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Editorial: Harmful Algal Blooms (HABs) in Latin America

Marius N. Müller[1]*, *Jorge I. Mardones*[2] *and Juan J. Dorantes-Aranda*[3]

[1] Department of Oceanography, Federal University of Pernambuco, Recife, Brazil, [2] Centro de Estudios de Algas Nocivas (CREAN), Instituto de Fomento Pesquero (IFOP), Puerto Montt, Chile, [3] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia

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Editorial on the Research Topic

Harmful Algal Blooms (HABs) in Latin America

"Harmful Algal Blooms" (HABs) describe the copious presence of certain pigmented planktonic organisms that interfere with the equilibrium or balanced state of aquatic ecosystems and reservoirs in terms of ecological functions (e.g., food web disturbance, subsurface oxygen depletion) and ecosystem services benefits to humans (e.g., fishery, water quality, and tourism). The effects of harmful algal species on aquatic systems are manifold and may include the discoloration of water, the presence of toxic substances and the accumulation of high biomass leading to low oxygen or anoxic conditions due to increased bacterial respiration. Aquatic reservoirs and ecosystems are intrinsically connected to human health and well-being as they provide resources, such as drinking water and food (e.g., through fisheries and aquaculture). The biogeographical occurrence and records of HAB events have increased in frequency, distribution and severity over the past decades, which have been linked to evolved monitoring techniques, increased research efforts and global climate change (Hallegraeff, 2010). The ongoing and projected anthropogenic changes of the coastal and freshwater marine environments are altering planktonic community structures, species distribution, and migration patterns (Gobler et al., 2017). Shifts in the biogeography and bloom dynamics of HABs pose a potential risk to the health and economy of coastal communities due to the possible occurrence of HABs in regions without proper recognition, monitoring, or mitigation capabilities. Secondary metabolites produced by HABs include toxins that can be bioaccumulated through the food web and ultimately affect human health due to a variety of syndromes, such as Amnesic, Diarrhetic, Neurotoxic, Azaspiracid, and Paralytic Shellfish Poisoning (ASP, DSP, NSP, AZP, PSP, respectively), as well as Ciguatera Fish Poisoning. More algal toxins have been described in recent years and have attracted particular attention due to their potency and emergent problematic issues (Assunção et al., 2017). This includes yessotoxins, palytoxins, and amphidinols as well as harmful compounds produced by ichthyotoxic algae that still remain to be fully characterized and understood.

The monitoring and mitigation of HABs are not trivial, and as a common routine activity, abundances of harmful algal species are observed to determine any potential bloom development in association with environmental parameters. Over the past decades, HAB research has substantially advanced and improvements in prediction and mitigation have been achieved (Anderson et al., 2012). Monitoring programs have been mostly implemented in regions of known HAB occurrence and those of economic importance (e.g., aquaculture and tourism). In the light of changes in HAB biogeography due to climate change and anthropogenic activities, it is likely that the occurrence of HABs will expand to unprepared regions. HAB phenomena with severe impacts, such as persistent events in Chile and Australia and sporadic events in the USA and the Persian Gulf, have impacted

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***Correspondence:**
Marius N. Müller
mariusnmuller@gmail.com

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coastal communities unexpectedly. This demonstrates the existence of gaps and difficulties in monitoring programs and, consequently, in the understanding and prediction of HAB dynamics to appropriately mitigate the impacts on human society as it has been achieved in regard to other natural phenomena, such as hurricanes and tsunamis. Nowadays, monitoring and mitigation of HABs should go hand in hand with the detection and discovery of toxic HAB metabolites, culturing of HAB species and communicating and integrating HAB science with society and policy makers to develop regional and local strategies.

This Research Topic was proposed to bring together HAB researchers from Latin America and to showcase current developments as well as challenges that regional scientific communities are facing. Contributions from 58 research/academic institutions distributed over 13 Latin American and 8 non-Latin American countries were received, which demonstrates a high interest and current research efforts performed by Latin American and international research communities. The articles published in this Research Topic can be grouped into reviews, observational/field studies, laboratory studies, and articles linking scientific research with the broader society and policy makers.

REVIEWS

Most reviews were focused on toxic dinoflagellates and demonstrated the major expertise and focus of Latin American researchers. Durán-Riveroll et al. reviewed the current knowledge on the distribution and the diversity of toxigenic benthic marine dinoflagellates in the tropical and subtropical Atlantic and Pacific. Morquecho focused on the importance of understanding the bloom dynamics of the dinoflagellate *Pyrodinium bahamense* and the associated impacts of Paralytic Shellfish Poisoning in the Mexican Pacific and the Gulf of Mexico. Menezes et al. summarized the occurrence of seven species of the dinoflagellate *Alexandrium* in Brazilian waters, whereby *A. tamutum* was documented for the first time and strains of *A. catenella* displayed genetic similarities with strains from Southern Chile and North America. López-Cortés et al. reviewed records and research on *Margalefidinium polykrikoides* in Latin America with regard to ecology, physiology, and toxic effects due to the production of reactive oxygen species, hemolytic and neurotoxic-like substances. Band-Schmidt et al. contributed with an overview on the ecology and physiology of paralytic shellfish toxin (PST) producing dinoflagellates, responsible for intoxications in various coastal areas of Latin America, and highlighted the distribution patterns of *Gymnodinium catenatum*, *Pyrodinium bahamense,* and several species of *Alexandrium*.

FIELD AND OBSERVATIONAL STUDIES

Plankton surveys are crucial to develop a fundamental understanding to evaluate current and future ecosystem changes and to monitor the distribution of toxigenic harmful algal species. Field and observational studies were conducted in tropical, subtropical, and temperate climate regions in coastal and continental shelf areas of Argentina, Brazil, Chile, Ecuador, El Salvador, and Mexico. Guinder et al. conducted a plankton multiproxy analysis and characterized the late winter plankton structure in terms of abundance, biomass, species composition, functional groups, and phycotoxin profiles in surface waters of the Northern Patagonian Shelf (Argentina). Phylogenetic analyses of newly isolated strains of *Alexandrium ostenfeldii* revealed a new ribotype group, suggesting a biogeographical distinction of this population. Bif et al. identified *Trichodesmium* species and their toxins during two oceanographic cruises in the Southwest Atlantic Ocean (Brazil) and gave hints that the cellular toxin production might be enhanced during aggregation at the ocean surface, inhibiting the growth of co-occurring microplanktonic organisms. Viana et al. recorded bloom events of the toxic raphidophyte *Chattonella subsalsa* in Guanabara Bay (Brazil) responsible for fish kills and highlighted the need to reduce the eutrophication levels in Guanabara Bay.

Paredes et al. illustrated the high genetic diversity of *Alexandrium catenella* responsible for high PST levels observed along the Southern Chilean fjords between 2014 and 2016. Borbor-Cordova, Torres et al. assessed the link between oceanographic variables and HABs occurrence on the Ecuadorian coast from a 20-year time series where a total of 67 HAB events were registered. Carnicer et al. provided and discussed baseline information on the spatial distribution of different dinoflagellate taxa in the Galápagos Marine Reserve (Ecuador). An oceanographic monitoring series of 4 years was evaluated by Torres et al. to study the association of El Niño/Southern Oscillation with upwelling events and dinoflagellates abundances on the Ecuadorian coast. Amaya et al. investigated the role of PST produced by the dinoflagellates *Gymnodinium catenatum*, *Alexandrium* sp., and *Pyrodinium bahamense* during large-scale sea turtle mortality events in El Salvador.

Paredes-Banda et al. associated the occurrence and accumulation of spirolids in farmed shellfish of Todos Santos Bay (Mexico) with the presence of the dinoflagellate *Alexandrium ostenfeldii*. Medina-Elizalde et al. investigated the transformation and depuration of paralytic shellfish toxins in the geoduck clam from the Northern Gulf of California and characterized the toxin profile in this shellfish species during a bloom of the dinoflagellate *Gymnodinium catenatum*. García-Mendoza et al. reported that mass mortalities of farmed tuna were associated with the presence of *Chattonella* spp. in the northwest coast of Baja California (Mexico). Irola-Sansores et al. investigated the distribution of epiphytic dinoflagellates in two coral reef systems of the Mexican Caribbean. The dominance of palytoxin producer *Ostreopsis* sp. demonstrated the potential risk that this species could create in touristic regions. Finally, the distribution and abundance of the dinoflagellate *Alexandrium tamiyavanichii* was reported for the first time in coastal and oceanic conditions of the central Mexican Pacific by Hernández-Becerril et al.

LABORATORY STUDIES

Laboratory studies are an essential step to understand the physiology and growth dynamics of harmful algal species under controlled conditions. These depend on the successful isolation and culturing of the target algal species, which require skills and good practices in HAB research. Mardones et al. shed light on

the underlying reasons of the outbreak of the dictyochophyte *Pseudochattonella verruculosa* in 2016 responsible for economic losses of US$ 800M due to farmed salmon mortalities. Results from laboratory experiments revealed the important effect of salinity on growth and ichthyotoxicity of *Pseudochattonella* species and highlighted the necessity to study the role of mucocysts in fish gill damage. Mendoza-Flores et al. reported that the acquisition and origin of saxitoxin genes in the dinoflagellate *Gymnodinium catenatum* was related to horizontal gene transfer from bacteria and that horizontal gene transfer from *Alexandrium* species toward *G. catenatum* did not occur. Silveira and Odebrecht evaluated the effects of temperature and salinity on the physiological performance and toxin production of the cyanobacteria *Nodularia spumigena* and revealed that cell growth, akinete formation, and the germination potential was negatively affected by low salinity. Müller et al. presented laboratory results on the physiology and the toxin production of the dinoflagellate *Karlodinium veneficum* in regard to changes in seawater pH and ocean acidification scenarios, indicating favorable growth conditions at elevated pH levels.

LINKING HAB RESEARCH WITH SOCIETY

The linkage between the scientific community and the society as well as policy makers is an essential aspect to develop a fast and effective information flow to secure human health and economic sustainability. Aguilera and Giannuzzi presented a book review regarding the result of the collaborative work between Argentinian researchers and the Ministry of Health raising awareness on the increased occurrence of toxigenic cyanobacteria in aquatic systems and the documented acute illnesses associated with exposure to cyanobacteria and cyanotoxins. Borbor-Córdova, Pozo-Cajas et al. assessed the knowledge, attitudes, and practices in relation to HABs in Ecuador and demonstrated that coastal communities and health authorities had limited knowledge of red tide impacts on human health. However, outreach activities, such as tailored workshops and communication between authorities and communities, could positively influence the risk perception and enhance algal bloom monitoring in the near future. Cuellar-Martinez et al. highlighted the 10-year existence of a regional HAB network of Latin American and Caribbean countries (supported by the International Atomic Energy Agency), which aims to provide training and capabilities for early HAB warning and mitigation.

FUTURE PERSPECTIVES OF HAB RESEARCH IN LATIN AMERICA

The impacts of HABs on human health are still an abstract concept for many communities in Latin American countries and additional efforts need to be implemented by the scientific community and stakeholders to reinforce the social and economic importance of HAB research. The existence of several national HAB networks and monitoring systems represent a basis for the development of additional regional HAB networks and a joint Latin American HAB program that could operate on an international basis with the existing GlobalHAB program (Berdalet et al., 2017). In Latin America there are two regional groups of the Intergovernmental Oceanographic Commission (IOC): *Algas Nocivas en el Caribe* (ANCA) and *Floraciones Algales Nocivas en Sudamérica* (FANSA), representing Central American/Caribbean and South American countries, respectively. Additionally, an independent Society for the Study of Harmful Algal Blooms (*Sociedad Mexicana para el Estudio de Florecimientos Algales Nocivos*, SOMEFAN) is present in Mexico. These groups have different backgrounds, biography and perspectives, but share a common challenge: consolidating and establishing strong HABs collaborative research activities. To date, there is no official body in Latin America identified as a leading agency for HAB research such as the IOC-UNESCO sub-commission for the Western Pacific (WESTPAC) where a Project Steering Group has been established. A leading agency or network might effectively promote and impulse research activities, integrating common efforts among countries. The main challenges to achieve these general interests are related to the limited available resources (infrastructure and equipments), the political situation within and amongst Latin American countries, the lack of trained human resources and strong policies oriented to trigger and maintain basic and applied research. The motivation and long-term research programs require a continuous and permanent IOC support and a clear integration with local governments. Meanwhile, the development of low cost monitoring programs (e.g., MicroToxMap http://microtoxmap.com/) and the increasingly availability of digital open access resources to store, share and transpose information are important developments to be adopted and potentially can advance HAB research in Latin America. We hope that this Research Topic demonstrates the advantages of regional cooperation amongst the scientific communities of Latin America to achieve common future goals.

AUTHOR CONTRIBUTIONS

MM, JM, and JD-A conceived and wrote the manuscript. All authors made direct and intellectual contribution to the work.

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