Global Ecology and Oceanography of Harmful Algal Blooms

BOOK OF ABSTRACTS

OPEN SCIENCE MEETING
on the
CORE RESEARCH PROJECT:
HABs IN FJORDS AND COASTAL EMBAYMENTS

Gala Hotel
Viña del Mar, Chile
26-29 April 2004

SCOR
SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
COMMISSION OCÉANOGRAPHIQUE INTERGOUVERNEMENTALE
COMISIÓN OCEANOGRÁFICA INTERGUBERNAMENTAL
МЕЖПРАВИТЕЛЬСТВЕННАЯ ОКЕАНОГРАФИЧЕСКАЯ КОМИССИЯ
اللجنة الدولية الحكومية لعلوم المحيطات
政府间海洋学委员会

GEOHAB

Global Ecology and Oceanography of Harmful Algal Blooms

OPEN SCIENCE MEETING ON HABS IN FJORDS AND COASTAL EMBAYMENTS
VIÑA DEL MAR, CHILE
26-29 APRIL 2004

PROGRAMME AND ABSTRACTS

The GEOHAB Scientific Steering Committee (SSC) is grateful for the support for this meeting supplied by the Intergovernmental Oceanographic Commission (IOC), Scientific Committee on Oceanic Research (SCOR), U.S. National Science Foundation (Division of Ocean Sciences), Comité Oceanográfico Nacional (CONA), Gobierno de Chile, Subsecretaría de Pesca, and Servicio Hidrográfico y Oceanográfico de la Armada de Chile.

International Council for Science
Scientific Committee on Oceanic Research

Intergovernmental Oceanographic Commission

NSF

CONA
Comité Oceanográfico Nacional - Chile

SHOA

GOBIERNO DE CHILE

CONICYT

SUBSECRETARÍA DE PESCA

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ORGANIZATION OF THE OPEN SCIENCE MEETING

Conveners

Allan Cembella, Germany Leonardo Guzmán, Chile

Co-ordinating Committee

Jorge Diogene, Spain Bengt Karlson, Sweden
John Largier, USA Suzanne Roy, Canada

Assistance with Meeting Preparation

Henrik Envoldsen, IOC Elizabeth Gross, SCOR
Phyllis Steiner, SCOR Ed Urban, SCOR

Assistance with Meeting Preparation (Chilean group)

Alejandro Cabezas (CONA)
Karim Kaiser (SHOA)
Miriam Seguel, Universidad Austral
Alejandro Clément (Plancton Andino Ltda.)

AN INTRODUCTION TO THE MEETING

Welcome to the GEOHAB Open Science Meeting on HABs in Fjords and Coastal Embayments.

The GEOHAB Programme, sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, is an international programme aimed at fostering and promoting co-operative research directed toward improving the prediction of harmful algal bloom events.

Core Research Project: HABs in Fjords and Coastal Embayments
The GEOHAB Implementation Plan describes plans for four Open Science Meetings designed to stimulate international input to focused research projects. This Open Science Meeting is the second in the series.

The GEOHAB Core Research Project on Harmful Algal Blooms (HABs) in Fjords and Coastal Embayments must be comparative, interdisciplinary, and international. It will directly address the goal of GEOHAB of improved prediction of HABs by determining the ecological and oceanographic mechanisms underlying their population dynamics, integrating biological, chemical, and physical studies supported by enhanced observation and modelling techniques. The overall objective is to understand and quantify the critical processes underlying HAB population and community dynamics in fjords and coastal embayments at temperate latitudes.

Fjords and coastal embayments are combined in this GEOHAB Core Research Project because they share features such as the importance of geographical constraints on water exchange and bloom retention and the dominance of meso-scale structures. Classic fjords, usually characterised by a high ratio of length to width, a deep wedge-shaped basin, freshwater input, and a sill located toward the mouth, create retention and/or initiation zones that favour the proliferation of a particular suite of HAB species. Many groups of key species (e.g., *Alexandrium* spp., *Pseudonitzschia* spp., and various raphidophytes) are virtually identical in fjords in the northern and southern hemispheres at similar latitudes. Such ecosystems are often only marginally affected by human activities because of low population densities; thus, they are usually not subject to eutrophication. Coastal embayments are a broader category of ecosystem type; generally, such systems comprise relatively shallow nearshore marine environments, partially surrounded by land, and often affected by terrigenous run-off, but on a smaller spatial scale than open coastal or upwelling systems. As with fjords, the hydrodynamic processes may be complex, with an accentuated role of tidal flux, storm surges, wind-driven mixing, and salinity and thermal stratification. The physical processes associated with HABs in these systems are most often related to "density adjustment" problems, that is, buoyancy and frontal dynamics, geostrophic adjustment, establishment of a pycnocline after a storm and perhaps topographic frontal motion. The effects of benthic-pelagic coupling are likely to be crucial in understanding HAB dynamics in fjords and coastal embayments. Coastal embayments with limited exchange to the open coast may serve as “seed beds” for benthic cysts or relict populations of HAB species. Such systems are particularly vulnerable to anthropogenic changes in the biological and chemical

regime, and the introduction of exotic species via deballasting and transfer of aquaculture stock. Many fjords and coastal embayments are well characterised in terms of long-term plankton records and toxicity events. Optical data sets on ocean colour and relevant plankton patches are becoming increasing available from these systems. Furthermore, basic circulation models (both 2-D and 3D) are already available from several locations around the world.

The purpose of this meeting is to obtain community input for the development of a detailed research plan for the GEOHAB Core Research Project on HABs in Fjords and Coastal Embayments. The first draft of this plan will be brought together on Friday, 30 April, by the OSM Co-ordinating Committee. The plan will be emailed to meeting participants for comment and will be augmented as additional planning occurs. Each GEOHAB Core Research Project is envisioned to last for about 5 years.

The GEOHAB SSC and OSM Co-ordinating Committee thank you for your participation in developing and implementing GEOHAB research.

Grant Pitcher	Allan Cembella	Leonardo Guzmán
GEOHAB SSC Chair	Co-Convenor	Co-Convenor

ABOUT THIS BOOK

We hope you will find this book to be helpful, both as a reference during the Open Science Meeting and afterward. The list of participants includes all those who completed registration for the meeting before this book went to print on 9 April 2004. Similarly, the abstracts, both for speakers and the poster sessions, reflect the status of the program for the conference on that date. Changes to the program will be announced and posted at the conference and you are advised to look for these.

LOGISTICAL INFORMATION

Transportation

From Santiago Airport to Viña del Mar: Take a bus TUR BUS (1200 pesos) or a taxi (4000 pesos) to Estación Pajaritos in Santiago, where you can catch a bus to Viña del Mar. From the terminal in Viña del Mar, take a taxi to your hotel (2000-3000 pesos).

Buses depart from Santiago every 10 minutes from 06.00 to 22.00; the travel time is about 1 hour and 45 minutes.

Buses depart Viña del Mar to Santiago every ten minutes from 06.00 to 22.00; trip about 1 hour and 45 minutes into Santiago. If you are going directly to the airport, it will take 1 hour and 30 minutes to the Taxi Stop to the Airport (3000 pesos). Ask the bus driver to stop at this place (it is not necessary to go all the way into Santiago city).

Hotels

HOTEL GALA HOTEL RONDÓ HOTEL HISPANO Arlegui 273 1 Norte N° 157 Plaza Parroquia N° 391 Viña del Mar Viña del Mar Viña del Mar Tel: +56-(0)32-321500 Tel/fax: 056-032-883144 Tel: 056-032-685860 E-mail: galahotel@galahotel.cl E-mail: rondo@hotelrondo.cl E-mail: hotelhispano@vtr.net

HOTEL ESPAÑOL HOTEL CROWN ROYAL Plaza Francisco Vergara N° 191 5 Norte N° 655 Viña del Mar Viña del Mar Tel: 056-032-685145 Tel: 056-032-682450 E-mail: hotelespanol@elhostal.cl E-mail: queen655@vtr.net

Meals

Breakfasts are included in the cost of the hotels. Lunches will be provided at the Gala Hotel. Dinners will be on your own.

PROGRAMME SUMMARY

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Opening Remarks

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Hosted by
CONA</td><td>16:20
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DETAILED PROGRAMME

Notes for Participants

Talks: Invited speakers will be expected to adhere to the allocated times for their talks. The chairs of the plenary sessions will be strict about the timing, in order to keep the conference running smoothly.

Posters: Posters can be set up from 8:00 to 9:30 a.m. and at lunch time on Monday, 26 April. All poster authors are expected to present their poster orally (10 minutes) to a rotation of small groups of participants. Details will be provided at the meeting. Posters may also be viewed during all coffee and lunch breaks. Supplies will be provided for mounting the posters. Posters will be left up for the entire meeting to make it possible for participants to view them during coffee breaks and lunch times. Posters should be taken down in the afternoon of Thursday, 29 April.

Monday, 26 April

9:30 - 10:15
Welcome and Introductory Addresses
Roberto Garnham, Presidente del Comité Oceanográfico Nacional
Leonardo Guzmán, Co-convenor of the Open Science Meeting
Ed Urban, Executive Director, Scientific Committee on Oceanic Research (SCOR)
Henrik Enevoldsen, Intergovernmental Oceanographic Commission (IOC)

10:15 – 10:35
The GEOHAB Mission and Comparative Approach: Core Research and Relevant Activities – *Grant Pitcher*, GEOHAB Scientific Steering Committee Chairman

SESSION 1: Bloom characteristics in fjords and coastal embayments

10:45 – 11:30
Unique features and processes that characterize HAB dynamics in enclosed and semi-enclosed coastal basins – *Allan Cembella*, Alfred Wegener Institute, Bremerhaven, Germany

11:35 – 11:55
COFFEE BREAK

11:55 – 12:40
Harmful algal blooms in the Chilean fjords – *Alejandro Clément*, Plancton Andino, Puerto Varas, Chile

12:45 – 14:00
LUNCH

14:00 – 14:45
HABs in Mediterranean coastal embayments: comparisons with high temperate latitudes – *Jorge Diogene*, IRTA, San Carlo de la Rapita, Spain

14:50 – 15:20
Session 1: General Discussion and Questions

15:20 – 15:40
COFFEE BREAK

15:40 – 17:00
Rotating Presentations of the Posters (Session 1)

17:00 – 17:30
General Discussion and Questions from Poster Session

17:30
Adjourn for the Day

20:30
Reception

Tuesday, 27 April

SESSION 2: Biological-chemical processes and bloom dynamics in fjords and coastal embayments

09:00 – 09:45
In situ determination of extracellular biotoxins and other potential allelochemicals in seawater – *Lincoln MacKenzie*, Cawthron Institute, Nelson, New Zealand

09:50 – 10:35
Cyst dynamics in coastal embayments – *Suzanne Roy*, ISMER, Rimouski, Canada

10:40 – 11:00
COFFEE BREAK

11:00 – 11:45
Life cycle strategies and in situ growth rate of HAB species in semi-enclosed systems – *Beatriz Reguera*, Instituto Español de Oceanographía, Vigo, Spain

11:50 – 12:20
Session 2: General Discussion and Questions

12:20 – 13:45
LUNCH

SESSION 3: Development and implementation of observational and monitoring systems for bloom dynamics in coastal areas

13:45 – 14:30
The Magellan Region Monitoring Programme: Integration and use of monitoring data on toxicity and HABs for scientific studies – *Leonardo Guzmán*, Instituto de Fomento Pesquero, Puerto Montt, Chile

14:35 – 15:10
Korean monitoring for the initiation and subsequent development of ichthyotoxic *Cochlodinium polykrikoides* blooms and fuzzy prediction – *Hak-Gyoon Kim*, Department of Oceanography and Marine Environment, National Fisheries Research & Development Institute, Pusan, Korea

15:15 – 15:30
COFFEE BREAK

15:30 – 16:15
Optical monitoring and moorages for bloom surveillance in coastal embayments – *Bengt Karlson*, Swedish Meteorological and Hydrological Institute, Västra Frölunda, Sweden

16:20 – 17:30
Rotating Presentations of the Posters (Session 2)

17:30 – 18:00
General Discussion and Questions from Poster Session

18:00
Adjourn for the Day

Wednesday, 28 April

SESSION 3 (continued): Development and implementation of observational and monitoring systems for bloom dynamics in coastal areas

09:00 – 09:45
Fine-scale measurements and vertical stratification of plankton in thin-layers in embayments - *Percy Donahay*, GSO, University of Rhode Island, Narragansett, USA

09:50 – 10:20
Session 3: General Discussion and Questions

10:20 – 10:40
COFFEE BREAK

SESSION 4: Integrated modeling of HAB dynamics with specific attention to fjords and coastal embayments

10:40 – 11:25
Circulation in bays: Stratification, retention, and exchange processes – *John Largier*, Scripps Institution of Oceanography, San Diego, USA

11:30 – 12:15
Multiparameter ecosystem models as tools for process modeling and prediction of HABs in fjords and coastal embayments – *J. Icarus Allen*, Plymouth Marine Laboratory, Plymouth, U.K.

12:20 – 14:00
LUNCH

14:00 – 14:45
Numerical modeling: Physical/biological coupling in coastal ecosystems – *Wolfgang Fennel*, Baltic Sea Research Institute, Rostock, Germany

14:50 – 15:20
Session 4: General Discussion and Questions

15:20
End of plenary presentation sessions

15:20 – 15:40
COFFEE BREAK

15:40 – 17:30
Group photograph
Afternoon Excursion Activity

20:30
Group Dinner

Thursday, 29 April

9:00 – 10:00
SESSION 5: Identification of interested participants and designated regions for comparative research

10:00 – 10:20
COFFEE BREAK

10:20 – 11:30
Rotating Presentations of the Posters (Session 3)

11:30 – 12:00
General Discussion and Questions from Poster Session

12:00 – 13:30
LUNCH

13:30 – 15:00

SESSION 6: Review of current national and regional projects/programmes in order to identify elements of research that could contribute to the core research

SESSION 7: Identification of gaps in national and regional research projects/programmes

15:00 – 15:20
COFFEE BREAK

15:20 – 16:30
SESSION 8: Formulation and design of a plan to guide core research in fjords and coastal embayments (Session Theme groups; plenary discussion)

16:30 – 17:30
SESSION 9: Identification of framework activities to support the research plan (Session Theme groups; plenary discussion)

17:30 – 18:00
Wrap-up plenary discussion

18:00
Adjourn

Friday 30 April

SESSION 10--CLOSED SESSION: The Core Research Project Co-ordinating Committee will meet to prepare a report of the Open Science Meeting comprising an implementation plan to guide core research

INVITED SPEAKERS' ABSTRACTS

Unique features and processes that characterize HAB dynamics in enclosed and semi-enclosed coastal basins

Allan Cembella, Alfred Wegener Institute, Bremerhaven, Germany
E-mail: acembella@awi-bremerhaven.de

Coastal embayments are a broad category of an ecosystem type that may be loosely defined as an enclosed or semi-enclosed marine environment along a land-mass margin. As these systems are partially surrounded by land, they are heavily affected by terrigenous run-off and are often areas of high primary productivity. With respect to HAB dynamics, although coastal embayments are highly diverse, and include certain estuaries, rías ("drowned estuaries") and fjords, they share features including a role as retention and initiation zones ("seed beds" and enhanced importance of meso-scale phenomena (winds, tides, flux of material). The hydrographic regime is complex and includes the formation of fronts, geostrophic adjustment, and vertical density gradients, which are in turn coupled to events in the adjacent open coast. In stratified waters the scale of these processes is normally of the order of the internal Rossby radius of deformation (*ca*. 10 km), therefore numerical models to define HAB dynamics should have a horizontal grid size small enough to adequately resolve one internal Rossby radius, preferably <1 km. Such coastal embayments are particularly amenable to study by deployment of bio-optical sensors on moorages and platforms, and shipboard sampling and profiling from small vessels.

In many cases, the species complement and successional processes in coastal embayments leading to HAB development are similar to that on open coasts but the temporal phasing and magnitude of the bloom is often attenuated. All of the known adaptive strategies and behaviours—encystment/excystment, layer formation, high biomass generation, vertical migration, heterotrophy, toxin expression—are found among HAB taxa that bloom in these ecosystems. It is noteworthy that many of the key HAB taxa of interest (e.g., *Alexandrium* spp., *Pseudo-nitzschia* spp., *Dinophysis* spp.) are virtually identical in coastal embayments of both the Northern and Southern Hemispheres at comparable latitudes. What is the reason for this apparent latitudinal cosmopolitanism? Fish-killing taxa, particularly certain raphidophytes and prymesiophytes, are particularly prominent in enclosed and semi-enclosed coastal systems. Is this adaptive or merely a reflection of our focus on species that harm fisheries and aquaculture? Comparative study of such systems will yield detailed knowledge on the effects of benthic-pelagic coupling on bloom dynamics and provide information for modelling changes in the coastal environment. Changes in HAB dynamics and distribution are likely to be more obvious and dramatic in embayments than in open coastal and oceanic environments and thus may be more easily tracked on appropriate (sub-decadal) time scales.

Harmful algal blooms in the Chilean fjords

Clément, A., [1]Aguilera, A., [1] Fuentes, C., [1] Grünewald, A.,[1] Dressmann, S.,[1] and Rojas, X.[2]
[1]Plancton Andino Ltda. www.plancton.cl Puerto Varas, Chile and
[2]Intesal, Puerto Montt, Chile
E-mail: alexcle@telsur.cl

Historically in the southeastern Pacific Ocean, toxic dinoflagellate blooms and shellfish poisoning have been restricted to the ecosystems of the southern fjords and channels of South America. In the last 15 years, however, a northern geographic extension and colonization has been observed, particularly with the *Alexandrium catenella* species. On the other hand, in the 1970s, *Dinophysis acuta* was detected recurrently in the Reloncavi Fjord, but we have not registered this dinoflagellate or significant outbreaks of DSP in the last 15 years in this fjord. Therefore, the first noteworthy observation and pattern to date is that toxic dinoflagellate outbreaks in general are bio-geographically restricted to the South American fjords and channel ecosystems.

Basically, the main difference between the coastal ocean and fjord-type waters are the density field (x,y,z) effects upon other chemical (macro- and micro-nutrients) and biological interactions (cyst germination, zooplankton predation, competition, etc.). Most flagellates require a niche to compete against assemblages of diatoms, under low silicate waters, a nutrient that usually is higher in lower density waters. However, a strong density gradient either horizontally or vertically, is not the only condition for a harmful flagellate blooms—an increase in the quality and quantity of light in the euphotic zone is also necessary. Hence recently, information such as hyper-spectral irradiance, CTDO, acoustic Doppler velocity data, and especially, phytoplankton and zooplankton abundance, is part of our research and monitoring of HABs in the Chilean fjords and coastal embayments.

Research Funded by: Conicyt-Fondef MR02I1004, Plancton Andino, Intesal, CONA

HABs in Mediterranean coastal embayments: Comparisons with high temperate latitudes

Jorge Diogène, Margarita Fernández and Dolors Furones
Unitat de Seguiment del Medi, Centre d'Aqüicultura, IRTA, Ctra. Poble Nou s/n, 43540 Sant Carles de la Rapita, Spain
E-mail: jorge.diogene@irta.es

The Mediterranean Sea could be defined as a well defined "semi-confined macrosystem" with specific geographical, oceanographical and climatological characteristics. Coastal embayments within the Mediterranean Sea, may be regarded as "semi-confined microsystems" where oceanographic conditions may drastically change from those found in Mediterranean open waters.

The evolution and incidence of Harmful Algal Blooms (HABs) in Mediterranean coastal

embayments can therefore be studied taking into consideration the interaction between Mediterranean open waters and Mediterranean coastal embayments characteristics.

Our presentation will summarize current knowledge and future research trends for the study of HABs in Mediterranean coastal embayments in relation with other coastal embayments in high temperate latitudes. Special emphasis will be on “Global” versus “Local” hypotheses and predicting strategies regarding “Bloom conditions” versus “NO-Bloom conditions”.

In situ determination of extracellular biotoxins and other potential allelochemicals in sea water

Lincoln MacKenzie, Veronica Beuzenberg, Patrick Holland, Paul McNabb, Andy Selwood
Cawthron Institute, Private Bag 2, Nelson, New Zealand
E-mail: lincoln.mackenzie@cawthron.org.nz

A simple and sensitive method that utilizes the passive adsorption of bioactive compounds dissolved in sea water onto porous, synthetic sorbent-resin filled sachets has been developed. Observations during blooms of dinoflagellates that produce a variety of putative lipid soluble polyether compounds have shown a significant proportion of these are actually dissolved in the sea water medium. The results of field trials demonstrate that this technique provides an excellent means of forecasting toxic algal bloom events and has the ability to predict the net accumulation of polyether compounds by mussels. It has the potential to offer a universal early warning screening method for all marine and freshwater biotoxins and provides a new tool for the study of phytoplankton allelopathy.

With the appropriate choice of adsorption medium it will probably work for all dissolved organic bioactive compounds, including those involved in allelopathic interactions determining phytoplankton succession.

In biotoxin monitoring programmes it could reduce the need for routine shellfish sampling. This would lessen costs and is especially useful where shellfish sampling is difficult or shellfish resources are limited or nonexistent.

The technique targets compounds of interest compared with the circumstantial evidence from conventional phytoplankton monitoring and genetic probe methods.

“Clean” extracts mean that matrix problems in chemical and biological analyses are reduced.

In vivo biotransformations of toxic compounds in shellfish are not an issue (c.f. many metabolic derivatives in shellfish extracts), analyses can confidently target parent compounds only (e.g., OA/DTX1).

Various test methods may be used (effect-based assays, immunoassays, LC-MS etc.), it provides the opportunity for an excellent marriage with rapid test kits (e.g., ELISAs).

Time-integrated sampling provides a good simulation of the accumulation of bioactive compounds in filter feeders.

High sensitivity provides lengthy early warning and conservative estimates of impending shellfish contamination.

Potential for better spatial and temporal sampling integration than shellfish or

plankton samples, rapid tracking of bloom progression.

Provision of independent data on the occurrence of repetitive contamination events during the shellfish depuration phase.

It is a useful bio-prospecting tool for harvesting and identifying the origin of bioactive compounds in the plankton.

Cyst dynamics in coastal embayments

Suzanne Roy, ISMER Université du Québec à Rimouski 310 Allée des Ursulines Rimouski, Québec CANADA G5L 3A1
E-mail: suzanne_roy@uqar.qc.ca

Several harmful algal (HA) taxa possess a benthic cyst phase that is part of their life cycle. Models of population dynamics of HA thus need to incorporate pertinent information on cyst formation, the duration of the cyst phase, cyst dispersal in the sediment, cyst viability and cyst germination. Some modelling attempts have indeed shown that cyst-bed dynamics may be a more important regulator of bloom success than hydrological and meteorological conditions. This presentation will review current knowledge on each of the previous themes and point out areas where information is lacking (particularly for cyst formation and events following cyst germination). It will also offer suggestions as to the major factors that need to be taken into account in future studies of population dynamics of HA.

Life cycle strategies and *in situ* growth rate of HAB species in semi-enclosed systems

Beatriz Reguera, Instituto Español de Oceanografía, Aptdo. 1552, 36200 Vigo, España
E-mail: Beatriz.reguera@vi.ieo.es

The central core of ecology is population dynamics, and that means understanding and measuring the rates of processes that add individuals to, or subtract them from, populations. The ecology of harmful algal blooms is no exception, and to develop the means to forecast bloom development, persistence, movement, and decline of a target species, a population dynamics approach is needed where the different physical and biological gains and losses are well identified. The species-specific intrinsic division rate (μ) is the best-known biological parameter, always included in "conventional" models of the free-swimming phase. The existence of different life cycle stages with distinct requirements than the vegetative cells—often catalogued as separate species—expands the range of conditions under which a species can survive. The formation of life cycle stages (temporary cysts, small cells, planozygotes, permanent cysts) that add/subtract individuals to the population is rarely considered in numerical terms, partly because of the difficulty to measure these rates, but very often because the life history strategies of the target organisms are poorly known and sampling designs are inadequate. In regions subject to chronic HAB events, a reasonable knowledge of the environmental conditions associated with population increase is already available, but numerous gaps in knowledge concerning initiation of blooms and the fate of declining populations await solution. Here we review results obtained with species-specific *in situ*

division rate measurements in coastal waters, with special attention to species that occur in low-to-moderate numbers and constitute small percentages of whole phytoplankton assemblages. A three-tiered life cycle paradigm is considered, as well as possibilities of specific, non-conventional sampling designs that could be applied to explore the distribution of overwintering or residual populations and other non-vegetative forms that may play key roles in bloom initiation and decline.

The Magellan Region Monitoring Programme: Integration and use of monitoring data on toxicity and HABs for scientific studies

Leonardo Guzmán,[1] Gemita Pizarro,[2] César Alarcón,[2] Hernán Pacheco,[2] and Máximo Frangópulos[3]
[1]Instituto de Fomento Pesquero, División de Investigación Acuícola, Puerto Montt
[2]Instituto de Fomento Pesquero, División de Investigación Acuícola, Punta Arenas
[3]Centro de Estudios del Cuaternario Fuego - Patagonia (CEQUA), Punta Arenas, Chile/Instituto de Fomento Pesquero, División de Investigación Acuícola, Puerto Montt, Chile
E-mail: lguzman@ifop.cl

Alexandrium catenella and Paralytic Shellfish Poisoning (PSP) have been reported for the southern coast of Chile in the last thirty years. Both were sporadically cited for the Magellan region (48º30´- 55º 00´), in 1972, 1981 and 1989. Since 1991, recurrent episodes have occurred, indicating a continual presence of this toxin and its inherent impacts. Up to the 1980s, these episodes were restricted to this region, but in the 1990s they expanded to the north. In 1994, the first PSP outbreak for the Aysén region was detected and in 2002, an outbreak was reported on Chiloé Island.

The Chilean zone between 41º and 55ºS has an intricate geography of fjords, channels and hundreds of islands. The southernmost portion is the Magellan region with approximately 132,000 Km^2 and thousands kilometres of coastline.

In 1997, a Red Tide Programme was established and its principal goals are to diminish risks to public health and to minimise disturbances to the fisheries sector and other economic activities, including actions to attain behavioural changes of particular groups and the community in general. The programme is conducted through four lines of action. This contribution is based on data provided by the Phytoplankton and PSP Monitoring line of action.

The information and samples are collected monthly from 48 fixed stations, except in winter months. In each sampling, mussels are collected for toxicity estimations; qualitative and quantitative phytoplankton samples and oceanographical and meteorological information were also collected.

Based on information available since 1994, defined spatial and temporal patterns will be presented, including (a) seasonal patterns for *A. catenella* and PSP; (b) PSP and *A. catenella* spatial patterns; (c) *A. catenella* abundances and mussel toxicity associations

with environmental variables; (d) relationship between *A. catenella* relative abundance and mussel toxicity; (e) interannual variations and variability of detected patterns between sectors; and (f) abundances of *A. catenella* and other phytoplankton, and mussels' toxicity relationships with planetary phenomena as El Niño and La Niña. Although these patterns have practical meanings, most of them have no scientific explanations, but the importance of collected information and the support provided by the Monitoring Programme is an attractive scenario to test diverse hypothesis that can be contributed to the GEOHAB Core Research Project on Fjords and Coastal Embayments.

Proyecto FNDR Programa Marea Roja XII Región de Magallanes

Korean monitoring for the initiation and subsequent development of ichthyotoxic *Cochlodinium polykrikoides* blooms and fuzzy prediction

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Ichthyotoxic dinoflagellate, *Cochlodinium polykrikoides*, blooms have developed into recurring and widespread fish-killing blooms in southern and eastern coastal areas of the Korean peninsula since 1995. The blooms have been initiated in offshore areas of the central South Sea, which is the mixing area of the inflowing Tsushima warm current and the indigenous eutrophic South Sea. It was clarified that *C. polykrikoides* blooms are initiated in this mixing frontal zone of optimal conditions triggered by nutrients from eutrophic coastal water and heat energy from the Tsushima warm current. Then the blooms are spread out to neighbouring inshore waters by winds and tidal currents, and are enlarged with co-occurring blooms therein and transported eastward, in the same direction as the Tsushima current. Therefore, the initiation and subsequent development of the blooms are dependent on inflow of the Tsushima current, coastal eutrophic state, wind and tidal currents.

Korean HAB monitoring has been implemented in two stages, with a four-dimensional observation system composed of ship cruising, patrolling waterfront, aircraft surveillance and remote sensing. The initial stage is to detect the fish-killing species and the next is to keep track of their subsequent development including movement and intensity. The principle monitoring parameters are oceanographic and meteorological parameters with remotely sensed surface temperature and chlorophyll concentrations to predict the susceptible bloom area. We have operated an on-line visual image communication network entitled "Remote televisual HABs monitoring network" since 1996. This system not only makes it possible to exchange microscopic images, but also makes it possible to overcome the shortage of identification experts and monitoring budget.

The present HAB prediction approach is the fuzzy model system. All HAB records, and meteorological, oceanographic and environmental data were compiled and analyzed to forecast spatio-temporal variation and movement of the blooms. Now Korea is very much

interested in bio-optical oceanography and remote sensing for the more efficient HABs monitoring and prediction system in near future.

Optical monitoring and moorings for bloom surveillance in coastal embayments

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Recent development in vertical profiling platforms and *in situ* optics makes it possible to observe high biomass blooms of phytoplankton with high vertical resolution in coastal embayments. In well-mixed environments fixed depth sensors may be sufficient for monitoring of high biomass blooms. Optical sensors rely mainly on the absorbance and fluorescence characteristics of phytoplankton, but also on other optical characteristics. More advanced sensors use spectral analysis of absorbance and/or fluorescence to identify groups of algae as defined by pigment characteristics. One of the main problems for longer deployments is biofouling. This problem has essentially been solved using copper as an antifouling agent. The main challenge for the future is to develop automatic techniques for studying low-biomass harmful algal blooms. Toxic algae of one or several species often constitute a very small part of the total phytoplankton biomass. One approach is to use *in situ* microscopes combined with flow cytometry and image analysis. Other novel approaches as well as the possibilities and limitations of remote sensing close to shore will also be addressed during the presentation.

Fine-scale measurements and vertical stratification in thin layers in embayments

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Phytoplankton and zooplankton can form layers that range in thickness from 10 cm to a few meters, but persist for hours to days and stretch for hundreds of meters to kilometers. Although such layers are too thin to be adequately sampled with standard methods using bottle and nets, the application of "smart" sampling methods has shown that these thin layers can contain high concentrations of harmful algae. This raises several issues: (1) what are the temporal and spatial scales of thin layers of harmful algae?; (2) what are the mechanisms that control the formation, maintenance and dissipation of thin layers of harmful algae?; and (3) what are the impacts of thin layers of harmful algae? Addressing theses issues creates six sampling challenges: (1) sample at fine enough vertical scales to resolve the distribution of the harmful algae; (2) simultaneously sample the biological, chemical and physical structures and processes hypothesized to control thin-layer dynamics and impacts; (3) avoid confounding of temporal and spatial variability; (4) sample over concentration ranges that control physical, chemical and biological

responses; (5) sample over long enough time to detect thin-layer formation, maintenance and dissipation responses; and (6) collect biological samples needed for identification and rate processes measurements. Herein, we will first considers the scales at which we need to make measurements, and then discuss how a series of new sensors and deployment techniques are allowing us to begin to address fundamental questions about the structure, dynamics and impacts of thin layers of harmful algae. Throughout the discussion, we will consider the strengths and weaknesses of existing techniques and suggest areas where new techniques are needed to meet GEOHAB objectives.

Circulation in bays: Stratification, retention, and exchange processes

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This discussion of the nature of stratification and circulation in bays, fjords, rias and lagoons will be informed by the likely links between this and the occurrence of dense blooms of phytoplankton. Large and persistent blooms have specific requirements for nutrient and light availability, as well as for reduced mixing and dispersion of the bloom, which can be satisfied in semi-enclosed basins. This will be the focus of the talk. Areas of strong freshwater inflow will receive only secondary attention as estuaries are addressed elsewhere in the GEOHAB program. While there is a remarkable diversity of types of "bays" of interest (i.e., bays, estuaries, fjords, rías, lagoons), attention will be given to circulation types rather than *a priori* distinctions based on topography or location. Specifically, tidal processes, wave-driven effects, wind-driven effects, offshore currents, density-driven exchange and mixing will be addressed with a view to how these processes may control nutrient supply, light levels, import of blooms, and export or dispersion of blooms. Ultimately, which physical environments (certain places and certain times) are conducive to the initiation, persistence and demise phases of algal blooms?

Multiparameter ecosystem models as tools for process modeling and prediction of HABs in fjords and coastal embayments

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This paper discusses the past, present, and future application of multi-parameter ecosystem models to fjordic and coastal embayment systems at temperate and high latitudes with specific reference to the development of Harmful Algal Blooms. The presence of HAB species in restricted exchange environments is dependent on many factors, such as the presence of other algal species, the degree of water exchange, weather conditions, the available nutrients, presence of grazers (both pelagic and benthic) and the optical, turbulent and hydrographic conditions. The application of multi-parameter ecosystem models coupled to hydrodynamic models is required in order to both enhance process knowledge and to

forecast bloom events. We will focus on the bulk biomass functional group approaches to ecosystem modelling which work well for cellular components of ecosystems. The role of data assimilation as a tool for constraining error propagation in models will also be discussed. Recommendations for the future development of such model systems are made.

Numerical modeling: Physical/biological coupling in coastal ecosystems

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Although HABs deal with the biology of algae, the occurrence of harmful algal blooms involves biogeochemical processes, physical-biological interactions and anthropogenic impacts. Quantitative theoretical descriptions of such systems with mathematical models allow “model experiments” and predictions of future developments.

Modeling can start with a highly simplified example system, but as soon as we describe real systems we involve their site-specific aspects. In general, each real system displays both specific and universal aspects of marine systems. This study uses the Baltic Sea as an example and presents an approach to model the dynamics of nutrients and phytoplankton. The harmful algal blooms in the Baltic are basically mass developments of cyanobacteria (blue green algae) which threaten environmental quality and public health in coastal areas. The blooms are dominated by *Aphanizomenon* and *Nodularia*. While *Aphanizomenon* is detectable throughout the year and with a strong summer peak, *Nodularia* is found only in the summer. This study presents a stepwise modelling approach, starting with simple chemical-biological models, which are developed further and eventually linked to three-dimensional circulation models.

Modelling harmful cyanobacteria blooms in the Baltic Sea focuses on two issues at different time scales:

(i) quantification of cyanobacterial blooms in responses to variations in climate and nutrient loads, and
(ii) forecasts of pathways of noxious surface detected accumulations.

The first issue amounts to “what-if” scenarios, for example, effects of changed N/P ratios or to elucidate the reasons for interannual variations of cyanobacterial HABs. The second issue concerns operational predictions of developments over the next few days and depend on availability of real-time data. The question to be addressed is how a detected bloom will spread and which areas are likely to be affected. To accomplish this operational task an infrastructure needs to be developed which comprises real-time observations and models with data assimilation capabilities.

POSTER ABSTRACTS

Distribution of toxic algae blooms of *Alexandrium catenella* and their impact upon the Chiloé Archipelago

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The paralyzing neurotoxin found in shellfish (VPM; saxitoxins) accumulates in bivalve mollusks, causing intoxications and deaths since 1972 in the fjord ecosystems of Chile. In 2002, a great part of the archipelago of Chiloé was affected by the arrival and colonization of the toxic dinoflagellate *Alexandrium catenella*, from Quellón (43 °, 20' S) to the island of Quinchao (42°, 23'S). Quellón had the highest concentrations with records of 789 cells/ml, which coincided with the maximum levels of VPM toxicity of 29520 ug/STX eq/100 g of flesh. The detoxification of Chilean mussels in situ occupied two synthetic components, requiring the passage of 3 and 16 days respectively. The detoxification rates of VPM in this area coincided with rates observed in similar species from coastal zones in other countries, confirming that the Chilean mussel comports as a rapid detoxifier. These rates were significantly faster than those determined in Aysén and Magallanes, The detoxification times were longer in areas where there were greater levels of toxicity—an observation coinciding with what has been reported in earlier publications.

Exploratory sampling conducted in February 2004 in Laitec and Guapiquilán near the southern end of Chiloé Island indicated an absence of vegetative cells of *Alexandrium catenella.* Phytoplankton abundance reached concentration maximums of 536 cells/ml with a dominance of diatoms. The toxicity results in mollusks measured by means of HPLC technique and electrophysiological testing indicated sub-toxic levels of paralyzing toxins (<50 µg STXeq./100 g). In the Guapiquilán transect, the maximum intensity of solar radiation within all of the sampling stations was registered at 493 nm. The CTD profiles varied between stations, ranging from a water column being completely mixed to others with moderate stratification.

In addition, training sessions are currently being conducted to certify inhabitants residing in affected areas to serve as environmental surveyors to assist in the collection of samples and the diffusion of the information.

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Circulation patterns in fjords of Southern Chile

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The main features of the hydrodynamics of selected fjords and channels in the Chilean Inland Sea to the north of 47º S are described using current measurements obtained with an Acoustic Doppler Current Profiler (ADCP).

The method consists of an ADCP instrument mounted in a catamaran looking downward, which is towed from a boat during one or two semidiurnal cycles to obtain repetitions over longitudinal or transverse transects. The results of at least 4 campaigns in fjords and channels are presented. The results show the main features of the circulation in these fjords and other phenomena of interest for physical oceanography.

In the transverse dimension, the vertical structure of velocities of the residual flows exhibits a three-layer distribution attributed to the effect of wind in Aysen Fjord, a geostrophic or quasi-gesotrophic dynamics balance at the surface in most of the studied fjords, the effects of bathymetry on accelerations of flow around bumps, and other phenomena of interest. In the longitudinal dimension, the effects of bathymetry and coastline geometry over accelerations are evident. There are evidences of two-layer vertical distribution of velocities, convergence regions and tendency of flow to rotate.

Further coupled physical and biological investigations are needed to assess the effect of these patterns in the beginning, development, and decay of harmful algal blooms in these environments.

Studies on the role of UV radiation in harmful algae blooms dynamic: The adaptive strategies of *Alexandrium catenella*

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Anthropogenic influences involving stratospheric ozone depletion have caused an increase in the UVB flux to the Earth's surface in recent years. UV radiation produces a broad spectrum of genetic and and cytotoxic effects in aquatic organisms. However, these responses are offset by various protection strategies such as avoidance, screening, photochemical quenching and repair. Some events of toxic blooms of the dinoflagellate *A. catenella* have been coincident with UVB radiation episodes in the southern region of Chile and Argentina. Moreover, the world's highest toxicity values have been recorded in this region, in coincidence with the occurrence of high densities (8×10^{5} cells l^{-1}) of a highly toxic *A. catenella* strain (325 pg/STX eq. $cell^{-1}$). However, a causal relationship has not been found among these processes. These observations have induced us to study the adaptive strategies of *A. catenella*

to UV stress. In this study we report the effects of short- and long-term exposition to PAR and UV radiation on the toxin, pigment and mycosporine-like amino acid (MAAs) synthesis in a clone of *A. catenella* isolated from the XI Region of Chile. Although our results demonstrated that *A. catenella* appear to be very sensitive to chronic UVB exposure, the increased synthesis rate of high amounts of MAAs and photoprotector carotenoids gave partial protection during the first days of exposure. Long-term exposure not only arrested growth and cell division but also blocked toxin production. The observed response time for the induction of the photoprotective mechanisms can be interpreted as an adaptive response linked with the migratory behaviour of *Alexandrium* species. Elucidating responses at the ecosystem level remains an ongoing challenge in this field.

Temperature and harmful algae in Aysen Fjord (45º26´S 73º00´W), Chile, between 1993 and 1999

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Blooms of DSP- and PSP-producing micro-algae and several other taxa linked to damage to caged salmon have been detected in fjord areas around the world. In Chile, these species are distributed throughout the fjord- and island-dominated area that extends south of Puerto Montt.

These blooms have been observed in Aysen Fjord (45º26´S 73º00´W) since 1991, but have increased in intensity and frequency in recent years. The outbreaks of *Alexandrium catenella* and *Dinophysis* species were recorded from 1993 until 1999, during a 6-year time series of qualitative phytoplankton samples and surface temperature measurements taken every 15 days. This was the first study to use such a long time series for elucidating the dynamics and temporal variability of the phytoplankton in the area.

During the analysis, a total of 116 taxa were identified: 84 diatoms species, 30 dinoflagelates and 2 silicoflagelates, from marine neritic, oceanic, estuarine, fresh water and benthic habitats.

Between 1993 and 1999, 34 blooms of *Dinophysis acuta*, and 45 blooms of *D. acuminata* were detected, while *Alexandrium catenella* was present in the samples on only 8 occasions. The toxic algae were present during March 1998, when 6 people died from PSP and DSP combined intoxication.

The surface temperature of the water showed normal annual fluctuations for a cold temperate region, with extreme values of 5,2º and 16,2ºC. In general, lowest temperatures were in 1996 and the highest in 1994 and 1998, which were years affected by ENSO phenomena. The warmer years showed a higher presence of toxic species inside the fjord, while the species harmful to the salmon culture and cryophilic species were associated with more estuarine

conditions. Analysis of the data showed an optimal temperature range between 10,5º C and 15,5º C for the three toxin-related species. These conditions were present in March 1998.

Pfiesteria-like dinoflagellates, the misunderstood phantoms

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Several species of small heterotrophic dinoflagellates with appearance and behaviour resembling that of the *Pfiesteria* complex have been described from all over the world. These voracious micropredators have been widely overlooked due to their small size, simple morphology under light microscopy and cryptic plate pattern. Also they live in sandy estuarine areas where they have an "ambush predator" behaviour.

This group is composed of various species, some of which are closely related genetically to *Pfiesteria*, but not related to their harmful effects.

Katodinium fungiforme has been observed in sandy areas of British Columbia and northern Washington State. It has also been found in Europe as *Gymnodinium fungiforme*, Australia and Japan. On the East coast of the United States it has been considered part of the "Cryptoperidionopsoids".

For this species we have obtained a complete thecal tabulation using SEM and special mounting techniques, and also a SSU ribosomal DNA sequence, which shows that it is neither a *Pfiesteria* nor a *Gymodinium*, but a new closely related genus that has similar characteristics of size, appearance, habitat and mode of peduncle use. No amoeboid stages nor toxin production or damage to fish have been seen in over a year of culture in our laboratory under various conditions.

These dinoflagellates prey on a wide range of organisms, from small flagellates and diatoms, to microzooplankton, such as rotifers and ciliates. Their main trophic role is as scavengers and swarm predators, having a highly developed chemosensory ability which allows them to rapidly detect wounded and dying organisms, and form groups to attack bigger and healthier prey. They also prey on undamaged dinoflagellates.

This organism has been severely overlooked, not only taxonomically, but also in their importance in estuarine trophic webs. This presentation will provide new information regarding this potentially important organism.

First approximation to a multidisciplinary study in a fjord system associated with PSP outbreaks and *Alexandrium catenella* blooms

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During the last 15 years, the Magellan region (48º-55º S), in the southern part of Chile, had been affected for a striking increase in distribution, frequency, intensity and persistence of Harmful Algal Blooms (HAB) related to Paralytic Shellfish Poison (PSP). The main source of these events is the toxic dinoflagellate *Alexandrium catenella*, whose outbreaks have resulted in a great impact with casualties, public health and regional economic issues. Moreover, there are two more toxic species, both occurring in the same hydrologic system, *Dinophysis acuta* and *Pseudonitzschia australis*, associated with outbreaks of Diarrethic Shellfish Poisoning (DSP) and Amnesic Shellfish Poisoning (ASP), respectively, in other parts of Chile. Blooms of *A. catenella* extend along all the Chilean fjords and channels system between 44º-55º and only local monitoring programs are available for data and information about the spatial and temporal dynamic of these harmful species.

At present, the hypothesis is that phytoplankton, and particularly the distribution and abundance of harmful species are influenced by glacier dynamics and the interaction with climatic (wind, pluviometry) and oceanographic (circulation, nutrients) factors, which also are affected by global climate changes.

Seno Ballena (53º40´S; 72º30´W) is a fjord system boundary with two adjacent zones that historically have showed high values in PSP toxicity caused by *A. catenella* (Bahía Mussell and Bahia Nash). Since this fjord is strategically very important (it is located near Isla Carlos III (53º38´S; 72º20´W), recently created by the Chilean government as a Whales Marine Reserve), it is an excellent place to begin specific studies about the main factors that are affecting the high productivity of this system.

In this presentation we will show preliminary results based on a cruise carried out during December 2003 in which physical, chemical and biological oceanographic variables were measured to explain the hydrodynamic processes associated with the productivity of the fjord and the distribution and abundance of the toxic species.

Proyecto CONICYT-Gobierno Regional XII región

Gene global expression of toxic dinoflagellate *Alexandrium catenella* in nitrate depletion conditions

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Several studies have shown that growth and toxicity in dinoflagellates depend upon nutrient availability, specifically upon nitrate and phosphate concentrations in the culture medium. *Alexandrium catenella* is a toxic dinoflagellate capable of producing Paralytic Shellfish Poisons (PSP), which are N-rich compounds. Therefore, any change of nitrogen concentration in the growth medium should have some effect on cellular toxin production and growth. There is no molecular data showing which proteins may be directly or indirectly affected by nutrient concentration in the growth medium. In the present study the proteins' electrophoretic pattern of *Alexandrium catenella* was evaluated under different nitrate concentrations. Nitrate-depleted cultures showed a decrease in the amount of total proteins. However, under nitrate-depletion, other proteins were over-expressed. These proteins might be involved in nitrogen uptake, the degradation pathways of saxitoxin, the cell cycle or they may be required passing to cyst stage. Four proteins showing an over-expression were sequenced by MALDI TOF mass spectrometry. This analysis indicated that the response mechanism(s) *A. catenella* shows under nitrate limitation may involve the over-expression of proteins that do not have homology with peptidic prints of proteins previously registered in the database. We therefore argue that these over-expressed proteins are not described so far.

Distribution patterns of *Alexandrium tamarense* (Lebour) Balech populations in the Golfo Nuevo (Patagonia, Argentina)

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Phytoplankton composition and abundance in the Golfo Nuevo, Argentina, have been studied from 1995 to 2001; together with water temperature, salinity, nutrient and chlorophyll a concentrations. The pattern of seasonal phytoplankton distribution showed recurrent blooms of *Alexandrium tamarense* during late winter and spring characterized by strong interannual fluctuations in magnitude. The morphological variability of *A. tamarense* was tested on field populations and on clones growing under different conditions. A great variability in the presence/absence of the ventral pore (an important character used to distinguish species of *Alexandrium*) was observed. The spatial distribution of the species was observed patchily and the density increased near the coast (maximum $22x10^3$ cells L^{-1} at the surface layer). *A. tamarense* cysts were observed in bottom sediments of the Golfo Nuevo. There was an increase in abundance from coastal stations (0-5 cysts cm^{-3} of sediment) to the offshore, deeper areas (100300 cysts cm^{-3}). Multiple regression analysis showed sunlight as the major source of temporal variability of the species in the area. The relationship of *A.*

tamarense cell abundance and that of the dominant phytoplankton species during the spring was investigated using Pearson correlation. *A. tamarense* cell abundance was significantly correlated with the dinoflagellates *Scrippsiella trochoidea* and *Prorocentrum micans* cell abundances and negatively correlated with phytoflagellates.

Kin selection in phytoplankton endotoxin producers?

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The evolution of endotoxicity in phytoplankton species may be explained by kin selection theory. The cells must be ingested, and then probably killed, in order for the predators to learn how to recognize the toxic cells and, hence, some cells take advantage of those cells that are consumed by the grazers.

As phytoplankton species usually reproduce asexually, endotoxicity might be of evolutionary significance because those cells that are consumed can increase their gene representation in future generations by helping close relatives (inclusive fitness). To test this hypothesis, unialgal and mixed cultures of two strains, one toxic and the other low-toxicity, of the marine dinoflagellate *Alexandrium minutum* were cultured in the presence or absence of predators (the copepod *Acartia clausi*). The toxic profile of the strains was used to identify the strains in the mixed cultures. The growth rate of the low-toxicity strain was always higher than the growth rate of the toxic strain, supporting the hypothesis that toxic species have a lower ability to compete for nutrients and, hence, the low-toxicity strains outcompete the toxic ones. The only exception was in the mixed culture with copepods, where the abundance of the toxic strain was higher than the abundance of the low-toxicity strain, because the copepods were able to recognize the toxic cells and fed selectively on the low-toxicity ones. These findings provisionally corroborate the hypothesis that endotoxicity might has evolved through kin selection.

Overestimation of the indirect benefits and underestimation of the direct fitness, that helping behavior is not correlated to relatedness, competition between relatives, the overlap with the group selection theory, and the mutualism or reciprocity are discussed as alternative explanations or problems in explaining the evolution of endotoxicity in phytoplankton through kin selection theory.

The Red Tide Programme of the Magellan Region

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The southeastern Pacific area along the coast of Chile between 43º-55ºS has been sporadically affected since the 1970s by PSP outbreaks caused by *Alexandrium catenella,* though recurrent events have occurred since the 1990s. As a consequence, a Red Tide Programme was established for the Magellan region (48º30'-56º00') in order to strengthen prevention. Its principal goals are to diminish risks to public health and to minimise disturbances to the fisheries sector and other economic activities, including actions to attain behavioural changes of particular groups and the community in general.

The programme is conducted as a whole, through four lines of action, each having interrelated specific objectives: (1) Phytoplankton and PSP Monitoring, (2) Information Dissemination, (3) Training Actions, and (4) Educational Activities.

The strategy adopted to reduce PSP effects considers local management based on PSP levels and *A. catenella* abundance, utilizing information collected at 48 fixed stations which are visited every month, and considering qualitative and quantitative phytoplankton samples, mussel samples for toxicity analyses and oceanographical and meteorological information. Also, specific activities oriented to the public (or community) are considered. These activities include: (a) an information dissemination strategy to inform and sensitise the community in general; (b) training of selected groups to achieve specific skills; and (c) the incorporation of HAB matters and their effects into formal education, encompassing basic and middle education. The capacitating strategy analyses consider technical elements to contribute to its design and re-design, oriented to attain capabilities or abilities according to the programme's objectives, which at the same time are based on the experiences and necessities of the objective groups.

The structure and organisation of this programme, including key results obtained in each line of action, are presented.

Proyecto FNDR Programa Marea Roja XII Región de Magallanes

Distribution of harmful species *Alexandrium ostenfeldii* and *Dinophysis acuta* in the Magellan Region

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It is known that in Magellan region, Chile (48º06' to 54º56' S) Diarrhetic Shellfish

Poisoning (DSP) toxins are present, which are associated with *Dinophysis acuta*. This species has been associated with DSP outbreaks during spring months, but not higher than 177 ng eq. OA g^{-1} hepatopancreas (enzyme phosphatase assay). Also positive samples by mouse bioassays have been detected in this area. On the other hand, it is unknown if *Alexandrium ostenfeldii* presence is associated with the production of spirolids as has been encountered in other countries, such as Canada and Norway. Both species has been registered during Paralytic Shellfish Poison (PSP) events and *Alexandrium catenella* monitoring across the Magellan region from 1994 up to now has shown that both species are present also in Aysén and Los Lagos regions (44.0º – 48.5º S; 42.0º – 43.5º S, respectively).

For the Magellan region, the density of *A. ostenfeldii* is lower than that of *A. catenella* and *A. ostenfeldii* is more frequently observed in the northern area of this region (48º 06' to 52º 11'). This species is absent during winter months, particularly in the northern and southern areas of this region (54° 49'S to 54° 56'S). Nevertheless, it is present all year round, but in low concentrations (63 – 13396 cells l^{-1}), in the central sector and nearby areas of the Strait of Magellan and adjacent fjords and channels. No blooms have been observed and the highest density until now was recorded in the summer of 1999. The spatial distribution of this species has not showed remarkable relationships with environmental variables, due to its discontinued temporal presence.

D. acuta is primarily restricted to the northern area of the Magellan region. Its density is rather low (50 – 5600 cells l^{-1}) and available data suggest that it changes in a few days or weeks. Its presence has been associated with east winds and higher air temperatures, and its relative abundance has been strongly correlated with *A. catenella* density.

Although no critical effects to public health associated with these species have been detected, it is strategic to continue the surveillance of both species, since spirolids production by *A. ostenfeldii* strain is still unknown for this part of the world.

Proyecto FNDR Programa Marea Roja XII Región de Magallanes. Proyecto CONICYT-Gobierno Regional XII región

Probable effects of El Niño-La Niña cycle on phytoplankton responses in fjords and channels of the Magellan Region

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In Southern Chile, along the fjords and channels (43º-55º S) a remarkable increase of the distribution, frequency and intensity of harmful algal blooms (HABs) associated with Paralytic Shellfish Poisoning (PSP) toxins has been observed. During the 1970s and 1980s, HABs of *Alexandrium catenella* were restricted to the Magellan region (48.5º – 55.0º S), appearing every 8-9 years, but from 1991 until now such blooms have been continuously

present. Since 1994, blooms of this species have extended toward the north, encompassing the Aysén region (44.0º – 48.5º S). During the summer of 2002, *A. catenella* blooms expanded further north to the Los Lagos region, along the inland sea beside Chiloé Island (42.0º – 43.5º S).

It has been suggested that triggering factors of *A. catenella* blooms are linked to the El Niño-La Niña cycle, although its maintenance could be a consequence of local factors. The information about both PSP outbreaks and *A. catenella* blooms since 1972 shows that these events occur at the end of La Niña events, but prior to an intense El Niño. During 1982-1983 and 1997-1998, the strongest El Niño events of the last fifty years were observed.

For the northern area of the Magellan region, since 1994 time series of phytoplankton abundance and relative abundance of *A. catenella* are available. Standardized anomalies of these variables are compared to pluviometry and air temperature standardized anomalies from Punta Arenas, as well as with the Multivariate Environmental Index (MEI) and the Southern Oscillation Index (SOI) from 1950 to 2003.

Our findings continue to show that for the 1990s, particularly 1997-1998, corresponding to one of the most intense El Niño events of the last century, a striking increase of phytoplankton abundance and relative abundance of *A. catenella* occured. Both biotic variables show correspondence with MEI and pluviometry standardized anomaly and an inverse behaviour with SOI, since air temperature did not show any correspondence. These trends are showing the influence in fjords and channels of El Niño and La Niña phenomena and the great impact that arise in the pluviometric regime.

Proyecto FNDR XII Región & Proyecto CONICYT-Gobierno Regional XII región

Spatial and temporal dynamic of *Alexandrium catenella* abundance and "Toxicity Geographic Nuclei" in the Magellan region

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Blooms of *Alexandrium catenella* and Paralytic Shellfish Poison (PSP) outbreaks have occurred in the Magellan region, Chile, in 1972, 1981, and 1989. From 1991 until now, the blooms and toxicity in mussels have persisted. During 1994, blooms extended to the Aysén region and during the summer of 2002, *A. catenella* blooms expanded further north to the inland sea of Chiloé Island (42.0º – 43.5º S, Los Lagos region). At present, 415 human intoxications have been registered, with 27 victims, 23 of which have passed away in the Magellan region. Information available since 1994 for the Magellan region (48º-55º S) is analysed, including mussel toxicity, density and relative abundance of *A. catenella*. Blooms and PSP distributions are different between years, considering *A. catenella* density, period of the year, geographic coverage and its duration, and toxicity level. The highest toxicity records in mussels and the greatest geographic coverage occurred in 1994 (52.920 μg eq. STX $100g^{-1}$). During 2002, the highest toxicity occurred in two localities located in the

northern area of this region (12.636 μg eq. STX $100g^{-1}$).

Our findings show areas with higher probabilities of occurrence of the motile stage of *A. catenella* and toxic shellfish during the year. At least three "toxicity geographic nuclei" have been identified. Its geographic coverage is variable between years. Annually, *A. catenella* blooms' duration and their geographic coverage, as well as PSP presence could be explained by local factors, which are further linked to meteorological and oceanographic seasonal conditions that are highly variable in high latitudes.

Proyecto FNDR Programa Marea Roja XII Región de Magallanes

Phosphate uptake behaviour of cyanobacteria: Numerical experiments

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Low nutrient concentrations, which limit the growth of phytoplankton, are a common phenomenon during the weeks after the spring bloom. However, not all nutrients are depleted and eutrophication in coastal regions may lead even to an excess of certain nutrients. For example, in the Baltic Sea, nitrogen concentrations are exhausted after the spring bloom whereas phosphate concentrations are still high and enable cyanobacteria to take up large amounts. The biological processes related to phosphorous uptake by cyanobacteria are investigated with a biological model which include nutrients, phytoplankton and cyanobacteria and is coupled to an ocean model.

The model results indicate that the observed high N/P-ratio in the biomass of cyanobacteria can be partly attributed to their ability to take up also organic phosphorous. In late summer this additional source enables the cyanobacteria to bypass nutrient limitation and thus to grow. The phosphorous uptake behaviour of cyanobacteria further affects the N/P-ratio of the seawater. A comparison with ships-of-opportunity data reveals a time delay between the minimum of the N/Pratio and a maximum of cyanobacteria.

Glutamine synthetase and Nitrate reductase activities of a bloom-forming dinoflagellate (Dinophyceae) in Southern Chile (41ºS): A field approach*

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In the Inner Sea of Chiloé (41-42ºS), a green dinoflagellate bloomed during March-April 2003. Given the potential importance of glutamine synthetase (GS) and nitrate reductase (NR) as descriptors of internal metabolic nitrogen pathways, we focused our efforts on investigating the relationships of GS and NR levels with chlorophyll *a* and environmental (nutrients and oxygen) variables at a fixed station occupied in a temperate coastal area off Puerto Montt, Chile (41ºS). An inverse relationship was found between NR and GS (r = -0.94, $p < 0.05$) where little NR activity (mean = 5.7 nmol h^{-1} L^{-1}, SD = 4.9) was observed during the green dinoflagellate bloom compared with the time period before the bloom (mean = 134 noml h^{-1} L^{-1}, SD = 74). High chlorophyll *a* concentrations (1000 µg L^{-1}) attributable to *Gymnodinium* cf. *chlorophorum* in surface waters were associated with high glutamine synthetase activity. Coincident with the bloom, dissolved inorganic nitrogen concentrations were near the detection limit (NO_3^- + NH_4^+ <0.5 µM). Since GS is involved in the assimilation of different sources on nitrogen, like nitrate, ammonium and urea, we suggest that GS activity seems to be a good indicator of dissolved organic nitrogen (DON) utilization in a period dominated by a single dinoflagellate species.

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Improved high-performance liquid chromatographic method for determination of domoic acid: pH effect

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Domoic acid (DA) is a naturally occurring amino acid that belongs to a group called kainoids, classified as neuroexcitants that interfere with neurotransmission mechanisms in the brain. It causes human intoxication called amnesic shellfish poisoning (ASP) following the consumption of shellfish contaminated with this amino acid.

A rapid and sensitive HPLC-UV method has been developed for analysis of DA in shellfish extracts. Isocratic chromatographic separation of DA and its isomers from shellfish matrix interferences and from the prevalent amino acid, tryptophan was achieved following the control of the pH of the mobile phase. A pH of 2.5 was found to be the optimized pH with chromatographic separation of DA and tryptophan greater than 3.0 min. Confirmation of this chromatographic separation was carried out by LC-MS^{1-3} analysis. Validation of the LC-UV method was achieved using DA standards and with spiked shellfish tissue samples. Sample extraction was verified with control extracts from specimens spiked at 5.0 and 10.0 µg/g of DA and with MUS-1B reference material. The extraction efficiency average was 98.5%. The

calibration, based on mussel tissue spiked with DA standard, was linear in the range 0.05 to 5.0 µg/ml (r = 0.9999) and the detection limit (3:1, signal/noise) was better than 25 ng/ml. The intra-day and inter-day precisions of the DA assay were 1.63% (X = 3.05 µg/ml, SD = 0.05, n = 6) and 3.7% (X = 2.95 µg/ml, SD = 0.11, n = 8). The day-to-day (n=5) variability of the method, for three DA concentrations (1.0 µg/ml, 2.5 µg/ml, 5.0 µg/ml; n=8) was less than 2.7%. This method was successfully applied to a Chilean shellfish samples, allowing the rapid screening of a large number of shellfish samples per day (2030).

Effect of domoic acid (Amnesic Shellfish Toxin) on pharmacokinetic of antipirine: Preliminary results

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Domoic acid (AD) is a neuroexcitant tricarboxilic amino acid belonging to the group of kainoids; it interferes with cerebral neurotransmission, destroying hippocampus areas when irreversibly opening glutamatergic calcium channels, producing irreversible loss of short-term memory. The main AD source is the *Pseudonitzschia* spp diatom, a frequent component of phytoplankton assemblages. The Antipyrine (AP) drug belongs to pirazolones; it is barely bounded to proteins and distributed widely in the corporal water. Its plasma clearance pathway is hepatic hydroxylation and was used to evaluate the metabolic capacity of the enzymatic oxidative hepatic system, *in vivo*. Our objective was to study in six healthy male rabbits, part of the mechanism of AD detoxification, studying the effect of the repeated oral AD doses, on antipyrine pharmacokinetic (AP); determining the plasma values of AP and one of its metabolites, hidroxiantipyrine (OHAP). The obtained pharmacokinetic parameters of AP, before and after AD administration, were: AUC_{0-} 41,1 y 39,4 (mg/mL x h), $C_{máx}$ 21,9 y 19,5 (mg/mL), $t_{máx}$ 15 y 15 (min.), t½ 32,2 y 32,4 (min.) and to OHAP AUC_{0-} 6,8 y 5,6 (mg/mL x h), $C_{máx}$ 2,9 y 2,8 (mg/mL), $t_{máx}$ 45 y 45 (min), t½ 28,7 y 30,4 (min) respectively. These data suggest no differences in the metabolism of AP before and after the administration of AD, which would indicate that the AD detoxification kinetics are not carried out through the oxidative microsomal hepatic system.

HABs in Golfo Dulce, Costa Rica: A unique fjord-like embayment on the Eastern Tropical Pacific

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Golfo Dulce (GD) in the Pacific coast of Costa Rica (8ºN - 83°W) is a fjord-like structure

with a deep inner basin (>200m) sheltered against the open ocean by a shallow sill (60m). Due to its morphology only sporadic water exchange occurs with the ocean, resulting in at least temporarily anoxic bottom waters in the inner basin, comparable to conditions in high-latitude fjords. Thus, as a "tropical fjord", GD is the only anoxic basin on the Pacific coast of the Americas.

Since 1990 cooperative research in GD has produced important scientific information. More recently N_2 production by the anammox reaction in the anoxic water column has been described, where 19-35% of the total N_2 is produced through this process. During 2001-2002 frequent HABs were reported for the Pacific coast of Costa Rica, with significant spatial coverage, and remaining in some places for many months. However, no HAB monitoring program is available for the GD to date. From March to May 2001 patches of *Pyrodinium bahamense* (up to 6 $x10^6$ cells/L) extending several kilometres were observed in GD. A year later, a deep red spot was observed near of the port Golfito made by the cyanobacteria *Trichosdesmium erytraeum*, which produces the "tamandaré" fever, forming trichoma chains of more that 30 cells, and by *Cochlodinium poyikikoides* (1 x 10^5 cells/L). In August 2003, red patches of the dinoflagellate *Akashiwo sanguinea* (0.5 and 1 x 10^5 cells/L) were observed. In January 2004, small patches (4 x 10^5 cells/L) of *Gymnodinium catenatum* were detected. Also present was *Pseudo-Nitzschia pungens.* The port of Golfito is within easy reach by daily scheduled plane and bus services. Our university has available laboratory space and small boats. Thus, GD offers a unique opportunity for comparative studies and cooperative research with foreign institutions is most welcome. The Gulf of Nicoya estuary, located to the north is an example of successful cooperative research programs since 1980, including the study of HABs.

Monitoring algal blooms in the Valparaiso Bay, Chile, using satellite imagery

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Curaumilla Point, located in the south of Valparaíso Bay, is one of the most active upwelling centers in the central coast of Chile; it generates extensive cold water plumes which can be visualized through satellite images. Oceanographic conditions during the coastal upwelling in the bay have been associated to diatom blooms in spring and summer, and in some occasions, to innocuous red tide phenomena. This research focused on the phytoplankton and chlorophyll-*a* dynamics in Valparaíso Bay, using satellite imagery.

Sea surface temperature and chlorophyll distribution were analysed through NOAA/AVHRR and SEASTAR/SeaWiFS satellite imagery, respectively, generated by the Pontificia Universidad Católica de Valparaíso and the Universidad de Chile. Three oceanographic stations located in the Valparaíso Bay were studied, from November 14 to December 5, 1997. The phytoplankton community was analysed by cell counts, pigment and phytoplankton biomass determinations.

Skeletonema costatum was the most abundant species, with concentrations varying from 2,753,736 cell L^{-1} up to 12,876,408 cell L^{-1}. The high phytoplankton values agreed with the presence of cold waters in the area, and in some cases, with high *in situ* values of chlorophyll (7,83 mg Chl *a* m^{-3}**)** and laboratory estimates of phytoplankton biomass (12,18 mg L^{-1}). Other species, such as *Asterionellopsis glacialis* and *Pseudo-nitzschia* cf. *australis*, did not exceed 800,000 cell L^{-1}.

Previous phytoplankton research projects using remote sensing technology carried out in the bay have been oriented to the monitoring of red tide phenomena; this is the first phytoplankton community study using this tool. Satellite technology is a useful tool for the detection of algal blooms, harmless or harmful, especially to determine their location and extension on the sea surface, such as bays and fiords. The early detection of blooms is important for human health and for taking appropriate fisheries management decisions.

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Growth and toxin production by the dinoflagellate *Alexandrium catenella* under controlled temperature conditions

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The south of Chile is rich in shellfish resources with an increasing mussel aquaculture industry, mainly in the fjords of Chiloé Island. More frequent red tide events produced by the toxic dinoflagellate *Alexandrium catenella* have been observed during the last years, with people reported to have suffered shellfish poisoning.

The objective of the present study is to know the growth and the production of STX equivalent by the dinoflagellate *A. catenella* under a wide range of temperatures similar to those observed at the natural environment (Chiloé Island). For this purpose, strains of *A. catenella* (ACC02) were cultivated in triplicate at 4 temperatures, 10, 12, 14 and 16ºC using 5L glass bottles in a culture chamber (temperature and photoperiod controlled). Growth of *A. catenella* was measured as the increase in cell number, chlorophyll a content, dry weight and toxin production, at different times during a complete growing period. Preliminary results show significant differences in growth between 14 and 16º C, with the highest value at day 45 at 14º C (24000 cels/mL), compared with 16º C, where the highest value reached 6390 cells/mL at day 50. These differences in growth resulted in higher values of dry weight and chlorophyll ***a***. Production of SXT equivalent was also significantly higher at 14º C until day 20, being very similar at day 30. The peak values for toxin production was reached at day 6 at both temperatures, with values as high 6158 fmoles/cell and 3262 fmoles/cell, for 14 and 16º C, respectively. Values lower than 500 fmoles/cell were obtained during the main part of the study.

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Dynamics of *Pseudo-nitzschia* group in Todos Santos Bay, Baja California, México

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Todos Santos Bay phytoplankton are normally characterized by a bimodal abundance curve. In this area HABs are due mainly to dinoflagellate blooms such as *Lingulodinium polyedrum, Prorocentrum* spp, *Gymnodinium sanguineum* and *G. flavum* with other species (*Ceratium furca, Scrippsiella trochoidea*), rarely dominant. This presentation is focused mainly on the *Pseudonitzschia* group because it includes potential domoic acid producer species. The most important are *P. multiseries, P. australis* and *P. delicatissima.* During the annual cycle, the *Pseudonitzschia* group is more important during spring and summer when average water temperatures are 17.9 and 20.3ºC, nitrates of 1.3 and 1.2 µM, nitrites of 0.01 µM, phosphates of 0.6 and 0.7 µM and orthosilicates of 4.2 and 2.7 µM, respectively. In September 2002, some sea lions died on the beach and a *Pseudo-nitzschia* bloom with densities higher than $3x10^{4}$ cells x l^{-1} was observed with values of 18ºC at surface to 15ºC at 20 m, 2.8 at surface to 13.31 µM at 20 m of nitrates, 0.4 at surface to 0.7 µM at 20 m of nitrites and 3.82 at surface to 1.6 µM at 20 m of ammonia. Seven days after this bloom, a colored water had a maximum density of $1.67x10^{5}$ cells x l^{-1}. In June 2003, another *Pseudo-nitzschia* bloom was observed with $1.2x10^{6}$ cells x l^{-1}, but this time it was south of Todos Santos Bay. We conclude that the development of the *Pseudonitzschia* group may occur after some days of upwelling condition, which may be an important consideration in HAB prediction. We propose to compare HABs between Todos Santos Bay (30ºN) and Valparaíso Bay (33ºS) and/or Herradura Bay (30ºS), including SEM identification, eco-physiology studies, oceanography monitoring, eutrophication changes due anthropogenic activities, socio-economic impact, and optical data on ocean color. We thank Israel GradillaMartínez[2] for technical help.

Phytoplankton size composition in austral fjords and channels in Chile: Association with environmental factors

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The occurrence of harmful algal blooms is generally related with high phytoplankton biomasses. In eutrophic and turbulent water columns with no light limitation, total biomass is high and microphytoplankton (>20 microns) dominated. In oligotrophic, stratified and light-limited water columns, pico- and nannophytoplankton are predominant and the total biomasses are low. In Chile, the fjords and channel from Aysén (43 - 47 °S) present high seasonal and local physicochemical variability which affects size composition and the total phytoplankton biomasses in these ecosystems.

Total biomass (TB) and three size fractions (>20, 11-20, <11 microns) of phytoplankton were measured as chlorophyll_a, at different depths in 67 locations during three cruises, winter and spring 2001 (CIMAR 7) and spring 2002 (CIMAR 8). These samples were analysed by the degrees of association (PCA) and the type of relationship (lineal and quadratic correlation through quantil regressions) between the TB logarithm with size fraction diversity (H'_{size}), temperature, salinity, dissolved oxygen, nutrients and water column stability. At high TB (>4 mg Chl_a m^{-3}) a linear relationship was found with microphytoplankton ($r^2 = 0.976$, $p = 0.001$) although the dominant size fraction and the relationship with TB changed seasonally and interannually. For the whole data set the relationship between H'_{size} and TB was unimodal (from 10th-95th quantile). Microphytoplankton and picophytoplankton were positively associated with temperature and negatively with nitrate and phosphate. The factors analysed, including the N:P relationship, presented significant quadratic coefficients above the quantile 50th with TB and H'_{size}, except for nitrate. The relationships between TB and H'_{size} with the environmental factors, explained at the large spatial and temporal scale by the hypothesis of maximum H'_{size} at intermediate perturbations, was obtained considering all the three series of data bases.

Proyecto CIMAR 7 & 8 CONA and Proyecto ENLACE-DID U. de Chile

Distribution of *Pseudo-Nitzscha australis* and *P. pseudodelicatissima* in the Magellan Region

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At a global scale, the same species of *Pseudo-nitzschia* could be toxic in some areas and not in others. *P. pseudodelicatissima* originally was found to be toxic only in the east coast from Canada (Bay of Fundy), but later was found also to be toxic in Denmark and New Zealand. The *Pseudo-nitzschia* spp life cycles are not completely studied nor are the locations of dormant stages known (silts, column of water). The blooms of *P. pseudodelicatissima* and *P. australis*, both present in the Pacific Ocean, generally occur at the warmest stations.

In Chile (48º06' to 54º56' S) both species are present and at least *P. australis* has been associated to Amnesic Shellfish Poison (ASP) outbreaks. This has been verified in molluscs from Atacama (English Bay, 27º08'S) and Coquimbo (Tongoy Bay, 30º 15'S), although it has also been detected in Los Lagos region, in the inner sea of Chiloé Island (43º10'-43º40'S).

In the Magellan region, both species have been registered during monitoring activities performed across the Magellan region from 1994 until now, but they are not associated to the ASP. However, trace levels of this toxin have been found in phytoplankton samples.

For the Magellan region, density of *P. australis* (50-17 078000 cel L^{-1}) is lower than that of *P. pseudodelicatissima* (50-64 000000 cel L^{-1}). Both species are more frequent in the northern area of this region (48º 06' to 52º 11'). During winter months both species are practically absent. The highest density until now was recorded in the spring of 1999. There are clear inteannual differences in the abundance of both species. In general, their densities are higher than other phytoplankton species.

Proyecto FNDR Programa Marea Roja XII Región de Magallanes

Prediction of harmful algal events in coastal bays which derive from wind-forced advection

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The embayments of southwestern Ireland are drowned river valleys, geologically similar to the rías of northwestern Spain, and are responsible for substantial aquaculture production of mussels, oysters, and caged salmon. Water circulation patterns within Bantry Bay, Dunmanus Bay and Long Island Bay are dominated by wind-driven exchanges, as tidal circulation is weak and the bays are orientated with the prevailing wind direction. Wind forcing results in frictionally damped two-layer oscillatory flows, which cause rapid, large volume exchanges of water between the bay and the continental shelf. The net result is that indigenous populations of phytoplankton rarely develop within the bays.

Harmful algal blooms in this region are primarily DSP events caused by *Dinophysis* or else high biomass blooms of *Karenia mikimotoi*. These arise from import of populations into the bays of southwestern Ireland caused by water exchanges linked to wind forcing. Prediction of these events can therefore be derived from local meteorological forecasting. Results of a correlation of meteorological data with phytoplankton and biotoxin monitoring results within Bantry Bay since 1991 are shown. The onset of a harmful bloom can be predicted with some success: all harmful events relating to *Karenia* or *Dinophysis* (events which were mutually exclusive) were linked to meteorological data using a wind index derived from a combination of recent and present wind speed and direction. What cannot be predicted is the persistence of a harmful event once, for example, contamination of shellfish with biotoxins has occurred. The practical benefits which can be derived from meteorological forecasting of wind-driven events alone are discussed within a national and global context.

Phytoplankton and HAB Monitoring Program in South Chiloé associated to salmonid farming

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A phytoplankton monitoring program has been carried out in the southern area of Chilóe Island, since February 2003. Its objective is to detect and follow harmful algal blooms which may cause negative effects on salmonid fish farms in the area.

Sampling frequency depends on the probability of occurrence of this phenomenon: twice a week during high-occurrence season, and weekly or quincenal during low-occurrence season. Bottle or net samples are taken from selected points associated with fish farms. When a bloom is detected, whether or not is caused by a potentially harmful species, it is followed on a more frequent sampling routine.

Tables and graphics are presented in order to show the spatial and temporal variability of phytoplanktonic community; and to discuss some relevant events along the first year of monitoring.

Mortality of seabirds from Falkland Islands by Paralytic Shellfish Poison

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From December 2002 through January 2003 a large-scale seabird mortality was recorded off the shores of the Falkland Islands, in the southeastern Atlantic Ocean (51º 45´ S, 59º 00´ W). Affected animals were mostly adult penguins, including Gentoo (*Pygoscelis papua*), Rockhopper (*Eudyptes chrysocome*) and Magellanic penguins (*Spheniscus magellanicus*). Several other species were also reported ill and/or dying, such as albatrosses, petrels and prions. Mortalities occurred at several seabird colonies located on different islands within the archipelago, mostly in islands located to the northwest and south.
In an attempt to determine the causes of these mortalities, analyses for the Paralytic Shellfish Poison (PSP) were conducted by HPLC (High-performance liquid chromatography) on a Shimadzu spectrofluorometric analyzer.

Results showed the presence of Neosaxitoxin (NeoSTX) and Gonyautoxin 4 (GTX4). Five of eleven individual penguins submitted tested positive (45%). Of these positive individuals,

one or more tissue samples had high levels of toxins (levels above those considered unsafe for humans: 80 μg eq. STX 100^{-1} g shellfish meat). Additionally, low or trace levels of other PSP toxins were detected, particularly GTX1, GTX2, GTX3 and STX. Higher toxin levels were recovered from intestine or intestinal content (80%), followed by liver (45%) and stomach content or stomach wall (33%). No toxins of this group were found in fat tissue or aqueous humor of the eye.

Previously, PSP has been detected in sardines (filter feeders) but also in higher level feeders, such as mackerel, but no information on toxin detections on the mentioned species has been reported. This is the first report of seabird mass mortality in the Falklands to affect such a wide range of species simultaneously and the first report of PSP affecting/killing seabirds in the South Atlantic. These events suggest that harmful algal blooms exhibit a higher geographic cover and a higher intensity toward the most southern zones of the south hemisphere.

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Development of immunological tools for the rapid detection and quantification of *Alexandrium catenella*

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Harmful algal blooms (HABs) have steadily increased in frequency, intensity and area of coverage throughout the world. In Chile, HAB events can extend from Chiloé Island to the Beagle Channel. HAB occurrences have been mainly linked to the blooming of the dinoflagellate *Alexandrium catenella*, producer of Paralytic Shellfish Poisoning. These blooms have endangered human health and caused important economic and social impacts.

The only way of minimizing the negative impact of HABs is through permanent monitoring, by evaluating both the toxin levels in marine organisms and the abundance of toxic alga in phytoplankton samples. However, the traditional method of microalgal species identification requires well-trained and specialized professionals, up-to-date species identification manuals and costly infrastructure. The latter restricts the possibility of reliable sample analyses to a few national laboratories, which are normally far from the monitored sites, whereas the obtained data are rarely immediately available. On the other hand, the reliability of monitoring also depends on individual experience in species identification. If the person analyzing the sample has little experience or if the sample contains low densities of the species of interest, the resulting error increases, which can lead to the adoption of inadequate resource management strategies.
The objective of the present project is the creation of immunological tools for the early detection in water samples of *Alexandrium catenella*, through the development of a simple semi-quantitative test for application in the field, in addition to a second highly sensitive

qualitative test for laboratory use. These tools have the advantage of being highly specific to *A. catenella*, of rapid analysis, low cost, ease of use, and independent of the experience of the observer.

Investigation and monitoring of marine toxins and harmful phytoplankton in the inner sea of Chiloé Island and adjacent fiords, Chile

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A proposal recently approved for a new activity in the inner sea of Chiloé Island and adjacent fiords is presented, including objectives, methods, activities, study area and expected results.

In the Chilean southern ecosystems, the dinoflagellate *Alexandrium catenella* recently has shown changes in its geographic distribution (2002), and overlapped with toxic outbreaks probably caused by the diatom *Pseudo-nitzschia australis*. Both facts have strongly impacted the regional economy, determining urgent needs of environmental information to support of decisions by official organizations and for producers related to aquaculture and shellfish fisheries of coastal waters.

The project will last 30 months, initiated on January 2004 and its objectives are:

To investigate the effect of physical environmental factors on phytoplankton assemblages. A characterization of the physical environment and the floristic successions associated with *A. catenella* blooms is considered, especially how phytoplankton species are adapted, to environmental conditions favoured by water transportation associated with nutrient enrichments or unstability in the water column. Consequently, environmental forcing variables will be characterized, such as wind and current regimes, which have importance for qualitative and quantitative phytoplankton distribution in shallow coastal waters.

To develop monitoring strategies for harmful phytoplankton and marine toxins such as Paralytic Shellfish Poison (PSP), Diarrhetic Shellfish Poison (DSP) and Amnesic Shellfish Poison (ASP), including oceanographic and meteorological variables. Information will be analyzed from an ecosystemic perspective to understand how physical environmental variables affect HAB distributions. The monitoring results will support a Geographic Information System managed by the Regional Government, including also a Web page. The relevant monitoring results will be distributed through mobile telephones to productive agents.

The project will be developed by the Instituto de Fomento Pesquero, Universidad Austral de Chile, Servicio de Gobierno Regional and Servicio de Salud Llanchipal. Also, the study will be supported by fishermen trade unions and aquaculture enterprises.

Proyecto FDI “Investigación y Monitoreo de Toxinas Marinas y Fitoplancton Nocivo en la X Región”

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