Harmful Algae News

An IOC Newsletter on Toxic Algae and Algal Blooms

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Mar Menor lagoon: an iconic case of ecosystem collapse

"Dead zone" illustrating the devastation after the autumn 2019 anoxic event in Mar Menor (Murcia, SE Spain). Photo: Javier Murcia Requena

Mar Menor (W Mediterranean, Spain) is the largest hypersaline coastal lagoon in Europe. In spring 2016, chl *a* concentration exceeded the average values ($\leq$ 1 µg L^{-1}) reported for this variable since reliable measurements started in the 1980's [1] by two orders of magnitude. The high values of 2016 were unprecedented and pointed to a "phase change" in the eutrophication process of Mar Menor initiated many years before by a long history of anthropogenic pressures including urban discharges, intensive agriculture, livestock, dredging, construction of marinas, artificial beaches, etc.

In 2016 pollution was so severe that a collapse of the lagoon ecosystem was feared. Light penetration was reduced to values below the threshold required to sustain photosynthesis by benthic macrophytes, which were the main primary producers in the lagoon system that strongly influenced ecosystem functions and services [2]. This situation led to the mobilization of thousands of tons of carbon and nutrients that followed death and decomposition of the macrophyte meadows below the 2.5 m isobath (Fig. 1).

Ecosystem disruptive Algal Blooms

Analysis of the phytoplankton community during the acute eutrophication events confirmed the key role played by the cyanobacterial genus *Synechococcus* [3]. Similar events triggered by species of the same genus in other semi-enclosed systems around the world had been reported before. These microalgal events are known as 'ecosystem disruptive algal blooms' EDABs. Unlike other HABs developed in open coastal areas, they are produced by a large variety of small-sized phytoplanktonic species (cyanobacteria, pelagophytes, trebouxiphytes, eustigmatophytes, haptophytes, dinoflagellates) that share some common traits e.g. the capacity to use alternative sources to inorganic nitrogen, as well as being toxic and having low palatability for grazers [4]. The high availability of regenerated nutrients in Mar Menor combined with the disruption of the food web dynamics led to a massive bloom of *Synechococcus*. This bloom triggered a feedback process that lasted for months and deeply modified the system. The *Synechoccus* EDAB was the unambiguous signal that some

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Content

Featured articles

Mar Menor lagoon: an iconic case of ecosystem collapse, *Juan M Ruiz, Jaime Bernardeau-Esteller, M Dolores Belando & Jesús Mercado* 1

The Mar Menor Oyster Initiative, *Eve Galimany, Sebastián Hernandis, Angel Hernández-Contreras, Francisco Gómez, Marina Albentosa & Fiz da Costa* 6

Extreme toxic events in Chile

Multi-specific toxic HABs in Chilean Fjord: A dangerous cocktail 8

Red Tide Adaptation and Response Network (REARMAR) 10

High Biomass HABs in new places

Unprecedented HABs in beaches of Rio, Brazil 12

Blooms of *Scrippsiella* in tropical estuary, Bahia State, Brazil 14

Limnoraphis robusta blooms in Hanabanilla reservoir, Cuba ... 15

Networking and International Cooperation

IOCARIBE HAB-ANCA launches 360 virtual reality courses 16

MixONET, new SCOR WG # 165 on Mxotrophy 17

GlobalHAB

GlobalHAB/EuroMarine WS on HAB Modelling and Prediction 19

The GlobalHAB SSC meets again 20

Forthcoming Events 22

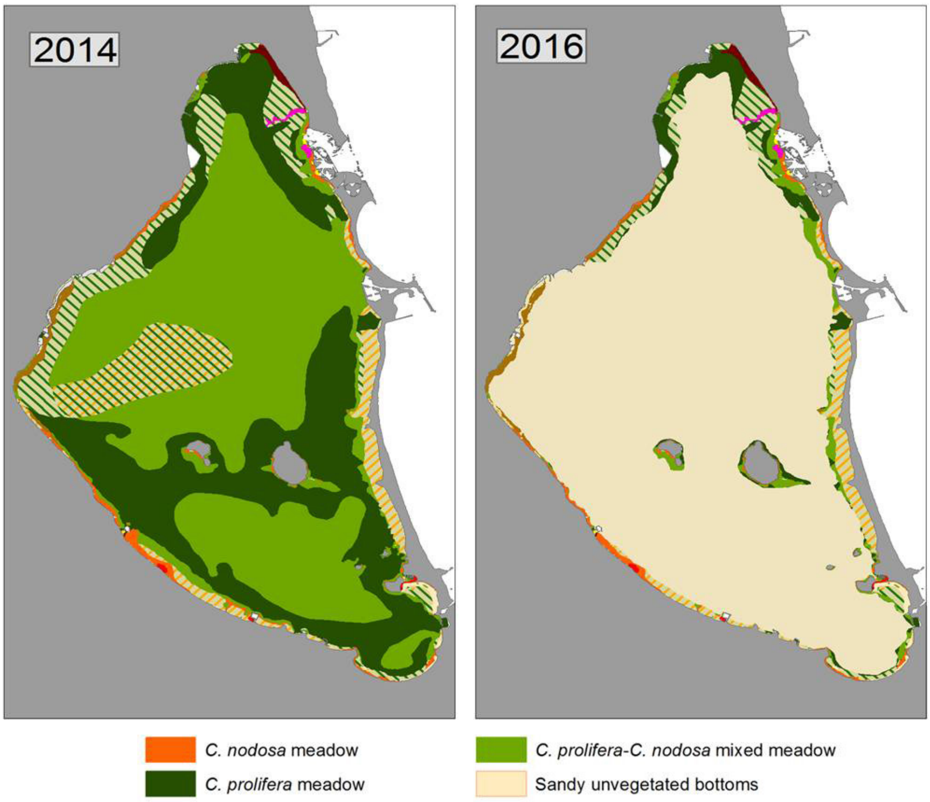

Fig. 1. Maps of macrophytes assemblages in Mar Menor lagoon before and after the 2016 anoxic event. Drastic changes in the distribution of the two dominant macrophyte species, the green alga Caulerpa prolifera and seagrass Cymodocea nodosa, are illustrated

thresholds, known in ecological theory as *tipping points*, had been crossed. Tipping points are levels of pressure beyond which the ecosystem can no longer cope with change, and suddenly shifts from one state to another (*ecosystem shift*), usually more deteriorated, but equally stable state [5].

How did this iconic ecosystem reach this condition?

In the first place, it is necessary to know the environmental framework of Mar Menor, a shallow (maximum depth 7m) hypersaline coastal lagoon with a catchment basin of 1,300 km^2 and a water renewal time of about 1 year [6]. According to available information on the semi-arid climate prevalent in the SE Iberian Peninsula, the only freshwater inputs to the Mar Menor are from runoff associated with a few torrential rains which occur every year (250 mm year^{-1}), and some more diffusive groundwater inputs. Recently developed models [7] indicate that the current input from runoff is quantitatively more important than that from aquifers. Nevertheless, the little and dispersed data available are not sufficient to provide reliable data for lagoon management.

1. Impact of the Estacio channel widening

In 1973, widening of the Estacio Channel, one of the five natural connections ("golas") between the lagoon and the Mediterranean, was carried out [8]. This public work, now considered a landmark of the anthropogenic transformation of the lagoon, changed the hydrodynamic regimen and led to a decline in salinity, from 50-52.5 in the early 1970's to the current values (42-48) which show an interannual variability determined by the frequency and intensity of the "DANAS" or "gota fría", i.e. intense cold spells bringing heavy rainfall. The increased exchange favoured the entry of some Mediterranean species and the decline of some others, members of the autochthonous fauna and flora. Water exchanges through the Estacio channel are now the main control of the lagoon hydrodynamics. One of the most favoured introduced species was the green macroalga *Caulerpa prolifera*, a well-known opportunistic macrophyte able to take up nutrients very efficiently and colonize extensive areas rapidly. This species has properties conferring the ability to outcompete native macrophyte assemblages, in particular meadows of the seagrass *Cymodocea nodosa* present in Mar Menor at least in the last decades. *Caulerpa* contains high levels of toxigenic secondary metabolites and contributes loads of labile organic matter to the sediments. Decomposition of this organic matter fuels anoxic processes and increased levels of reduced carbon, nitrogen and sulphur compounds.

2. Introduced macroalgal species and uncontrolled wastewater discharges

There is no argument about the increased primary production and deposits of organic matter sedimented in the lagoon during the last 60 years [9], but the negative impact of these changes on the ecosystem may have been overestimated, and conclusions have not been based on scientific evidence. A good example of this criticism concerns the supposed regression of native seagrass meadows, in particular *C. nodosa*, as a consequence of the expansion of *C. prolifera* [10]. Recent studies have confirmed that angiosperms did not decline during the decades preceding the collapse. Conversely, these studies provided evidence of the coexistence of the two macrophytes at least during the last forty years before the 2016 event [11] (Fig. 2) indicating a benthic primary production enhancement. Increased primary production supported by high availability of nutrients is an intrinsic feature of eutrophic ecosystems [12]. Therefore, man-made changes induced on the lagoon hydrodynamics were not the only factor that explained the expansion of *C. prolifera*.

Uncontrolled discharges of untreated wastewaters from urban and tourist developments took place years before the channel widening. In the 1990's, the wastewater treatment plan for Mar Menor was completed and wastewaters were no longer flushed into the lagoon (at the expense of being discharged into adjacent Mediterranean waters). Nevertheless, problems related with high nutrient inputs persisted or even increased due to the rapid development of intensive agriculture which started in the 1950's [13]. This kind of agriculture replaced the traditional drylands at the expense of aquifer overexploitation. The new agricultural practices marked another step towards deterioration of the lagoon [14]. Today, the irrigation area occupies 40% of the total drainage basin and is a major source of European winter vegetable production. But the transferred water resources, clearly insufficient to sustain such production, had to be complemented with aquifers that had suffered previous overexploitation and became brackish. These brackish aquifers needed treating in desalination plants which systematically diverted their nitrate rich (up to 600mg L^{-1}) waste into the lagoon. The intensive agriculture activities increased the nutrient load of the aquifers (ca 150 mg nitrate L^{-1}).

The fact that after decades of massive inputs of nutrients, these were not reflected in any apparent damage to the lagoon is paradoxical. At least until 2016, relatively clean waters and seabeds dominated by conspicuous communities of benthic macrophytes [15] were observed. In fact, different experimental approaches have provided evidence that before the collapse, macrophyte meadows played a key role in the control of man-driven nutrient inputs in the lagoon [16]. Benthic communities of filter feeder, in particular bivalve molluscs such as the flat oyster (*Ostraea edulis*) and the giant Mediterranean fun mussel, or Nacra (*Pinna nobilis*), that reached populations of 135 and 1.4 million individuals respectively [17, 18], may also have contributed to this control although specific studies supporting such hypothesis do not exist.

3. Alternative hypotheses

Another possible mechanism to explain the abovementioned paradox is stoichiometric imbalance of the main macronutrients (N, P, Si). For example, phosphorus is not very abundant in groundwaters, and its input to the lagoon mainly takes place by surface runoff through the watershed. Therefore, inputs of different nutrients are uncoupled in time and space. Intensive agriculture is a major cause of soil erosion and N and P transported by runoff have contributed to a sharp rise of nutrients in the lagoon in recent decades. In addition, climate change is expected to contribute to increase the frequency and intensity of extreme climate events.

As an example, during the 2019 DANA, about 60 million m^3 of water containing between 150 and 190 t of dissolved phosphate entered the lagoon [1] (Fig. 3). Phosphates are immediately taken up by the vegetation and/or deposited in the sediments, and only after resuspension and/or remineralization may become bioavailable again. There are other mechanisms, such as denitrification that may contribute to recycling but unfortunately, knowledge about biogeochemical cycles in the Mar Menor and its associated basin are practically non-existent. These cycles, together with the sources of the elements integrating them, the relative importance of each one and the entry routes and transformation processes are crucial aspects that need to be unveiled before taking measures to reduce the nutrients load and recover the ecosystem.

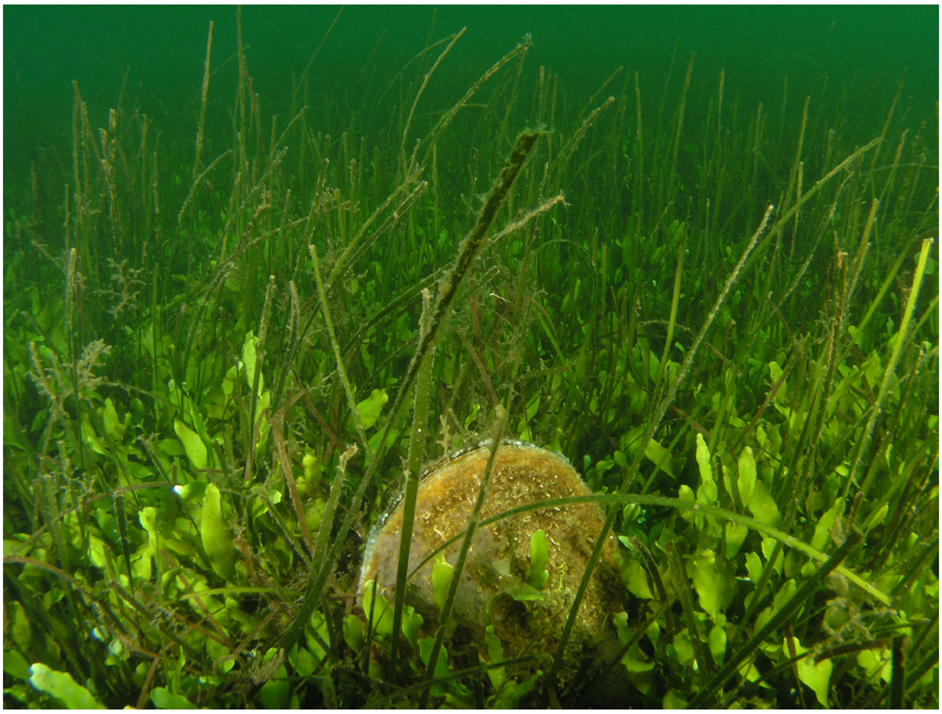

Fig. 2. Before the 2016 event, benthic macrophyte communities with dominance of seagrass Cymodocea nodosa (thin long leaves) and chlorophyte Caulerpa racemosa (wider shorter fronds) occupied large areas in Mar Menor. The giant fun mussel Pinna nobilis was a typical bivalve species in this ecosystem. Underwater photo taken in summer 2014 at 5 m depth in a site where the seagrass has completely disappeared. Photo: Juan M. Ruiz

A new alternative state?

As a result of the collapse in 2016, a large part of the lagoon resilience mechanisms and its ecosystem services were severely damaged. Eighty-five per cent of the macrophyte meadows extension and 95% of the giant mussel *Pinna nobilis* [2, 18], both with key roles in the control of nutrients and dissolved organic matter in the water column, were destroyed. The loss of these control mechanisms was clear evidence of the degree of deterioration reached (Fig. 4). Unfortunately, very little information is available about other components of the lagoon ecosystem to give a global evaluation of the disaster. Nevertheless, the reported losses agree with the growing feeling that the lagoon is nowadays a much more unstable system as compared with decades ago, more fluctuating and more vulnerable to environmental changes. In fact, since 2016 there has been a succession of phytoplankton blooms and high turbidity alternating with periods of clear water. But in contrast with the massive bloom of *Synechococcus* reported in 2016, blooms from recent years were dominated by the diatom genera *Nitzschia*, *Cyclotella*, *Cylindrotheca* and *Chaetoceros*, with the potential to trigger low oxygen events that threaten marine organisms as was the case during the mass mortalities of fish and other components of the wild fauna and flora in summer 2021. The first mass mortality event occurred in autumn 2019 (Fig. 5), although in that time it was forced by strong and persistent water column stratification after the massive discharge of freshwater into the lagoon (Fig. 3). These extreme events are characteristic of coastal areas in an advanced process of eutrophication. Nevertheless, despite their huge negative socioeconomic impact, little is known about the drivers and mechanisms behind the unreported high biomass HABs before the 2016 event.

Fig. 3. Satellite image (Sentinel 2) after torrential rainfall in September 12th and 13th in the Mar Menor watershed. Tons of terrigenous sediments, carbon, nitrogen and phosphorous are dragged by water runoff from agricultural lands into the Mar Menor lagoon (downloaded from https://www.copernicus.eu/)

Some of these events occurred without a previous increase in dissolved inorganic nutrients. This shows that these blooms are regulated by highly unstable biological processes, probably linked to the activity of other trophic levels, such as the bacterial control of the N cycle or benthos-mediated changes in vertical fluxes of nutrients. In any case, there is hardly any knowledge about the mechanisms behind the uncoupling of these processes. Understanding these processes is essential for a better assessment of ecosystem health to provide to decision makers

The foregoing indicates that a sound scientific knowledge of the Mar Menor and its associated basin ecosystem is a challenge that needs to be faced. Let's hope that the last disastrous events represent a tipping point for the authority's lack of awareness, and that it leads to a commitment to recover this unique ecosystem.

Acknowledgements

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Fig. 4. Following the collapse, high biomass blooms of filamentous and mucilaginous algae are observed with increased frequency in periods of nutrient-enriched freshwater discharges. These algal masses, now common in spring months, suffocate benthic communities and promote sediment anoxia. Photo: Javier Murcia Requena

provided by President and Staff of the harbours Club Nautico Lo Pagán, Club Náutico La Puntica and Centro de Actividades Náuticas (San Pedro del Pinatar, Murcia, Spain).

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Fig. 5. The Mar Menor noxic event in September 2019 was so severe and extensive that bivalves from infaunal communities could not tolerate oxygen depletion in the water column (top) and fishes were not able to escape and died. Photo: Javier Murcia Requena

JuanMa Ruiz. Research Professor, IEO-CSIC

The Mar Menor Oyster Initiative, a strategy to prevent algal blooms in a eutrophic lagoon in Spain

Fig. 1. Map of study in Mar Menor, Murcia, SE Spain

Marine ecosystems are exposed to a wide range of pressures including water quality degradation, habitat decline, overfishing and climate change, in some instances leading to negative environmental, social and economic consequences. Different approaches can be taken to ameliorate the multiple human stressors altering the oceans, including the restoration of services which have declined through oyster restoration [1]. Oysters provide a variety of ecosystem services and are recognized for their potential to contribute to developing Blue Economies. From water quality improvement to sustainable maintenance of good habitat condition and coastal resilience, oysters can contribute to Nature-Based Solutions to restore impaired aquatic ecosystems [2]. Fossil records provide evidence that these essential services have been developed for millennia but bivalve stocks have decreased worldwide and with their disappearance, coastal ecosystems have also lost their ecologic and economic services [3]. Further declines in water quality and habitat serve as stressors to the bivalves that remain, which may lead to increased disease prevalence or feeding suppression, which can add to the loss of services provided.

Typically, coastal lagoons suffer from anthropogenic actions including the massive release of nutrients causing eutrophication (often associated with high biomass harmful algal blooms (HB-HABs). HABs are natural phenomena which may pose risks to human health, environmental sustainability and/or aquatic life due to the production of toxins or the accumulated biomass when increased production is no longer balanced by grazing [4]. In this last case, the high biomass from large algal blooms formed in eutrophic ecosystems may led to a cascade of negative ecological effects including seagrass mortality, fish kills and oxygen depletion [5]. For example, the harmful brown tides caused by the pelagophyte *Aureoumbra lagunensis* have led to seagrass die off and massive fish kills in Texas and Florida (USA) for their high concentration and persistence but not for the release of toxins [6]. Different ecosystems have suffered the effects of algal blooms, including the Mar Menor, a coastal lagoon suffering from severe eutrophication in Western Spain (Fig. 1). This is one of the largest hypersaline coastal lagoons in Europe with an area of about 135 km^2 and an average depth of 3.6 m (maximum 7 m). This lagoon ecosystem is particularly vulnerable to the impacts of human activity because it is a semi-enclosed body of water with a 1-year water residence time. It is particularly affected by the intensive tourism and agricultural development experienced in the area during the last decades, which led to the overlap of several environmental protection measures [7]. Before the anthropogenic influence on the lagoon increased, it was characterized by its oligotrophic and hypersaline waters (70-53 ppt) with the seabed containing sediment with seagrass. After receiving an excess of nutrients during the last three decades, the lagoon suffered from a massive proliferation of plankton in summer 2015, a sign of a eutrophication process that collapsed the entire ecosystem [8] (Fig. 2). Algal blooms recurrently appeared in the following years being *Synechococcus* sp. the most abundant species in August 2016, November 2017 and January

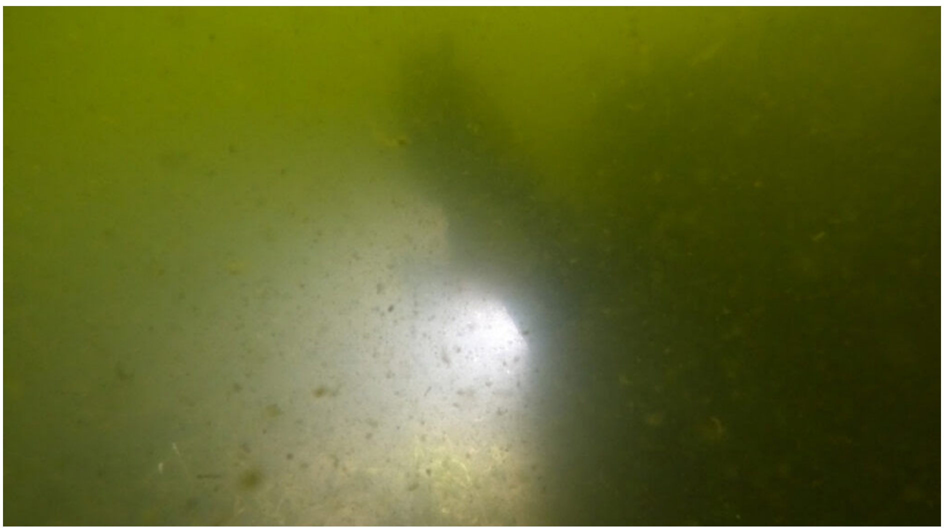

Fig. 2. High biomass microalgal bloom in the north basin of Mar Menor at 6 m depth. Photo ©P.García/ANSE on October 1st, 2021

Fig. 3. European flat oyster (O. edulis) in Mar Menor. Photo taken on February 25th, 2022

2018 with densities up to 6 x 10^6 cells mL^{-1} [9]. Mamiellophyceae also reached abundance peaks up to 4. x 10^6 cells mL^{-1} in 2016-2017 although this picoeukaryotic group was only present in sufficient abundance for quantification in summer or early fall [9]. The different recurrent algal blooms had cascading effects that ended in several mass mortality episodes and 70% mortality of seagrasses.

In an attempt to ameliorate the problems caused by algal blooms, and contribute to actions that must be put in place to decrease the introduction of nutrients to Mar Menor, a new initiative was launched in 2020 to use bivalves as a *Nature-based Solution* to filter the excess of phytoplankton in the water. Native European flat oysters (*Ostrea edulis*) (Fig. 3) had a population of 135 million oysters in Mar Menor in the late 80's but the last evaluation, carried out in 2006 reported an almost 10-fold reduction and the current status of the oyster populations in the lagoon is unknown [10,11]. With the oysters disappearing, the ecosystem services they provided were also gone. Knowing the historical natural abundance of the species in the area, and with the support of NORA (*Native Oyster Restoration Alliance*, https://noraeurope.eu/), the initiative aims to collect local oysters to use as broodstock, evaluate their filtration and reproduction potential, and restore the oyster seed obtained from an experimental hatchery, back to Mar Menor waters. Similar actions have been successfully implemented in lagoons in the USA, such as in Chesapeake Bay [12], but this is the first time to be proposed in a Spanish coastal lagoon. Recent funding has allowed the launch of *RemediOS* project (https://remediosproyecto.wordpress.com/), a proof of concept for the production of flat oyster seed with local broodstock from the Mar Menor. Several actions are taking place including the development of an experimental hatchery (Fig. 4) with scientific assessment and multiple outreach activities to engage the local community, fisheries and administrations associated with the initiative to help recover Mar Menor. The project collaborates with *ANSE* Foundation (https://www.fundacionanse.org/) to grow out the oyster seed in the Marchamalo salt flats, located in the south basin of the lagoon. The rationale of this project is to involve all interested stakeholders for successful large-scale restoration programs, which need public and political support, research, and outreach actions [13].

Fig. 4: Flat oysters in the experimental hatchery. Top: Broodstock; bottom: juveniles from hatchery larvae

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Multi-specific Harmful Algal Bloom in a Chilean Fjord: A dangerous phytoplankton cocktail

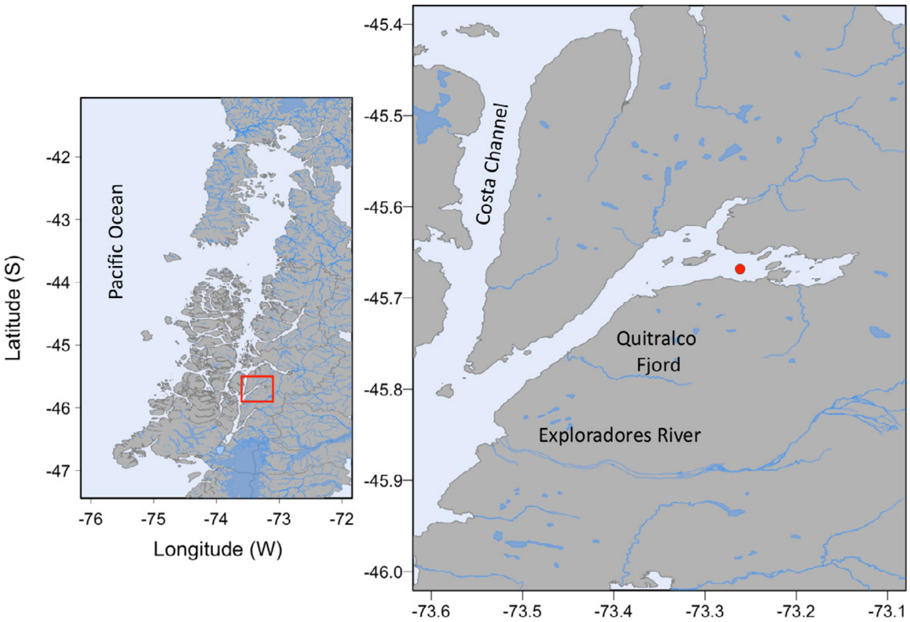

Fig. 1. Maps of study area showing: left, NW Patagonian fjords; right, Quitralco Fjord

Harmful Algal Blooms (HABs) in Southern Chile (Patagonian fjords) have followed the global trend of increasing reports and recurring negative impacts in the last decades [1,2]. Consequently, HABs in this fjord system have become a major problem that affects artisanal fisheries, aquaculture and tourist resources as well as coastal and inland ecosystems, and public health [3]. Recurrent events of Paralytic Shellfish Toxins (PSTs) producing species *Alexandrium catenella* pose the main threat to aquaculture and public health in Southern Chile [3]. Amnesic Shellfish Toxins (ASTs) events caused by the diatom genus *Pseudo-nitzschia* and Diarrheic Shellfish Toxins (DSTs) by endemic *Dinophysis* species (*D. acuta* and *D. acuminata* complex— producers of Okadaic Acid (OA) derivatives and Pectenotoxins, PTX) also threaten the Patagonian fjords ecosystem [1]. In addition, blooms of Yessotoxin (YTX) producers, such as the dinoflagellate *Protoceratium reticulatum,* recurrent in Southern Chile, have been associated with mass mortalities in Northern Chile [4].

In 2022, an intense summer bloom of toxic species, *Pseudo-nizschia* spp, *Alexandrium catenella*, *Dinophysis acuminata* and *Protoceratium reticulatum,* was detected in the southern fjords of NW Patagonia (Fig. 1A). The Quitralco Fjord, located south of the Aysén region, was the area most impacted (Fig. 1B). This diverse Harmful Algal Bloom (HAB) generated intense brown patches of water close to the head of the fjord (Fig. 2). In February 22, measurements of physical-chemical properties were carried out at a station inside Quitralco fjord to study fine-scale distribution of the HAB species. Vertical distribution (CTD profiles) of temperature (°C), salinity, *in vivo* fluorescence (equiv. µg L^{-1} Chl-*a*) and dissolved oxygen (mL L^{-1}) as well as water samples at 2m intervals from surface to 20 m (Niskin bottles) for microphytoplankton analyses were collected.

CTD profiles showed a stratified water column with salinity ranging from 26.8 to 29.5 and temperature from 13.5 °C to 10.5 °C between surface and 20 m (Fig. 3A). An intense subsurface chl-a maximum (SSCM) was detected from 3 to 5 m, with a maximum of 22.6 µg L^{-1} at 4 m depth (Fig. 3A). The phytoplankton community was dominated by *Pseudo-nizschia* (72%) and the dinoflagellate *Alexandrium catenella* (10%). Maximum cell densities of *Pseudo-nizschia* spp. (2 x 10^6 cells L^{-1}) and *A. catenella* (267 x 10^3 cells L^{-1}) were detected at 4 m depth, coinciding with the chl *a* maximum (Figs. 3B, C). High densities of *D. acuminata* (6.0 x 10^3 cells L^{-1}) and *P.*

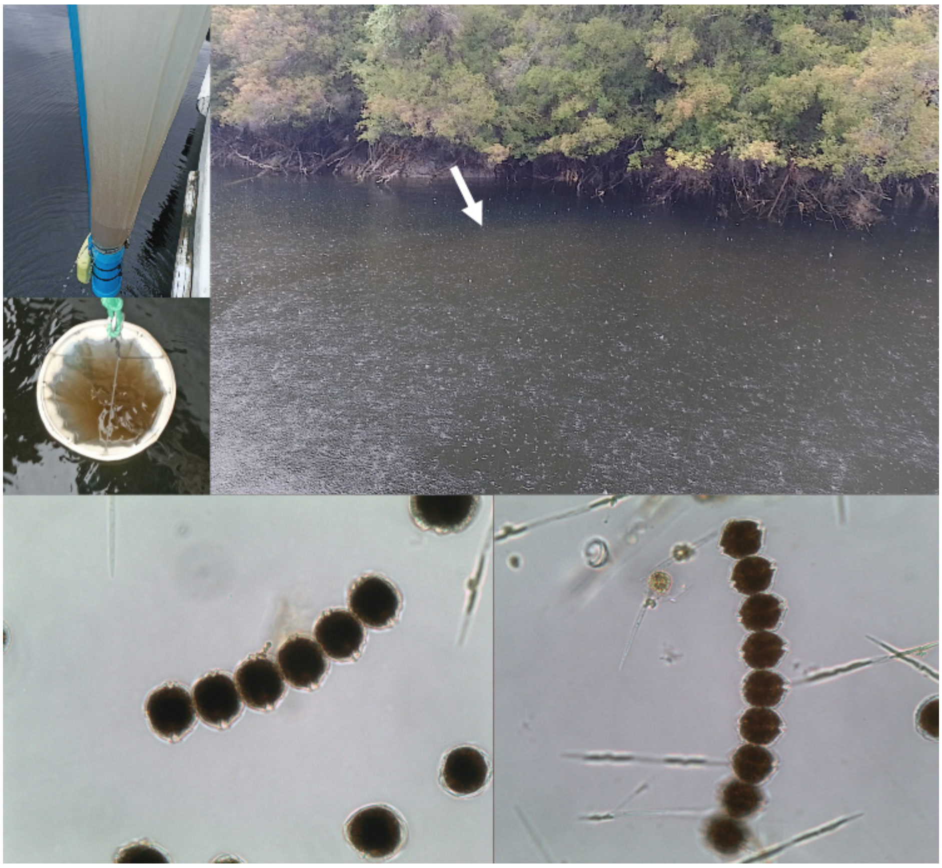

Fig. 2. Photographs of the red tide (upper panel) and light microscopy micrographs of Alexandrium catenella and Pseudo-nitzschia spp. (lower panel) from Quitralco Fjord

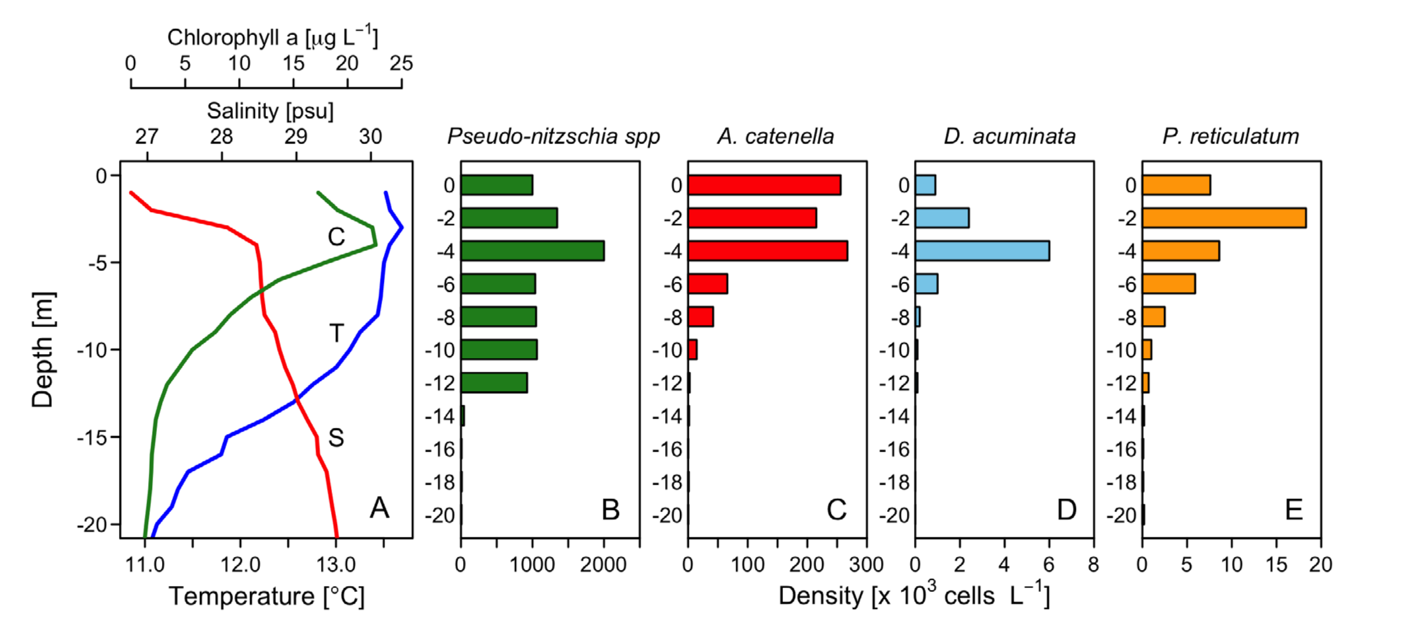

Fig. 3. Vertical distribution of A) temperature (blue line), salinity (red line) and chlorophyll a (green line); B) Pseudo-nitzschia spp; C) A. catenella; D) D. acuminata; E) P. reticulatum at a sampling station close to the head of Quitralco Fjord on February 22, 2022

reticulatum (18.3 x 10^3 cells L^{-1}) were detected in the same surface layer (Figs. 3D, E).

The bloom caused six human intoxications including two fatal cases and serious ecosystem loss. Fish mortalities (juvenile hake) were observed close to the head of this fjord. According to official reports from the Chilean Health Ministry Monitoring Programme record levels of PSP toxins (~14 x 10^3 µg STX eq. 100 g^{-1}) were found in clams (*Ameghinomya antiqua*) from Quitralco Fjord at the time of this event. The magnitude of these toxicity levels is similar to that recorded during the summer 2009 bloom of *A. catenella* [3]. Nevertheless, unlike the 2022 event the 2009 episode was caused by a monospecific bloom of *A. catenella* [5]. Although the Patagonian fjord and channel system have a high recurrence of HABs, multispecific blooms of toxic species are rare because each species exploit a different environmental niche. Thus, while optimal growth of *A. catenella* is observed in high salinities (~35) [6], *D. acuminata* and *P. reticulatum* occur in areas with high thermohaline stratification [7]. Different HAB species, even if belonging to the same genus, may exhibit distinct responses to changing environmental conditions [8]. This multispecific bloom gives a unique opportunity to determine the realized niche of these four toxic species and identify the optimal environmental conditions that they exploited during this event. *Pseudo-nitzschia* spp. showed a broader realized niche with greater tolerance to environmental conditions, in contrast to *A. catenella* that showed a smaller niche, being mainly restricted to the surface layer (0-4 m). *Dinophysis acuminata* and *P. reticulatum* showed a similar niche.

Considering the synoptic climate in the Chilean Patagonia (declining precipitation; 5-7% per decade and global temperature increase), these intense HAB events may become more recurrent in the coming years. Finally, the occurrence of this type of toxic phytoplankton cocktail may have synergistic effects and increase the risks for public health (human intoxications) as well as social and ecosystem impacts (invertebrate and vertebrate mortalities) and substantial economic losses.

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Red Tide Adaptation and Response Network (REARMAR): bridging local, scientific and policy knowledge for small-scale benthic fisheries in the northern Chilean Patagonia

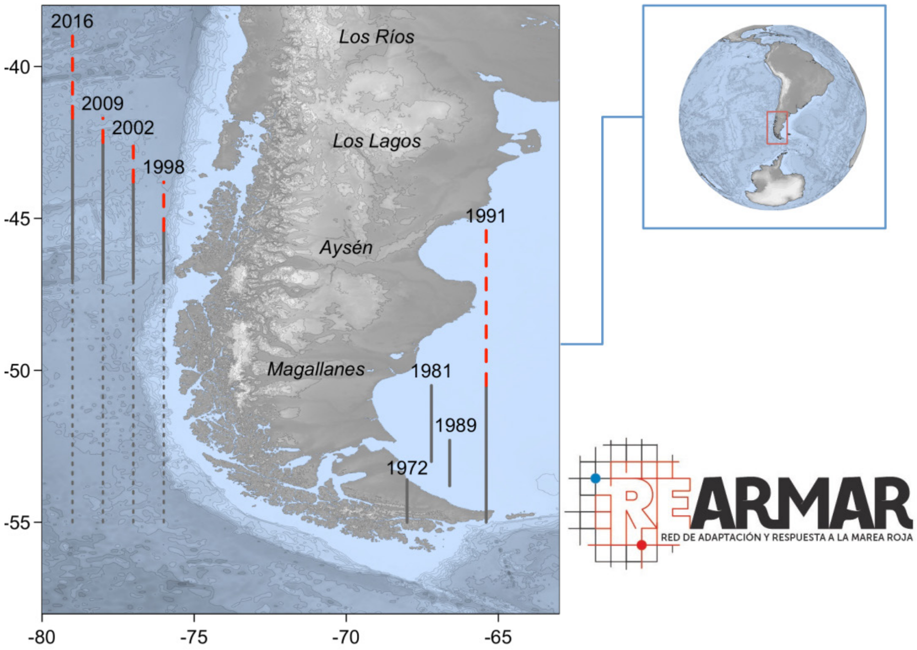

Fig. 1. Expansion of Alexandrium catenella-related PSP outbreaks recorded in the last four decades in Chilean Patagonia. Dashed lines indicate: red, the northward progression with respect to the last bloom; grey, the northward shift of the centre of gravity of PSP events distribution, from the Magellan to Aysén Region. Modified from Guzmán et al. [2].

Harmful Algal Blooms (HAB), particularly toxic blooms of the dinoflagellate *Alexandrium catenella*, have shown an impressive geographical expansion along the Chilean Patagonian coast in the last 50 years (Fig. 1). After the first confirmed fatal case of Paralytic Shellfish Poisoning (PSP) in Magallanes in 1972, *A. catenella* blooms have been reported to expand northward in the following decades at 44 Km per year. In 2016, the presence of toxic PSP events above regulatory levels expanded more than 230 km north from the latest known limit in Canal de Chacao (41°47'S) up to Mehuín (39°26'S) [1].

In Chile, various regulatory and policy initiatives have been put in place to address health and economic problems derived from HABs. In 1995, the "National Program for Prevention and Control of Red Tide Intoxications" was created under the Chilean Health Ministry. Ever since, permanent sampling of shellfish landings for toxin analyses has been carried out in key regional ports where PSP occurrence is confirmed. During extended closures, the government has often implemented subsidies to mitigate the economic effects of HABs on formally registered artisanal fishermen. In addition, 'risk' communication campaigns are frequently developed to protect fishermen and consumers from the potential threats of PSP on human health. The main foci have been to detect and prevent the sale and consumption of contaminated shellfish resources, and to mitigate economic impacts on fishers. Nevertheless, efforts to build long term adaptive capacities among resource users and managers have been limited.

More extended coastal areas affected by HABs imply increased numbers of impacted fishing communities. During the severe 2016 PSP event an estimate of 15,200 fishermen, divers and gleaners operating in the zone were affected by sanitary closures. High levels of toxins were detected in the flesh of key target species harvested, including clams (almeja, *Ameghinomya antiqua*), ribbed mussels (cholga, *Aulacomya atra*), mussels (chorito, *Mytilus chilensis*), hard razor clams (navajuela, *Tagelus dombeii*) and loco (*Concholepas concholepas*).

In what ways do HABs impact inexperienced fishing communities? Several interviews and workshops carried out in fishing villages or *caletas* affected by HABs in 2016 for the first time revealed that coastal communities were lacking the capacity to make sense of and cope with this new threat (Fig. 2).

- Fishermen alleged insufficient information and education about HABs. Public health teams and fishermen had no previous relationship when shellfish sampling started; hence, rapport had to be built from the ground up. Participants also expressed that the presence of HAB experts and researchers in the field when PSP toxin levels peaked —to exchange knowledge and experience—was missed; e.g. knowledge about toxin detection methods was lacking. In addition, existing communication channels between local

Fig. 2. Word cloud of experiences reported by workshop participants during their first HAB event in 2016 (larger font sizes represent higher use frequency).

fishermen leaders and fishery and health authorities were considered inappropriate. Several coordination problems arose when an authorized 6,000 loco landing could not be placed on the market because results of laboratory tests —detecting toxins slightly above the regulatory limit (80 ug STX eq. 100 g meat)— arrived too late to the *caleta*.

- Information and understanding gaps were quickly filled with rumors and beliefs about the origins and causes of HABs. Fishermen' discontent and frustration when their activity was forbidden led to their explanations and search for liable parties. In some *caletas*, people observed rare environmental signals the days before the official HAB alert, such as an increase of water temperature, intense brown patches, and invertebrate and seabird mortalities. The red tide event was therefore associated with human intervention and industrial pollution. An overall climate of suspicion and mistrust prevailed among fishing communities in their relationship with authorities and other local and regional parties.
- The arrival of HABs to their fishing zones, a dire threat to sustaining their livelihood, is considered to have increased the uncertainty to which they were already accustomed. In addition to changing conditions in climate, market and resource availability, the potential presence of PSP toxins in some of the economically important resources implies reduced stability and predictability. In some *caletas*, landing closures lasted over 18 months, negatively impacting families' income and traditional diet. This forced resource users to rely on or shift to other economic activities, such as farming and cattle raising, foresting, or professional diving. As a critical warning, benthic fisheries in the southern Aysén Region, where high levels of PSP toxins exist almost permanently, have dramatically declined in the last decades due to HAB effects. Therefore, shaping different future trajectories becomes an urgent need for fishers in northern Patagonia.

Fig. 3. During the "Red Tide Tour", fishermen leaders from Los Ríos Region visited the Health Service Laboratory in Puerto Montt, where shellfish samples are analyzed.

In 2019, the Red Tide Adaptation and Response Network (REARMAR) was created to address increasing disinformation, distrust, and uncertainty among fishermen organizations. The vision of REARMAR is to offer a learning platform to co-create relevant HAB knowledge and bring fishermen and scientific and policy actors together. Drawing on a social capital framework [3], weaving the network has included activities connecting different scales and closing existing knowledge gaps. Workshops were held to 1) nurture bonding (social glue) and bridging relationships (social lubricant) by exchanging people's experiences and concerns about red tides at the *caleta* level and also between *caletas* affected by HAB; 2) foster linking ties (social pipelines) between fishermen and researchers to share people's communications and discuss the state-of-the-art of scientific knowledge about HABs; 3) improve communication between fishers and sanitary authorities and to open the "black box" of PSP toxin analysis and detection. As shown in Fig. 3, the "Red Tide Tour" brought fishermen leaders from distant *caletas* in Los Ríos Region to visit the Health Service Laboratory in Los Lagos Region. They witnessed the procedure followed to detect PSP in samples taken from their shellfish landings, aiming at increasing trust and legitimacy among parties. REARMAR is also committed to science communication initiatives, such as micro documentaries [4], opinion columns, and online social platforms [5].

Conventional approaches to respond to HAB impacts have mostly focused on health problems, top-down command and control policies, and an early detection approach. More initiatives such as REARMAR are necessary to boost such efforts, and to enhance a fisheries management focus, bottom-up and participatory strategies, and proactive and adaptive approaches in Chile and elsewhere.

Acknowledgements

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An unprecedented harmful algae bloom in the beaches of Rio, Brazil

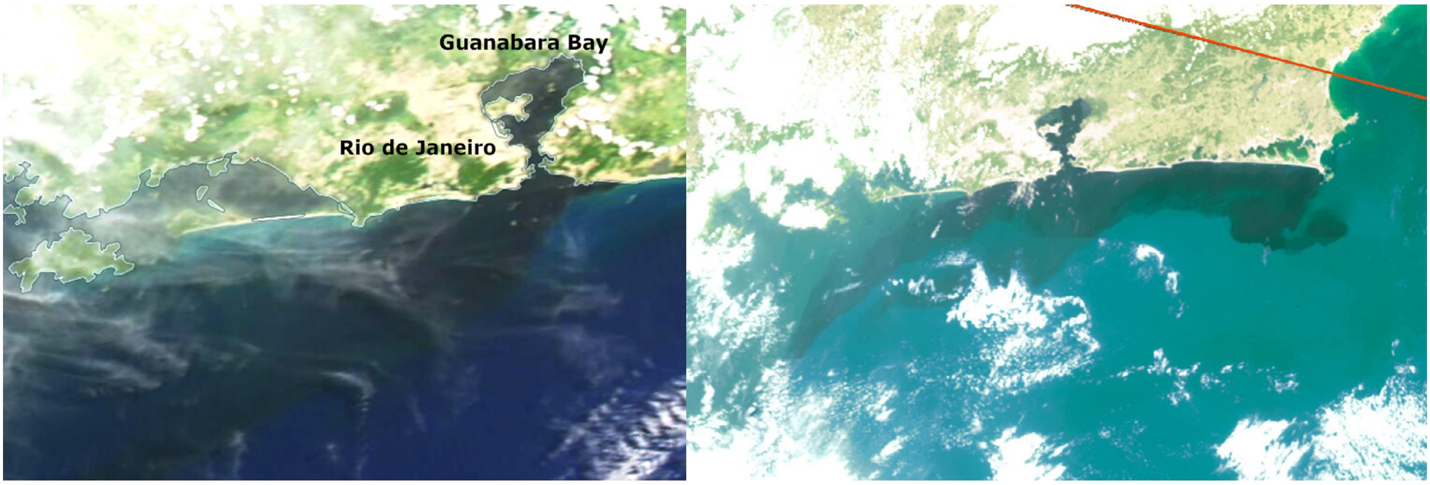

Fig. 1. Images acquired by Sentinel-3's Ocean and Land Colour Instrument – OLCI, on A) November 16th, 2021; B) December 5th, 2021. The dark water patch indicates the algal bloom. Source: Priscila Kienteca Lange, UFRJ

An extensive and long-lasting bloom tinted the waters of the famous Copacabana and Ipanema beaches in Rio de Janeiro city in late austral Spring 2021. The bloom was first seen on satellite images on November 3rd, 2021, and water samples taken on November 16th from the western part of the city of Rio (Recreio beach) revealed that the darkred patches were dominated by the ciliate *Mesodinium rubrum*, together with the flagellate *Tetraselmis* sp. This flagellate is common in Guanabara Bay (GB) and a satellite image from 16th November 2021 showed dark waters coming out from GB towards the beaches of Rio (Fig. 1a).

Two weeks later (3rd of December), coastal currents transported the bloom easterly towards Arraial do Cabo, a scuba dive paradise, where the usually clear waters became dark brown. This massive bloom was evidenced in satellite images from December 5th, 2021 (Fig. 1b). The beaches of Rio city were dark brown with a pink foam during several days in December (Fig. 2). Water samples were taken from several beaches in Rio and from Arraial do Cabo for phytoplankton species identification and quantification and for pigment analysis by HPLC and are still under analysis.

Preliminary results showed that, on the 6th of December, filamentous cyanobacteria of the family Pseudanabaenaceae, *Tetraselmis* sp. and *Scrippsiella* sp. were abundant in Rio beaches. Pseudanabaenaceae are generally dominant in GB during spring and summer, while the dinoflagellate *Scrippsiella trochoidea* is often found in high abundances in the bay [1]. At Arraial do Cabo in the same day, the bloom was mainly composed by *Tetraselmis* sp., *Scrippsiella* sp. (Fig. 3) and one unidentified dinoflagellate species. The presence of the pigment gyroxanthin in samples from Arraial do Cabo indicated the occurrence of type two chloroplast dinoflagellates, probably of the family Kareniaceae. Between the 12th and the 18th of December, the water of beaches along more than 150 km between Rio and Arraial do Cabo were dark brown.

Patches of dark orange-glowing water (Fig. 4) were still observed in calm inlets in GB on December 21st. These water patches showed a diverse community of dinoflagellates (both auto- and heterotrophic) and the ciliate *Mesodinium rubrum*, along with small flagellates (Cryptophytes and

Fig. 2. Leme beach, Rio de Janeiro on the 10th of December. A) dark brown waters, B) pink foam. Photo by Silvia Nascimento

Tetraselmis). We speculate that these calm inlets could have possibly been the source of the massive offshore bloom, but further image and data analysis needs to be conducted.

The coast of Rio de Janeiro state is subject to coastal upwelling of the South Atlantic Central Water (SACW water mass) at Arraial do Cabo, driven by the occurrence of persistent Northeasterly winds from September to March [2]. The deep nutrient rich water fertilizes the surface ocean, where there is plenty of light for photosynthesis, supporting the increase in primary production. This productive water mass is usually dragged west (by the wind), often reaching the coast of the city of Rio in Spring and Summer. This phenomenon supports the diverse and abundant marine life and high fishery catch in Rio's coastal waters.

In 2021, unusual wet weather conditions occurred in September-October, with 6 cloudy weeks of constant rainfall, that probably contributed with nutrients to the coastal area. Off shore from the coastline, seawater was cold (upwelled) clear and blue. In early November, the weather became sunny. We hypothesize that the long day light periods, strong sunlight, clear nutrient-rich waters, and weak wind conditions led to this unprecedented bloom event.

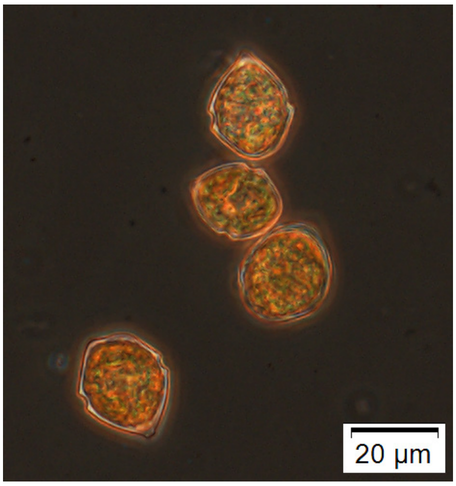

Fig. 3. Scrippsiella sp. from a sample collected on the 3rd of December, 2021 at Arraial do Cabo. Photo by Lohengrin Fernandes

Harmful algae blooms have occurred in Rio and are usually seen in a couple of beaches when heat waves hit the city; but in 2021, instead of fading, the bloom spread. The sunny days and calm seas lasted for weeks. On late December, as the weather conditions changed, with more cold fronts from the South bringing rain and clouds, the bloom was slowly pushed towards the ocean.

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Fig. 4. Dark orange-glowing water in the inlet of Botafogo, Rio de Janeiro, observed on December 21st. Photo by Priscila Kienteca Lange

High Biomass Bloom of a dinoflagellate (*Scrippsiella* sp.) in a tropical estuary in northern Bahia State, Northeast Brazil

A bloom of *Scrippsiella* sp. was observed in the Rio Real estuary of Northeast Brazil (Figure 1A; 11º 18' 28'' S; 37º 16' 45'' W). According to the Köppen-Geiger climate classification [1], the climate of the region is characterized as humid tropical (AfA), with an average annual temperature ranging from 21ºC to 31ºC with a dry season (September-March) and a rainy season (April-August). The locality has a semidiurnal tidal regime with maximum range between high and low tide of 2.1 m [2]. The Rio Real estuary has a total area of 4,968.44 km^2, of which 2,567 km^2 is drainage area, 458.06 km^2 is perimeter and 110.7 km^2 corresponds to the main axis. The source area of Rio Real corresponds to 18.6% of its total area and is located within a region with a semi-arid climate. The surrounding vegetation is comprised of predominantly mangroves. Several activities are linked to this environment, such as subsistence fishing and shellfish harvesting, tourism, agriculture, subsistence cropping of various sorts and shrimp farming. The sediments found in the environment come from the Lagarto formation, Grupo Estância, and are composed of fine sandstones, clay, shales and silt.

Phytoplankton were sampled at eight stations along the estuary (Figure 1), following the salinity gradient, during four field campaigns — two in the dry season, January 2014 (22 mm of rain) and 2015 (10.1 mm), and two in the rainy season, July 2013 (241 mm) and 2014 (211.4 mm). Qualitative sampling was performed with subsurface horizontal hauls using a mesh of 30 µm pore diameter and the samples preserved with Transeau solution. Quantitative sampling was performed with a Van Dorn bottle and the samples preserved with 4% Lugol's iodine solution. Water samples were also collected and stored in one-liter plastic bottles refrigerated at 4º C for subsequent nutrient analysis: total phosphorus (TP), orthophosphate (PO_4+), total nitrogen (TN), nitrate (NO_3-), silicate (SiO_2) and chlorophyll a (Chl-a). Temperature, salinity, and dissolved oxygen (DO) were measured in situ with the aid of a HORIBA multiparameter probe. Cell counts were made using an Olympus CKX41 inverted microscope, with 400x magnification, according to [3]. The results are expressed as absolute density (cells L^{-1}).

Mean salinity for the four campaigns ranged from 3.6 (Station A8, upstream) to 27.8 (Station A1, downstream). Stations A1 to A3 were polyhaline, stations A4 to A6 were mesohaline, and stations A7 and A8 were oligohaline [4]. The estuary can be divided into three regions based on the ecology of the phytoplankton species collected: the lower estuary, represented by sampling stations A1, A2 and A3, is characterized by a greater abundance of marine, oceanic and neritic species; the middle estuary, comprising sampling stations A4 and A5, is characterized by a greater abundances of brackish species typically from estuarine environments; and the upper estuary, comprising stations A6, A7 and A8, is characterized by typically freshwater species. The bloom of *Scrippsiella* sp. (mean = 9.2 x 10^6 cells L^{-1}), which occurred in July 2014, was located in the lower and middle estuary regions from station A2 to A5 (Figure 1.A); these regions are close to urban concentrations and shrimp farms, which may have favored cell growth due to the input of nutrients with the greater continental runoff in the rainy season. Stations A1 and A6 to A8, did not have significant concentrations of *Scrippsiella* sp. The high concentrations observed resulted in low phytoplankton diversity compared to the other periods sampled.

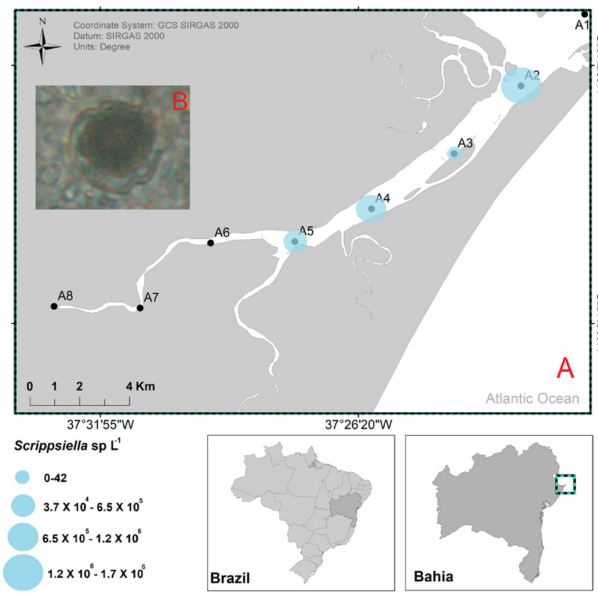

Fig. 1. (A) Location of the study area, NE Brazil, with sampling stations along the Rio Real estuary, showing overall (yellow to red color pattern) and Scrippsiella sp. (circle diameter) cells density (cells L^{-1}). (B) Image (400x) of specimen of Scrippsiella sp.

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Limnoraphis robusta bloom in Hanabanilla reservoir, central-southern Cuba

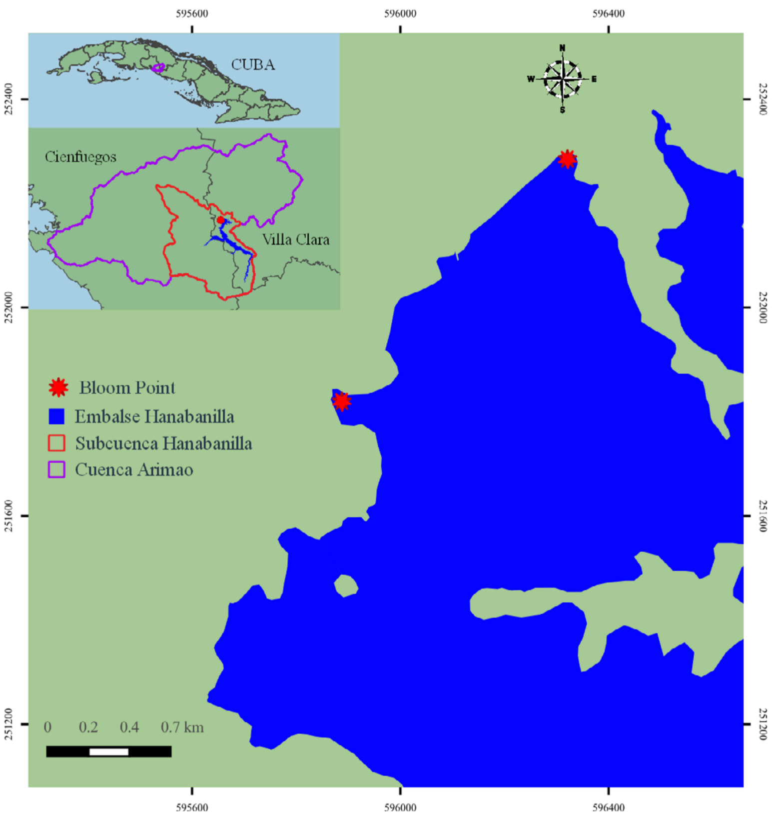

Fig. 1. Map showing the areas where the Limnoraphis robusta bloom occurred in Hanabanilla reservoir.

Harmful cyanobacterial blooms in freshwater ecosystems can form major water discolorations, threaten ecosystem functioning and degrade water quality for recreation, drinking water, fisheries and human health [1-3]. Cyanobacterial blooms have increased worldwide in the last years, and they are likely to expand further in coming decades owing to continued eutrophication, rising atmospheric CO_2 concentrations and global warming [3-4].

Hanabanilla reservoir is an artificial lake with mesotrophic to oligotrophic conditions, located in the mountainous region (364 m in height) of central-southern Cuba (Fig. 1). The reservoir occupies an area of approximately 19 km^2, an average depth of 1.2 m and a volume of 31 m^3; with a climate influenced by the two annual seasons: dry from November to April and rainy from May to October. Hanabanilla reservoir represents the principal source of drinking water supply in the Cienfuegos and Villa Clara provinces. Other uses include energy production (hydroelectric power) and recreational boating [5].

A bloom of *Limnoraphis robusta* (Parakutty) Komárek was identified in mid-February 2021 in Hanabanilla reservoir. Dense green mats were only noted in two areas of the reservoir (Figures 1-2). The bloom did not have noxious effects on human health or on other ecosystem organisms, although previous *L. robusta* blooms in the reservoir have been associated with small-scale deaths of juvenile turtles and aesthetic damage in the reservoir.

Morphological characters of *L. robusta* from Hanabanilla reservoir were in agreement with those observed during previous studies in Cuba and other tropical regions [5, 6]. Filaments ± straight or slightly curved, with free (or in clusters only in mass development) uniseriate trichomes enveloped by firm, thick, mucilaginous and colorless sheaths. Trichomes were 15–17 µm (mean of 16.1 ± 0.64 µm) wide, straight; cells were 4–8 times shorter than wide, green to green-brownish in colour, with aerotopes. Trichomes uniseriate, cylindrical, isopolar, usually not constricted at cross walls; end cells were widely rounded, without calyptra. Heterocytes and akinetes are lacking (Fig. 3).

Reproduction was by production of uniseriate hormogonia (Fig. 3), although they were very scarce, which indicate that *L. robusta* population

Fig. 2. Limnoraphis robusta bloom forming dense green mats in the reservoir.

from Hanabanilla was mainly in early vegetative stage. In contrast, some morphological characters which are indicators of later growth stage such as red-brownish trichomes and hormogonia were present in high abundance in a previous *L. robusta* bloom from Hanabanilla reservoir [5].

L. robusta occurred in high densities (average of 9.0 x 10^6 cells mL^{-1}, and chlorophyll-*a* of 18.9 µg L^{-1}), an almost monospecific bloom; similar to the previous bloom of this species in the Hanabanilla reservoir during 2014 [5]. Environmental conditions, such as high stability in the water column during the dry period, were favorable for the start of the cyanobacteria bloom although nutrient levels were below the detection limit (N-NO_{2-} <0,005 mg L^{-1}, N-NO_{3-} <0,01461 mg L^{-1}, N-NH_{4+} <0,01 mg L^{-1}, P-$PO4_{3-}$ <0,05 mg L^{-1}).

Despite *L. robusta* not being a toxic species and there was no apparent damage in the reservoir during this event, blooms of this cyanobacteria could cause environmental problems in the future.

Acknowledgements

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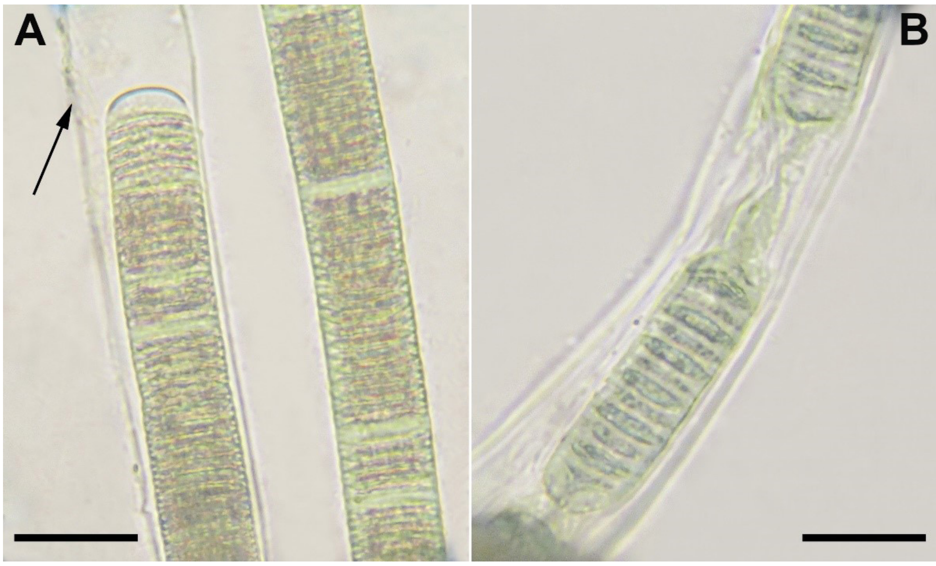

Fig. 3. Light micrographs of Limnoraphis robusta trichomes. A. Vegetative trichomes, arrow indicate the presence of a mucilaginous sheath. B. Trichome with hormogonia. Scale bars = 20 um.

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IOCARIBE HAB-ANCA launches the HAB Virtual Course in 360 virtual reality

This course is an immersive and interactive hands-on laboratory and sampling experience to learn about HABs. The App is a support for laboratory practices that encourages user autonomy, allowing them to learn at their own pace and anywhere.

The user only needs a mobile device and internet access to download the content. The App can be used in online and offline mode.

The course is designed in three learning paths: (1) Summary and Context; (2) Sampling and (3) Microscopic observation. Additionally, it includes the calculation of an aerobic mortality risk indicator – IRMA. This index developed to forecast the mass mortality of fish due to anoxia in a tropical coastal lagoon, corresponds to a eutrophication index, and is based on the concentration of three variables: dissolved inorganic phosphorus, chlorophyll and dissolved oxygen.

This HAB 360 course is a development led by IOCARIBE HAB ANCA, in alliance with the National University of Colombia, INVEMAR and the spin-off Nova Transmedia. It is a completely free course, for the moment only in Spanish. It can be downloaded from Google Play: “Florecimientos Algales Nocivos FAN”.

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MixONET, a new SCOR Working Group # 165 on Mixotrophy in the Ocean

Traditional and contemporary methods in Biological Oceanography assume a false plant/animal dichotomy for plankton. This dichotomy has been the bedrock of marine science, operationally separating organisms into phototrophic or phagotrophic compartments wherein about half of Earth's carbon fixation and oxygen production are due to activities of microscopic marine phototrophic phytoplankton. These phytoplankton are ingested by microbial zooplankton which are then preyed upon by metazoan grazers etc. We now know that most of these protist phytoplankton can photosynthesise **and** ingest food while a third of the microbial zooplankton can photosynthesize through acquired phototrophy in addition to hunting prey thus contributing to **both** primary and secondary production. These protist plankton are now recognised as an important community of marine life – the mixoplankton [1-3] (Fig.1).

During the current UN Ocean Decade, marine researchers are faced with the challenge of answering how climate change will impact biology, productivity and carbon sequestration, food-webs, and allied ecosystems services in global oceans. Mixoplankton are at the heart of all these processes, for example, dominating production in various ecosystems (e.g., temperate summers) and supporting juvenile fish growth [3]. Biogeography studies have shown the ubiquity of mixoplankton [4,5]. Well-known phytoplankters that are actually mixoplankton include the coccolithophore *Emiliania huxleyi* [6]; the diverse bacterivorous phytoflagellates of the microbial carbon pump [7]; the toxin-producing dinoflagellates *Alexandrium* and *Dinophysis* whose blooms result in shellfish contamination and harvesting closures [8]. The traditional "microzooplankton" which are now recognised as mixoplankton include various plastidic ciliates, such as *Strombidium* and *Mesodinium* that support farmed and wild fish [9] as well as the green *Noctiluca scintillans,* a bloom forming dinoflagellate that harbours photosynthesizing endosymbionts. Ecosystem disruptive blooms of this green *Noctiluca* are leading to the collapse of the traditional phytoplankton-mesozooplankton link in the food-web in the Arabian Sea [10].

The base of the oceanic food-web is thus comprised of photosynthesizers that also eat and consumers that also photosynthesize, muddying the photo-autotroph/phago-heterotroph distinction that has dominated biological oceanography. This recognition where most oceanic primary producers cannot be analogized as miniature plants has led to a paradigm shift in trophic studies, and there is thus a critical need to evaluate how new sampling and monitoring methods and global plankton databases can be optimized for this new perspective. A cross-disciplinary team is required to address these needs; thus in 2021 we submitted a proposal for a working group to SCOR - MixONET.

The newly funded SCOR working group # 165 *Mixotrophy in the Oceans; Novel Experimental designs and Tools for a new trophic paradigm* (MixONET) (January 2022 – December 2024) is an international brainstorming effort involving experts with knowledge of ecophysiology and molecular biology of mixoplankton, new sampling and observation technology, biogeochemical cycling and ecosystem services (Fig.2).

Our overarching aim is to update biological oceanography to quantitatively accommodate the mixoplankton paradigm, and to evaluate which emerging methods and technology will enable accurate assessment of mixoplankton abundance and activities. MixONET will thus integrate the mixoplankton paradigm with traditional and novel methods of plankton research to provide tools for predicting the response of the ocean's biological communities and element cycles in the face of ongoing climate change to better understand how humanity can maintain healthy sustainable oceans. MixONET is co-chaired by Aditee Mitra (Wales, UK) and George McManus (USA); the membership (Fig.3) includes Beatriz Reguera (Spain), Helga Gomes (USA), Anukul Buranaprateprat (Thailand), Amany Ismael (Egypt), Áurea Ciotti (Brazil), Ahmed Al-Alawi (Oman), Fernando Unrein (Argentina), Hae Jin Jeong (S. Korea), KB Padmakumar (India), Koji Suzuki (Japan), Luciana Santoferrara (USA), Maite

Fig. 1. Artistic representation of example mixoplankton species. a: Lithoptera fenestrata, b: Strombidium conicum, c: Gymnodinium catenatum, d: Karlodinium veneficum, e: Akashiwo sanguinea, f: Alexandrium sp., g: Laboea strobila, h: Prorocentrum micans, i: Mesodinium rubrum, j: Pfiesteria piscicida, k: Heterocapsa triquetra, l: Tripos furca, m: Prymnesium parvum, n: Dinophysis acuta, o: Teleaulax amphioxeia, p: Noctiluca scintillans. Organism size is to scale; scale bar: 10 µm. Image credit: Claudia Traboni (2019) MixITiN project.

Maldonado (Canada), Mengmeng Tong (China), Michaela Larsson (Australia), Patricio Diaz (Chile), Robinson Mugo (Kenya), Tina Šilović (France).

The first meeting of the working group was held in silico (February 2022) with the second hybrid meeting scheduled to be held in Baiona (Galicia, Spain) in June 2022. Further details about the project and outputs will be available on the project website www.mixotroph.org/mixonet

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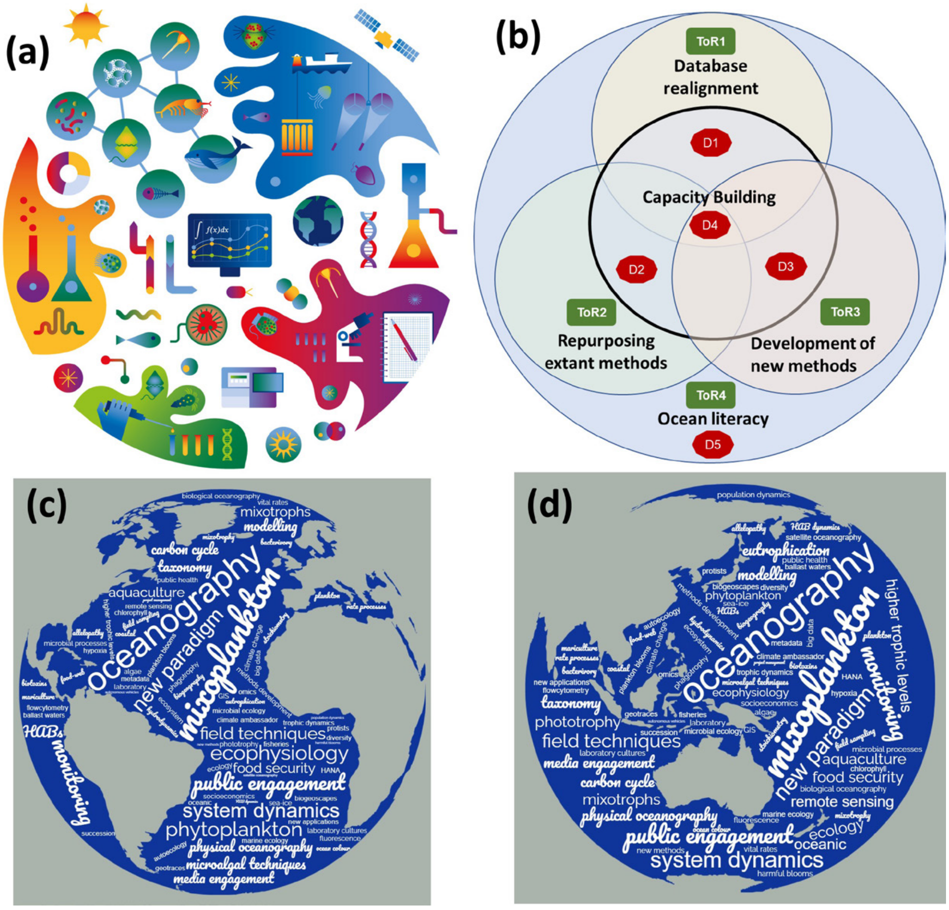

Fig. 2. Schematic depictions of the MixONET programme. (a) Integration of facets of mixoplankton science. Working clockwise from 12 o'clock these include field studies and monitoring, determination of rate processes, taxonomic and genomic analyses, chemical analyses leading to stoichiometric ecology, trophic dynamics, ecosystem services and sustainability/profitability. The centre denotes the focussing of all these activities through modelling for hypothesis testing and predictive purposes. © Aditee Mitra (b) The MixONET project envisions four major terms of reference relating to global databases, new and traditional methods of studying plankton, and ocean literacy. The Venn diagram shows the interconnectivity between the terms of references and deliverables for the project. (c) & (d) Word cloud created from the MixONET proposal to SCOR. From the relative sizes of the terms, their importance to MixONET can be inferred.

Fig. 3. MixONET team members come from 18 different countries and include early-career and more senior researchers. Some use traditional methods (e.g., microscopy) and others use new technologies (satellite sensors, flow cytometry, 'omics) in their research.

GlobalHAB/EuroMarine Workshop on Modelling and Prediction of Harmful Algal Blooms

The typical harmful algal bloom is a regional- or local-scale phenomenon, a "perfect storm" of environmental conditions, ocean transport and mixing patterns, and microbial ecology. Because of this complexity, prediction of HABs is a grand challenge that requires multidisciplinary dialogue among physical scientists, biologists, computer modellers, and technologists, as well as community stakeholders and the government and industry end-users of prediction systems. The GlobalHAB/EuroMarine WS on Modelling and Prediction of HABs was held on 9-12 May 2022, at the University of Strathclyde, Glasgow, UK. **This 4-day workshop brought together 39 scientists from 17 countries for a combination of oral and poster presentations, round-table discussions, and tutorials,** in order to increase awareness of the range of modelling and observational tools that are in our community toolbox, and help scientists and technologists develop creative approaches to meeting the needs of coastal communities, governments, and industry worldwide.

Discussions consisted of:

- Engaging with stakeholders (facilitated by Aletta Yñiguez and Dave Clarke)
- Scalable solutions: bringing large-scale community tools to local applications (by Clarissa Anderson)
- Building blocks of early-warning systems (by Dave Clarke)
- Combining automated plankton observations and modelling (by Bengt Karlson)
- New directions in mechanistic plankton modelling: where do HABs fit in? (by Neil Banas, Onur Kerimoglu, and Bingzhang Chen)
- HAB model-observation systems for 2050: anticipating future societal needs and assessment tools (by Clarissa Anderson)

Tutorials consisted of:

- Getting started with machine learning using tidymodels in R (Johnathan Evanilla, Kasia Kenitz, and Bingzhang Chen)
- Satellite methods (Clarissa Anderson)
- Getting started with Individual-based modelling (Aletta Yñiguez)

Organising committee

- Representing GlobalHAB: Neil Banas (U Strathclyde, UK), Clarissa Anderson (Scripps/SCCOOS, USA), Dave Clarke (Marine Institute, Ireland), Aletta Yñiguez (U Philippines), Bengt Karlson (SMHI, Sweden)
- Local committee: David McKee, Bingzhang Chen, Paul Udom (U Strathclyde), Sofie Spatharis, Martin Llewellyn (U Glasgow), Keith Davidson, Dmitry Aleynik (SAMS)

Sponsors

The workshop was supported by GlobalHAB, NOAA's *National Centers for Coastal Ocean Science (NCCOS) Competitive Research Program (CRP)*, NOAA's *Integrated Ocean Observing System (IOOS)*, and *EuroMarine*. A follow-on, one-day event on Industry Perspectives supported by the Sustainable Aquaculture Innovation Centre deepened the engagement between workshop participants, the Scottish aquaculture industry, and companies building systems and monitoring technology to support that industry.

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Participants at the GlobalHAB/EuroMarine Workshop on Modelling and Prediction of Harmful Algal Blooms, Glasgow, UK, 9-12 May 2022.

Meeting of the GlobalHAB Scientific Steering Committee, Glasgow, Scotland, May 2022

On May 14th -15th, 2022, the Scientific Steering Committee (SSC) of the IOC-SCOR programme, GlobalHAB, celebrated its first hybrid meeting in Glasgow, UK, following virtual meetings throughout the Covid19 pandemic.

The GlobalHAB programme was launched in 2016 and the first SSC membership was partially *renewed* through a virtual meeting in May 2020. Since then, periodic meetings were held virtually in order to manage and make progress on implementing the programme's terms of reference and action items. Unfortunately, not all members of the SSC could travel to Glasgow, and therefore joined virtually (picture below).

The SSC meeting, co-sponsored by IOC-SCOR *GlobalHAB*, NOAA *National Centers for Coastal Ocean Science (NCCOS)*, the U.S. *Integrated Ocean Observing System (IOOS)* and the *EuroMarine* European Research Network, was held following the *Workshop* on Modelling and Prediction held on May 9-13, 2022 at the University of Strathclyde. The outputs of the workshop are currently being processed and reviewed and will be soon made available to the international community. After being postponed for the last two years during the pandemic, participants were delighted to finally attend the Workshop to present and discuss various aspects of modelling and prediction of HABs. A series of webinars were conducted in 2021 as a preparatory activity for this workshop.

The SSC reviewed the forthcoming activities that had been also postponed in the 2020-2021 period.. These activities include:

- The *GlobalHAB symposium* on automated in situ observations of plankton, to be held in Kristineberg Marine Research Station, Sweden, this August 2022, coordinated by Bengt Karlson.
- The Workshop on *Sargassum*, in preparation now, to be held in Mexico, coordinated by Brigitta van Tussenbroek and the GlobalHAB *Subcommittee* on *Sargassum*.
- The qPCR workshop organized by Raffaele Siano which aims at promoting the use of eDNA approaches in monitoring harmful algae and specifically the use of qPCR for species detection. The workshop will convey international experts on HAB qPCR approaches in order to foresee to which extent eDNA and qPCR can be used in HAB monitoring. Virtual meetings will be organised before the in person meeting in 2023.
- A workshop on solutions to control HABs in marine and estuarine waters co-organized by Vera Trainer and Marc Suddleson in coordination with PICES and ISSHA. This workshop will build on lessons learned from freshwater HAB control.

The SSC also analyzed the objectives of the *13 Themes* that structure GlobalHAB to identify new activities for the last period of the programme, i.e. from 2023 to 2025.

One objective of this new period is to engage the international community working on HAB research through *projects endorsement*. The GlobalHAB programme was implemented to serve scientists and resource managers covering the full breadth of marine and freshwater harmful algal bloom research. Endorsement by GlobalHAB can help foster international collaborations that are fundamental for the progress of our knowledge on HABs dynamics, their prediction and mitigation of their impacts. The GlobalHAB SSC has committed itself to increase communication with the international community by encouraging endorsement by GlobalHAB and by strengthening the links with IOC regional groups such as ANSA, FANSA, HANA, WESTPAC, etc.

Another objective is to consolidate information on freshwater HAB monitoring programmes, to better understand the global impact of freshwater HABs, data gaps, and trends.

Finally, GlobalHAB explored ways to actively participate in the *United Nations Decade of Ocean Science for Sustainable Development (2021-2030)* and contribute to the UN Sustainable Development Goals, a call for action by all countries – poor, rich and middle-income – to promote prosperity while protecting the planet.

The GlobalHAB endorsement application form available from the *webpage*. *GlobalHAB webpage (www.globalhab.info)* or on request from *yu.sun@unesco.org*.

Members of the SSC at the Merchants House of Glasgow and screenshots during the remote connection. Bottom image, from left to right, first line: Aletta Yñiguez, Elisa Berdalet, Heather Raymond; second line: Clarissa Anderson, Sun Yun, Malin Olofsson, Bengt Karlson, Neil Banas, Raffaele Siano, Dave Clarke. Po Teen Lim (top, right picture), Raphael Kudela (middle, right picture), and Marc Suddleson (not pictured) joined virtually.

The international community is invited to participate in the GlobalHAB programme, through seeking endorsement of relevant research, monitoring, and modelling activities

GlobalHAB APPLICATION FORM FOR ENDORSEMENT OF ACTIVITIES AND PROJECTS

To be completed in English and emailed to the Chair of the GlobalHAB SSC.

For further guidance consult the Chair and/or Vice-chair of the GlobalHAB SSC. Emails of the GlobalHAB SSC members can be found at http://www.globalhab.info/organization/scientific-steering-committee

Date:

1. PROJECT TITLE:

Planned duration of activity, from: to:

2. APPLICANT(S):

Principal Investigator name, title:
Address: Tel/Fax:
E-mail: Home page URL: (if applicable)
Other **key persons** (name, title and institution):
Contact person name and email:

3. PROJECT DESCRIPTION:

Include a brief summary or abstract and the relevant details of your project (maximum 5 pages).

Project web site (if applicable):
Contact person:

4. BENEFITS FROM GlobalHAB:

Please comment on
a) how the activity could benefit from endorsement by GlobalHAB
b) how the SSC might assist the activity

5. CONTRIBUTION TO THE GlobalHAB SCIENTIFIC OBJECTIVES AND TOPICS

Please specify how the project contributes to the Implementation of the objectives of GlobalHAB. The applicants are advised to refer to GlobalHAB Science and Implementation plan (available at www.globalhab.info) for write up in this section.

6. CONTRIBUTION TO coordination of HAB research

One of the missions of GlobalHAB is to foster international coordination and cooperative research to address the scientific and societal challenges of HABs (http://www.globalhab.info/about-us/goal-and-mission). Please, indicate how your project will contribute to it.

7. LINKAGES WITH OTHER PROGRAMMES:

Is the project part of a National Programme? Yes: ___No: ___ If yes, give title:

Is the activity part of, coordinated with, or affiliated with, other international/regional programs? Yes: ___ No. ____ If yes, give program title:

8. FUNDING
Has funding been obtained? Yes: No: (Prospective) source(s):

9. CONTRIBUTION TO UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT 2030 AND UN SUSTAINBALE DEVELOPMENT GOALS (UN SDG)

Please specific how the project contributes to Ocean Decade challenges or outcome (https://www.oceandecade.org) and the UN SDG (https://sdgs.un.org/goals).
Tick one or more if appropriate, refer to Decade Implementation Plan for more information.

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Please feel free to contact any of the editors if you have article, ideas for article or special issues and we will work with you!

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