Hazards and Risks from Harmful Algal Blooms / Red Tides in the Philippine Archipelago: Policy and Action Plan Considerations

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SUMMARY

Harmful Algal Blooms (HABs), commonly referred to as "red tides", have been reported in the Philippines since 1983 when Samar-Leyte and Sorsogon coastal and marine waters were affected by the bloom of *Pyrodinium bahamense*, a Paralytic Shellfish Poisoning (PSP) causative species, resulting in more than a thousand cases of poisoning and some deaths. Aside from negatively impacting public health with varied types of potential poisonings or afflictions, some HAB species continue to cause other socio-economic problems such as massive fish kills in natural harvest and aquaculture sites. On several occasions, the occurrence of HABs has necessitated the declaration of "state of calamity" in certain areas in the archipelago in order for the local governments to mitigate the impacts of their hazards and risks.

It is recommended that a thorough review of the monitoring and management of HABs in the Philippines be undertaken by relevant government agencies with the participation of stakeholders. A foresighted and science information-based management scheme with strategic research should be prepared and implemented. The innovative change is needed considering the increase in the number of newly- and regularly- affected areas by HABs and the apparent effects of climate change which should be included in the general scheme of Philippine HAB / Red Tide monitoring and management that was created almost three (3) decades ago.

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ABBREVIATIONS

ASP, Amnesic Shellfish Poisoning; BFAR, Bureau of Fisheries and Aquatic Resources; CFP, Ciguatera Fish Poisoning; DOH, Department of Health; DSP, Diarrhetic Shellfish Poisoning; ECTI, Expert Center for Taxonomic Identification; ENSO, El Niño Southern Oscillation; IPHAB, International Panel on Harmful Algal Blooms; HAB, Harmful Algal Blooms; LGU, Local Government Unit; PhilHAB, Philippine Harmful Algal Bloom Program; PhilSA, Philippine Space Agency; PSP, Paralytic Shellfish Poisoning; RBA, Receptor Binding Assay; UNESCO, United Nations Educational, Scientific and Cultural Organization

HARMFUL ALGAL BLOOMS IN THE PHILIPPINES

Based on the reports of the Bureau of Fisheries and Aquatic Resources (BFAR), Harmful algal blooms (HABs) have been observed in 44 bays and coastal waters in urban and rural areas in the Philippines (BFAR 2015; BFAR 2016). These are actually records of blooms of toxic species primarily causing Paralytic Shellfish Poisoning (PSP), which sometimes cover entire areas for months depending on the weather and other environmental conditions.

Figure 1 illustrates the different types of HABs that occur/may occur in the country. Species that have already caused and others that may lead to human poisoning, such as Paralytic Shellfish Poisoning (PSP), Amnesic Shellfish Poisoning (ASP), Diarrhetic Shellfish Poisoning (DSP), and Ciguatera Fish Poisoning (CFP) have been so far collected and identified from several monitoring and research collection and study sites. However, only PSP and CFP are the human poisonings from HABs that have been documented in the country. Fish kill events attributed to algal blooms/red tides have also been recorded since 2004.

Figure 2 shows the organisms already collected in the Philippines and that have been attributed to PSP events.

Records of human toxicity associated with HABs in the Philippines are summarized in Table 1.

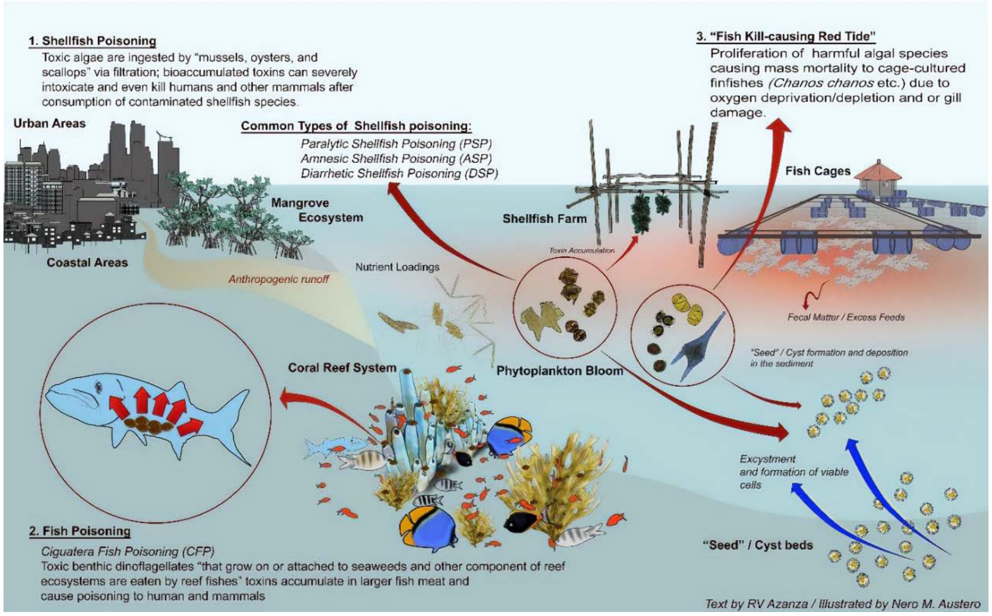

Figure 1. Organisms already collected in the Philippines and have been attributed to PSP events.

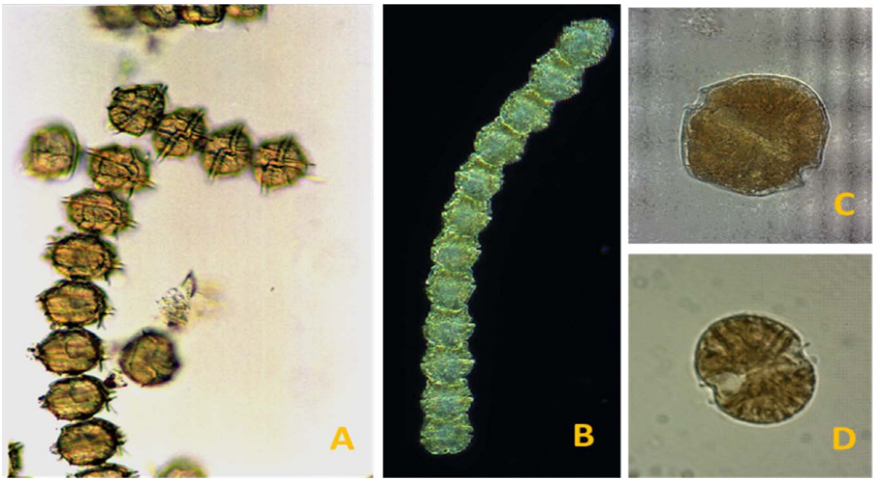

Figure 2. Paralytic Shellfish Poisoning (PSP) causative organisms occurring in the Philippines. (A, *Pyrodinium bahamense*; B, *Gymnodinium catenatum*; C and D, Alexandrum species)

Table 1. Summary of records of toxicity associated with HABs in the Philippines

Year	HABs	Places	References
1983 2021-2022	Paralytic Shellfish Poisoning *Pyrodinium bahamense*	Sorsogon, Samar and Leyte waters New records: Guiuan, Samar; Panay Coast; San Benito, Surigao Norte and Lanao Norte waters All year round: Milagros, Masbate; Tagbilaran, Bohol; Leyte Coast; Murcielagos, Zamboanga; and Dumanguillas, Zamboanga	Azanza 2017 BFAR Shellfish Bulletin
2018 2021	Ciguatera fish poisoning (CFP)- genus *Gambierdiscus carpenteri*	Confirmed: Bolinao, Pangasinan	Vacarizas et al. 2018 Yniguez et al. 2021
1976 Yearly or with a skip of one or a few years	Fish kills/ Red tides *Prorocentrum cordatum* (2002) *Chattonella subsalsa*, *Skeletonema* sp., *Rhizosolenia* sp., and *Takayama* sp.	The first documented fish kill in the Philippines was in 1976 in Tawi-Tawi Northwestern Philippine coastal waters of Bolinao and Anda, Pangasinan, sites of extensive fish cages and fish pens for milkfish (*Chanos chanos*). In many occasions, the waters in Bolinao-Anda, Pangasinan had very high plankton abundances yet no fish kills were reported	Maclean 1984 Yniguez et al. 2021, PhilHABS 2014

SOCIO-ECONOMIC IMPACTS OF HABs

The overall socio-economic impact of HABs is complex and covers four main costs: (1) human health; (2) fishery; (3) tourism and recreation; and (4) monitoring and management costs. Other countries spend significant amounts on monitoring and management of HABs. Australia, for instance, spends USD 8.7 million annually for monitoring and contingency planning for HABs (Rigosi et al. 2014).

Identified as a major aquaculture site for seaweeds and shellfish in the Southeast Asian region, the Philippines is recognized as the most heavily damaged by harmful algae (UNESCO IOC WESTPAC HAB Website). The only reported estimate of the economic impact of HABS in the Philippines was during the first occurrence of PSP-related series of events in Samar Sea in 1983 which had a loss of USD 5 million for the mussel industry, excluding losses incurred by the fishing industry (Gonzales 1989).

Another catastrophic HAB occurrence was in Manila Bay in August and September 1988 when inaccurate news reporting by misinformed reporters caused a public scare also called a "halo effect" in a disaster. Consequently, losses of up to USD 300,000 per day were incurred. Japan and Singapore banned shrimp exports from the Philippines which resulted in the loss of potential earnings of USD 500,000 per day. Moreover, the losses of mussel growers during the three-month period of depressed market amounted to about USD 950,000 (Corrales and Maclean 1995).

Over the last decade, local government units sometimes declare HAB-affected areas under state of calamity upon confirmation by the Bureau of Fisheries and Aquatic Resources and the National Disaster Risk Reduction and Management Council. In other areas in the Philippines, state of calamity due to HABs has been declared since 2010. However, during the 2019-2021 COVID-19 pandemic years, there are no updates found on the BFAR website regarding this (Shellfish Bulletin, revisited on 15 January 2023).

HAB MONITORING AND MANAGEMENT

As in many HAB-affected countries, an awareness and information campaign helps in the reporting and eventually the management of this phenomenon. Red tide/HAB monitoring and information campaign programs started in the Philippines in the late 1980s.

The monitoring and management of HABs has evolved from the 1980s to the present. From an Inter-agency Red Tide Committee, co-headed by the Director of the Bureau of Fisheries and Aquatic Resources (BFAR) and the Secretary of the Department of Health (DOH), the processes have been streamlined with BFAR, with the help of Local Government Units (LGUs), leading the Red Tide monitoring and management, actually referring to those causing PSP. The regular monitoring reports, previously called "Red Tide Bulletins" are now under the heading "Shellfish Bulletins" and the occurrences of PSP toxicity (toxic values and cases not provided) are signed by the BFAR director and made available on the website (https://www.bfar.da.gov.ph).

From the earliest report to the present, the type of HABs and the causative species have diversified for both toxic blooms and fish kill events (Azanza 2017; Azanza et al. 2017; Yniguez et al. 2021) necessitating a review and enhancement of the country's HAB monitoring and management. Based on the records of the monitoring agency (BFAR Shellfish Bulletin), there has been an expansion in the number of sites affected by toxic algal blooms through time, with new sites affected recently and other sites more regularly.

HAB RESEARCH: HAB Origin, Expansion, and Bloom Dynamics

The expansion of the mussel industry in the country could likely have transported shellfish with HAB causative species from affected sites to new mariculture sites (Azanza 2017), thus, serving as vectors of transfer and subsequent blooms using the cysts/seeds of *P. bahamense* (PhilHABs 2014); It should be noted that many of the HABs in these new areas have not been studied to verify this.

Marine litter and boats/ships can also serve as HAB transport vectors (Azanza 2017) and in some sites as in the Manila Bay, advection of cells and/or cysts can initiate their bloom in separate embayments. Cysts are carried and could withstand long-distance transport (Azanza et al. 2018) and act as a progenitor of a bloom in new areas. In previously affected areas, the presence of seed beds has been well documented for *Pyrodinium bahamense, Alexandrium* spp, and other species here and in other counties (Anderson1998; Azanza et al. 2018).

The role of eutrophication of the Philippine coastal waters in HAB occurrences and apparent expansion in time and space is not well understood. One of the fast-growing countries in the region with more than half of the population living at or near the coast, coastal development in the country has been at a fast pace. Treatment/management of waste water flowing into the ocean has not been in place including the regular monitoring of water quality for example in Manila Bay and the globally recognized tourist destination of Boracay (Jacinto et al. 2006). The role of eutrophication on HAB occurrences has been more concretely demonstrated in Bolinao-Anda, which has a long history of problem related to the number of fish pens/cages, stocking densities and feed amounts and quality (San Diego-McGlone et al. 2008; Ferrera et al. 2016).

Climate Change and HABs in the Philippines

Due to the limited long-term information available, it is difficult to discern at this point if climate change impacts, such as increase in temperature and changes in rainfall patterns, play a role in the patterns of HABs in the Philippines. Prior to determining climate change effects, the influence of the El Niño Southern Oscillation (ENSO) needs to be understood since this phenomenon is a significant contributor to periodic shifts in temperature and rainfall in the region (Juneng and Tangang 2005; Lyon and Camargo 2009). Azanza and Taylor (2001) suggested that conditions during El Niño (e.g., warmer sea surface temperatures) seem to be correlated with HAB occurrences in Southeast Asia. Considering the mechanisms promoting *Pyrodinium* blooms and fish kills, it seems possible that transitions from dry to rainy conditions that promote increased nutrient run off and a more stable water column can be the triggering factors that initiate and promote HABs (Villanoy et al. 2006; Azanza 2014; Ferrera et al. 2016; Yñiguez et al. 2021).

HABs are species-specific and site-specific: More species and sites to be studied

HABs have been found to be site-specific and causative organism with specific growth requirements. This means that HABs could possibly only happen in specific areas where causative organisms could make use of the environmental conditions depending on their inherent or genetic capacity. Understanding the **bloom dynamics**—what, when, and how HABs occur or recur—is therefore based on knowledge about the ecology of the organisms in a specific area, which is then used to predict the occurrence/recurrence of such events to be able to cope with or prevent their negative impacts. Along this line, *Pyrodinium bahamense* coud be the most well-studied PSP organism in the Philippines.

In the Western Pacific, Malaysia and Indonesia have also reported HABs species. Other PSP-causative organisms in this region include *Alexandrium* spp. and *Gymnodinium catenatum*, which have been reported in other Asian countries such as China, Malaysia, Indonesia, Thailand, the Philippines, and Japan. Another public health hazard caused by HABs is **ciguatera fish poisoning (CFP)**, a sparsely studied phenomenon in the Philippines, although the causative organisms have been reported in the country, especially in mariculture areas like Sorsogon and Bolinao, Pangasinan.

Many HAB-causative organisms have been identified and isolated in the milkfish mariculture sites of Bolinao, which have the highest biodiversity of HAB-causative organisms in the country. Their blooms seem to be related to the monsoon fish kills caused or intensified by HABs have been reported in the country especially in mariculture areas like Sorsogon and Bolinao, Pangasinan. Fig. 2 shows where HAB monitoring and research have been done or initiated.

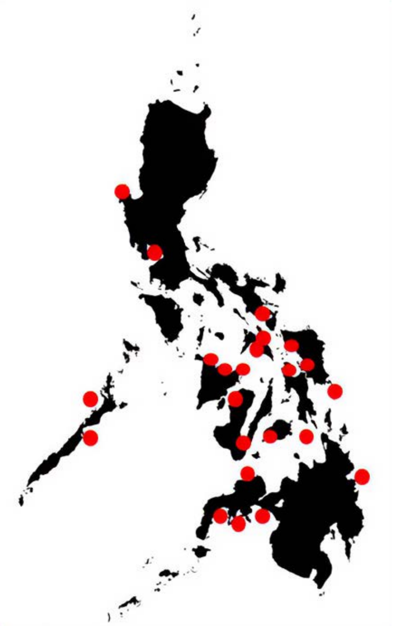

Figure 3. Areas in the Philippines where HAB research has been initiated (Azanza et al. 2017)

Guide for HAB HAZARD AND RISK MANAGEMENT and Future Research

Hazard is defined as an agent that has the potential to cause harm to a vulnerable target; risk is the probability that exposure to a hazard will lead to a negative consequence. Put more simply, a hazard poses no risk if there is no exposure to that hazard. Hazards and risks to HABs could either be health and or socio-economic in nature (Fig. 4).

As shown by HAB trends in the Philippines and the rest of the world, HABs, which have a long history may always be part of humanity's existence. Their recurrence is complicated by heightened anthropogenic activities in the coastal areas and climate change would only exacerbate their impacts. Hallegraeff (2010) believes that some tropical dinoflagellate species benefitting from anthropogenic inputs (i.e., nutrient run-off from land and rain, increased seawater temperatures, coral reef destruction) may become more successful and can continue to recur and expand. Cold water-loving species may be pushed or driven pole-ward (i.e., they would become more limited by temperature rise brought about by climate change).

There is an increasing need to define the niche (specific role in its living space) of HAB species, remembering the fact that HABs are species-specific and area-specific, key points in the prediction of "winners" and "losers" in a changing environment. **Long-range data sets about the organisms and their living condition preference should be gathered and analyzed (and modelled) for forecasting and hind casting** (Azanza 2017).

Blooms of *Pyrodinium bahamense* has been recurring in many bays in the country and the species found to be present in more than about 44 bays. With the predicted increase in surface sea temperature as a result of climate change, this tropical toxic phytoplankton species could widen its range of distribution. This PSP causative organism also dominated the phytoplankton in areas of Southeast Asia, South America, and South Pacific (Maclean 1989) and that there is evidence that the organism exhibited expansion during prolonged El Niño (Azanza and Taylor 2001; Azanza 2014; Azanza et al. 2017). Seeds of some phytoplankton organisms have been found in areas beyond tropical sediments, an evidence indicating that they existed or could have bloomed in these environments in the past and may once again bloom, causing problems in these areas.

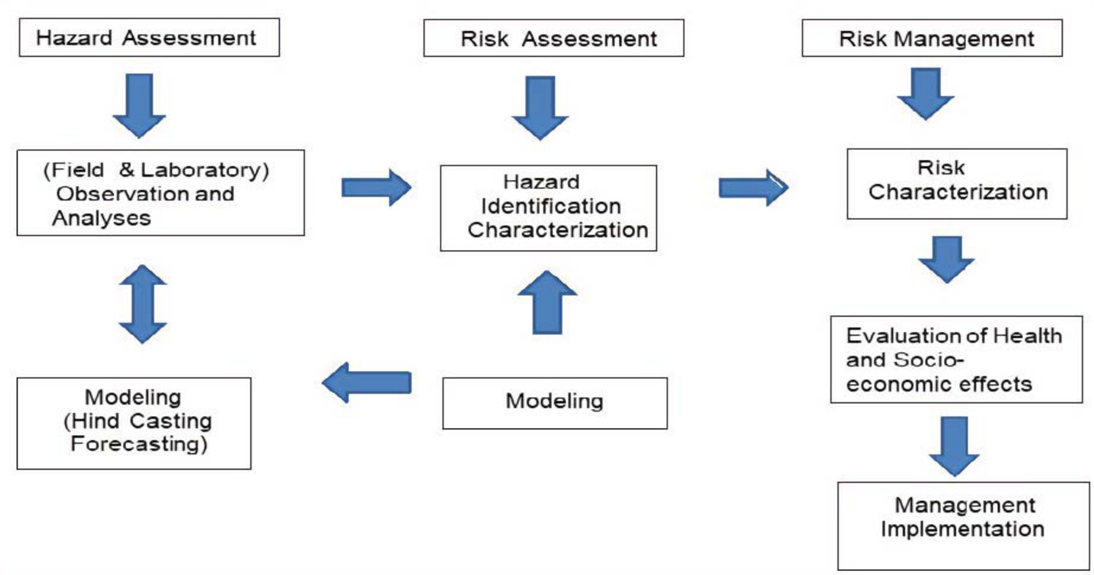

Figure 4. Assessment and Management of HAB Hazards and Risks (van Dolah et al. 2001)

Hallegraeff (2010) has made predictions for other HAB species in connection with climate change. He stated that we can expect: (1) range expansion of warm-water species at the expense of cold-water species, which are driven poleward; (2) species-specific changes in the abundance and seasonal window of growth of HAB taxa; (3) earlier timing of peak production of some phytoplankton; and (4) secondary effects for marine food webs, notably when individual zooplankton and fish grazers are differentially impacted ("match-mismatch") by climate change.

Since many of the toxins produced by HAB organisms are new or not yet identified, it is essential that they are characterized to make them more available as standards for testing samples, monitoring, and research. **Efforts for innovation can also be accelerated with the isolation and culture of causative organisms where culture in large amounts can result in application of knowledge and development of technologies. Innovative research on the use of HAB toxins for pharmaceutical and cosmetic use should be encouraged.**

Modern techniques and tools for toxin detection developed and tested like the receptor binding assay (RBA) remains to be more widely adopted for PSP detection, monitoring, and research. Likewise, field detection of cells need to be further enhanced to enable faster but accurate results—genomics and proteomics, i.e., in situ tools to identify HAB species. Furthermore, **long-term data sets analysis should be continued and studies be done in collaboration with the Philippine Space Agency (PhilSA) so that predictions of HAB occurrence in susceptible areas can be made.**

Pyrodinium blooms are expected to occur in many waters of the Philippines during the Southwest monsoon (i.e., June to September), sometimes even up to October or November, depending on weather conditions (Azanza 2017) The harvest and consumption of shellfish could therefore be managed based on HAB knowledge from research and regular monitoring. Consumers should be made aware of such events and the corresponding health risks. Information, education, and communication about HABs for various types of audiences should be continued and heightened.

The multi-media identification of HAB species through electronic information systems can provide guided identification of causative organisms. For example, Linnaeus II, a software created by the Expert Center for Taxonomic Identification (ECTI) of UNESCO, is available on CD and online (Schalk and Pierrot-Bults 2005). **Local researchers and managers should be made aware of the**

knowledge and tools already available for their utilization and enhancement to meet local conditions and challenges.

Hazards and risks that could be imposed by coastal and marine phenomena, such as HABs, need not be damaging to the local communities when research/science-based management schemes are put in place, including timely and appropriate advice to stakeholders. With national and international efforts geared toward enhanced HAB studies and networking, the future could be bright for HAB management.

SYNTHESIS and POLICY/ACTION PLAN RECOMMENDATIONS

Monitoring of PSP causative organisms has been initiated in some and continuing in many areas in the country with regular reports of the occurrence of toxins although not quantified in the "Shellfish Bulletin" of the Bureau of Fisheries and Aquatic Resources.

The present Philippine scheme which monitors, analyzes, and manages the HAB hazards and risks, however, needs to be appraised by an intergovernmental panel with experts from the academe as consultants. This assessment would have to consider changing conditions in the environment, government systems and the coastal community's socio-economic needs. Other human poisonings from toxic algal blooms, particularly those in which the causative organisms, have been identified in the country should be included.

A foresighted integrated HAB, research monitoring and management framework is vital because of the following: (1) continued expansion of aquaculture, thus, increasing risks for toxic algal blooms and fish kills; (2) recurrence or continued presence of previously reported and novel HAB species in old and new sites; and, (3) increased eutrophication and climate change impacts on the HABS.Ongoing research and monitoring endeavors on HABs have been continued internationally through the UNESCO-International Panel on Harmful Agal Blooms (IPHAB) and the UNESCO Western Pacific HAB program, using existing knowledge and generating new ones coming from collaborators in key areas.

The missions and vision of the Philippine Harmful Algal Bloom Program (PhilHAB) funded by the Department of Science and Technology (DOST) until 2017 and was part of the UNESCO Global Ecology and Oceanography Program of UNESCO-IPHAB, are within the core of contemporary national research efforts like the HABwatch program. Nevertheless, **a nationwide conference/workshop should be undertaken to develop a future oriented evaluation and planning for Philippine HAB research within the abovementioned integrated HAB framework, for policy making and management decision.**

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ABOUT THE AUTHOR

Dr. Rhodora Azanza is recognized for her significant contributions and accomplishments in the field of biology and ecology of harmful microalgae, specifically her pioneering studies on toxic dinoflagellate species responsible for Paralytic Shellfish Poisoning in the Philippines. Her original study in culturing the dinoflagellate *Pyrodinium bahamanse* var. *compressum*, the main Paralytic Shellfish Poisoning causative organism in the Philippines and in Southeast Asia, has paved the way in opening opportunities for further studies on the biology and eco-physiology of the dinoflagellate. Such studies have led to the identification of the factors that affect the occurence of algal blooms and have contributed to the design and implementation of proactive strategies that can mitigate the harmful effects of red tides and other algal blooms. Thus, negative socio-economic impacts specially on the coastal people have been minimized, if not prevented.

Dr. Azanza is a member and former president of the National Academy of Science and Technology Philippines. She is also a Professor Emeritus and former Dean of College of Science, University of the Philippines Diliman.

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