FINAL REPORT FOR THE TRAINING PROGRAMME ON

Detection of HABs in Southeast Asia by Remote Sensing: Operational Warning and Regional Monitoring Protocols

Under the Auspices of:
The Nippon Foundation – Partnership for Observation of the Global Oceans (NF – POGO)

As a Component of:
The NF – POGO Centre of Excellence in Observational Oceanography (CofE)
Alfred Wegener Institute of Polar and Marine Research (AWI)

In Association with:
The Marine Science Institute (MSI)
University of the Philippines Diliman (UPD)

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Venue:
Bolinao Marine Lab, Marine Science Institute, University of the Philippines, Diliman
Bolinao, Pangansinan, Philippines

Dates:
23 February – 15 March 2014

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

A NF-POGO CofE-AWI Regional Training Programme was held at the Bolinao Marine Lab, Pangasinan, the Philippines, from 24 February to 15 March 2014. The programme topic was "Detection of HABs in Southeast Asia by Remote Sensing: Operational Warning and Regional Monitoring Protocols".

The causes and consequences of HABs vary from country to country within the SEA region. The premise of this training programme is that, despite the country-by-country differences, there exists a single common set of detection methods and protocols that could be implemented, regardless of the region, for detection of HAB events in the early stages of bloom formation: these same methods and protocols could also serve as a platform for the development of an early-warning system.

The basic idea for the Early Warning System is to combine remote sensing (RS), integrated modelling, and holistic monitoring programmes specific for each country; together, these

provide an operational framework for a set of protocols that can be implemented in each region to help understand and detect HAB events (Figure 1).

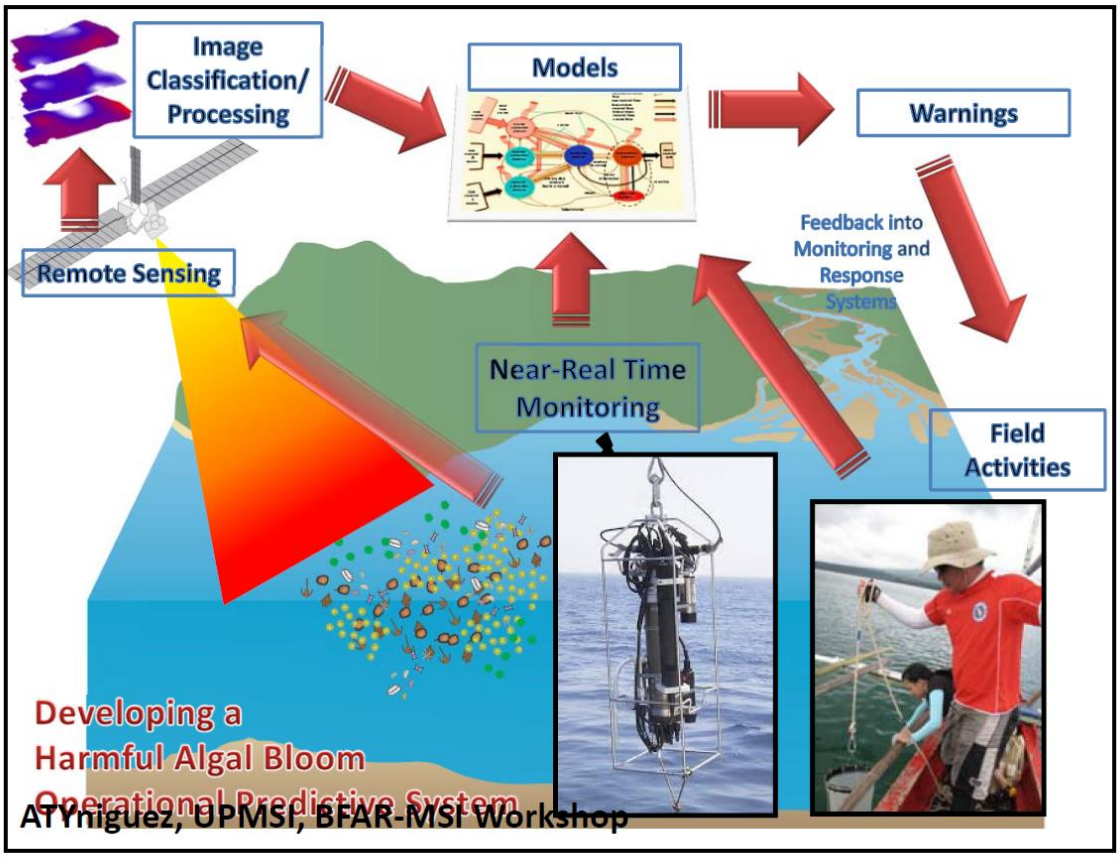

Figure 1. Schematic of anticipated HAB Early Warning System for Southeast Asia.

One difficulty with this integrated approach is that it requires individuals with expertise in three disciplines, remote sensing, modeling, and on-the-ground monitoring. Moreover, some level of expertise in chemical, biological and physical sciences is required. In response to these broad needs, an intensive three-week training program was offered to scientists in the SEA region who have experience in one (or more) areas of HABs, but generally have modest or no prior experience the other fields of study.

The program goals were to provide the trainees with fundamental interdisciplinary knowledge on HAB dynamics, give them the capability to assess HAB sites using satellite remote sensing technology, design standardized monitoring protocols, provide initial skills and tools to begin to develop integrated HAB models, and help them to develop early warning systems for HABs in their home countries. Topics covered ranged from physical, to chemical to biological.

The training programme included lecturers from the Philippines, Malaysia, Singapore, Japan, South Africa and the USA. In addition, 14 staff members from the UPD-MSI main campus and/or from the Bolinao Marine Lab (which is part of UPD-MSI) provided expert technical and teaching advice and training. A total of 24 trainees from six SEA countries participated in the training programme.

The Regional Training Programme at Bolinao Marine Lab was a very successful endeavor. The setting (Bolinao) was remote and beautiful, providing a tranquil setting for all to focus on the science without distractions that frequently impede teaching/learning. The lecturers provided excellent presentations and made themselves available for the numerous questions asked by the trainees. The Trainees, diverse in culture, academic training, and geographic perspectives, were enthusiastic throughout the training programme. Many trainees learned new skills for the first time, while others honed their skills and were able to "rub elbows" with world class scientists. The presentation of research projects at the termination of the programme was a highpoint of the three weeks, demonstrating the hard and dedicated work accomplished by the trainees.

2. LOCAL HOSTS AND ORGANIZERS

The local organizers and hosts of the Philippine Regional Training Programme were Drs. Laura T. David, Aletta T. Yñiguez, and Rhodora V. Azanza, all from the Marine Science Institute, University of the Philippines, Diliman (MSI-UPD). Mr. Joseph Dominic Palermo and Mr. Aldwin Almo, also from MSI-UPD, seconded the Training Programme.

3. REGIONAL AND EXTERNAL LECTURERS AND SUPPORT STAFF

In addition to the local organizers, there were six additional lecturers from the Philippines, mostly from UPD-MSI. Other quest lecturers were from Japan (1), Malaysia (1), South Africa (1), Singapore (1) and the USA (2). A representative from the CofE-AWI also attended the training programme.

In addition to the guest lecturers, 14 staff members from UPD participated in the training programme. Most were from the MSI group located in Diliman though a few were resident at the Bolinao Marine Lab. These well-trained individuals proved to be excellent teachers, some giving lecturers, providing help with various teaching duties, and/or providing hands-on demonstrations within their subject areas.

4. TRAINEE INFORMATION AND BACKGROUND

A total of 24 selected trainees from six regional countries attended the training programme. The trainees included individuals from were from India (3), Indonesia (4), Malaysia (3), Philippines (9), Thailand (1), and Vietnam (4).

The trainees were selected from a number of different research fields and with widely divergent interests in teaching, research, and outreach. The educational level of the trainees varied from undergraduate students to PhD/professors. Each trainee was asked to list his/her "position"; responses included student (undergrad and graduate), technician, junior and senior research assistant/associate, lecturer, researcher, junior and senior scientists, and professor. The number of years of experience varied from 1-2 years at the low end, to a much higher number for those who hold senior positions in their home countries.

Due to the diversity of backgrounds and disparities in prior experience with HABs, lectures were started at a basic level and slowly progressed toward more advanced matters. In general, the level of training was very high, but with only the more advanced trainees able to grasp the more complicated issues. Fortunately, there was a very robust level of communication between the trainees, with much inter-trainee assistance.

5. BRIEF OVERVIEW OF PREVIOUS NF-POGO ACTIVITIES IN THE PHILIPPINES

The 2014 NF-POGO CofE-AWI Philippine Regional Training Programme at Bolinao Marine Lab represented the most recent capacity building capacity of POGO in the Philippines dating back to 2008. In 2008, Mr. Joseph Palermo was a trainee in the Year 1 NF-POGO CofE-BIOS (BIOS = Bermuda Institute of Ocean Sciences). Ms. Kathleen Silvano was a Year 2 NF-POGO CofE-BIOS trainee. In 2011, Ms. Irene Alibia attended a NF-POGO CofE-BIOS Regional Training Programme offered in Nha Trang Vietnam. In 2012, Ms. Silvano co-wrote a NANO Regional Research Proposal with a colleague from Vietnam to study HABs in Southeast Asia (NANO-SEA). Subsequently, Drs. Laura T. David and Aletta T. Yñiguez attended the NANO Southeast Asia (SEA) Regional Research Project Workshop in Nha Trang, Vietnam, in 2012. Drs. David and Yñiguez, with Mr. Palermo, subsequently participated in the NANO-SEA Regional Research Project, in collaborations with their NANO Colleagues in Vietnam. In November (?) 2013, Drs. David and Yñiguez and Mr. Palermo hosted the second NANO Regional Research Workshop on the UP Diliman campus; attendees were from Vietnam and Thailand. In summary, Philippines ocean scientists have a strong and increasingly growing strength in working with POGO to bring capacity building enhancement efforts to Southeast Asia. The current Regional Training Programme hosted by MSI-UPD has provided additional evidence that our colleagues in the Philippines are actively engaged in POGO related missions, including both education (capacity building) and research.

6. SCOPE OF THE COURSE

Harmful algal blooms, HABs, are historically present but represent a growing concern in Southeast Asia. HABs appear to be increasing in space, time, and intensity; this has been attributed to transport of resistant stages, for example through ballast water, increasingly

eutrophicated waters, as well as changing climate conditions that favor growth of HAB species.

Over the past approximately 20 years, a number of HAB symposia, workshops, and training programmes have been offered in the SEA region. Earlier work focused on identification of algal species and toxins, with later work focused on ecological, chemical, biological and/or physical processes. Two major HAB toxins, saxitoxin and, to a lesser extent, domoic acid, were identified as the predominant problems, but low oxygen levels caused by HAB blooms have also been problematic in many regions.

Given that saxitoxin is the predominant HAB toxin in SEA, it is potentially informative o focus on encystment and excystment of dinoflagellates as a means to identify regional HAB events. Cyst-forming dinoflagellates, such as *Pyrodinium bahamense* var. *compressum* (Pbc) and *Alexandrium* sp., are important contributors to harmful (toxic) algal blooms in the Philippines and other parts of Southeast Asia. The alternation between benthic cysts and motile cells, and the factors influencing each stage and the transition in between the stages are important in bloom formation. Studies on Pbc in Manila Bay, as well as other cyst-forming species in other parts of the world have shown that cysts play a critical role in harmful algal blooms. The cyst stages provide a means of going through periods when environmental conditions are not conducive to vegetative cell growth and survival.

Physical parameters (e.g., tides and waves) and biological factors (e.g., bioturbation) are necessary for cyst resuspension which give rise to the opportunity for germination, and if conditions for growth are already appropriate, blooms could then develop.

Light, temperature, salinity and nutrient conditions are significant biological requirements for phytoplankton growth and reproduction. Observations of these factors can thus help in understanding and forecasting the development of blooms. Water mass stratification has also been observed to play a significant role in bloom development. This is due to the dinoflagellates' intolerance to increased shear-stress associated with water column mixing, high velocity coastal currents and turbulence. For instance, in Manila Bay, blooms of Pbc in the late 80s and early 90s coincided with the onset of the southwest monsoon where warm water temperatures and freshwater flux resulted in strong water column stratification. Similarly, the seasonal fluctuation of temperature and salinity in the bay shows the compounded effect of convection and water column stability regulating the vertical movement of plankton and the resources necessary for its growth. HABs frequently occur in areas where stratification is strong. Moreover, where HABs occur and stratification is pronounced, very low dissolved oxygen in the water column (hypoxia) follows, resulting in fish kills especially in mariculture areas where the fish are enclosed in pens or cages.

Combining field activities (e.g., cyst/cell mapping) with remote sensing and modelling of indicators and consequent integration of best knowledge in a flexible framework is

necessary to address the large challenges in understanding and helping to determine potential bloom conditions.

Understanding, much more forecasting these harmful blooms is not a trivial task owing to the large number of species responsible with a range of biological characteristics embedded within the complex attributes and dynamics of coastal waters. Blooms and any ensuing toxicities are a function of the interplay between physico-chemical factors, the life histories of the responsible organisms, and their interactions with other organisms. These challenges thus necessitate multi-pronged, spatially and temporally extensive approaches in order to more fully determine the relevant conditions and mechanisms contributing to bloom development and consequent toxicities. Recent advances in marine observational technologies and modeling tools provide at least the initial means to approach setting up operational early warning systems for harmful algal blooms.

The use of remote sensing technology and biophysical models coupled to monitoring and management is an area of rapid advancement. For instance, in the Gulf of Mexico, blooms of *Karenia brevis,* which causes respiratory illness in humans, are forecasted based on real-time chlorophyll, temperature, salinity, wind, cell concentrations and physical models (http://tidesandcurrents.noaa.gov/hab/). In the Gulf of Maine, targeted field monitoring of currents, temperature, salinity, nutrients, cells and cysts, are combined with a model integrating the biological and physical conditions to forecast blooms of *Alexandrium fudyense*. Typically, these systems need near real-time information on various ecosystem parameters, both from *in situ* and remotely sensed data for model initialization, calibration and validation; a means to analyze and integrate these various information into a meaningful and coherent manner; and the dissemination of and response to the ensuing information. These feedback systems are important to minimize uncertainties, and would also serve to provide a robust monitoring and response system. Underlying these technologies though is still basic knowledge on the causative organism and under what environmental conditions HABs are likely to occur.

7. OVERVIEW OF TRAINING PROGRAMME

The training programme consisted of a number of lectures given by experts for each topic area, several hands-on exercises including computer modeling and laboratory exercises, field trips, and independent research projects. A broad overview of these activities is available in Appendix 4 and 5, while a more detailed "daily blog" is available in Appendix 6.

8. SPONSORSHIP

The Centre of Excellence in Observational Oceanography (CofE) offered at the Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research was the primary external sponsor of the Philippine Regional Training Programme; the CofE-AWI is sponsored by and supported through NF – POGO.

9. ACKNOWLEDGEMENTS

We would like to recognize the critical support of the Bolinao Marine Laboratory (BML) resident senior staff Dr. Ronald Villanueva, administrative officer Ms Charina Caalim and the rest of the BML staff and resident researchers. We also acknowledge the invaluable time and effort provided by many MSI researchers and staff in the organization and conduct of the training. Funding for the research activities on harmful algal blooms in the Philippines has been provided by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD-DOST). This has allowed for the development of expertise and greater understanding of this phenomenon.

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APPENDIX 4. DAILY SCHEDULE

Date	Day	Time	Topic	Lecturer(s)
Feb. 24	Mon	8:00 - 9:00	Registration	
			Opening Ceremonies	
		9:00 - 9:15	Welcome Remarks	Dr. Ronald Villanueva, BML Resident Scientist Bolinao Mayor or Representative
		9:15 - 9:45	Introductions	
			HABs Overview	
		9:45 - 10:30	Understanding and Managing HABs (knowledge and tools)	Dr. Rhodora V. Azanza
		10:30 - 11:00	BREAK	
		11:00 - 11:45	HABs in SEA	Dr. Rhodora V. Azanza
		11:45 - 12:30	HABs in particular countries: challenges and opportunities	experts and participants
		12:30 - 1:30	LUNCH	
		1:30 - 3:30	HABs in particular countries: challenges and opportunities	experts and participants
		3:30 - 4:00	BREAK	
		4:00 - 5:00	Operational warning systems and monitoring frameworks for HABs	Dr. Laura David
		6:30 - 9:00	Welcome Dinner	
Feb. 25	Tue		HABs Monitoring and Detection Methods	
		8:00 - 9:00	HAB Taxonomy and Phylogenetics	Dr. Chui Pin Leaw
		9:00 - 12:00	HAB Taxonomy and Phylogenetics: Hands-on	Dr. Chui Pin Leaw
		12:00 - 1:30	LUNCH	
		1:30 - 3:00	HAB Physiology and Toxins	Dr. Chui Pin Leaw/Christopher Mendoza
		3:30 - 5:00	HAB Physiology and Toxins: Hands-on	Dr. Chui Pin Leaw/Christopher Mendoza
Feb. 26	Wed	8:00 - 9:00	Geology of HABs: Sediment dynamics of HABs	Dr. Fernando P Siringan
		9:00 - 12:00	Geology of HABs: Sediment dynamics of HABs - Hands-on	DR. Fernando P Siringan
		12:00 - 1:30	LUNCH	
		1:30 - 2:30	Geology of HABs: Dinoflagellate cyst dynamics	Dr. Katzumi Matsuoka
		3:00 - 5:00	Geology of HABs: Hands-on	Dr. Katzumi Matsuoka
Feb. 27	Thu		Physical oceanography of HABs	
		9:00 - 10:00	HAB development/dissipation and transport and mixing processes	Dr. Cesar Villanoy

		10:00 - 12:00	HABs in estuarine systems	Dr. Cesar Villanoy
		12:00 - 1:30	LUNCH	
		1:30 - 5:00	Physical oceanography of HABs: Hands-on	Dr. Cesar Villanoy
Feb. 28	Fri		Chemical oceanography of HABs	
		9:00 - 10:30	Nutrients and HABs	Dr. William Cochlan
		10:30 - 12:00	Fish kills and HABs	Dr. Gil Jacinto
		12:00 - 1:30	LUNCH	
		1:30 - 5:00	Chemical oceanography of HABs: Hands-on	Dr. Gil Jacinto/Dr. William Cochlan
Mar. 1	Sat		Free Time	
Mar. 2	Sun		Field Trip/Cultural Trip	
Mar. 3	Mon		**Ecology of HABs**	
		9:00 - 10:30	Biological and Physical Controls of HABs	Dr. Raphael Kudela
		10:30 - 12:00	Fine-scale biological processes in HABs	Dr. Raphael Kudela
		12:00 - 1:30	LUNCH	
		1:30 - 2:30	Fine-scale biological processes in HABs: Harmful Algae Interactions with Marine Planktonic Grazers	Mr. Joseph Dominic Palermo
		2:30 - 5:00	Ecology of HABs; Hands-on	Dr. Raphael Kudela/Mr. Joseph Dominic Palermo
Mar. 4	Tue	9:00 - 12:00	Group Discussions (First Week Experience: Monitoring of HABs)	Facilitators: Mr. Joseph Dominic Palermo and Mr. Aldwin Almo
		12:00 - 1:30	LUNCH	
			Early-warning systems for HABs	
		2:00 - 4:00	Overall framework of early-warning systems for HABs	Dr. Raphael Kudela
		4:00 - 5:00	Project Time	
Mar. 5	Wed	9:00 - 10:00	Introduction to ocean color	Dr. Stewart Bernard
		10:00 - 12:00	Application of ocean color to HABs	Dr. Stewart Bernard
		12:00 - 1:30	LUNCH	
		1:30 - 5:00	Ocean color: Hands-on	Dr. Stewart Bernard
Mar. 6	Thu	9:00 - 5:00	RS for HABs in Case 2 waters and embayments	Dr. Laura David
Mar. 7	Fri	9:00 - 5:00	Validating RS HAB models	Dr. Laura David/ Dr. Liew Soo Chin
Mar. 8	Sat	9:00 - 10:00	Integrating the Biology and Physics of HABs in Models	Dr. Raphael Kudela
		10:00 - 12:00	Project Time/ Consultations	
		12:00 - 1:30	LUNCH	
		PM	Free Time/Field sampling for projects	Facilitator: Mr. Aldwin Almo
Mar. 9	Sun		Free Time/Field sampling for projects	Facilitator: Mr. Aldwin Almo
Mar. 10	Mon	9:00 - 12:00	Hydrodynamic Models of HABs	Dr. Cesar Villanoy
		12:00 - 1:30	LUNCH	
		1:30 - 3:00	Hydrodynamic Models of HABs: Hands-on	Dr. Cesar Villanoy

		3:00 - 5:00	Project Time	
Mar. 11	Tue	9:00 - 12:00	Hydrodynamic Models of HABs: Hands-on	Dr. Cesar Villanoy
		12:00 - 1:30	LUNCH	
		1:30 - 5:00	Intro to ecological modelling/ Coupled biophysical models of HABs	Dr. Aletta T. Yñiguez
Mar. 12	Wed	9:00 - 10:00	Biophysical modeling of HABs in the Philippines	Dr. Aletta T. Yñiguez
		10:00 - 12:00	Biophysical modeling of HABs: Hands-on	Dr. Aletta T. Yñiguez
		12:00 - 1:30	LUNCH	
		1:30 - 3:00	Project Time	
		3:00 - 5:00	Project Time	
Mar. 13	Thu	9:00 - 10:00	Linking with response and management systems	Dr. Maria Lourdes San Diego-McGlone
		10:00 - 12:00	Clay Demonstration	Dr. Maria Lourdes San Diego-McGlone
		12:00 - 1:30	LUNCH	
		1:30 - 5:00	Project Time	
Mar. 14	Fri		Writeshop and Project Presentation Drafts	
Mar. 15	Sat	9:00 - 12:00	Project Presentations	
		12:00 - 1:30	LUNCH	
		1:30 - 2:30	Project Presentations	
		3:00 - 5:00	Closing Ceremony	
		6:00 - 9:00	Farewell Dinner	

APPENDIX 5. RESEARCH PROJECTS – WORKING GROUPS AND RESEARCH TOPICS

INDIAN GROUP

Comparative evaluation of HAB situations in coastal waters of India and bays of Philippines

Nashad. M, Nandini Menon. N and Muhamed Ashraf. P.

VIETNAM AND THAILAND GROUP

(HARMFUL) ALGAE BLOM DETECTION AND MONITORING IN THE GULF OF THAILAND AND THE SOUTH CENTRAL OF VIETNAM

Khanittha Uthaipan, Tran Thi Mai Phuong, Nguyen Thi Thai Hoa, Hoang Phi Phung, and Ha Nam Thang

PHILIPPINE GROUP II

Detection of toxic Alexandrium bloom using Remote Sensing and In Situ Data in West Coast of Manila Bay from 2010-2013

Garry Benico, Graceous Von Yip and Amor Damatac II

MALAYSIA AND INDONESIAN GROUP

TIME SERIES ANALYSIS IN INDO MALAYAN AREA USING REMOTELY SENSED DATA: HABs DETECTION

Yazid Ridla, Umi Zakiyah, Sazlina Salleh, Nurul Aini, August Daulat

MALAYSIA, PHILIPPINES AND INDONESIA GROUP

COMMUNITY STRUCTURE OF PHYTOPLANKTON IN BOLINAO, PANGASINAN: FIELD DATA

ARIF SENO ADJI, SANCHO VILLANUEVA BILOG, MARIA VICTORIA GOPEZ HILARION, SING TUNG TENG

PHILIPPINE GROUP I

*The 2006-2011 Pyrodinium bahamanse var. compressum Bloom in Sorsogon Bay Philippines: A Retrospect Using Remote Sensing and In-situ Cell Density and Historical Shellfish Toxicity Data**

Ronnel R. Dioneda Sr., Farida J. Saavedra, Soledad S.Garibay and Adonis S. Floren

APPENDIX 6. TRAINING ACTIVITIES – A DAILY BLOG

24 February: The Training Programme was opened by Dr. Yñiguez. Mr. XXXX, Mayor of Bolinao, provided welcome comments, as did Dr. Ronal Villanueva, Deputy Director of the Bolinao Marine Lab, and Dr. Gerald Plumley, Coordinator of the NF-POGO CofE-AWI, who provided a welcome on behalf of NF, POGO and AWI.

Dr. Azanza provided background information on HABs, with special attention to problems in the Philippines, then issues throughout Southeast Asia; the history of HAB events was central in both parts of Dr. Azanza's presentations. The trainees then held their first group working group discussions, with break-out meetings by country, to prepare presentations on "HABs in Our Home Country: Challenges and Opportunities". The presentations revealed a number of both similarities (e.g., same species in many cases; similar timing of HAB events) and differences (e.g., different driving mechanisms) between HAB events in each country. One obvious conclusion was that no country has the complement of agencies, (universities, Government, or NGOs) to adequately address HAB issues in such large geographically dispersed areas with miles and miles of coast line. The lack of well-trained individuals to study, monitor and/or manage HAB events, and their associated consequences, remains a critical issue in Southeast Asia.

Dr. David gave a very strong introductory lecture on "Operational Warning Systems and Monitoring Frameworks for HABs." This lecture laid a firm foundation for the RS and modeling work that would form the foundation of the Training Programme in the next few days. A good round-table discussion followed.

The first day of classes with the Philippine Regional Training Programme ended with a presentation by Dr. Plumley on the NF-POGO CofE-AWI. Many trainee questions were asked about the programme during the three week training programme.

February 25: Dr. Chui Pin Leaw started day two with two lectures that provided an overview of HAB taxonomy and phylogenetics. The first lecture touched on classical morphological characters, but emphasized a variety of molecular methods and highlighted the need for specialized equipment (e.g., electron microscopes) in modern HAB taxonomy. The second lecture focused on traditional morphological traits used for taxonomy. The morning ended with a hands-on demonstration of algal taxonomy, including a quiz on toxic dinoflagellates.

Dr. Chui Pin Leaw started the afternoon session with an introductory lecture on the physiology of toxin production. The lecture focused primarily on *Alexandrium spp*.; there are six toxic species in SEA coastal waters. Differences in salinity, light intensity,

temperature, and N:P ratios were shown to affect growth rates and toxicity (per cell) differently for the different strains. Overall, the results of culture work demonstrate remarkable variations in physiological adaptability of these toxic species.

Mr. Christopher Mendoza covered HAB toxins from the standpoint of human clinical symptoms as well as the molecular mechanism of action of the toxins. Toxin detection and quantification methods (e.g., HPLC, MS, receptor binding assays, etc.) were covered along with field monitoring data of water samples and different shellfish species. The emphasis was on saxitoxins, the predominant problem in the Philippines (and throughout SEA).

Mr. Joseph Palermo led the afternoon hands-on session on algal sampling techniques and processing protocols for algal cell counts. The session was very highly received by trainees. . Trainees took many notes as well as made video recordings using their cell phones/tablets.

February 26: Dr. Fernando P. Siringan led the morning session with a lecture on the Geology of HABS. Life cycles of algae were highlighted, with an emphasis on cysts, which are most likely to be preserved in sediments. Details on sampling were provided that included methods (e.g., coring devices) as well as selection of sampling locations based on local conditions (e.g., currents) and geological characteristics of the sediments.

The morning session ended with two demonstrations: 1) a sampling trip aboard one of the outriggers to deploy sediment traps and take sediment cores and "grab" samples; and 2) procedures for handling cores once they are returned to the laboratory. In both cases, the emphasis was on sediments (i.e., the geology). . Trainees took many notes as well as made video recordings using their cell phones/tablets.

Dr. Kazumi Matsuoka continued the theme of HAB Geology, but with a focus on the algae. The lecture started with the history (almost 300 years) of dinoflagellate studies. Impacts of eutrophication were covered as well as coverage cyst germination protocols and the more modern topic of single-cell PCR as a means to identify the motile form of cysts as well as the identity of dinoflagellate prey.

The late afternoon session was a hands-on demonstration of cysts processing protocols. Samples included those collected during the morning trip aboard outriggers. Trainees took many notes as well as made video recordings using their cell phones/tablets. The day ended with trainees viewing cysts under the microscope. Smiles all around.

February 27: Ms. Camilla Jane Bollozos and Mr. JD Palermo led the morning session with a "hands-on" demonstration of how to use a CTD (SeaBird) and ADCP. Trainee questions

were numerous and diverse. It was clear that many participants wanted to learn this "new" technology, having seen it, but in general not having used it or having it explained.

Next was a hands-on demonstration of Ocean Data Viewer software and protocols for processing CTD and ADCP data. As is typical for such a group (with diverse backgrounds), some trainees were two steps ahead, others two steps behind. Overall, it was a productive experience, as the trainees started to group in pairs, with the more experienced users starting to work with the neophytes (i.e., the best team-building exercise to date). All trainees soon had a map of Sorsogon Bay on their laptop screens and were enjoying "playing" with the data; the trainees had to be "forced" to stop for lunch.

For the afternoon session, trainees were split in two groups, with each group receiving a different data set from Bolinao Bay, one data set from December and the other data set from yesterday (i.e., Ms. Bollozos and Mr. Palermo collected the data the day before, as part of the NANO Research Project). The conditions in the bay were remarkably different, with very clear water in the recent sample, while there was a very large bloom (non toxic) in the December data. One team member from each group gave a short oral presentation summarizing the data, then Bollozos and Palermo explained the data – with the trainees able to pick up most of the salient points about the environmental conditions. A wonderful session.

February 28: Dr. William (Bill) Cochlan gave an extensive and intensive overview of global nutrient concentrations and algal physiological ecology. N, P, and Si were emphasized as well HAB species, but other nutrients and non-HAB species were brought into the discussion for illustrative purposes. Most of the lecture focused on field data/conditions, but culture work was introduced to clarify important concepts. In addition to covering nutrient concentration (and impacts on growth and/or toxicity), nutrient ratios (i.e., Redfield ratios) and nutrient stress (i.e., starvation) were discussed. The lecture ended with recently published data about the effects of co-cultivation of algae on toxicity (i.e., a toxic dinoflagellate was grown with a non-toxic diatom – the toxin/cell varied in totally unexpected ways when the toxic strain was grown with vs. without the diatom). Since natural populations of algae are never monoculture, this work has potentially broad implications.

Dr. Gil Jacinto continued the morning lectures on chemical oceanography of HABs with coverage of fish kills. The lecture focused on fish farming (pens and cages), as this has been practiced heavily in the Philippines for more than 20 years. The industry constructed too many cages per unit area, which led to eutrophication and very high BOD, and concomitant fish kills, both of caged fish as well as native fish. Even with reduction in cages/area, fish kill problems continue. The algal species during bloom events changes from year to year in

the same area; moreover, in most cases the algae are non-toxic. This has led to the conclusion that low oxygen is the problem.

The afternoon hands-on session involved the determination of ammonium levels in seawater using a spectrophotometric protocol and a fluorometric protocol. Water sampes were taken from two points with in the in-house seawater system, once just as the water reached the building, the second after the water had passed through the filtration system. Additional samples were taken from mariculture holding tanks and other places within the station. While samples were incubating, there was a short lecture on sampling methods, creating/using a standard curve, a description of the difference between precision and accuracy, and basic statistical methods for data analyses.

March 2: A cultural exchange field trip to 100 Islands. The trainees took a Jeepney ride from the station to the field site; it was quite the cultural experience. The 100 Islands is a national treasure, much visited by the locals and tourists. We took a boat ride to several islands, each offering its own charms and attractions. We visited caves and "cliff jumped" into the warm waters to start our daily swimming. We snorkeled over beautiful corals and saw the famous giant clam. Lunch was a fantastic Philippino buffet of fish and chicken with a number of vegetables and fruit; eaten on the beach, it was very memorable. The day ended with a jeepney ride home, dinner, and a long night of sound sleep, well-earned after a busy and rewarding day.

March 3: Dr. Raph Kudela started the lecture with an overview of HAB monitoring programs around the world in which he was already involved. This was a great intro, as it allowed Raph to explain the similarities and differences between the various sites, the differences arising because of the HAB species involved, the local physical conditions, etc. etc. The NPZ model was introduced as a "easy" conceptual model that allows use of math/numbers to quantitate the various biological processes that are involved in all HAB events. A very concise summary of the PvsI curve was presented along with a description of how this allows the use of RS to monitor/study/evaluate algae and HAB events. Temperature effects on HABs was "explained" based on Eppley's seminal studies – then updated to current knowledge of HAB species. The morning ended with a series of slides showing HAB blooms in different locations around the world: each HAB event was characterized by occurring at a very specific position in the water column (i.e., at a very specific depth), with the depth for each species representative of the WOO (window of opportunity) for each species, where its growth rate was maximized (e.g., optimal light, nutrients, salinity, temperature, etc.). In contrast to those species that produce a bloom at a define depth, other species are motile and have the ability to migrate vertically during the day to maximize nutrient availability (i.e., at depth) and sunlight (i.e., near the surface).

The next lecture started with a basic question – If you wanted to model a HAB organism, how would you do it? This was followed by a series of questions, e.g., why do HAB species make toxins? Several hypotheses have been proposed for toxins, e.g., anti-grazing compounds, cell-cell communication, competition (e.g., metal chelators), and ability to rid the cell of harmful, internally toxic, compounds. While it is difficult to answer the question (why make toxins), Solid Phase Adsorption Toxin Tracking (SPATT) was developed by MacKenzie to track toxins in the water column. The small devices hold different filters with different chemistries, allowing for adsorption of different toxins. This low cost, easy-to deploy method drew many questions from the trainees. The next question was: what is the role of mixotrophy on HAB events? Attention then returned to the NPZ model, which allows incorporation of environmental conditions (e.g., temperature, nutrient concentrations, etc.). Grazer-dilution experiments were then discussed as a means of understanding the NPZ interactions. The morning ended with a provocative assertion that "biology" is not important in predicting blooms: recently introduced wind and current models have proven remarkably correct at predicting coastal HAB events.

The afternoon session was led by Mr. J.D. Palermo, a NANO Alumnus. The topic was grazing. The first approach was to describe grazing in terms of energy and carbon flow, but using chlorophyll as a proxy, because it is relatively easy/inexpensive to utilize. The lecture focused mostly on methods, Raph having presented much of the theory, with an emphasis on prior experiments conducted by JD. It was good to see that trainees asked a large number of questions, showing great interest in the lecture and its well delivered presentation.

The remainder of the afternoon was spent in the laboratory, going over protocols to conduct grazing experiments (e.g., chlorophyll determination by fluorometry).

March 4: Trainees spent the morning in their six research working groups, discussing what they had learned during week 1 of the Training Programme and what they thought was important in their home countries in terms of implementing a HAN Early Detection System. At the end of the morning, the trainees gave oral presentations of their conclusions and recommendations. It was a very good first step in finalizing precise research topics for each group.

Dr. Kudela started the afternoon session with a lecture on HAB Monitoring Systems. He used his extensive global experience, including recommendations from various agencies, organizations and/or governments around the world. In many cases, the trainees were pleased to see that their preliminary recommendations for a HAB Early Detection System in their home countries paralleled those summarized by Dr. Kudela. In other cases, there were many suggestions that had not been considered and/or the trainees failed to realize

the investments (financial and manpower) required to conduct some monitoring programmes.

The afternoon ended with the trainees returning to their six research working groups to reprioritize their ideas for a HAB Early Detection System. Dr. Stewart Bernard had arrived on the station by this time and he, along with Dr. Kudela and Mr. Aldwin Almo, were instrumental in working through preliminary ideas, refining what was feasible, both in terms of an overall Monitoring System and in terms of what could be completed during the final 10 days of the Training Programme. Each of the six groups gave a final presentation of their ideas. The session ended well past the scheduled 1700 hr time point, with many trainees huddled together or in conversation with Drs. Bernard and Kudela well into the evening and during dinner.

March 5: The days started with a tour of the Bolinao Marine Lab Hatchery. It was led by three research associates/technicians, each with a different area of specialization. There were three stations, corals, giant clams, and corals (and macrophytes). It was a very informative morning, with many many questions from trainees.

Dr. Stewart Bernard gave the first lecture of the day, opting for a low tech approach: no microphone, no Powerpoint slides – only a white board and pen. His lecture started with a few very simple drawings about sunlight, water, and "things" in the water – and with the idea that there was a satellite overhead looking down on the water and its contents. A few basic terms were introduced along with a few simple equations. Dr. Bernard then moved to an Excel spreadsheet (viewed via a projector on screen) where he showed a simple model; model outputs included (in graphical format) reflectance, adsorption and backscattering. Unknowns included phytoplankton size (um), Chl a (mg-m3), diatom/dinoflagellate ratio, non-algal particles, and CDOM. Trainees were given the spreadsheet and challenged to match the variables with conditions in their home countries.

The post-snack lecture by Dr. Bernard focused on Ocean Colour and HABs. The material covered became simultaneously more interesting, more useful, and more difficult. An intriguing slide was entitled "How to become and educated ocean colour cynic: your first steps". The next several slides covered details about the contribution of algal assemblages to ocean colour. Examples were then shown where it was possible to use various algorithms to detect HABs from RS data. The morning ended with an overview of IOCCG/GEOHAB key conclusions.

The afternoon session was a hands-on demonstration of RS data based on BEAM, which was led by Dr. Bernard. Trainees were given a handout of step-by-step instructions of how to use BEAM and were then walked through each step; each trainee followed on his/her

own laptop. As has occurred many times throughout the workshop, when a hands-on demonstration and independent learning activity is involved, trainees stay well past the scheduled end time (1700 hr) and are enthusiastically working to master the details.

March 6: Dr. Laura David with help from Aldwin Almo led the largely hands-on training session on RS of HABs in case 2 waters. Numerous exercises were given (e.g., analysis of time series data of chlorophyll), BEAM, ODV, etc. etc. The group worked through lunch with only a small break and then stayed well past the 1700 hr end point, working on the various models/software that had been demonstrated.

March 7: Dr. Liew Soo Chin gave the opening lecture on RS and HABs. The lectures started with the basic properties of water and light and then moved slowly and methodically through more advanced topics, introducing various models/equations with increasing frequency.

During the second half of the morning, the trainees made a trip via boat to different locations to collect water samples. Each trainee then looked at the spectrum of his/her samples using an Ocean Optics USB650 Red Tide spectrophotometer.

Dr. Liew's afternoon lecture focused on the reflectance of light from water. Several models were presented, including a spreadsheet that the trainees were able to manipulate (e.g., CDOM levels).

Trainees spent the rest of the day working on their sample date and/or working on other RS models/software. It has been a long week and there are classes and lab work scheduled for tomorrow (a Saturday), so all were glad to end a few minutes early – though only a few left the classroom (most stayed to continue their work on their independent projects).

March 8: Dr. Kudela started the Saturday lecture with an overview of models (i.e., principles, practices, etc.). The Finite Element Model concept was introduced; there are clear reasons to use this approach in physical oceanography, but not ecology or Newtonian physics. The NPZ model was introduced, moving from the conceptual to the empirical. Twop very useful sites, complete with on-line models, were given:

1. Physical (and some biology) – http://www.gotm.net/index.php (Generalized Ocean Turbulence Model, GOTM)
2. Biology and Ecology – http://faculty.washington.edu/banasn/models/NPZ visualizer/
3. EOF-based method to fill in missing data from geophysical fields, such as clouds in sea surface temperature (DINEOF): http://modb.oce.ulg.ac.be/mediawiki/index.php/Download_DINEOF

The lecture ended with two models used by the Kudela group to monitor and predict red tides on the California coast. One approach that seems to have promise is the use of 5-day hindcast data to model the next 10 days – and then to use the modeled data to predict the next 5 days. In total, this approach is allowing HAB predictions 10 days in advance with some fidelity. Predictions beyond 10 days remain problematic.

Trainees split into their respective working group and spent the rest of the morning and afternoon working on their projects. One group did field sampling while the other groups downloaded data, worked on models, etc. etc.

March 9: Though officially a vacation day, many trainees took the opportunity to visit the various "farms" associated with the Bolinao Marine Lab hatchery. The tour was made possible by the marine lab, complete with boat and leaders with hands-on expertise. Sites visited included the giant clam nursery (truly a magnificent site), the seaweed grow-out facilities, and the sea cucumber farm. This was a fantastic cultural exchange event, with a strong scientific message.

Many trainees stayed behind to work on their independent research projects. By the end of the day, most of the trainees were in the classroom working, singly or in small groups. The session ended around midnight.

March 10: Dr. Cesar Villanoy (along with DinDin Bollozos, Menche Lazarte, and Anabel Gammaru) gave an initial lecture on Hydrodynamic Modeling. After an easy to understand intro to hydrodynamic models, the group was led in a hands-on demonstration of Deltares, using the Bolinao Bay and the channel in front of the Marine Lab as a study site. Within a couple of hours, the trainees had downloaded a map, digitized the image, set up their grids, downloaded and set the bathymetry (i.e., depth) and set the boundaries. A decision was made to run the model using "tides" as the driving force (other interesting options were available, but for simplicity, tides were chosen as the only parameter). Observation sites were chosen (a program requirement) and the output parameters set (to hours, a reasonable unit for tides). The trainees had their first Delft3D model running and/or had their initial results before lunch.

The next project was to model a pollutant and its distribution within the bay. The idea was to monitor pollution introduced as part of the local fish farming activities (i.e., nutrients/eutrophication). The first step was to go into the model parameters and to check "pollutants". Trainees quickly had model results, but realized worked was needed (e.g., How many discharge sites are present? What is the discharge frequency e.g., a one-time event, daily, weekly? Location of discharge site(s) relative to main tidal flux). Trainees spent the remainder of the session fine tuning their nutrient/pollutant models.

Dr. Plumley took a few minutes between sessions to go over background material on POGO, the CofE-AWI, and NANO. All trainees were encouraged to submit the application form and all agreed to be included on the NANO mailing list. It seems several will apply to the CofE-AWI for its future activities. All were interested in the NANO Regional Research Projects.

The late afternoon session was devoted to project time.

March 11: Dr. Cesar Villanoy continued his lectures and hands-on demonstrations with the modeled developed on the 10th – today calculating residence time. For the initial model, water inside the model was given a concentration of "1", while water outside the model was given a concentration of "0". After the model run, trainees were shown how to determine the residence time for specific points in the grid (e.g., a fish cage) and then the residence time for larger areas within the grid.

Dr. Aletta Yñiguez led the afternoon session on Ecological Modeling and Coupled Biophysical Models of HABs. The initial session focused on the biological ecology and provided an overview of the model building process.

After break, Dr. Yñiguez turned attention to Ecosystem Models. As before, the "currency" is generally considered in terms of C, N, or perhaps energy. The NPZ model was presented as simple "ecosystem". Concepts of competition were described, as were the Michaelis-Menton and Droop equations for nutrient uptake, several models for grazing, and a predator-prey model/equation. The differences in Eulerian vs. Lagrangian concepts were used as an introduction of how to couple biological and physical models. In addition to the physical properties of water, the ambient conditions of light and temperature were introduced, along with the variations of these with depth.

The session ended with a hands-on demonstration of the NPZ model using MatLab. After getting the model to run, trainees where shown how to manipulate the parameters and test the model outputs.

March 12: Dr. Aletta Yñiguez led the morning session on Predictive Models for HABs. The three Philippine-wide study sites for UPD include Sorsogon Bay, Murcielagoos Bay, and Bolinao-Anda. There are several different toxins present in these areas, produced by a number of different HAB species (both dinoflagellate and diatom). All three areas have low flushing rates/high residence times, which seem to favor *Pyrodinium* blooms. In addition to the long-term monitoring of physical, chemical and biological pararmeters, a new approach is to use the Infinity ME Fluorescence Photometer to monitor conditions on a continuous/rapid basis. Preliminary results show a very favorable ability to monitor *Pyrodinium* cell abundance.

In terms of RS, the UDP-MSI group is working on a SeA-HABS (Semi-Automated HAB Detection System), which will automatically download RS data to stakeholders and flag conditions that would alert locals to increase their *in situ* monitoring efforts.

The current/preliminary biophysical model for Sorsogon Bay is beginning to yield promising results. For example, for *Pyrodinium* there are known cyst beds and the conditions for encystment/excystment are well described. These data, coupled with water circulation characteristics of the Bay provide insights into bloom conditions and spread. There is an interesting story developing with HAB blooms and stratification, while the inter-annual variability remains very problematic (the 2010 volcanic eruption near Sorsogon Bay and the input of particles, rich in silicates, resulted in increase in diatoms, e.g., *Skeletonema*, and decline of *Pyrodinium*).

Ms. Jennifer Mary Maister presented the Toxin Submodel for HABs in the Philippines. The model is a predator-prey model based on toxin transfer through the digestive system of the predators, bivalve shellfish. The works is in an early stage of development, but has the potential to provide novel insights into HAB bloom dynamics.

March 13: Dr. Maria Lourdes San Diego-McGlone gave the morning lecture on Management and Mitigation of HABs. Management issues were covered first, as these are essential components of monitoring, mitigation, and control. Following an overview of strategies in the Philippines, trainees provided a brief overview of the monitoring strategies in their home countries. Turning to mitigation strategies, a variety of different methods were considered (e.g., chemical, biological, genetic, mechanical, etc.). Clay is being tested in the Philippines as a mechanical control mechanism.

The hands-on demonstration included a field trip to collect "parcels" of water (approx. 1 cubic meter each). Clay particles were added to some parcels while other parcels served as controls. Water samples were taken at intervals and algal cell counts made.

March 14: Trainees worked independently in small groups and/or with assistance from lecturers on their research projects.

March 15: The trainees were placed in one of six working groups during the initial week of the training programme in terms of designing and conducting independent research projects. Details of the research projects and the trainees involved are available in Appendix 5.

During the last morning of the training programme, each trainee presented his/her part of the research project as part of an oral presentation. Each research group also submitted their written report.

APPENDIX 7. PHOTOGRAPHS OF TRAINEE ACTIVITIES