattern in geochemical parameters reflecting a gradient in the source of allochthonous and autochthonous organic matter, with a clear terrestrial signal in areas near the mouths of major rivers (Puelo, Coquamó and Petrohue rivers).
- Diatoms dominated the siliceous assemblage preserved in the sediments with an average value of 98% (silicoflagellates, phytooliths, and cryptophyte cysts represented minor contribution).
- Marked fluctuations in allochthonous vs. autochthonous sources during the past 800 years, with a clear decrease in the allochtonous material since ~1650 AD. This can be associated with the reduction in the Puelo River streamflow and rainfall reconstructed from tree rings. During the last century, these fluctuations would be related with the Southern Annular Mode. Our terrestrial OC accumulation data are in good
agreement with the streamflow data of Puelo river for the last 250 years. Increased terrestrial OC supply between 1500 and 1800 AD may be interpreted as higher precipitation during the beginning of the Little Ice Age.

- In our reconstruction of the last 800 years, we found evidence of earthquakes and paleotsunamis that affected the Reloncavi Fjord: turbidites (sand layers) associated with the historical earthquakes of 1960, 1837, 1737 and 1575 AD, and an earlier period for which there is no historical information, 1200–1400 AD.
- Sand layers were characterized by low abundance of total diatoms, and increased contribution of *Paralia sulcata*, an indicator of high energy environments.

Results from the Relocavi fjord were presented at the 11th International Conference on Paleoceanography held in Barcelona-Sitges, September 2013 (Rebolledo et al.; http://www.icp2013.cat/USB/PDF/P-478.PDF). Additionally, a manuscript is being prepared to be submitted to Quaternary Research in the first semester of 2014 (Rebolledo et al., “Fluctuations in the source of organic matter and siliceous productivity during the last 800 years in the Reloncavi Fjord (41°S, 72°W, Chile”), and an abstract has been submitted to sessionTS5.2/NH4.5/SM2.4: Earthquake Geology and Seismic Hazard Assessment at EGU 2014, Vienna April/May 2014 (Rebolledo et al. # EGU2014-15574).

The initial studies in the Baker-Martinez fjord complex focused on the spatial distribution of organic matter, organic carbon, total nitrogen and the C/N ratio in surface sediments, based on previous data. Additionally, the preliminary analysis of smear slides in the Jorge Montt glacier area revealed that microfossils were present ca. 7 km away from the glacier outlet, and absent at stations in the immediate vicinity of the glacier (undergraduate thesis Paola Cárdenas, R+D Line 2). New sediment samples recovered during the writing of this report will add to our dataset and help with interpretation of spatial distribution.

With respect to factors that control changes in precipitation regimes and freshwater input to Northern Patagonian, we used geochemical and sedimentological data obtained from sediment core PC29A (Quitralco fjord, 46°S) to reconstruct late Holocene changes in precipitation seasonality in the Andes of Northern Chilean Patagonia. A decrease in precipitation seasonality recorded in core PC29A roughly corresponds with a major reorganization of the climate system throughout the world, which is frequently associated to the Little Ice Age. This new record of a precipitation seasonality proxy indicates that relatively small latitudinal shifts in the Southern Westerly Wind (SWW) belt result in large changes in precipitation seasonality. Our sediment record suggests a poleward-shifted SWW belt between 600 and 1200 AD (or CE = Common Era), followed by a gradual shift towards the equator between 1200 and 1500 AD, and stabilization in a sustained equatorward position between 1500 and 1950 AD. The most recent part of the record displays a return to a slightly poleward shifted SWW, in agreement with recent trends observed in climatological data. Comparison with SST reconstructions off Chilean Patagonia shows a tight link between latitudinal variations of the SWW belt and SSTs during the late Holocene, with the SWW being systematically shifted poleward when SSTs are high and vice versa. This pattern resembles the variability that occurs at glacial-interglacial timescales. We suggest that late Holocene variations in the SWW are driven by changes in the strength of the polar cell, which responds to temperature variations at the high latitudes of the Southern Hemisphere (R+D Line 2 and international colleagues at Ghent University, WHOI, and MIT; Bertrand et al., submitted to Quaternary Science Reviews, “Covariability of precipitation seasonality and sea surface temperature in Northern Chilean Patagonia during the Late Holocene”).

Regarding SST reconstructions, we also continued with our studies on alkenone-derived SST estimates on fjord surface sediments and sediment cores, driven by two main goals: 1) to detect the potential seasonality in the alkenone-derived SST signal; and 2) to fill the gap of paleoclimate information between high and mid-latitudes of southwestern South America, describe regional patterns of paleoclimate changes and identify common forcing mechanisms. Results on alkenone-SST were summarized in a manuscript submitted to Quaternary Research in December 2013 (Caniupán et al. “Holocene sea surface temperature variability in the Chilean fjord region”) which is a collaborative effort of R+D Line 2 with international colleagues from AWI Bremerhaven, the Leibniz Institute for Baltic Sea Research IO-Warnemünde, the Department of Geology at University of Trier, and the Department of Earth and Atmospheric Sciences at University of Houston.
The scientific knowledge gained by the COPAS Center during Year 6 reported here (Apr 2013 to Mar 2014) was communicated in the form of presentations at national (13) and international (17) congresses, and workshops (18), of which >30 presentations involved results of our studies in Patagonia. In addition, we published 40 ISI articles (total average impact factor of 2.1); 6 non-ISI publications; and 1 book and 1 book chapter. Of the 40 total ISI publications, 14 were dedicated to the Patagonian fjord region.

During Year 6 COPAS Sur-Austral has also organized scientific events including workshops in the Concepción area, Valparaíso, Coyhaique and Puerto Cisnes (7), conferences by national and international colleagues (9), one course in Puerto Cisnes, and the Austral Summer Institute XIV (Appendix A5).

2.- Training of human resources of excellence

The Center’s educational strategy is to emphasize university-based graduate and undergraduate education. COPAS Sur-Austral researchers are strongly involved in teaching regular undergraduate courses in Marine Biology and Engineering in Marine Biotecnology and Aquaculture; and in teaching graduate core courses within the Graduate Program in Oceanography. Also, the Center trains technical personnel, who are a key component of field and laboratory activities. It is important to note that the collaboration between COPAS Sur-Austral and CIEP has provided the students with the exciting opportunity of working in remote areas such as the Chilean fjords.

At present, the Center hosts a total of 75 students (21 PhDs, 35 MSc, and 19 undergraduates) (Appendix A8). Of these, 1 PhD, 9 MSc and 10 undergraduate students have successfully defended their theses and obtained their degree in 2013/2014. There are currently 46 graduate students who defended their thesis project (qualifying exam), and are working on their theses within the Center’s scientific objectives. The ongoing thesis work of 7 PhD and 13 MSc students focuses directly on the southern region of Chile. Although most of our graduate students are of Chilean nationality, COPAS also hosts students from other countries (mainly from Latin America); they represent 16% of the graduate student pool.

During Year 6, 7 postdoctoral fellows engaged in COPAS research themes; 5 of them are directly associated to the COPAS Sur-Austral objectives. Extramural funding from FONDECYT is the most important source for including postdocs into the scientific activities of the Center (Appendix A9).

COPAS Sur-Austral has continued to be actively involved in the organization of the yearly Austral Summer Institutes (ASI; http://www.udec.cl/oceanoudec/oceanografia), an initiative headed by S. Pantoja who holds an UNESCO IOC Chair in Oceanography. ASI XIV “Coastal and Open Ocean Studies through Multiple Approaches” was held during January 2014, and included the following courses:

- Multi-disciplinary satellite oceanography; Platforms, data and applications (6-10 January, 2014) by Dr. Andrew Thomas, University of Maine, United States
- Changing biogeochemical cycles in the coastal ocean (6-10 January, 2014) by Dr. Kay-Christian Emeis, University of Hamburg, Germany
- Fluvial and glacial sediments impacting coastal ocean processes: An interdisciplinary perspective (13-17 January, 2014) by Dr. Charles Nittouer, University of Washington, United States
- Análisis de Series de Tiempo en Ciencias Naturales (6-11 January, 2014) by Dr. (c) Rodrigo Montes, COPAS Sur-Austral, Universidad de Concepción, Chile

These courses were held at the Main Campus of the University of Concepción.
- Ecology and Diversity of Marine Microorganisms VIII (ECODIM-VIII) (6-25 January, 2014) by Drs. Kurt Hanselmann (University of Zurich, Switzerland); Daniel Vaulot (Station Biologique de Roscoff, France); Mathew Sullivan (University of Arizona, United States); Ger van den Engh (BD Biosciences, United States); Rodrigo De la Iglesia (P. Universidad Católica de Chile, Chile); Nicole Trefault (Universidad Mayor, Chile); and Osvaldo Ulloa (University of Concepción, Chile)

ECODIM was held at the Marine Biological Station of the Department of Oceanography of the University of Concepción in Dichato.
A total of 80 students participated in ASI XIV activities; countries of origin were: Argentina (10), Belgium (1), Brazil (16), Chile (41), Colombia (1), Cuba (2), Ecuador (2), Germany (1), Peru (2), Spain (1), USA (2) and Uruguay (1).

3.- Application of the research results into actions that contribute to increment the competitiveness of Chilean economy (Industry, civil society and public bodies or policy makers)

There are several ways in which the research results are helping the public and private sectors:

- **Products for public and/or private users**

  The oceanographic buoy anchored in the northern part of the Puyuhuapi channel has continued to provide information to the aquaculture sector. Additionally, UV and PAR sensors were installed in Magdalena island (1000 m distance from the buoy). The data generated can be accessed at http://sur-austral.udec.cl/productos/series-de-tiempo-canal-puyuhuapi/ and at www.ciep.cl/sio. In addition, the company Los FIOROS distribute the data to all their feeding centers in Puyuhuapi channel.

  **Tide tables for 2013 and 2014; Tide predictions for Reloncavi (3 sections), Puyuhuapi Channel, Aysén Fjord (two sectors) and Tortel** are made available through the program's website http://sur-austral.udec.cl/productos/tablas-de-mareal. These forecasts are highly required by residents and users often operating in these localities, both from the private and the public sector. Waters of Patagonia, a company that bottles and exports water from the area of Montt Glacier (48°S 73°W) (http://crevassewaters.com) benefits from the tidal-height forecasts produced by COPAS Sur-Austral and at the same time provides logistical support to conduct research in the Jorge Montt glacier area, led by C. Moffat (R+D Line 2). This company has benefited, and has actively supported a proposal recently submitted by C. Moffat to FONDEF, which aims to setup a real-time oceanographic monitoring program in the area, with buoys at the entrance and head of the Baker Channel. COPAS Sur-Austral and Waters of Patagonia are in the process of signing a memorandum of understanding to continue this collaboration during the Continuity Plan.

  **Oceanographic sensors on ships with usual route in Patagonia.** During December talks began with the company Naviera Austral S.A., based in Puerto Montt (www.navieraustral.cl), to establish a collaborative project involving the following issues: a) Installation of oceanographic sensors on ships with permanent routes in Patagonia. For this initiative, the SIMAS equipment that was developed in Phase I COPAS Sur-Austral Program will be adapted. b) Installation of meteorological sensors to allow continuous recording of variables such as temperature, atmospheric pressure, wind, and humidity. This equipment would be acquired by the Company. All of the information obtained (time series) will be compiled and analyzed by researchers of the Program. c) Disseminate weather, oceanographic, ecological, and the journey itself (distance, time, data of interest for passengers) information (through short audiovisual capsules or tips), using the audiovisual media onboard passenger ships. We are currently managing the records of ownership of ideas and completing the technical design for sensor installations on the selected ships (installation spaces, distances to bridge connections, energy, among others), which will be presented to Naviera Austral during April. The proposed design for audiovisual dissemination will be presented at the same session.

  **Fuzzy logic models for management of salmon farming:** A proposal for collaboration was presented to Marine Harvest S.A. in October 2013 (R+D Lines 4 and 8), “Estimación indirecta de capacidad de carga en acuicultura para la construcción de una plataforma de toma de decisiones”. Contact person: Mr. Kevin Scherpenisse G. (Head of the Department of Environment). Please see V. Lessons Learned.

  **Ceparium:** The collection produced by the COPAS Sur-Austral Program is composed of 57 strains of marine microalgae (51 Chilean) including 15 species of diatoms, 5 dinoflagellates, 3 chlorophytes, 4 cryptophytes and 2 raphidophytes. It includes microalgae from the Los Lagos and Aysén Regions. During Year 6, the requirement of strains was used in teaching, research projects and training in phytoplankton.

  **Catalogue of Microalgae:** This catalogue is an excellent training material, and during the reporting period we sold 48 catalogs to the private sector, aquaculture businesses and consultants (1 to Universidad Austral de...
Chile, 7 to NIVA Chile S.A., and 40 to Laboratorio ETECMA in Castro, Los Lagos Region, for €.capacita).

Catalogue of Crustaceans: During the reporting period, and in order to facilitate understanding through rapid visualization, spatial distribution maps for each species were developed, with images for each species, diagnostic characters, spatial distribution and bathymetric individual records. Also 2 other species not initially contemplated were included. These improvements delayed the final edition of the catalog projecting its publication in May 2014. The catalog is directed to public interest entities that require species identification, e.g. SERNAPESCA.

Catalogue of fjords: During 2013 the multidisciplinary team that has participated in this initiative completed the validation phase of hydrographic and oceanographic calculations of the 7 fjords contained in this catalog. In January 2014 the final phase of thematic maps construction began which will be completed in April 2014. In parallel, between March and June 2014 the graphic design stage will be completed. The editing and publication phase will take place in July. The catalog is directed to a wide audience, from school and university students, to professionals in public entities (Regional Governments, Chilean Navy, SERNAPESCA, Regional Commission for Coastline Usage) and the private sector (consultants, aquaculture centers, environmental managers). We expect it to be used as a reference tool in the decision making process for i.e. territorial planning, appropriate areas for aquaculture, production planning and investment.

- **New Participation in Technical and Scientific National Committees**

  Dr. Giovanni Daneri (R+D Line 1): a) Member of the Regional Commission for Coastline Usage of the Aysén Region; and b) Partnership with SalmonChile/Intesal for red tide studies in Region XI. INTESAL is an entity linked to SalmonChile A.G., a grouping that brings together the leading producers and suppliers of the salmon industry in Chile, and has the objective of scientific and technological research related to aquaculture (especially of salmon and trout).

  Dr. Sergio Neira (R+D Line 4) participates in the following National Scientific Committees: a) Demersal resources from the central-south zone; b) Demersal resources from the south-aural zone; and c) Chilean Scientific Committee for the Convention for the Conservation of the Antarctic Marine Living Resources (CCAMLR). Under the new Chilean Fisheries Act, committees a) and b) have the responsibility of assigning the range for the Biologically Acceptable Catch which is the base for the Total Allowable Quota. The new Fisheries Act, enacted on February 9, 2013, provides for the establishment of scientific and technical committees as a tool to achieve the sustainability of the fisheries resources by placing the scientific criteria over the economic and political considerations (http://www.ifof.net/es/node/497). In addition, Dr. Neira is the University representative in the Fisheries Council for the Biobío Region. This Council advises the Undersecretary in several issues, such as territorial users right in areas for the management of benthic resources.

  Dr. Rodrigo Wiff (R+D Line 4) is a member of the following National Scientific Committees a) Demersal resources from the south-aural zone, and b) Demersal resources Deep Waters.

  Dr. Leonardo Castro (R+D Line 3): Member Executive Committee of the CIMAR-FIORDOS program of CONA (Comité Oceanográfico Nacional), in charge of research grants for research in fjord and remote areas. CONA is a public institution whose main function is to coordinate the universities/institutions that conduct research and activities related to marine science in Chile.


  Dr. Silvio Pantoja (COPAS Director and R+D Line 2) is a member of the Technical Committee for Regional EXPLORA, Biobío Region.

  Mr. Ricardo Norambuena (Line 6), invited to join the team of experts of the Educational Program on Disasters of UdeC (Equipo de Expertos(as) del Programa de Educación en Desastres (PED) de la Universidad de Concepción), whose purpose is to design, implement and monitor educational activities related to building a culture of prevention among citizens.
4.- Activities of support to other national research groups

The COPAS-CIEP (Center for Research on Patagonian Ecosystems) alliance has been remarkable in the development of both institutions. Professionals and scientists from both institutions have together developed important projects key to providing fisheries information to local stakeholders including local fishermen organizations, and the Aysén regional government. Additionally, the close relationship has facilitated the organization of workshops and seminars directed to the public and private sectors, and has allowed new training opportunities. Research has also benefited from sharing human and logistic resources from both institutions.

There is an ongoing collaboration with glaciologists Andrés Rivera and Francisca Bown from the Centro de Estudios Científicos (CECS) based in Valdivia. Joint glaciological and oceanographic measurements have been conducted at the Jorge Montt glacier over the past few years, and constitute the core of Francisca Bown’s M.Sc. thesis at UdeC (C. Moffat thesis advisor). A manuscript aimed at understanding synoptic-scale variability in glacier retreat related to oceanographic processes, titled “Recent calving dynamics of Glaciar Jorge Montt (Southern Patagonian Ice field) based on feature tracking techniques and oceanographic surveys” and coauthored by COPAS Sur-Austral and CECS researchers, will be submitted in late 2014. In addition, a summer field campaign in March 2013, with collaborators from the University of Washington (UW) and the Centro de Estudios Científicos (CECS) in Valdivia, generated a rich dataset of hydrographic and circulation data, photographic evidence of the glacier’s retreat and sedimentary records of the evolution of the sediment deposition from the glacier in the last few decades. Work on publications is ongoing, and a new grant continuing these efforts will start in 2014.

In late 2012 the new Interdisciplinary Center for Aquaculture Research (FONDAP-INCAR, www.incar.cl) was founded whose mission is to generate relevant scientific knowledge as a tool for converting aquaculture in a productive activity that is sustainable from the ecological, economic and social points of view. We have started collaborations with this new Center by means of contributing with our expertise (lectures given by Drs. Neira and Tapia) to the graduate course “Tópicos avanzados en patógenos relevantes de la salmonicultura chilena: Una mirada interdisciplinaria” held on 25–29 November 2013 at the Centro de Investigación Marina Quintay (Universidad Andrés Bello). Emphasis was put on biological, environmental, social and economic effects of the three main diseases that affect the Chilean salmon aquaculture: Piscirickettsia salmonis, ISA virus and Caligus rogercresseyi. In addition, Dr. A. Astuya (R+D Line 1) has contributed with co-authorship of a recent publication in J. Molluscan Studies. Given the common goals between COPAS Sur-Austral and the INCAR Center with respect to sustainable aquaculture, during 2014 we will strengthen and formalize ties for the benefit of both centers.

We expect new activities of support as well as future applications from the following new products and infrastructure:

Oceanographic Observation Network for the Patagonia (ROP for its acronym in Spanish); grant AIC-45 (C. Moffat, PI). Since its installation in March 2013 in Cochrámó (Reloncavi Fjord) the ocean component of the observatory (the LOBO buoy) has been operating uninterrupted and therefore continuously capturing data 24 hours a day. The weather station has developed optimum performance from mid-May 2013, collecting data continuously 24 hours a day. Because all teams have the ability observatory streaming the data obtained can be viewed and obtained at the website currently located in http://reloncavi.loboviz.com. Broadcast a video highlighting the features of the platform, registered variables and paths for the scientific community, and potential users of public and private sector was generated. With regard to storage and online data visualization that allows anyone with an Internet connection to access the data of the observatory, the maintenance plan includes redundant backup data Atlantic servers (hosting the data as part of the acquisition system) and the University of Concepción, using the server acquired for this purpose by the FONDEQUIP project. This system allows nowadays graph and copy all the data generated by the online system, and would also meet the viewing...
needs of users that may arise in the future.

This system has collected nearly one year of hourly data from both the surface ocean and the atmosphere. Although data analyses are still ongoing, the information collected thus far shows strong synoptic-scale variability (Fig. 5).

Figure 5. Sample of the multi-variable dataset collected by the LOBO buoy deployed at Cochlomó, Reloncavi Fjord, in March 2013. Upper panels show time series of physical-chemical properties measured at the surface whereas colored bottom panels show temporal and depth-variability in both components of current velocities measured by a downward looking ADCP.

The small oceanographic vessel that will operate from our coastal laboratory at Caleta Tortel, in the Aysén Region. The 10.5 m vessel was built near Concepcion during 2013. We are proud to announce that it was launched at the port of Talcahuano in January 2014, and sailed from Talcahuano to Caleta Tortel (~900 nm) in a 7-day journey that was completed on March 18, 2014 (Fig. 6). This new platform will provide us – and other researchers interested in this region – with the safety conditions, autonomy and necessary equipment to sample water, plankton and sediments over much greater ranges of depths and distances to port than we have been able to span thus far. It will also increase our ties to the local community through outreach and a closer interaction with the local elementary school.
The benthic water sampler (MAB for its Spanish acronym) is an oceanographic portable equipment, easy to use and inexpensive to obtain water at the water-substrate interface. The tool can close its covers 25 cm up the sediment when making contact therewith, while minimizing disturbance of the environment. The locking mechanism was protected by Utility Model Patent number 314 (INAPI, 2013). During this year a demonstration video was developed which will be presented to the National Fisheries and Aquaculture as potential users. Environmental regulations require periodic reporting of the farms to protect water quality and aerobic conditions in the sedimentation area. The threshold concentration of dissolved oxygen from the bottom must be equal to or greater than 2.5 milligrams per liter.

We have an extensive collaborative network with national and international colleagues that represent public and private sectors which is key for scientific and educational initiatives, transfer of knowledge, as well as for successful attraction of extramural funding to complement, in part, COPAS Sur-Austral funding. Relevant collaborative work during Year 6 includes:

Developing food webs models and ecological indicators based on the fishery of austral sardine in the Patagonian system, R+D Line 4 with Dr. Hugo Arancibia (Departamento de Oceanografía Universidad de
Concepción) and Dr. Edwin Nikitchek (Centro I-Mar Universidad de Los Lagos).

Developing recruitment indicators for the southern hake and hoki in central south Chile, R+D Line 4 with Dr. Tony Pitcher (Fisheries Centre, University of British Columbia, Canada), and Dr. Rosemary Hurst (NIWA, New Zealand), and Mr. Sergio Lillo (Instituto de Fomento Pesquero de Chile).

Development of the mathematics behind the ecological model based on allometric aspects of individuals, R+D Line 4 with Dr. Roberto Riquelme (Departamento de Ingeniería Matemática, Universidad de Concepción).

With this model we will relate the Patagonian ecosystem with other marine systems of Chile; and test several ecological and management scenarios.

Research efforts in marine biosafety and applied marine microbiology opened extensive collaborations of R+D Line 5 with colleagues at the University of Concepción: Unit of Marine Biotechnology (Dr. Alejandra Llanos, Engineer Jorge Silva, and Dr. Alisson Astuya of R+D Line 1), the Department of Molecular Biology (Dr. Marta Bunster), the Faculty of Pharmacy (Dr. Carolina Gómez), and the Center for Spectroscopy and Electron Microscopy (CESMI). Also, collaborations were established with the company Salmones Antártica S.A. with regard to standardization of HPLC technique to determine DHA, EPA in food for salmonids, and for salmon tissues infected with *Piscirickettsia salmonis*.

Nucleotide sequences of the 18S rRNA gene of *Caligus rogercressseyi* is an international collaborative work of R+D Line 5 with Dr. Karl Andreu (IRTA, Spain).

Research on *Heterosigma akashiwo* is being carried out by R+D Line 1 in collaboration with Dr. Jorge Fuenteaibal (Screening of Neuroactive Compounds Unit, Department of Physiology and Biomedical Center, UdeC), and Mr. Luís Roa (Agri-Food Laboratories-Concepción, SGS Chile Ltda. in Talcahuano).

Developing coupled physical and biological models (as well as carrying capacity models) of fjord areas in Scotland and the Aysén region leads to collaborative efforts of R+D Line 1 with the Marine Scottish Laboratory (Drs. Alexander Murray and Berit Rabe) working on the adaptation of a uni dimensional coupled physical-biological model for the simulation of fjord and channels dynamics. The model also includes the effects of the aquaculture industry.

New methods of temporal resolution of solids and fluids mechanics including equations that describe fjord hydrodynamics is a collaborative effort of R+D Line 1 with the University of Shanghai (China, Dr. Jiao Tong) and the Polytechnic University of Cataluña (Spain, Dr. Yongxing Shen and Dr(c) Vahid Ziaei).

Research Line 1 also established collaborations with Dr. Giorgio Bavestrello (University of Genova) related to the study of the impact of aquaculture on hard bottom fauna; with Dr. Dennis Hansell (University of Miami) on DOM dynamics; and with Dr. Duncan Purdie (University of Southampton), an expert in marine phytoplankton ecology and biogeochemistry.

Research Lines 1 and 3 with Dr. Arnold Valle Levinson and PhD student Lauren Ross (University of Florida, Gainesville), working on physical processes associated with plankton dynamics.

Collaboration with Dr. Rafael Vicuña (Department of Molecular Genetics and Microbiology at P. Universidad Católica de Chile) to study the role of lipids in response of hydric stress in cyanobacteria was established during Year 6 (S. Pantoja R+D Line 2). This work relates to the Doctoral Thesis of Ms. Catalina Urrejola, who has access to SP’s laboratory to use a Gas Chromatograph-Mass Selective Detector. This collaboration will continue when a new HPLC-MS is operational at the same laboratory. Silvio Pantoja is the external member of Ms. Urrejola’s Thesis Committee Member.

The thesis work of Susannah Buchan (blue whales) is a collaborative work among R+D Line 4, the Universidad Austral de Chile (Dr. Rodrigo Hucke-Gaete), the ONG Centro Ballena Azul, and two international colleagues, Dr Luke Rendell (University of St Andrews) Kathleen M. Stafford (University of Washington).

Editing work of the Bathymetric Catalogue of the Fjords and Channels includes collaboration of Research Lines 4, 6 and 2 with the EULA-Chile Center (“Centro de Ciencias Ambientales”) of the University of Concepción.

At the level of international institutions, we have developed new and maintained partnership/alliances with:

On October 28 2013, a Memorandum of Understanding was signed between the University of Concepción and the Leibniz-Institute for Baltic Sea Research, IO-Warnemuende, Germany, “to promote a general scientific
cooperation of two institutions, covering research, education and training in the field of marine sciences”. This agreement was in the framework of the Department of Oceanography at UdeC, where COPAS Sur-Austral is hosted. An initial workshop is planned for the near future.

International Associated Laboratory (LIA-MORFUN), a French-Chilean partnership that started in 2011 and is devoted to the study of environmental changes and the responses of sensitive ecosystems such as the Med Sea and Patagonia. As mentioned in the Continuity Plan, LIA-MORFUN finishes its first phase during 2014. In June we will present the Final Report to CNRS (France) and a Continuity Plan. The latter includes two periods: 1) A 4-year extension of LIA-MORFUN with the addition of two new research lines, connectivity and species conservation and environmental ecotoxicology; and 2) the creation of an International Associated Unit (UMI) in Chile starting in 2019.

The alliance with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) continues, and the planned cruise onboard the RV Mirai to the Chilean Patagonian region for austral summer 2016/2017 (reported in Year 5) has now been approved with some modifications which will be settled in Japan during the month of April. Dr. Carina Lange (Deputy Director) is maintaining e-mail correspondence with Dr. Naomi Harada (chief scientist of the cruise) at JAMSTEC.

The second cruise proposal with colleagues from the AWI in Bremerhaven for the use of the German icebreaker Polarstern in the Drake Passage area (also reported in Year 5) has also been approved with slight modifications which are being discussed right now in Germany. This Polarstern proposal has been the motivation for a parallel work, namely the writing of an IODP pre-proposal (847 “Plio-Pleistocene decadal-scale reconstruction of ocean, atmosphere and ice-sheet interactions through the Drake Passage”) which has been approved by the IODP Science Evaluation Panel during the January meeting San Diego (Jan 6-9), meaning that we will proceed to the next round with a full proposal later during the year. This is an international cooperation involving many institutions, led by the University of Kiel and AWI-Bremerhaven, also including JAMSTEC, LDEO, OSU, IO-Warnemuende, Kiel University. Dr. Lange is one of the proponents of the proposal and PI for the Chilean party.

5. Outreach and dissemination of the Center’s activities and/or synergies with science education

Outreach, New Agreements and Projects

During 2013 the agreement of collaboration between the COPAS Sur-Austral Program and the Municipality Tortel was reinforced, with the signing of the official document by the Mayor of Tortel Mr. Bernardo López and the Rector of UdeC, Mr. Sergio Lavanchy. This agreement in conjunction with the new vessel harboured in Tortel will open new possibilities for outreach/educational activities.

A collaboration Agreement between COPAS Sur-Austral and the Liceo Arturo Prat Chacón at Puerto Cisnes was signed in May 2013 by the two institutional Directors. The purpose of this agreement is to strengthen the vocational training of students of the educational institution through theoretical and/or practical talks, data exchange and dissemination of information (e.g. EXPLORA), the formation and maintenance of specific working groups (clubs or other), logistical support in the field work and laboratory practices of students, and exchange and/or internships. Under this agreement, a training session was held at the Auditorium of the school: the INNOVA Project "Ocean Information System for the sustainability of aquaculture in the Aysén Region", specifically to publicize the objectives and scope as developed technical details operation of oceanographic stations installed in the Puyuhuapi and Jacaf channels (04.2013), an EXPLORA Club was formed (05.2013), we collaborated with donations of publications and books to the High School Library (05.2013), and we trained and installed UV and PAR sensors (07.02.2013).

The installation of UV light sensors in coastal and rural locations with appropriate early warning systems to local communities is a collaborative work of COPAS Sur-Austral with Dr. Ernesto Gramsch (Department of Physics, Universidad de Santiago de Chile). As mentioned above, the sensor is installed and running at the Liceo de Puerto Cisnes, and in the first half of 2014 we will install another one in the Tortel school, after we resolve the permanent energy supply required by the equipment. During 2014 we expect to finish the graphic
design to display real-time measurements of UV and make it available to the public. We are in the process of signing an agreement with the Head of the Physics Department of Universidad de Santiago de Chile to formalize the agreement of distribution of open information.

Recently awarded Project EXPLORA Chile MIO funded by CONICYT is aimed at facilitating access to information and oceanographic knowledge available for a multitude of groups - from children to adults - and from school to college students or even scientists. Interactive tools based on physical and digital environments that facilitate understanding of various oceanographic concepts are used. As pilot regions the Project will use oceanographic information and knowledge from Biobío and Aysén.

Club EXPLORA Waiwen ("favorable south wind" in Mapudungun language), presented by Commander Luis Bravo school, in Tortel. The Club was formed in 2013 to strengthen and motivate Tortel students through a school investigation applied to the wind as an energy source. The Project "Assessing the feasibility of wind energy to supply electricity to Tortel" with the participation of 11 students, the teacher and our scientific advisor won the 2nd prize in a regional Congress organized by CIEP, in October 2013 in Coyhaique.

Club EXPLORA project "Variability of salinity in the Puyuhuapi channel as an important environmental factor in aquaculture production" presented by Arturo Prat Chacón High School of Puerto Cisnes. Students performed temperature, salinity and dissolved oxygen measurements in the vicinity of Puerto Cisnes. They analyzed data from oceanographic stations associated to Sur-Austral Program located in southern Puyuhuapi channel and they presented their findings at the VIII Regional School Science and Technology Congress, CONICYT 2013, Aysén Region.

In August 2013, a Cooperation Framework Agreement between COPAS Sur-Austral and the Center for Training and Learning Resources (CFRD, for its acronym in Spanish) at UdeC, was signed by both directors. The purpose of this Agreement is to develop joint initiatives to promote and disseminate the work and experience of each institution in the community shares. The areas of collaboration identified include the development of applied research projects, strategies and actions of dissemination, creation and development of multimedia teaching materials, and the integration of technologies in the transfer of scientific knowledge directed to the community.

Outreach Activities: COPAS has a variety of outreach and extension activities with the objective of informing and educating different types and levels of non-specialists in oceanography. The target audience is large, including local communities, public institutions, private or non-governmental organizations, school and university students, among others. During 2013 a number of activities involving the participation of several COPAS Sur-Austral researchers, and undergraduate and graduate students were performed (please see Appendix A10). Activities with the school community have always been a key issue for the Center as a way of disseminating information and involve teachers and students in hands-on activities. New material for dissemination was designed and distributed during the events: badges, bookmarks, bags, which incorporated the seven principles of ocean literacy.

Among the various activities we cite:
- Science Camp that involved the participation of 160 students from the Bio Bio Region “Month of the Ocean” at the CICAT facilities in Coronel (VIII Region), attended by over 1,000 students, and talks submitted by our researchers and students (May).
- Beach Cleaning Initiative: Researchers and undergraduate students, carried out in Dichato (September).
- Congreso Provincial Escolar de Ciencia y Tecnología Provincia de Arauco. Workshop “La Oceanografía”. 50 participants. (September)
- Science Day when several educational talks were issued involving the participation of 210 people (October).
- Science Fair at the Instituto de Humanidades in Concepción, with the participation of 100 High School students (October).
- Feria Antártica Escolar. Scientific advice to the Science Group of “Colegio Salesianos” of Concepción (October)
- Talks to disseminate our work to the educational community at the Liceo Arturo Prat Chacón in Puerto
Cisnes, Aysén Region; 70 students and teachers participated (October).

- Practical activities referred to the Fjords Teaching Kit which is a pedagogical tool developed by COPAS Sur-Austral during Phase I. It was implemented and transferred to educators (30) from Elementary schools of Lebu, Cañete, Tirúa and Los Alamos in the Biobío Region (December), in a phase of trial run in order to validate practical activities guides, and then proceed to the protection of Copyright and subsequent mass dissemination in educational institutions.

- Open Doors Program (Programa Puertas Abiertas) of the University of Concepción, where more than 1,000 people visited the offices and laboratories of the COPAS Center (October).

- Photographic Contest “MarCIENCIA” (September). This contest was organized to encourage undergraduate and graduate students at the Faculty of Natural Sciences and Oceanography to present photographs of their research and activities. Three prizes were awarded (first, second and third place).

- Conference “El uso de la ciencia y la tecnología en la prevención de riesgos ante la ocurrencia de tsunamis” given by Ricardo Norambuena (R+D Line 6) in Coyhaique as an activity within Jornada de Educación para el Desarrollo Sustentable y Prevención del Riesgo de Tsunami directed to school teachers; attended by 70 people (August).

Conferences/seminars were also held for a wide audience, including school and university students, teachers, the general community, government officials, and the private sector, such as the Conference “Ecología y acústica de las ballenas azules en el Golfo Corcovado” given by PhD student Susannah Buchan (R+D Line 4) in Concepción as an activity within “The Month of the Sea”, attended by 200 people (May).

**Dissemination to non-academics**

As a result of research dissemination activities during Year 6, our Program has been cited in a number of articles and interviews published in written and digital media (web sites): local newspapers (6 times), national newspapers (12 times), 22 times in the University of Concepción Newsletter (Panorama), 26 times in specialist magazines (AQUA, Versión Diferente, Mundo Acuícola). We also started with the recording of scientific modules based on a short interview where a researcher explains an oceanographic concept or the results obtained by our program. At present we have recorded 7 scientific modules which were broadcasted during 2013 through the University of Concepción radio. Three TV programs were also broadcast during the year. All information on dissemination activities can be found at the COPAS Sur-Austral web site [http://sur-austral.udec.cl/category/noticias-programa-sur-austral/](http://sur-austral.udec.cl/category/noticias-programa-sur-austral/).

During 2013 our website was visited 6,675 times, of which 3,629 (54%) were new visits. Of the total number of visits 5,628 (84%) were from Chile followed by USA, Peru, Mexico, Argentina and Brazil. Of the Chilean visits (5,628), 63% came from the Biobío Region, followed by Región Metropolitana (17%), Valparaíso (6%), Los Lagos (5%), Aysén (3%) and Los Ríos (1%).

**Transfer of Knowledge**

During 2013 R+D Line 6 started the transfer Project "Implementation of productive projects of seaweed farming on a pilot basis in areas of management and exploitation of benthic resources (AMERBs) in the Aysén region". This project is funded by the Fisheries Administration Fund (FAP by its Spanish acronym) of the Undersecretariat for Fisheries and Aquaculture (SUBPESCA 2013-12-FAP-2) The challenge of technology transfer and especially on the artisanal fishermen culture has shown remarkable progress both in the implementation of the pilot farm (installation of infrastructure, farming systems, seaweed growth) and the capabilities of the people involved that have proven to be understood and they can cultivate with simple techniques and scaling from the pilot (1 ha) to a small-scale farm. The pilot phase of this project ends in July 2014, and we are working on an extension of the project. This initiative was published in the magazine AQUA on March 11, 2014 (http://www.aqua.cl/2014/03/11/cultivo-de-algas-se-convierte-en-una-alternativa-real-de-diversificacion-para-la-pesca-artesanal/). This pilot project (2013-12-FAP-2) motivated two actions: 1) A formal Collaboration Agreement between COPAS and the company ALGORG Ltda. (Producción de algas orgánicas Ltda.) governing cooperation between the parties, in research, transfer and university extension; and 2) The
The recent approval of a project presented by ALGORG Ltda. to Fundación para la Innovación Agraria (FIA) with technical assistance from COPAS Sur-Austral (“Producción permanente de algas rojas de alta calidad vía cultivo in situ, una alternativa innovadora y sustentable para la industria acuícola y alimenticia”, PYT-2014-0010).

Please highlight unexpected or unanticipated outcomes and indicate what has been done to deal with them (new research lines, alliances, discoveries, difficulties, etc.). Use as much space as needed.

One of the unanticipated difficulties for our research efforts during Year 6 stems from the delay in the process of building and equipping the new research vessel (Fig. 6). The reasons for the delay are primarily two-folded:

1) our own inexperience as ship builders (the entire process, from blueprint to actual boat was lead and overseen by one of our principal investigators, Dr. F. Tapia PI award FONDEQUIP CONICYT AIC-09); and

2) unanticipated bureaucratic hurdles along the way forced us to revise our time table more than once, and generated a 9-month delay in the launching and delivery of the new vessel to the Tortel laboratory (from June 2013 to March 2014). As the completion of several research activities (surveys, experiments) planned for Year 6 hinged on this new platform to be operational, some of those activities had to be postponed (e.g., scientific cruise and outreach activities) whereas others has to be conducted under the less-than-optimal conditions offered by locally available boats. The planned austral summer 2013/2014 cruise has now been rescheduled for June 2014 (as a winter cruise) and will be followed by a summer cruise in 2014/2015.

Another theme is the measuring physical properties in fjords which is particularly difficult because these systems are very deep but at the same time show significant variability in thin layers near the surface. Computation of fluxes and property budgets requires, critically, the measurement of velocity fields throughout the water column. This has proven difficult using traditional shipboard configurations and existing equipment, as we have not been able to capture both the deep water structure and the details of the surface flow. As a direct result of the identification of this issue, researchers in R+D Line 2 are developing a new shipboard measurement system using multiple sensors that will allow the computation of property fluxes from the surface to the bottom. The system will use a setup with two Acoustic Doppler Current Profilers (ADCPs) mounted on a custom-build frame to be used with any available ship on our study sites. Apart from the custom hardware, the system also requires new software to process and display the data in real time. When finished, the system will be able to capture, with a first high-frequency ADCP, the surface layer velocity starting at a meter or less from the surface, with high resolution in the first 20 meters or so (the typical maximum thickness of the freshwater layer). The second low-frequency ADCP will sample the entire water column starting at three to four meters from the surface, but with lower vertical resolution. The data from both instruments needs to be reprocessed and combined to form final velocity fields. Additionally, sensors will be added to the frame to collect continuous observations of salinity and temperature during the surveys. Testing of a prototype is expected for mid-2014, and use during research cruises later in the year.

Underwater glider activities had to be put on hold during 2013 due to equipment failure which required an intensive repair job at Teledyne Webb Research Falmouth, MA. The glider returned to Concepción in August 2013 and the underwater glider group led by Dr. O. Pizarro, R+D Line 1) performed further checking and calibration of sensors. Plans include its deployment in austral spring 2014 along a transect from offshore waters into the Corcovado Gulf through the Boca del Guapo, using the AGS-61 Cabo de Hornos. A proposal from COPAS Sur-Austral for the use of the Cabo de Hornos has been submitted in 2013 and we are awaiting response. The data collected by the underwater glider in 2011 was the first set of high resolution data in the region, which is key to understand the dynamics of the water exchange of the entire Chiloé Inland Sea. Additionally, future plans for glider observations in Chile are also oriented to maintain regular observations off Concepción (as a contribution to the COPAS time-series) in order to better resolve the seasonal cycle of oceanographic conditions over the continental shelf and to evaluate interannual variability related to El Niño.
and La Niña events. These new data will contribute to validate regional model simulation and to evaluate the relative importance of the remote equatorial forcing in the region.

During the last year a regulatory law on fisheries that also includes aspects on research and management, started to be implemented in Chile. This new regulatory frame states that the National Fisheries Research Institute (IFOP) will be responsible of conducting most stock assessment projects. Some of those projects were formerly run by our COPAS Sur Austral investigators and that was one of our ways to provide the authorities updated information and scientific knowledge along with recommendations on several aspects on fisheries. To overcome this new scenario, we have approached IFOP investigators offering them to continue collaborating in these assessment projects and so far their answer has been positive. Currently we are in the process of being formally involved in several of their 2014 projects (subcontracts). Also, we have collaboration with IFOP in two monitoring studies. One of them relates to acoustical estimation biomass of small pelagic fish within inner waters of the X and XI Regions. The other one consists of surveys to evaluate the spawning stock biomass of common sardine and anchovy off central-southern Chile. A second way to transfer our knowledge in the decision making process and channel recommendations in the frame of the new law, is the involvement (since early 2014) of one of our investigators (S. Neira) in the Fisheries Committee in charge of dictating yearly regulations to some of the fisheries (“Demersal fisheries of the central and south-austral zones”).

We miscalculated the financial effort of maintaining two buoys (LOBO in Reloncavi and the buoy in Magdalena/Puyuhuapi) and three automatic stations in waters of southern Chile, which represented our first step to set up a network of on-line oceanographic information for Chilean Patagonia. Some of the relevant aspects that we overlooked (or actually surprised us) include: 1) Reliable data transmission has been difficult to achieve due to logistical problems associated with “in situ” functioning of salmon farms; specifically, during the rotation of farms related to the productivity cycle we have been asked to retrieve our instruments from the water. 2) The automatic stations in Puyuhuapi measure properties of the water column at the surface and at 15-m depth. We had some installation/technical problems with the sensors at depth due to lack of experience from the suppliers. These 2 issues led to a budget allowances that were over stretched due to the need to deal and solve the problems encountered. We are reviewing the functioning, use of data generated, and the budget involved in each of our five platforms. Plans for potentially diminishing the number of buoys, and allocating personnel (and funds) to look after these issues are being discussed within COPAS Sur-Austral. This would represent a handicap for our program since the extension of the region requires a great number of oceanographic platforms.
IV. PROJECT MANAGEMENT

Please use this section to summarize the management activities of the Center during the period. Amongst others, this section should include the alignment of the organization and management model with the objectives of the Continuity of the Development Plan. In the case of changes made after the approval of the Continuity of the Development Plan, please modify the organizational flowchart.

As mentioned on page 5, during Year 6 Dr. Silvio Pantoja became the Director of the COPAS Center, replacing Dr. Carina Lange who had been in this position since 2004. Since the start of the COPAS Sur-Austral Program, Dr. Pantoja has been the Deputy Director, in charge of supervising the fulfillment of goals proposed for each of the strategic areas and research lines identified, working closely with the researchers in charge of the different research lines and coordinating human resources, infrastructure, and equipment required to meet their objectives. Now as the Director, he i) dictates the necessary guidelines and internal regulations for the Center's operations; ii) administers the goods of the Center; iii) designs and execute policies leading to obtaining external financial resources, and iv) decides on the yearly budget. Dr. Lange, on the other hand, i) continues to support the Director’s daily activities (as Deputy Director of the COPAS Center); ii) collaborates in maintaining (and also seeking new ties) the international network of the Center; iii) is in charge of organizing and writing the annual reports; and iv) is the Coordinator of the COPAS Center Time Series Studies at Station 18 off Concepción (http://cimas.udec.cl/eng/research/serie/). This is an ongoing effort of the Center which started in 2002 and encompasses physical oceanography measurements, biogeochemistry, pelagic and benthic biology, as well as paleo-oceanographic studies (Lange, C.B. & Escribano, R., 2012. Long-Term Ocean Observations off Central-Southern Chile. POGO, Observing the Oceans for Science and Society - Climate, Ecosystems. http://ocean-partners.org/attachments/295_Ocean_observing_article_COPAS.pdf).

Since the beginning of the COPAS Sur-Austral program, Ms. María Angélica Carmona has been in charge of coordinating the activities among the various units of the program (Program Coordinator), as well as acting as a liaison between UdeC-COPAS Sur-Austral and the associated institutions, CIEP and SHOA. In Year 6, Ms Carmona joins R+D Line 6 to help with generation of products, dissemination of activities, and logistical support in proposal writing for outreach and transfer of knowledge.

Starting in 2013, Mr. Ricardo Norambuena is the PI of the Outreach and Transfer R+D Line 6, and links COPAS Sur-Austral with the productive sector and public services. He is in charge of i) designing and implementing an effective transfer platform of oceanographic information and products and services for public and private stakeholders; ii) organizing the dissemination of the program’s results in all available media (press, TV, radio, websites, magazines); and iii) coordinating outreach activities to the educational community. Building on the information and experience gained during Phase I, R+D Line 6 focuses on transfer of knowledge, concentrating particularly in the Puyuhuapi and Tortel areas.

At the start of Year 6, the Director and the six Principal Investigators met to set the goals and milestones to be achieved for the first two years of Phase II, and met on a regular basis during the year to assess progress made and difficulties encountered, plan field work, and resources employed.
Current Organizational Flowchart of the Center

Board of Directors
1. Rector University of Concepción
2. Dean of the Faculty of Natural and Oceanographic Sciences
3. Head of SHOA
4. Executive Director of CIEP
5. General Manager for INTESAL/Salmon Chile
6. Director COPAS Center

Director
Silvio Pantoja

Deputy Director
Carina Lange

External Advisory Committee
Daniel Nieto
Gustavo San Martin

Program Coordinator
Ma Angélica Carmona

Administration
Ma Jesús Toledo

R+D Lines

Line 6
Technological and Knowledge Transfer
Ricardo Norambuena

R+D: Line 1
Oceanographic observation for the sustainable development of aquaculture
PI: Giovanni Daneri

R+D: Line 2
Environmental variability and ecosystem patterns associated with changing freshwater inputs in Patagonian fjords
PI: Fabián Tapia

R+D: Line 3
Ecosystem Variability and Demersal and Pelagic Fisheries
PI: Leonardo Castro

R+D: Line 4
An ecosystem approach to Patagonian Fisheries
PI: Sergio Neira

R+D: Line 5
Marine Biosafety and Biotechnology
PI: Rodrigo González

Postdocs
Graduate Students
Professionals
Technicians
Undergraduates
V. LESSONS LEARNED

The following section should provide information on substantive lessons about the research, teaching and training, knowledge and technology transfer, alliances with other institutions, outreach and other activities undertaken. An explanation should be provided on why things are going right, why things are not working out as anticipated and what the project is doing about it.

Include here a summary of the response to the recommendations during the continuity evaluation process given by the International Panel (if any) and indicate how they have been considered in the reported period and their projections.

Do not extend further than 5 pages. Indicate the need of confidentiality if required.

On the issue of data management and availability: As the COPAS Sur-Austral Program generates an increasing volume of data from multiple sources and characteristics (continuous vs. discrete, physical and biogeochemical, etc.) a data management and publication challenge has become more urgent. The program recognizes the benefits of making data public to users both inside and outside the scientific community, and it has taken steps to publish a number of key datasets (e.g. hydrographic surveys, real-time mooring data, tidal predictions). However, Chile lacks the online, publicly available database systems funded and maintained by state agencies in other countries, such as NODC in the US or the BODC in the UK. SHOA does maintain an oceanographic database, but data retrievals from the database are by request only. Thus, the program is in need of a flexible, online, database and publications system to both receive data submissions from program researchers and to make these datasets available to all users. The program has been consulting with the developers and maintainers of databases both in Chile and overseas to improve data management and publication.

On the issue of contribution by the private sector: During Year 6 we continued with our efforts for interaction with the private sector offering projects, partnerships and agreements. The results were lower than expected, especially from those sectors that make intensive use of our environmental resources (i.e. aquaculture). We have made an enormous effort in trying to convince salmon farm managers that not only quantitative information will be useful for modelling purposes, but qualitative knowledge can also be used and incorporated into the fuzzy logic model as expert judgments’ criteria. A demonstration of the use of the fuzzy logic model has already been conducted to salmon farm managers. Special emphasis has been applied in demonstrating that the model can also be used by them combining quantitative and qualitative information reducing the risk of the decision making process under uncertain environmental scenarios and deteriorated health status of salmon populations. The fuzzy logic model application requires as an input the use of environmental information (e.g. temperature, salinity) as well as key information directly related to the management of farms like stocking density, growth, feed intake, mortality rates, data that is available in all major companies. The use of real and fine scale data is necessary for the proper functioning of our model. This type of data has been requested to the salmon farm industry for the past two years but we have not received the proper data yet in spite of multiple efforts.

In general, we perceive that there is no incentive to invest in research if there is no immediate solution to a quota problem, that is, to get a service or product with a solution in the short term. Considering this difficulty, one of the strategies adopted refers to selecting oceanographic research initiatives that may be accompanied by immediate and useful information for the private sector. For example, in December 2013, we proposed a pilot project to a shipping company (Naviera Austral S.A.) that carries freight and passengers on various routes in Patagonia (see also # 3 Application of Research Results). The project has two objectives and areas of action: a) Information by installing oceanographic sensors on ships transiting specific routes in Patagonia. This will generate time series of valuable information at a very low cost from which we can develop models that explain the behavior of certain variables; and b) Installation of weather stations on ships that continuously
record meteorological parameters, useful for navigation and safety of passengers and cargo. Our program funded oceanographic sensors and the shipping company would invest in the weather deck. The joint operation of both platforms to generate information in real time and analyze ocean-climate relationships can become valuable and useful knowledge for navigation and for other users (aquaculture, fisheries, tourism).

VI. PERFORMANCE INDICATORS

See Appendix 2

COMMENTS ON THE INDICATORS

If applicable, in no more than 2 pages include your comments on the indicators; explain possible gaps between the ones reported v/s the ones estimated in the proposal.

1. We published 40 ISI articles (total average impact factor of 2.1); of these, 14 were entirely dedicated to the Patagonian fjord region.

2. Average number of citations per article: Because the published papers presented in this report are the most recent ones achieved during Year 6, the number of citations is of course low and range from 0 to 4.

3. Amount and % of the Center’s income from other non-government sources: Our estimated value of MM$342.6 included a pending proposal (Marine Microbiology initiative G&B Moore Foundation) which unfortunately was not funded. We will apply for new projects and/or resubmit failed ones to reach the value committed.

4. Participation in Projects related to the topics of the Development Plan: The noticeable increase in the number of new projects is related to the recent funding of 6 postdoc projects and 6 others awarded to 4 of our new associate investigators that joined our program in Phase II.

5. Trademark: This is a new indicator that identifies and distinguishes the source of the goods of one party from those of others. It is a valid strategy, different from a patent, which provides legal protection to the owner, and guarantees exclusive right of use for a period of 10 years (renewable indefinitely).

6. Number of Master students and Number of Ph.D. Students: An increase in this indicator is evident which may be related to two reasons: 1) UdeC’s Graduate Program in Oceanography has changed to a more aggressive strategy for the recruitment of graduate students (e.g., more publicity, new web page), and 2) the interest of new students to be working in Patagonia-related issues.

7. Collaboration among researchers of the Center has also increased not only due to co-tutoring of students but also collaboration between the Center’s researchers with other national and international groups.
VII. FINANCIAL STATEMENT

FUNDS OBTAINED

Please indicate the funds obtained in the reported period using the following table:

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**Private Sources - National or International Non-Profit or For-Profit Organizations**

**National Sources**
- Exportadora Los Fiordos Ltda.
  - 4,698
  - 100%
- *INTESAL de SALMON CHILE*
  - 25,260
  - 100%

**International Sources**
- BJERNES CENTER (Norway) - CL
  - 3,857
  - 0%
- International Associated Laboratory (LIA)
  - MORFUN - CF
  - 24,000
  - 50%
- MARUM-U. Bremen Germany - CL
  - 25,000
  - 100%
- Observatoire Oceanologique de Banyuls sur Mer (CNRS-Universite Pierre et Marie Curie) – France - CL
  - 11,700
  - 100%
- OCEAN-CERTAIN - Ocean Food-web Patrol EU-FP7-project number 603773 – JLI/HG
  - 100,000
  - 0%
- Proyecto NTNU 216607 Norwegian University of Science and Technology, Norway – JLI/HG
  - 30,000
  - 0%
- CNRS - CF
  - 20,996
  - 100%
- IMBER - SP
  - 1,293
  - 100%
- Partnership for Observation of the Global Oceans, POGO - SP
  - 2,645
  - 100%

**Contributions from the Sponsoring Entity**
- Universidad de Concepción
  - Código: 213.114.001-1AP – F.C.
  - 9,000
  - 0%

**TOTAL FUNDING M$ (without CONICYT-PIA-PFB Financing)**
- 4,966,436

**COPAS PFB-31 43**
APPENDIXES

1. Appendixes A1 to A16 (Excel file)
APPENDIXES

2. Performance Indicators of the period reported (Year 6; Excel file)