Monitoring and Identification of Harmful Algal Blooms in Southeast Asia to Support SDG 14.1

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One of the targets of **SDG 14** on conservation and sustainable use of oceans, seas and marine resources for sustainable development adopted in September 2015, indicates that (**SDG 14.1**): By 2025, "marine pollution of all kinds in particular from land-based activities, including marine debris and nutrient pollution, shall have been prevented and significantly reduced." One of the UN indicators for achieving the said target is the "index of coastal eutrophication." By definition, "eutrophication is the enrichment of water as a result of an increase in nutrients, especially nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life, which can have negative impact on the marine and coastal environment."

The Singapore-based SEAFDEC Marine Fisheries Research Department (MFRD) has embarked on a Japanese Trust Fund Project on "Chemicals and Drug Residues in Fish and Fish Products in Southeast Asia – Biotoxins (ASP, AZA and BTX) and Harmful Algal Blooms (HABs) in the ASEAN Region" which includes monitoring of biotoxin-producing harmful algal bloom (HAB) species, which ensures that fish and shellfish are not contaminated with these toxic algae or their toxins, and enhances regional capabilities in identifying biotoxin-producing HAB species. This is considering that in recent decades, many coastal countries in Southeast Asia have experienced an increasing trend in pollution-associated problems caused by massive blooms of harmful and toxic algae, known before as "red tide" and now better known as "harmful algal bloom" (HAB). The occurrence of HAB in fresh and marine waters has led to mass mortalities of wild and cultured fish and shellfish, human illnesses and to some extent, death from contaminated shellfish or fish, death of marine mammals, seabirds, and other animals, and alteration of marine habitats or trophic structure through shading, overgrowth, or adverse effects on life history stages of fish and other marine organisms, hampering the sustainability of fisheries and aquaculture.

Common HAB species in the Southeast Asian region

Harmful Algal Bloom species (HABs) are overgrowths of algae in water, some of which produce dangerous toxins in fresh or marine waters as well as non-toxic blooms that harm the environment and national economies. HABs grow in waters with considerable amount of sunlight and are slow-moving with large amount of nutrients, especially nitrogen and phosphorous. Nutrient pollution from human activities makes the problem on HABs worse, as this could lead to much more severe blooms that occur more often. Many studies have indicated that HABs can produce extremely dangerous toxins that can make not only people sick leading to deaths but also high mortalities in aquatic animals (GEOHAB, 2010). By creating dead zones in the water, the occurrence of HABs can lead to high treatment costs for drinking and clean water, damaging the industries that depend on clean water for their operations including the aquaculture industry.

The most common HABs in the ASEAN region include: *Cochlodinium polykrikoides* - a chain-forming dinoflagellate associated with massive fish kills; *Pyrodinium bahamense* var. *compressum* – chain-forming dinoflagellates that produce Paralytic Shellfish Poisoning (PSP) toxins; *Alexandrium* - another dinoflagellate genus which contains PSP toxin-producing species; *Prorocentrum minimum* - causes mass mortality of aquacultured fish in Japan, Philippines, and Singapore; *Karenia mikimotoi* - forms red tides in western Japan and in other waters in Southeast Asia; *Phaeocystis globosa* - a prymnesiophyte which occasionally causes extensive blooms, leading to fish kills and mortality of caged fish and lobsters in waters of China and Viet Nam; and *Noctiluca* - a monospecific genus of large unarmored heterotrophic dinoflagellates.

HABs can be broadly classified into two groups, namely: biotoxin producers which cause biotoxin contamination in fish and shellfish resulting in human illness and death when the fish and shellfish are consumed, such as PSP, Diarrhetic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP); and high–biomass producers which can increase cell populations in a short time and cause mass mortalities of fish and other marine life. Timely detection of HABs and the toxins produced is a critical component of most fish and shellfish safety management plans. Such information, if made available earlier in the process of toxic HAB initiation and development, can provide coastal resource managers, fishers, aquaculture operators, and public health officials with the data needed to recommend or take actions for mitigating the effects of toxic HABs. In addition to routine surveillance for biotoxins in fish and shellfish at import control as well as in wholesale and retail markets, monitoring of biotoxin-producing HABs is crucial to detect the presence of toxic algae or development of harmful blooms, and provide early warning to aquaculture operators and other concerned parties. Fast, early warning of increased toxic HAB cell numbers can help biotoxin monitoring programs in ensuring the safe harvest of fish and shellfish from toxin-free areas of the coasts, as well as redirecting resources to target more vulnerable locations.

Massive bloom of the algae *Noctiluca* spp.

The ecological and economic impacts of HABs in the Southeast Asian region are enormous and apparently increasing, especially that many ASEAN Member States (AMSs) generate the highest amount of production of cultured fish and shellfish in the world. Thus, the impacts from HABs on these resources in the region would be high. In addition, the Southeast Asian region has been characterized as having a high diversity of harmful syndromes and causative organisms; an apparent increasing trend of HABs throughout the region; and an increasing trend toward regional eutrophication.

The causes behind the increasing trend of HAB incidences are varied ranging from natural mechanisms of species dispersal to a host of human-related phenomena such as increasing nutrient-rich pollution, climate change, or transport of algal species via ship ballast water. Many countries are faced with a bewildering array of toxic or harmful species and impacts, as well as disturbing trends of increasing bloom incidence, more impacted resources, larger areas affected, and higher economic losses. It is with this backdrop that MFRD expanded its project on "Chemical and Drug Residues in Fish and Fish Products in Southeast Asia - Biotoxins Monitoring in the ASEAN Region" to include monitoring and identification of biotoxin-producing HABs.

Enhancing Regional Capacity in Monitoring and Identifying Biotoxin-producing HABs

Marine biotoxins represent a significant and expanding threat to human health in many parts of the world. The impact is visible in terms of human poisoning or even death following consumption of contaminated shellfish or fish, as well as mass killings of fish and shellfish, and death of marine animals and birds. The Codex Alimentarius Code of Practice for Fish and Fishery Products (CAC/RCP 52-2003) defines biotoxins as poisonous substances naturally present in fish and fishery products or accumulated by the animals feeding on toxin producing algae, or in the water containing toxins produced by such organisms. Therefore, monitoring seafood toxicity is essential to manage the risks. However, there are several limitations in monitoring for toxicity such as variations in toxin contents between individual shellfish; different detection and extraction methods for various toxins; decision needed on which toxins should be tested for; and frequency of sampling to ensure that toxicity does not rise to dangerous levels in temporal or spatial gap between sampling times or locations. Furthermore, the growing harvest of non-traditional shellfish (*e.g.* moon snails (Family: Naticidae), whelks (Family: Buccinidae), barnacles) could increase human health problems and management responsibilities.

The aforementioned five-year project of MFRD on biotoxins monitoring was initiated in 2009, primarily covering the DSP toxins, lipophilic toxins, PSP toxins, and Tetradotoxin (TTX). Prior to the completion of the project in 2012, many AMSs identified other biotoxins that need to be dealt with, such as the ASP toxin (Domoic Acid), Azaspiracids (AZA), and Brevetoxins (BTX) which cause Neurotoxic Shellfish Poisonong (NSP). The AMSs also proposed to conduct monitoring survey on PSP toxins in the respective AMSs. Moreover, the AMSs also pointed at the importance of identifying toxic HABs to complement the existing biotoxins monitoring activities to ensure that fish and shellfish are not contaminated with toxic algae or their toxins. Thus, MFRD was specifically asked to enhance regional capabilities for the identification and monitoring of toxic HABs, as well as monitoring and testing of fish and shellfish. This MFRD project was therefore extended for another five years (2013-2017) to continue the monitoring of other biotoxins including biotoxin-producing HABs, in line with relevant provisions in the 2011 Resolution and Plan of Action (SEAFDEC, 2011) shown in **Box 1**.

Box 1. Provisions in the 2011 Resolution and Plan of Action related to the MFRD project on "Chemical and Drug Residues in Fish and Fish Products in Southeast Asia - Biotoxins Monitoring in the ASEAN Region"

Resolution 21: Improve technologies and facilities to ensure fish quality assurance and safety management systems, taking into account the importance of traditional fishery products and food security requirements, and promote the development of fishery products as an alternative supplementary livelihood for fisheries communities.

Plan of Action D61: Strengthen fish quality and safety management systems that support the competitive position of ASEAN fish products on world markets, including moving towards ISO/IEC 17025 accreditation of national fish inspection laboratories, strengthening capacity and acknowledging the recognized national laboratories, risk analysis and equivalence agreement such as the Mutual Recognition Agreement (MRA) and promote the implementation of the quality and safety management systems among small and medium enterprises in the ASEAN region.

Plan of Action D63: Promote and conduct training programs and develop training materials to upgrade the technical skills and competencies of personnel in the public and private sectors on fisheries post-harvest technology and food safety management system.

Management of HABs in the Southeast Asian Region

Under the framework of the project and with support from the Japanese Trust Fund, MFRD convened the "Regional Technical Consultation (RTC) on HABs in the ASEAN Region" in Singapore on 5-6 August 2015 for the AMSs to report on toxic HAB occurrences and incidences as well as the management of toxic HABs in their respective waters, and to plan for the subsequent activities under the project. The RTC was attended by representatives from the AMSs and Japanese Experts on HABs, *Dr. Yasuwo Fukuyo* and *Dr. Hiroshi Oikawa*. The status of HABs monitoring and management as well as the constraints and future plans of the AMSs are shown in **Box 2** (MFRD, 2015).

Box 2. HABs occurrences, management and future plans in the ASEAN Member States
Brunei Darussalam
HABs Occurrences: First recorded occurrence of red tide in country's waters was in 1976
Actions taken: Routine was established to monitor red tide phenomenon that includes plankton monitoring and shellfish toxicity testing, to prevent or mitigate adverse impacts on humans and economic losses to the fishing industry
Issues and Concerns: Lack of experts and trained personnel on HAB management; involvement of multi-level agencies; difficulties in sampling at adequate temporal and spatial scales; lack of tracking method and modelling; lack of infrastructure, *e.g.* analytical facilities and monitoring tools; inadequate public outreach efforts and centralized database
Future Plans: Activate regularly the National Red Tide Action Plan established in 1992 to disseminate information to the public quickly and correctly in order to reduce impacts of red tide on public health and the fishing industry; promote massive information dissemination to increase public awareness; develop monitoring and identification technologies and strategies; enhance coordination with neighboring countries to disseminate early reports on occurrence of red tide in their respective waters
Cambodia
HABs Occurrences: Paralytic Shellfish Toxin (PST) was detected in brackish and freshwater puffer fish (April 2005-January 2006) using high performance liquid chromatography (HPLC) that caused deaths to consumers; Tetrodotoxin (TTX) was also detected in brackish and freshwater puffer fish (Tetraodontidae) and horseshoe crabs (*Carcinoscorpius rotundicauda*) from April 2005 to January 2006) using liquid chromatography-mass spectrometry (LC/MS)
Actions taken: Fish and green mussel specimens were sent to Viet Nam for analysis as there are no facilities for this purpose in the country
Issues and Concerns: National Laboratory could not analyze biotoxins; limited budget; collected data not sufficient to reflect the actual situation of biotoxins and HABs in cultured and wild fish in the country; no plans on monitoring of biotoxins and HABs
Future Plans: Training of laboratory staff to enhance their knowledge and skills on methods of analyzing biotoxins and HABs; support the promotion of Inter Laboratory Proficiency Testing for Biotoxins and Harmful Algal Blooms; support the establishment of networking system to develop the methods of analyzing biotoxins and HABs for the region
Indonesia
HABs Occurrences: Although data on food poisoning assosiated with biotoxin arises from consumption of seafood are rarely observed in the country, some cases were reported, such as: blooming of *Trichodesmium erythraeum* in Lampung and thousand islands reported in 1991 that caused mortalities in cultured shrimps; consumption of shellfish *Meritrix meritrix* caused human deaths in Makassar, South Sulawesi (1987) and Sebatik Islands, East Kalimantan (1988); deaths after consumption of 'bia manis' (*Hiatula chinensis*) was reported in Ambon in July 1994, the samples that were taken showed presence of *Pyrodinium bahamense* var. *compressum* (Pbc); blooming of *Pyrodinium bahamense* in Lampung in 2013 caused mortalities in cultured fish; blooming of phytoplankton in Jakarta Bay in 2004 caused massive fish kills
Actions taken: Implementation of Shellfish Monitoring Program since 2015; Monitoring of Ciguatoxin for coral fish since 2016; Monitoring of HABs since 2016
Issues and Concerns: Causes of such poisoning were unknown and problems caused by "red tide" were seldom serious or probably not reported due to: as an archipelago, Indonesia has a long coastline and 2/3 of the Indonesian zones are oceans, insufficient knowledge on the part of fishers, inadequate data and information although many institutions are dealing with biotoxins, lack of funds, lack of coastal resources management, lack of knowledge on biotoxins, lack of laboratory capacity to analyze biotoxins
Future Plans: Continue Shellfish Monitoring Program (started in 2015) in Ambon, Jakarta Bay, Lampung, East Java, Tanjung Balai; Continue monitoring of ASP, AZA and BTX: develop testing methods; Continue monitoring of Ciguatoxin for coral fish (started in 2016) in Lampung, Makassar, Bali, East Java, Papua, Gorontalo; Continue monitoring of HABs (started in 2016) in Ambon, Jakarta Bay, Lampung, East Java, Tanjung Balai
Lao PDR
HABs Occurrences: No data on occurrences and monitoring activities on HABs; no activities or training on HABs monitoring
Actions taken: Management system of HABs is undertaken by the Aquaculture Management Section of Namsouang Aquaculture Development Center
Issues and Concerns: No authority in charge on HABs monitoring; lack of specialists or experts on HABs; Laboratory for HABs analysis is not yet set up; Need financial and technical support to carry out the country's future plans
Future Plans: Conduct research and related activities on HABs in freshwater bodies of the country; Capacity building on HABs such as training and monitoring activities; Cooperate on lab-testing of HABs with neighboring countries; Set up laboratory for HABs analysis

Box 2. HABs occurrences, management and future plans in the ASEAN Member States (Cont'd)
Malaysia
HABs Occurrences: West coast of Sabah (1976): 202 people were intoxicated and there were 7 deaths due to *Pyrodinium bahamense* var. *compressum*; Johore Strait (1985): heavy shrimp kills due to *Chattonella marina*; Sebatu, Malacca (1991): shellfish contamination and 3 people were hospitalized due to *Alexandrium tamiyavanichi*; Johore Bharu, Johore (2002): water discoloration due to *Prorocentrum minimum*; West Coast of Sabah (2004): massive fish kills in cages and shellfish contaminated with *P. bahamense* var. *compressum* and *Cochlodinium polykrikoides*; Off-shore Miri (2004): localized warning but no impact due to *C. polykrikoides*; West Coast of Sabah (2005): massive fish kills in cages due *P. bahamense* var. *compressum* and *C. polykrikoides*; Lawas, Limbang (2005): localized warning but no impact due to *P. bahamense* var. *compressum* and *C. polykrikoides*; Pangkor, Lumut, Penang (2007): water discoloration due to *Ceratium furca*; West Coast of Sabah (2009): shellfish contamination due to *P. bahamense* var. *compressum*; Kuantan, Pahang (2013): shellfish contamination and 2 were hospitalized due to *P. bahamense* var. *compressum*; West Coast of Sabah (2013): more than 40 people were intoxicated and there were 3 deaths due to *P. bahamense* var. *compressum* and *C. polykrikoides*; Lawas (2013): localized warning but no impact due to *C. polykrikoides*; Kuantan, Pahang (2014): fish kills in cages due to *P. bahamense* var. *compressum*; Johore Strait (2014): massive fish kills due to *Karlodinium austral*; West Coast of Sabah (2014): fish kills in cages and shellfish contamination due to *P. bahamense* var. *compressum* and *C. polykrikoides*; Johore Strait (2015): massive fish kills due to *K. austral*; West Coast of Sabah (2015): fish kills in cages due to *C. polykrikoides* and *Notiluca scintillans*
Actions taken: Regular and constant monitoring since 1976; Results for over 20 years indicated that PSP levels widely varied for different periods, locations, and species; intensify public warning through localized warning intended only for affected district and PSP level exceeding the danger limit (400 MU), and Statewide warning issued through press releases, radio and TV broadcasts when HAB outbreaks widely spread and the PSP level exceeds the danger level in all high risk areas in each affected State; Public Education through distribution of "easy-to-understand" leaflets on guidelines and precautions to be taken during PSP outbreaks to the fishing community and general public; HAB awareness campaign-cum-exhibition during state festivities; Public HAB forum with local communities, students
Issues and Concerns: Lack of long term scientific knowledge on biology, taxonomy, eco-physiology, mechanism of blooms and toxin chemistry of HABs; Insufficient comprehensive and cost-effective monitoring programs and techniques country-wide to provide early warnings to prevent human intoxication, massive fish kills and economic losses to the fishery industries; Inadequate mitigation measures to minimize impacts and economy losses to the fishery industries; Lack of strategic plan to educate and promote public awareness in targeting all level of communities in the affected areas; Insufficient funding to strengthen laboratory facilities to conduct internationally recognized techniques with trained, dedicated and responsible manpower in monitoring and analysis activities; Inadequate enforcement during occurrence of HABs to prevent selling of contaminated fishery products that cause harm to the consumers; Lack of structured training and capacity building programs on HABs and biotoxins for personnel of national competent authority
Future Plans: Recent occurrences of HABs in the country that caused human intoxications and massive fish kills need to be addressed seriously to safeguard consumers on seafood safety and minimize economic losses of fishery industries; Department of Fisheries Malaysia to continue making efforts to address issues and challenges pertaining to HABs and biotoxins in the country, with cooperation among relevant government agencies, research institutions, universities and international organizations, to achieve systematic and consistent management of HABs in the near future; To continue management of biotoxins by identifying and focusing on biotoxins of high priority, especially those having significant impacts on human and animal health and the health of ecosystems, harmonizing and standardizing analytical methods that are internationally validated with standard operation procedures (SOPs) for all the diagnostic laboratories for each individual aquatic biotoxin, identifying the most appropriate analytical instruments for each individual aquatic biotoxin of high priority, assessing the capabilities and facilities of the existing diagnostic laboratories for further enhancement and improvement, establishing toxin standard development, maintenance, and distribution system, so that these toxins are equally accessible and available to all diagnostic and research laboratories, conducting training programs to increase human resource capabilities to produce experience and skillful laboratory analysts in public and private laboratories, effectively coordinating the resources and facilities that are currently in government agencies, research institutions and universities, developing rapid (*e.g.* in situ detection) and cost-effective methods for detecting and quantifying biotoxins that are accepted internationally
Myanmar
HABs Occurrences: No data
Actions taken: Survey of molluscan shellfish conducted in 2015 for *Crassostrea belcheri* (oyster) and for *Perna viridis* (green mussel) which started recently
Issues and Concerns: Project funding is very limited and not sufficient for over all survey expenses; at present, the enzyme-linked immunosorbent assay (ELISA) method of biotoxins analysis is used to analyze the survey results because LC/MS/MS is more expensive than the ELISA method
Future Plans: Enhance knowledge and awareness of Myanmar people on biotoxins; Minimize biotoxin incidents on seafood consumers; Control biotoxin outbreaks by implementing surveillancean monitoring program; Improve capacity of human resources and skilled laboratory staff for biotoxins analysis; Comply with uniform objective of biotoxins monitoring in all AMSs; Upgrade laboratory capabilities for testing biotoxins in fish and fishery products; Establish national Biotoxins Monitoring Programs for ASP, AZA, DSP, and BTX; Improve knowledge and understanding of the levels of biotoxin occurrences and incidences in fish and fishery products of the country and ensure that fish products are safe from biotoxin contaminations
Philippines
HABs Occurrences: June 1983 - 1st recorded occurrence of *Pyrodinium bahamanse* var. *compressum* (Pbc) in Samar; 1987 – Pbc observed in coastal waters of Zambales and Western Samar; Succeeding years - Pbc blooms sighted in Manila Bay and in different coastal waters in the Visayas region; 1990s - spread of Pbc bloom in most coastal waters of the Philippines was observed; 2003 - *Alexandrium minutum* was first recorded in coastal waters of Bolinao, Pangasinan; 2006-2007- Pbc blooms were reported only in Sorsogon Bay and Juag Lagoon, Matnog in Sorsogon Province

Box 2. HABs occurrences, management and future plans in the ASEAN Member States (Cont'd)
Actions taken: 1984 – the Philippines initiated a monitoring program for all red tide affected areas to detect the bloom at its early stage; 1987 – Bureau of Fisheries and Aquatic Resources (BFAR) conducted national training courses on red tide detection, identification and monitoring to give timely alert and response to the public at local level should a threat of Pbc bloom become imminent; 1988 – due to the considerable negative impacts of Pbc blooms, the National Red Tide Task Force (NRTTF) was created as one of the task forces of the Inter-Agency Committee on Environmental Health (IACEH). The main task of NRRTF is to come up with monitoring and management schemes. Policies made by the NRTTF were published in the Philippine Guidebook on Toxic Red Tide Management, where the monitoring and management strategies in the guidebook serve as guide for red tide managers both in the local and national levels; 1989 – PSP Monitoring started as a project of BFAR and subsequently adapted as a national program; 1990 – the Local Red Tide Task Force was established as PSP problems expanded geographically; 1999 to 2001 –BFAR-JICA Technical Cooperative Project was implemented; 2005 – BFAR took over the monitoring program in accordance with **Republic Act (RA) 8550**; PSP management has since then been jointly conducted by BFAR and concerned local government units (LGUs); BFAR regularly releases shellfish advisories countrywide through its regional offices and the LGUs, based on the results of analysis of the Marine Biotoxin Laboratory and those from other red tide laboratories managed by the different LGUs; BFAR releases shellfish bulletins regularly every two weeks and whenever necessary
Issues and Concerns: Frequency of plankton blooms has increased nationwide; Undetermined causes of country-wide expansion of toxin-producing planktons considering that HABs did not occur when investigations were carried out by transplanting infected shellfish seeds in non-infected areas
Future Plans: Continue the Marine Bitoxin Monitoring Program through improved analysis for okadaic acid (OA) toxins, Dinophysistoxin (DTX) and Ciguatera Fish Poisoning (CFP) toxin, Use of screening techniques for PSP, ASP and DSP detection in the laboratories at regional and local levels, Adoption of the Association of Official Analytical Chemists (AOAC) Accredited Isotope-Based Receptor Assay for PSP, Establishment of baseline data for PbTX and AZP
Singapore
HABs Occurrences: Recent incidences occurred in 2009, 2014 and 2015 that led to mortalities in farmed and wild fish; in the 2015 incident, fish loss was estimated at 500-600 metric tons; water discoloration (brown) was observed at farming areas; the main plankton species was *Karlodinium veneficum* that caused damage to fish gills resulting in death of the cultured fish
Actions taken: The Tropical Marine Science Institute (TMSI) of the National University of Singapore is among the leading experts in the field of phytoplankton studies, and is engaged in the current research on biology and toxicology of HAB species. During HAB events, the Agri-Food & Veterinary Authority of Singapore (AVA) works closely with TMSI to identify the causative plankton species. Fish farmers on their part, reduce the impacts of plankton bloom through the use of canvas and closed containment or transfer fish stocks to non-affected areas, and in some cases emergency harvesting is made after the AVA tested that fish is safe for consumption. AVA also assists affected farms by providing technical advisory on mitigation measures, monitoring water quality and providing SMS alerts to farmers; providing dead fish disposal services; and facilitating transfer of fish stocks to unaffected areas; and assisting in emergency harvest and liaising with cold storage owners
Issues and Concerns: Frequency of blooms associated with fish mortality has increased; Complex blooms consist of multiple plankton species; What Can Be Done to Minimize impacts - require faster detection, more scientific information on species and detailed study of toxins, and possible control and prevention measures
Future Plans: Understanding the cause(s) of plankton blooms through conducting studies on plankton blooms and hydrodynamic modeling, continued consultations with experts; New technologies to reduce impact of future blooms through development of Closed Containment Aquaculture System, and technology providers to provide effective counter-measures; Assistance to farmers to build resilience against future blooms for farms to develop an operationally ready farm contingency plan, and adopt new farming technologies that can reduce impact of blooms
Thailand
HABs Occurrences: 1957s to 2007s – occurrence of dominant species *Noctiluca scintillans* (non-toxic producing phytoplankton); May 1983 in Pranburi River, Prachuap Kirikhan Province, where there were 63 victims from eating mussels
Actions taken: Field survey conducted in 1984 in Pranburi for PSP causative organism; abundance of phytoplankton monitored in the Gulf of Thailand and Andaman Sea; training courses on monitoring toxins in phytoplankton and bivalves have been conducted
Issues and Concerns: Need to control sources of pollution from the land along the coast, due to increased development and utilization of coastal areas; reduce and control discharge of sewage including organic contents of nutrients and sediments because bacterial contamination of the sea increases during expansion of the communities and industry; develop strict control measures and law enforcement of the relevant government agencies; integrate agencies involved in water quality management
Future Plans: Join the proficiency test of phytoplankton with Bequalm Marine Institute in Copenhagen, Denmark
Viet Nam
HABs Occurrences: Red tide phenomenon occurs mainly in the central coast areas rather than in the Gulf of Tonkin and in the southern part of the country; in May 1995 algal bloom *Noctiluca scintillans* occurred in Van Phong Bay of Khanh Hoa Province causing mortalities to about 20 metric tons of lobster and losses of VND 6 billion; Disaster "red tides" in Binh Thuan in mid-September 2002: red tide occupied wide area of over 40 km^2 killing about 90% aquatic animals living in tidal areas, including fish and shrimps in cages; Red tide caused hospitalization of 82 people after swimming in affected sea that resulted in itching and blistering of sensitive areas; Based on statistical data from 1999 to 2007 in Binh Thuan Sea, red tide phenomenon often occurs with increasing frequency: once in March 1999, July 2002, July 2004; twice in August 2005, July and September 2007. During July 2011 - August 2012, five harmful algal events occurred in Ha Long Bay causing losses of $US3.0-5.0 million for local fisheries.

Box 2. HABs occurrences, management and future plans in the ASEAN Member States (Cont'd)
Actions taken: National Monitoring Program for Bivalve Mollusk Production Areas was established and implemented since 1999 covering 20 bivalve and mollusk production areas in 12 cities and provinces: Ho Chi Minh City, Tien Giang, Ben Tre, Tra Vinh, Kien Giang, Binh Thuan, Ha Tinh, Thanh Hoa, Ninh Binh, Thai Binh, Nam Dinh and Quang Ninh. Species monitored include: *Meretrix lyrata*; *Paphia* sp.; *Tegillarca granosa*; *Anadara subcrenata*; *Anadara antiquata*, *Chlamys nobilis*; *Lutraria philippinarum*; *Crassostrea gigas*, parameters collected include microorganisms, toxic algae, marine biotoxins, heavy metals, organochlorinate pesticides
Issues and Concerns: The National Monitoring Program for Bivalve Mollusk Production Areas is currently focusing on supervision of the fluctuations of toxic algae species in some areas (mainly harvesting of bivalve mollusks), not monitoring all the harmful algal species, especially that algae that often cause HAB in all coastal areas of the country; Still using traditional methods for analysis of toxic algae in the National Monitoring Program, in which using a microscope requires complex, takes time to process (sampling, storage, transportation and must analyze in the laboratory), depends on analyst and chemical usage; no comprehensive national monitoring program on harmful algae phenomenon for early warning of HABs occurrence, although many scientists as well as several projects of the country are engaged in researches on HABs and toxin-producing HABs; Research on HABs is mainly carried out by scientists from research institutes (*e.g.* Institute of Oceanography, Marine Research Institutes) and results of their studies are published in scientific journals or newspapers, but are seldom disseminated to other people, especially the fishers, who are not aware of HABs and the necessary measures to be taken when HABs occur
Future Plans: Establish a national monitoring program for all harmful algal species in coastal waters as it is essential for early warning of HABs occurrence; Conduct of training for people, particularly the fishers to increase their understanding of HABs and the measures to be undertaken during occurrence of HABs; Set up advanced methods and equipment for quantitative analysis of harmful algae, *e.g.* portable equipment for quick testing in the field; online quantitative monitoring of algae to measure and monitor the algae with different levels of warning on HABs occurrence

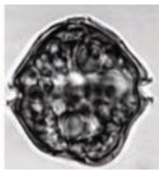
HABs Occurrences and Management in Japan

In Japan, the major toxic HAB species are *Alexandrium tamrense*, *A. catenella*, *A tamiyavanichii*, *Gymnodinium catenatum*, *A. ostenfeldii* that cause PSP; *Dinophysis fortii*, *D. acuminate* that could lead to DSP; *Gambierdiscus toxicus* that causes ciguatera fish poisoning (CFP); and *Ostreopsis* spp. that causes Palytoxin-like fish poisoning. While causative dinoflagellates are regularly monitored, distribution of high-risk fishes is prohibited as an immediate measure. No incidences of neurotoxic shellfish poisoning, amnesic shellfish poisoning, and azaspiracid shellfish poisoning had been reported in Japan (Oikawa, 2015).

Monitoring System of PSP and DSP in Japan

The monitoring system for PSP and DSP in Japan includes HAB monitoring, bivalve monitoring and sampling inspection.

Toxic HAB monitoring: Cell count by research department in a local government (microscopy) is carried out, after which prediction of contamination of bivalves with PSP and DSP toxins is established.



Bivalve monitoring: Toxicity assay by local government and/or fishermen (mouse bioassay) is carried out and voluntary controls are promoted to prevent toxic shellfish from being shipped to the market.

Sampling inspection: Toxicity assay is undertaken by local government (mouse bioassay) and control is enforced by Food Hygiene Law in the market.

Local government is responsible for the monitoring and inspection activities. Some local governments also set the reference cell density for toxic HABs, and for such reason, the reference cell density varies among species.

Monitoring of Toxic HABs in Osaka Bay

The local government conducts sampling for density of *A. tamarense* once a week from February to May, in at most 20 sampling sites. If density of *A. tamarense* is greater than 5 cells/ml, caution of toxic HABs is issued; if density of *A. tamarense* is greater than 10 cells/ml, warning of shellfish toxin is issued and shellfish from the area is surveyed; if density is greater than 4 MU/g* (= 80 µg STX /100 g) - the regulatory limit for PSP in Japan, the fishing area is closed. The information is then relayed to fishers through the local government office on the same day and to the public through website by the next day.

Red Tide Events in Japan

In 2013, about 262 red tide cases were reported of which 27 caused damages on the fisheries due to fish kill. The major toxin species that caused fish kill in Japan are: *Chattonella* spp., *Karenia mikomotoi*, *Heterocapsa circularisquama*, *Cochlodinium polykrikoides*, and *Heterosigma akashiwo*.

The local government and fishers through fishermen's cooperatives are responsible for on-site monitoring of red tide events in Japan. The information from such monitoring across the country is summarized by Fisheries Agency of Japan. Training courses for HABs monitoring supported by Fisheries Agency of Japan are also conducted every year at the National Research Institute of Fisheries and Environment of Inland Sea of the Fisheries Research Agency (FRA) of Japan. The course contents include lectures on toxic HABs, fish kill due to HABs and their cysts; microscopic observation

Photos by Fisheries Research Division, Oita Prefectural Agriculture, Forestry and Fisheries Research Center

of major HAB species in Japan; and identification techniques or morphological and molecular biological methods.

Capacity Building on HABs Identification and Monitoring

Taking into consideration the need for capacity building as one of the major concerns raised by the AMSs, MFRD organized the "Regional Training Course on Identification of HAB Species in the ASEAN Region" on 18-22 July 2016 in Singapore in collaboration with the Intergovernmental Oceanographic Commission-Sub-committee for the Western Pacific (IOC-WESTPAC). Besides obtaining knowledge on identification of HAB species through lecture and practical sessions as well as field trips and sampling sessions, a team headed by the Philippines and consisting of a representative from each AMS was formed to prepare posters on red tide causing species and HAB species. The AMSs would provide relevant photographs of the species for the posters which will be distributed to the Southeast Asian region for knowledge sharing. After the training course, the AMSs are expected to establish appropriate methodologies in their respective laboratories for identifying toxic HABs. The participants also highlighted the need to enhance their knowledge and skills on specimen preservation and culture techniques of HABs. In this connection, MFRD would organize the Regional Training Course on Specimen Preservation and its Application in HAB Monitoring and Studies to enhance the capabilities of the AMSs in managing toxic HAB incidences. The said training course would include topics on specimen preservation methods and techniques, use of fluorescence and electron microscopy and flowcytometry. Moreover, another Regional Training Course on Culturing HAB Species, Identification and Toxin Characterization will also be conducted by MFRD under the framework of the project, to include topics on isolation, culturing and cell harvesting methods and techniques for morphology, molecular and toxin characterization of HAB species.

Way Forward

As part of the project's framework, "Biotoxins Monitoring Surveys" have been carried out in the AMSs starting 2015 until 2017. Results of the countries' surveys would be published as a Technical Compilation in 2019. The Technical Compilation would comprise biotoxins analytical methods and biotoxins monitoring survey reports of the AMSs, the methodologies for the isolation, culturing, preservation, identification and monitoring of toxic HAB species, country reports on toxic HAB occurrences and incidences as well as the management of toxic HABs in the AMSs, and a directory of responsible national authorities and HAB experts in the AMSs. This is intended to increase the awareness of stakeholders on

Regional Technical Consultation on HABs in the ASEAN Region, Singapore, 5-6 August 2015, also served as a forum for compiling information from the ASEAN Member States on toxic HABs occurrences and incidences as well as the management of toxic HABs in the region, to be included in the Technical Compilation to be published in 2019

One of the capacity building activities on HABs was the Regional Training Course on Identification of HAB Species in the ASEAN Region organized by MFRD on 18-22 July 2016 in Singapore

mitigating the impacts of HABs on public health, well-being of aquatic animals, and the environment.

Specifically, the outputs of this MFRD project would include enhanced capabilities of the AMSs in monitoring, identifying and management of HABs; and continued cooperation among the AMSs in information dissemination, especially in providing early warning of the occurrence of HABs in the AMSs. Finally, it is expected that the outputs of this project would contribute to the realization of SDG 14.1, mainly in reducing marine pollution in order that the level of coastal eutrophication in the Southeast Asian region is reduced to the barest minimum.

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