HABs, ocean colour remote sensing, bio-optical monitoring in fjords and aquaculture activities

Prepare for:
IV Int. Ocean Colour Science meeting (IOCS-2019)
Busan, South Korea 10 April 2019

Hosted by Korea Institute of Ocean Science and Technology (KIOST)
iocs.ioccg.org/programme/schedule/

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Since 1998: 21 years

Plancton Andino is a local private company and our mayor focus of interest are environmental assessment and monitoring HABs for aquaculture and government.
OBJECTIVES

1. To study HAB events in optically-complex 
   waters of Chile’s Patagonian fjords, and 
   apply ocean color remote sensing and bio-
   optical methods.

2. To improve our understanding of HABs to give 
   support and recommendations to people in the 
   decision making process.
42°- 55 °S, Pacific margin of South America represents a 200–300 km wide shelf with thousands of islands and a fjord system across the Andes. During Last Glacial, most of these fjords were proglacial lakes. After the Last Glacial Maximum (LGM) global sea level rise led to marine transgression into the continental margin. (R. Kilian et al. 2007).
Extreme event:
Calbuco Volcano Eruption April 22, 2015 18:18

• Recent Eruption:
  • Chaiten       May 2, 2008
  • Cordon Caulle June 4, 2011
Source: Garreaud et al 2013
Photos from Germán Weil

March April 2019
Climatic anomalies, rain falls as an Example
Data Source [www.meteochile.cl](http://www.meteochile.cl)
In honor to Dr. Steve Neshyba

Silva & Neshyba, 1977
Ancapichún, S Garcés-Vargas J 2015

Warmer summer & flows of FW/Si during last decades in southern Chile, real time position using RS.

Southeast Pacific Subtropical Anticyclone (SPSA)
Extreme HABs

EL NIÑO & SAM

HIDDEN FLORA

Pseudo-nitzschia

PDO

TASMANIA

CHILE

UNITED STATES

Alexandrium

Pseudo-chattonella

Trainer V et al in press  Drawing from Jorge Mardones
HAB is

1. A scientific problem and ecological phenomema, but also...
2. An economic impact (> US $ 700M)
3. A social and fake news
4. After 2002 a political issue
1. Phytoplankton Functional Types: bio-optical properties and remote sensing ocean color.

2. Do we observed a higher frequency of flagellates blooms? *A. catenella*, *Cochlodinium*, *Pseudochattonella*, *Karenia* & *Prorocentrum* spp.

3. What are the triggering factors for *A. catenella* blooms?
Basic Conceptual Model of Water Column interactions with aquacultures in fjords systems (Clément 2013)
Ecological basic questions

1. Are fjords and coastal ocean during summer/early fall a more competitive habitat and niche for flagellates blooms?


3. Nutrients concentrations, ratios & freshwater flow [N/P/Si].

4. Underwater Light attenuation due to particles (Secchi < 2,5 m)

Remote Sensing and Ocean color data from Southeastern Pacific Ocean and the Inland sea.


Cochlodonium blooms in South Korea Ahn et al 2006

WATER COLOR AND BIO-OPTICS
HABs, Patches and water color

A. catenella

Chaiten Vn Eruption plume

G. chlorophorum
Methodology, data management and visualization

Phytoplankton Monitoring Programs for Mussel (PSMB) and Salmon aquaculture industry (POAS).

• On line Data base and SQL server  http://sispal.plancton.cl/PAL/index.asp
• **Bus. Intelligence & cloud computing** data visualization Bime Analytics  pdf
• Biological, Optical & Physical variables.
  • Microscopy observations and flow cytometer (flow Cam ) for cells ID and counting
  • User require and demand rapid time response after sampling < than 24-48 hours.

Complement activities of Photoautotrophic cells classification with optical techniques.

• CTD-O and Chl a *in situ* profiles
• EcoTriplet Fluorometer, *in situ* chlor a, Backscattering Bb(460 & 660 nm)
• Total Absorption coefficient marine water a(λ) Future Collaboration Nagur Cherukuru CSIRO
• Discrete water column samples from above 20 m. more than **800 samples/month**
• Sampling frequency 5-20 days depending the season and risk.
• **Ocean color remote sensing (Rrs)** as an intermediate users WINSOFT
• others
Applications of Bio-optics in optically complex ocean waters

1. Absorption Coefficient ($\alpha_{ph}$) QFT  Greg Mitchell

2. Backscattering ($b b 440 \ y 660 \ nm$).

Appreciate inputs of Steward Bernard, Collin Roesler & V. Martinez.

1. Chlorophyll $a_\text{Chl}$
   1. Passive and in situ and In vitro
   2. FRRf3, Variable & Active chlor $a_\text{fluorescence}$  Fo, Fm, Fv, Fv/Fm, Sigma  Kolber et al 1998  Oxborough et al  Chelsea Technology Group, UK

2. Hyperspectral Irradiance  $I(\lambda, t)$
Hyper-spectral radiometry, before during max peak of HAB N° 122
WISP-3 spectra & IN SITU CHL a

Different Reflectance spectra and Water Column Chl a in situ, phytoplankton abundance, and water color perception

simple algorithm base upon water column & spectral shape

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<th>Fecha</th>
<th>Hora</th>
<th>Estación</th>
<th>secchi (m)</th>
<th>Color del agua</th>
<th>Cielo</th>
<th>Z (m)</th>
<th>cel/mL</th>
<th>clora (ug/L)</th>
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Chl, SST using InsightExplorer

6.12.17  7.12.17

Chl a: 1 al 5 y 1 al 6 de diciembre del 2017
Lepidodium chlorophorum a green dino producing blooms, Remote Sensing Chl and SST Using WINDATA/WINSOFT from M. Kahru & Google maps *.kmz dates 81-84

<table>
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<th>Fecha</th>
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<th>Latitud (S)</th>
<th>Longitud (W)</th>
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<td>-73,684625°</td>
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Bb (λ) and Absorption Coefficients of *Alexandrium catenella* motile culture cells

Stuart et al 2004
Absorption (λ, t, z) near a fish farm in a fjord
FRRf3 Induction Curves of PSII Dinoflagellates from culture, *Pseudochattonella, S. costatum*, from Marine Inland Sea

*A. catenella* cultured cells

*Skeletonema* field cells

*Pseudochattonella* cells from 2016 bloom

*Pseudochattonella*, among others, all the high biomass Harmful blooms studied with FRRf have really high Fo (13) & Fm (30) values. Light and Photosynthesis 7353-0 huito bloom.
Harmful diatom bloom in Aysen Fjord
*T. seudonanna* (5 um)

Photosynthetic parameters with FRRf3 (RLC)
QUANTUM EFFICIENCY OF PSII (Fv/Fm) vs. CROSS SECTION OF PSII
Data from natural assemblages

Photosynthetic Efficiency vs Absorption Cross Section of different HABs cells

- bloom criptoficea bh pmc 22.11.2016
- Pesudochettonella bloom POAS 7353 00
- Prorocentrum cf. cordatum bloom POAS 17953
- Lepidodinium cf. chlorophorum bloom POAS 17953
Puqueldón - Clor-a vs Fo
\[ y = 0.0931x + 0.3126 \]
\[ R^2 = 0.8267 \]

NO Is Francisco - Clor-a vs Fo
\[ y = 0.1516x - 0.1682 \]
\[ R^2 = 0.8096 \]

Refugio - Clor-a vs Fo
\[ y = 0.1216x + 0.3021 \]
\[ R^2 = 0.2132 \]

Valverde 1 - Clor-a vs Fo
\[ y = 0.0557x + 0.0985 \]
\[ R^2 = 0.9459 \]

Izaza - Clor-a vs Fo
\[ y = 0.1216x + 0.3021 \]
\[ R^2 = 0.9459 \]

Bahía Edwards - Clor-a vs Fo
\[ y = -0.0137x + 0.2966 \]
\[ R^2 = 0.0037 \]

Lagreze Norte - Clor-a vs Fo
\[ y = 0.1297x + 0.0623 \]
\[ R^2 = 0.8382 \]
QUANTUM EFFICIENCY OF PSII (Fv/Fm) vs. CROSS SECTION OF PSII
Data from natural assemblages
Extreme Event of HAB 2016
1. At the max subsurface chl a value it is observed a minimum variability of particles backscattering coefficient ratio (Bb440/Bb660 ratio), and a very consistent relationship between BB and Chl a.

2. Dominant cells in thin layer maximum belong to *Pseudochattonella* (max 4000 cells/mL).

3. Bb distributions at 470 and 660 nm, and ratios could be used as a proxi for *Pseudochattonella* blooms

Clément et al 2017
HABs of *Pseudochattonella*, *in situ* Chl \( a \) Fluorescent, Bbp (470 and 660) 7-3-16, 14:51
Phytoplankton Abundance, *Pseudochattonella, in situ* Chl a Fluorescent, Temperature, & Sigma-t. 7-march-2016, 14:51 (Clément et al 2017)

Thin layer, bio-optics and HABs of *Pseudochattonella*, in situ Chl a Fluorescent, Bbp (440 and 660 nm) 7-march-16, 14:51

**Bb and cells size**

Particulate Backscattering 470 and 660 nm

At Sub Surface Max chlor is observed minimum variability of backscattering Bb440/Bb660 ratio, & consistent relationship between BB and Chl a. At this thin layer we observed max Pseudochattonella abundance 4000 cell/ml

In situ Chlor a (mg/m3) and Backscattering ratio (470/660)

Spectral shape bbb(k) proposed as indicator of PSD (Loisel et al. 2006; Kostadinov et al. 2009) and to characterize phytoplankton community structure (Kostadinov et al. 2010; Fujiwara et al. 2011).

Bbp(470 nm) vs Chl in Fjords waters during HAB events

Hout et al 2008 Case 1 waters $R^2 > 0.8$

Complexities but best fit is precisely at thin layer, i.e., optically and biologically active layer.

Chl and uniform cells sizes and almost single specie niche.
PHYTOPLANKTON TYPYSES, HABs cells,
Separated by FLOW CYTOMETER (FLOWCAM)
POPULATIONS OF DIFFERENT SPECIES, FORMING HABs, SEPARATED BY FlowCam PARAMETERS

Ratio [Red/Blue] vs cell Diameter

Diameter X Ratio Red / Blue

Diameter X Ratio Red / Green

A cat
Karen
G chlor
T pseu
P cf cord
POPULATIONS OF DIFFERENT SPECIES, FORMING HABs, SEPARATED BY FLOWCAM PARAMETERS

Thalassiosira pseudonana

L chlorophorum

Karenia spp.

Prorocentrum cf cordatum

Alexandrium catenella
POPULATIONS OF DIFFERENT SPECIES, FORMING HABs, SEPARATED BY FLOWCAM PARAMETERS

**Alexandrium catenella**

**Karenia spp.**

**Prorocentrum cf cordatum**

**Thalassiosira pseudonana**

**Lepidonomium chlorophorum**
Characterization and digital libraries of dinoflagellates using FlowCam from Chilean fjords
Damaged cells of *A. catenella* after decline of summer 2018 bloom in Archipelago of Chonos
CONTRIBUTION OF THE HABf INDEX FOR FISH FARMS RISK ANALYSIS

Alejandro Clemente 1, Thomas Honoré 1, Sofia Clément 1, Francisca Muñoz 1, Marcela Saldivia 1, Carmen Brito 5, Roberta Cresmin 1, Nicole Corena 1, Karolina Telgrod 1, Stephanie Sánchez 1

Note: most are women, Plancton Andino, Puerto Varas 1, Castro 1, Coyhaique 1, Chile

OZOF Puerto Montt 1 Chile

Proud to celebrate 20 years creating service, value and human capital

ABSTRACT

In recent years in southern Chile we observed numerous HAB events, particularly with flagellate species, which have been causing problems in fisheries and aquaculture. We have been monitoring and studying intensively the Chilean fjord ecosystem with emphasis on phytoplankton species, their phenotypic diversity, and risk characterization and distribution with FlowCam and remote-sensing water color.

All the above results are valuable information as we develop an understanding of the oceanographic and climatic significance of the HAB events. However, we need in addition an on-line indicator such as HABINDEX for the fish farmers, authorities and generausers.

The HABINDEX is based upon a relatively simple algorithm that considers different weighting factors and risk coefficients of each harmful alga abundance divided by its critical or threshold value for fish.

We have tested the HABINDEX retrospectively, checking large datasets connected directly to a server and a business intelligence software (BI). While the preliminary results of the HABINDEX show a close correlation with harmful algae blooms impacts on salmon farms, there are few challenges to solve.

INTRODUCTION

Southern Chile is an important marine ecosystem that offers multiple services for society and economic development. HABs are increasing in frequency, magnitude, and duration worldwide (Gilbert et al. 2014), but it seems that climate anomalies are playing an important role as one of the triggering factor (Clément et al. 2017; Lamblin-Muñoz et al. 2018).

One of our major focus is to use pollution-free technology for monitoring HABs. The local companies have been monitoring for more than 20 years (Clément & Gamale 1995; Clément & Lembeye 1996; Gamale & Clément 2016; Seguel et al. 2005), being A. carterae, Pedinomonas spp., and Heterosigma spp., the main species of concern.

Under this biological environment we have developed an HABINDEX to improved monitoring data visualization for authorities and fish farmers.

Andersen et al. (2014) develop an interesting HAB index for shellfish toxicity for the coastal environment of Maine. Also exists the E. coli HAB index (EERI), based upon remote-sensing detecting and classifying the toxic diatom plume (Fuarda et al. 2009).

METHODOLOGY & RESULTS

HABINDEX is a simple algorithm of a series of variables and coefficients, such as water column weighted average concentrations of phytoplankton and a specific harmful algae in relation with the critical or threshold value from a water sample from a marine fish farm.

After year 2002, in at least two cases, it has been observe blooms of Gymnothorax danicus during several weeks in Southern Chile and then blooms of Prorocentrum.
FINAL REMARKS

1. Thin layers formation, sub-surface max, above pycnocline based on cells counts, \textit{in situ} Chl, Bb(\(\lambda\)), Fv are essential features of \textit{P. verruculosa} bloom, in addition ichthyo-toxicity. More info Andersen et al Hansen, Hallegraeff, Ishimatsu

2. FRRF3 is very useful tool for HAB monitoring, particularly during high Chl values (> 5 mg/M3) \textbf{and small sizes cells}. Aysén Fjrod case.

3. It is feasible as a proxi \textit{in situ} and/or \textit{in vitro} bio-optical/physical techniques to monitor HABs but demand a lot of data processing.

4. Phytoplankton OC-Rrs & bio-optical techniques have been studied for more than 35 years, however, is hard to predict Phytoplankton Functional Types (PFT) in \textbf{optically complex waters}, (IOCCG 2014, Bracher et al 2017).

5. The combination of standard microcopy, molecular biology, active Fluorescent (Fv/Sigma), cell imaging, IOP and RS OC are useful technique for monitoring optically complex waters. The challenge is data management, integration, modelling and \textbf{forecasting HABs}

This study was support by POAS, Fondef, CORFO, Plancton Andino