Fish Health Section Webinar 2021 • Asian Fisheries Society

Harmful Algal Blooms and Fish Kills

Po Teen LIM
Institute of Ocean and Earth Science,
University of Malaya
Malaysia

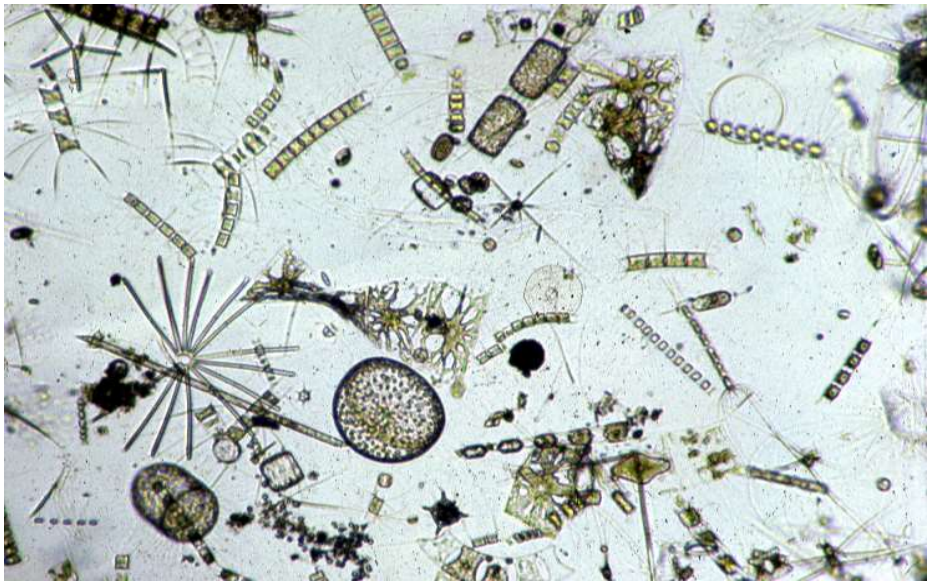
1

Outline

- What is HAB? – species, types, causes
- HAB-related fish kill events
- How HAB kill fish?
- How to manage and mitigate?

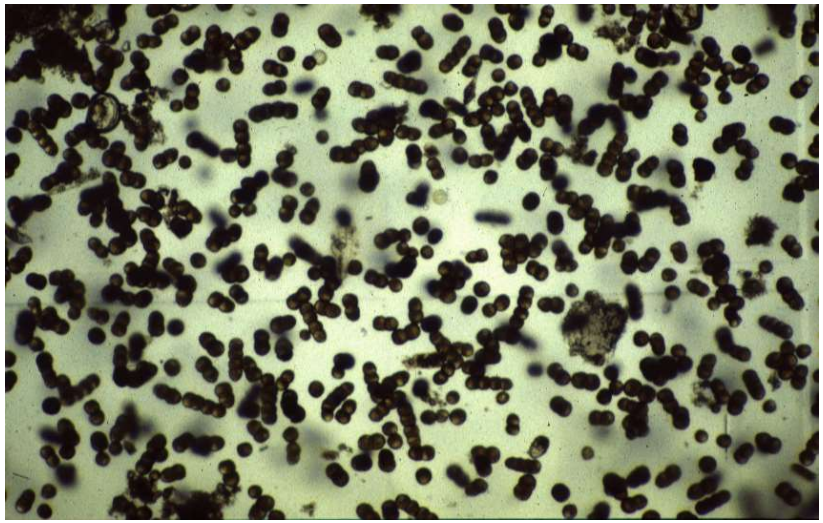
What is Harmful Algal Blooms?

Typical Phytoplankton Community

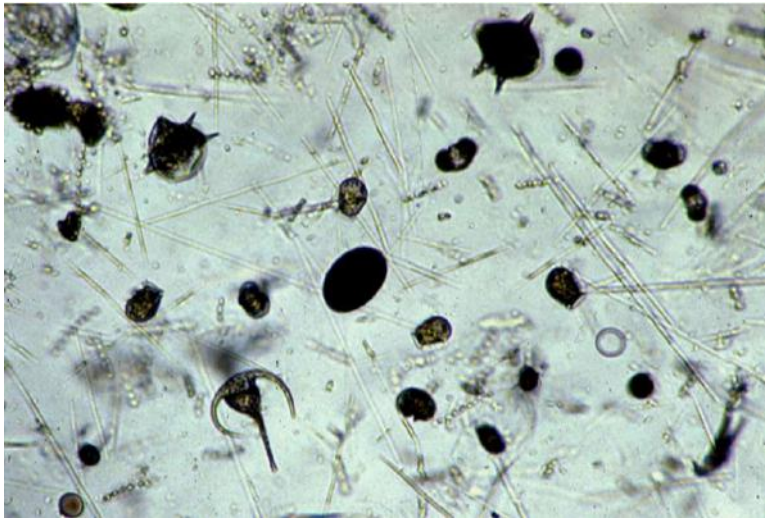


Phytoplankton composition changes due to various environmental factors (temperature, pH Salinity, nutrient, light, current, rainfall etc.).

HABs!



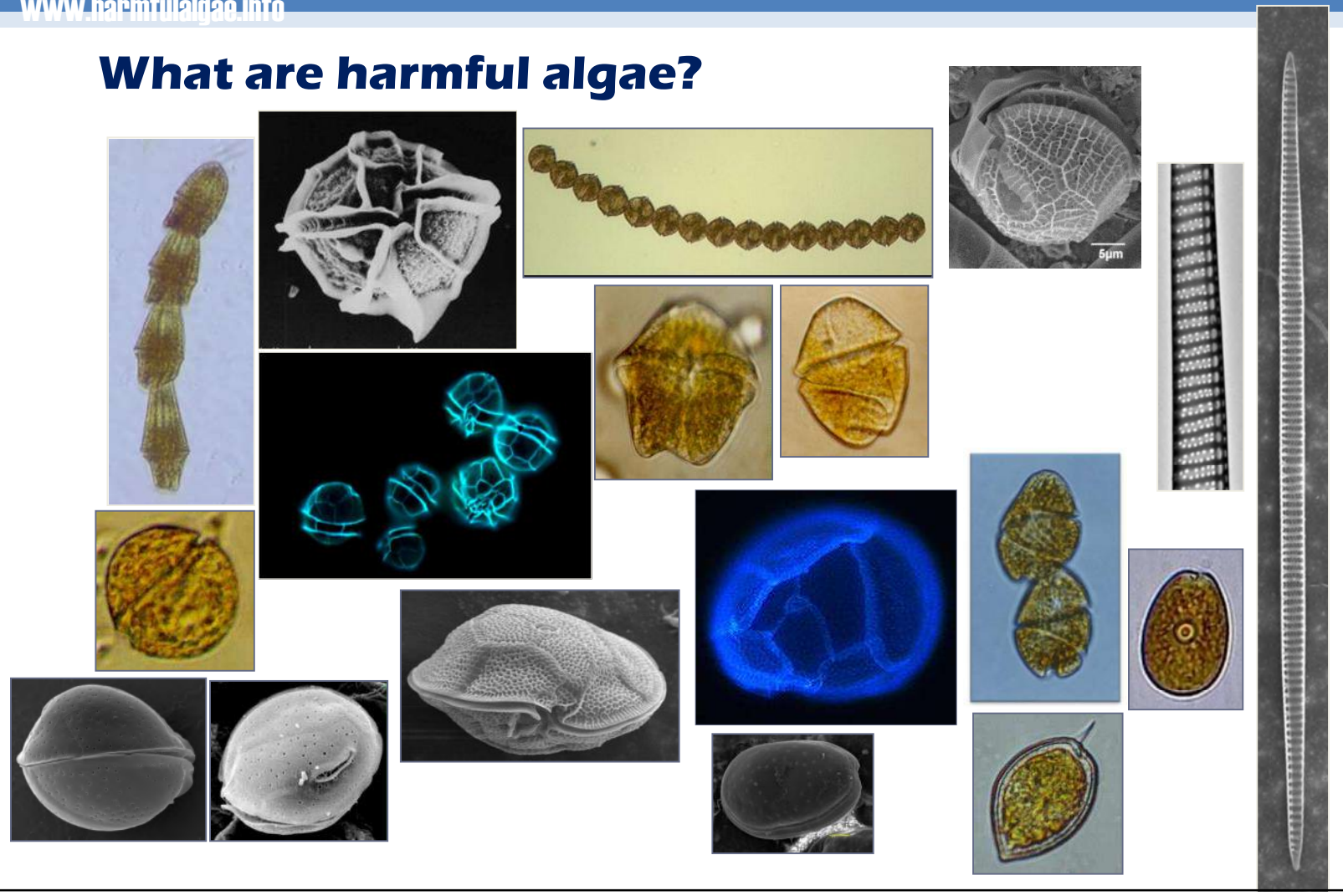
High biomass –
tend to form discoloration visible by naked eye



Toxic plankton -
at a concentration as low as 20 cell/L is enough to cause shellfish contamination

www.harmfulalgae.info

What are harmful algae?



5

www.harmfulalgae.info

6

SOCIO-ECONOMIC IMPACTS OF HABs

$ 133 m 1991-92

$ 82 m

Annual (1987-2000)

$ 37 m public health

$ 38 m commercial fisheries

$ 4 m local recreation & tourism

$ 3 m coastal monitoring

€ 850 m

Annual

€ 687 m tourism

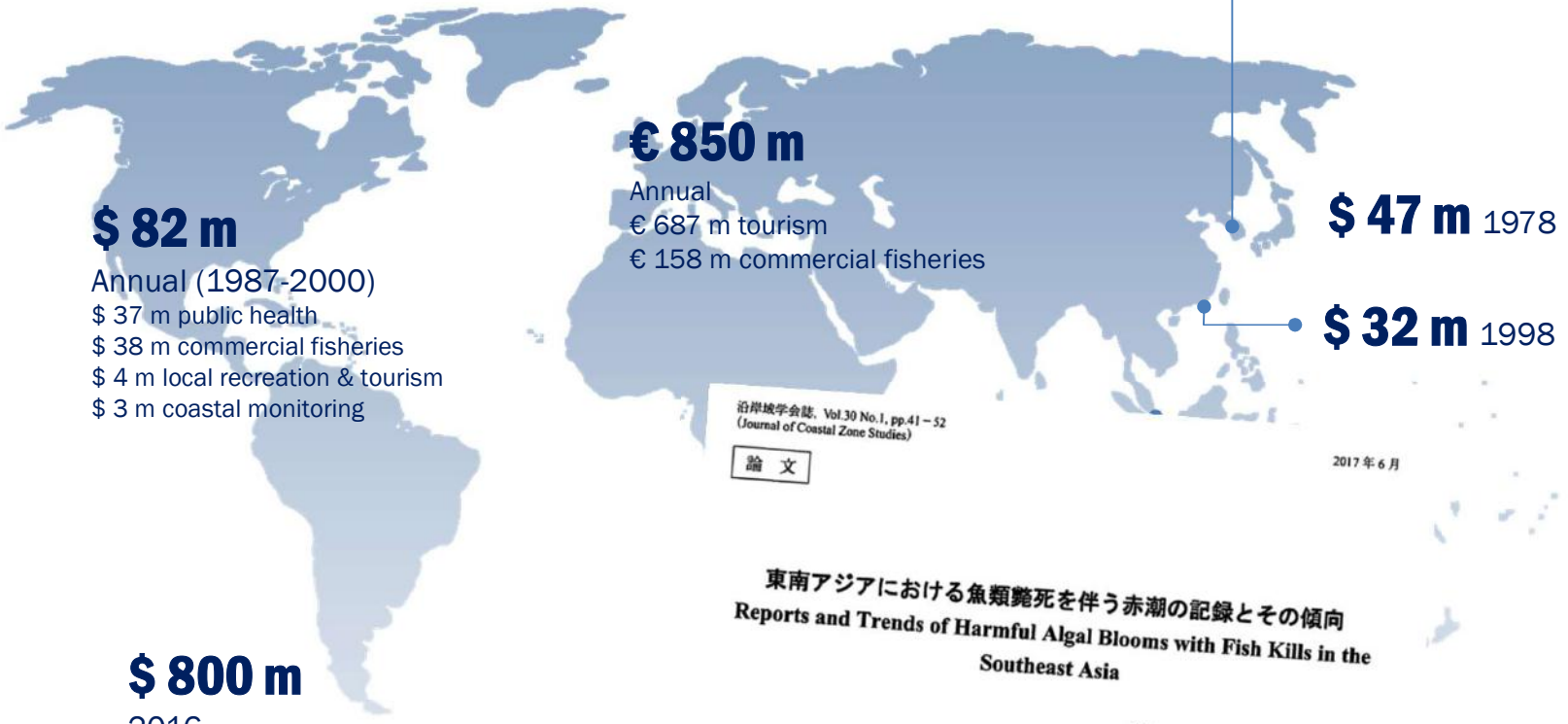
€ 158 m commercial fisheries

$ 47 m 1978

$ 32 m 1998

$ 800 m

2016



沿岸域学会誌, Vol.30 No.1, pp.41－52
(Journal of Coastal Zone Studies)

論 文

2017年6月

東南アジアにおける魚類斃死を伴う赤潮の記録とその傾向

Reports and Trends of Harmful Algal Blooms with Fish Kills in the Southeast Asia

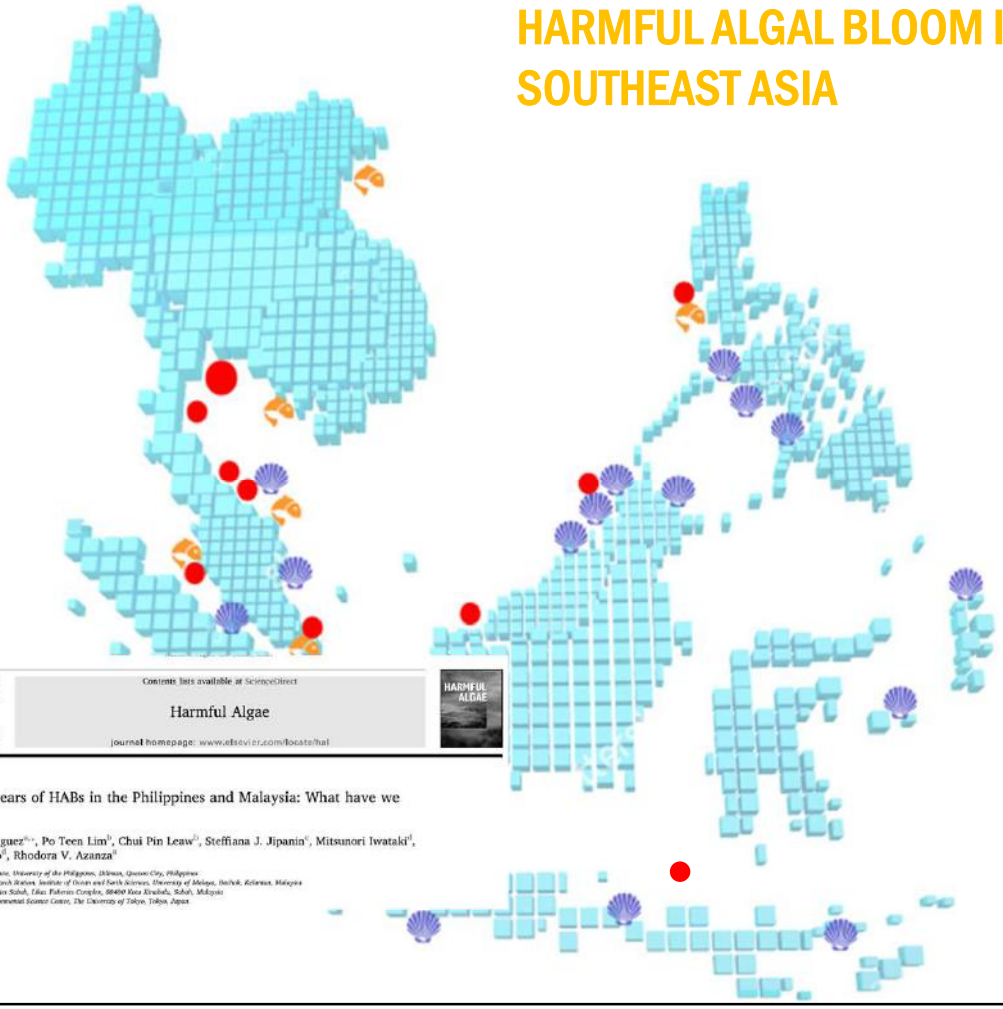
脇田 和美*・岩滝 光儀**

Kazumi WAKITA and Mitsunori IWATAKI

7

www.harmfulalgae.info

HARMFUL ALGAL BLOOM IN SOUTHEAST ASIA



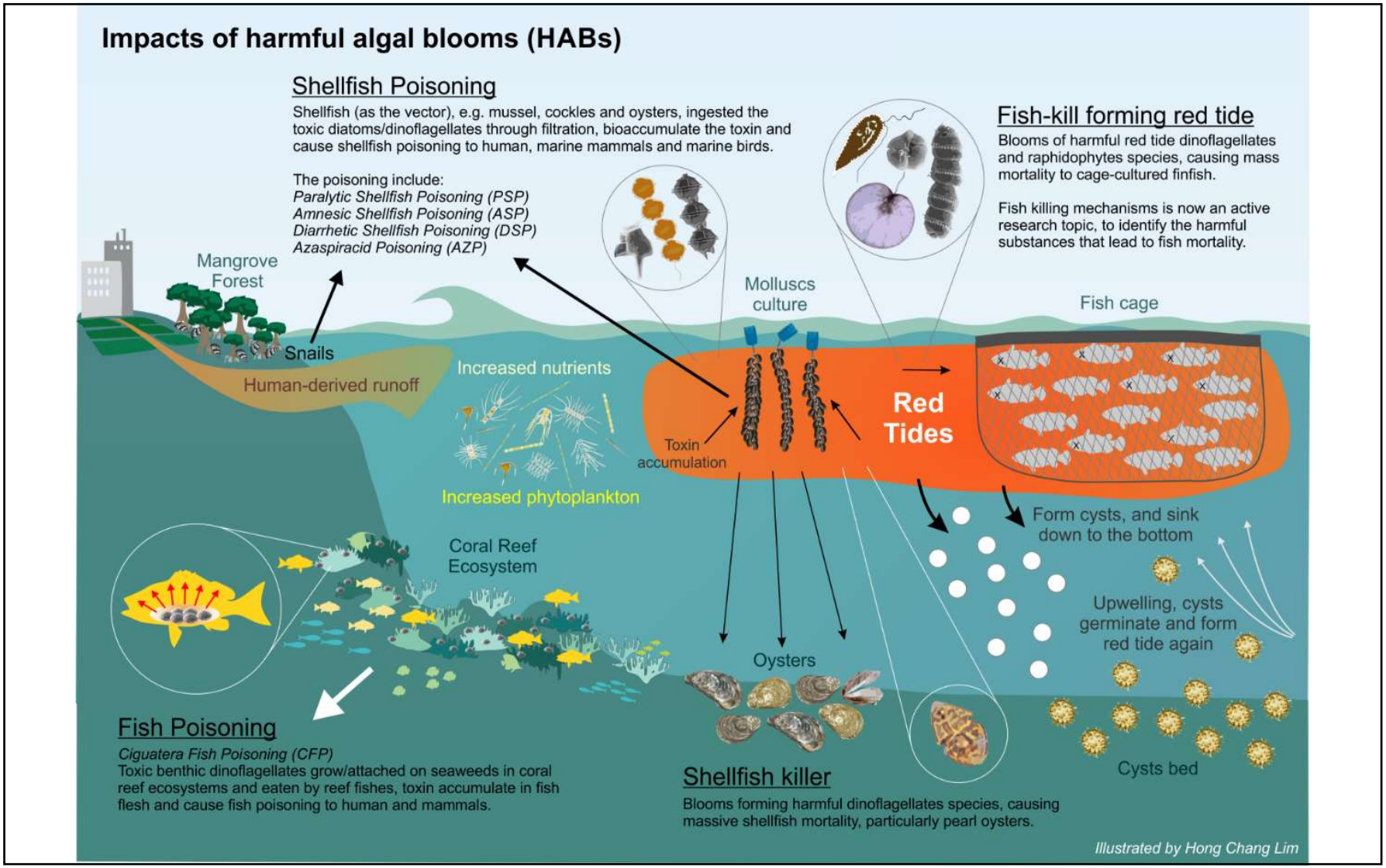
- Shellfish poisoning
- Massive fish kills
- Water discoloration

Contents lists available at ScienceDirect
Harmful Algae
journal homepage: www.elsevier.com/locate/hal

Over 30 years of HABs in the Philippines and Malaysia: What have we learned?

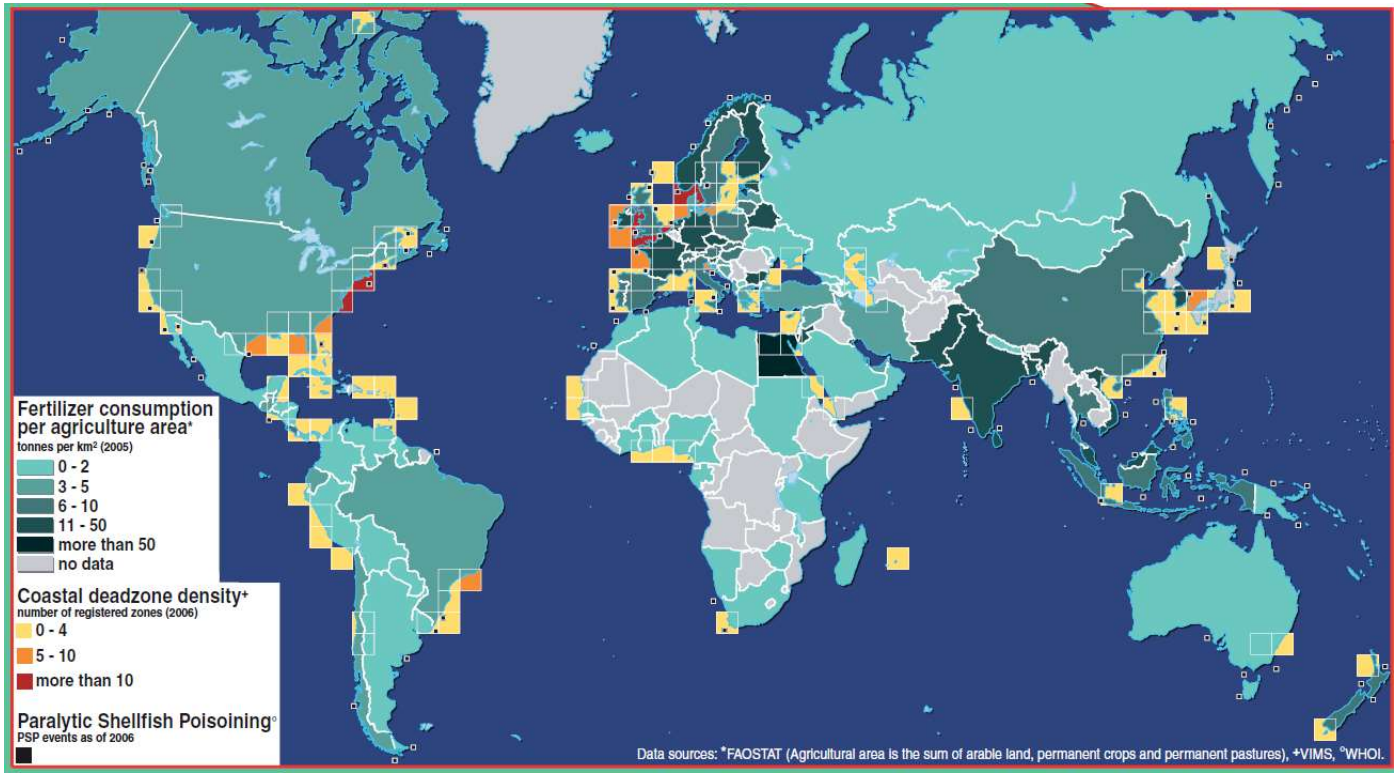
Aletta T. Yñiguez[a,*], Po Teen Lim[b], Chui Pin Leaw[c], Steffiana J. Jipanin[c], Mitsunori Iwataki[d], Garry Benico[a], Rhodora V. Azanza[a]

8


Impacts of harmful algal blooms (HABs)
Shellfish Poisoning
Shellfish (as the vector), e.g. mussel, cockles and oysters, ingested the toxic diatoms/dinoflagellates through filtration, bioaccumulate the toxin and cause shellfish poisoning to human, marine mammals and marine birds.
The poisoning include:
Paralytic Shellfish Poisoning (PSP)
Amnesic Shellfish Poisoning (ASP)
Diarrhetic Shellfish Poisoning (DSP)
Azaspiracid Poisoning (AZP)
Fish-kill forming red tide
Blooms of harmful red tide dinoflagellates and raphidophytes species, causing mass mortality to cage-cultured finfish.
Fish killing mechanisms is now an active research topic, to identify the harmful substances that lead to fish mortality.
Mangrove Forest
Snails
Human-derived runoff
Molluscs culture
Fish cage
Increased nutrients
Toxin accumulation
Red Tides
Increased phytoplankton
Form cysts, and sink down to the bottom
Upwelling, cysts germinate and form red tide again
Coral Reef Ecosystem
Oysters
Cysts bed
Fish Poisoning
Ciguatera Fish Poisoning (CFP)
Toxic benthic dinoflagellates grow/attached on seaweeds in coral reef ecosystems and eaten by reef fishes, toxin accumulate in fish flesh and cause fish poisoning to human and mammals.
Shellfish killer
Blooms forming harmful dinoflagellates species, causing massive shellfish mortality, particularly pearl oysters.
Illustrated by Hong Chang Lim

9

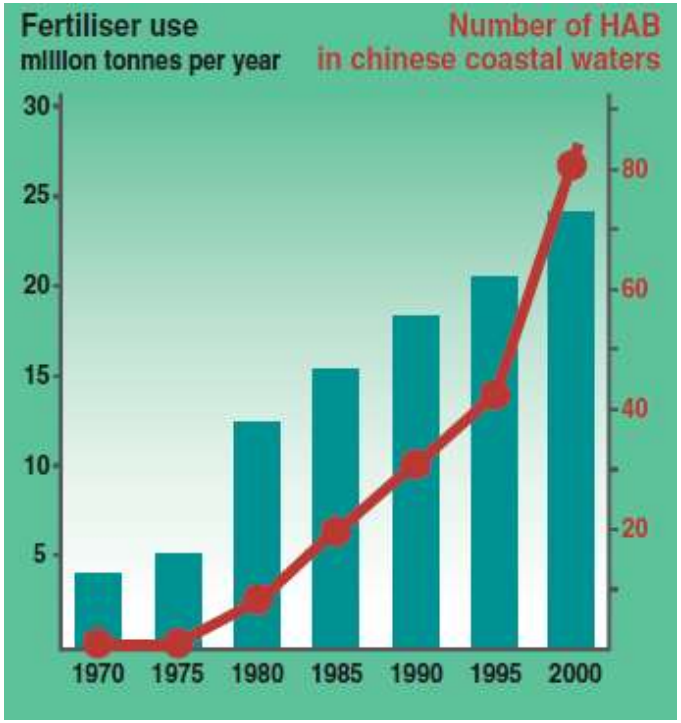
www.harmfulalgae.info



Relation between fertilizer consumption, coastal dead zone and Paralytic shellfish Poisoning (UNEP 2008)

Mariculture

- Mariculture is crucial to meet up the demand from growing population and depletion of captive fisheries.
- The industries faced various threats from the changing environments and other anthropogenic activities.
- HABs are promoted by enrichment of coastal waters by organic/inorganic nutrients from unused feed; posed threat to the sustainability of the industries.



(Furuya et al. 2010; FOA)

www.harmfulalgae.info

Fish Kills Related to Prymnesium parvum N. Carter (Haptophyta) in the People's Republic of China

March 1996 · Journal of Applied Phycology 8(2):111-117 · Follow journal

DOI: 10.1007/BF02186313

Mingxin Guo · Paul J. Harrison · F. J. R. Taylor

NEWS | Politics | Food | Environment

Harmful Algal Blooms Kill Farmed Salmon near Tofino

Cermaq first reported the die-off on Nov. 15. A local environmental group estimates thousands of fish were affected.

Andrew Nikiforuk, 20 Nov 2019 | TheTyee.ca

Andrew Nikiforuk is an award-winning journalist who has been writing about the energy industry for two decades and is a contributing editor to The Tyee. Find his previous stories here.

ELSEVIER

Harmful Algae

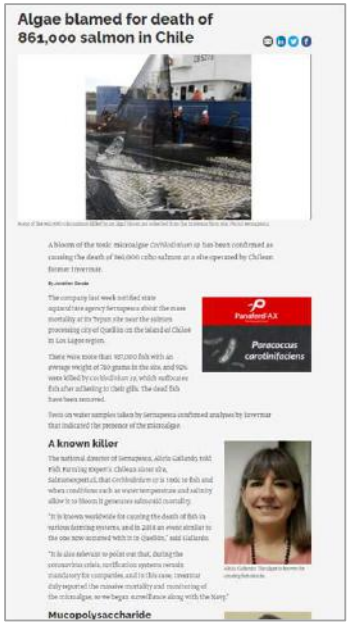
Volume 102, February 2021, 101989

Review

Harmful algal blooms and their effects in coastal seas of Northern Europe

Bengt Karlson [a], Per Andersen [b], Lars Arneborg [a], Allan Cembella [c], Wenche Eikrem [d, e], Uwe John [c, f], Jennifer Joy West [g], Kerstin Klemm [c], Justyna Kobos [h], Sirpa Lehtinen [i], Nina Lundholm [j], Hanna Mazur-Marzec [h], Lars Naustvoll [k], Marnix Poelman [l], Pieter Provoost [m], Maarten De Rijcke [n], Sanna Suikkanen [i]

Chaetoceros spp.



Alexandrium catenella, Pseudochattonella

"HABs have threaten the development of mariculture industries worldwide, partly due to the alteration of ecosystem balance from various anthropogenic activities, including waste from aquacultures "

12

Socio-economic impacts to fisheries

HAB-RELATED FISH KILL EVENTS

mass mortality of fishes

(Courtesy of Y Fukuyo)

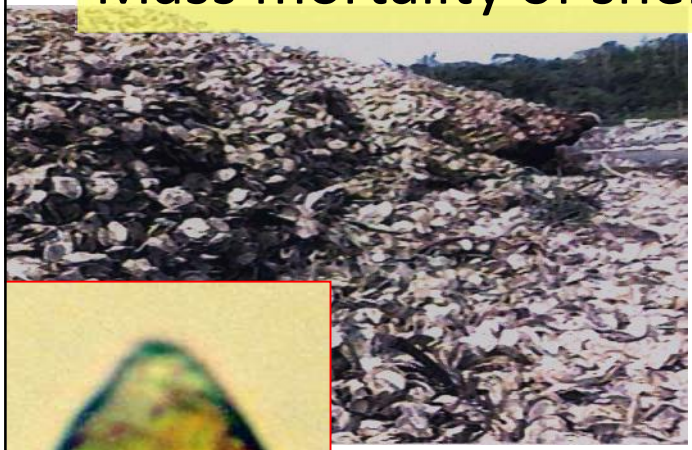
Cochlodinium in Korea

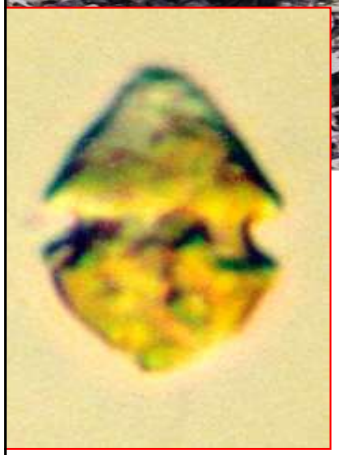
Chattonella sp. in Japan

Karenia in Hong Kong

14

Mass mortality of shellfish





Ecology | Published: 21 October 2019

Who is the "murderer" of the bloom in coastal waters of Fujian, China, in 2019?

Jingyi Cen, Jianyan Wang, Lifen Huang, Guangmao Ding, Yuzao Qi, Rongbo Cao, Lei Cui & Songhui Lü

Journal of Oceanology and Limnology **38**, 722–732(2020) | Cite this article

139 Accesses | **3** Citations | Metrics

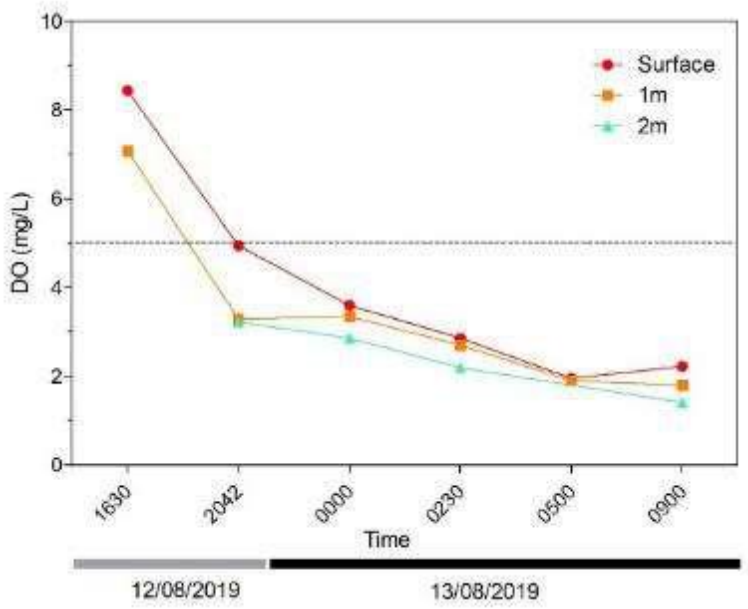
Abstract

HAB-related Fish kills

- Mechanisms of fish kills:
  1. low oxygen level in water (hypoxia/ anoxia) due to degradation of blooms;
  2. Physical clogging and mucus-induced suffocation;
  3. Ichthyotoxins;
  4. Micropredation;
  5. production of ammonia by certain dinoflagellate species.

1. **Hypoxia** due to bloom degradation

Massive fish kills caused by **hypoxia** along the Malacca Strait in 2019

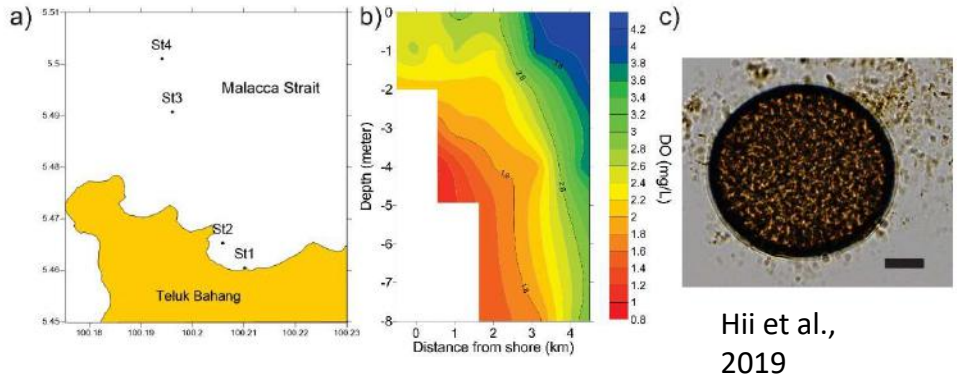


Hii et al. 2019 (*Harmful Algae News*)

Massive fish mortality in Teluk Bahang, Penang

Massive fish mortality in Teluk Bahang, Penang, Malaysia caused by a hypoxia-inducing algal bloom

HARMFUL ALGAE NEWS NO. 63 / 2019



Hii et al., 2019

- On August 11, 2019, a massive fish kill event was reported in Teluk Bahang, Penang, Malaysia (Fig. a).
- The local farmers claimed losses of over 50 tons of caged fishes, estimated of USD 190,000.
- Dissolved oxygen (DO) level in the water columns was deficient; the lowest DO level was observed at fish cage area, with the surface DO level of only 2.47 mg/L, and 0.94 mg/L at the bottom (4 m depth) (Fig b).
- Microscopic observation have showed the highest occurrences of phytoplankton species were *Cosinodiscus* sp. (2.5×10^4 cells/L; Fig. c), followed by *Chaetoceros* spp., *Proboscia* sp., *Rhizosolenia* sp., *Guinardia* sp., and *leptocylindrus* sp.
- Excessive nutrients in the environment was inducing the massive phytoplankton blooms.
- The bloom-induced hypoxia has caused massive fish mortality in the area.

4. Micropredation

Fish killing mechanisms by *K. australe*

Harmful Algae 99 (2020) 101926

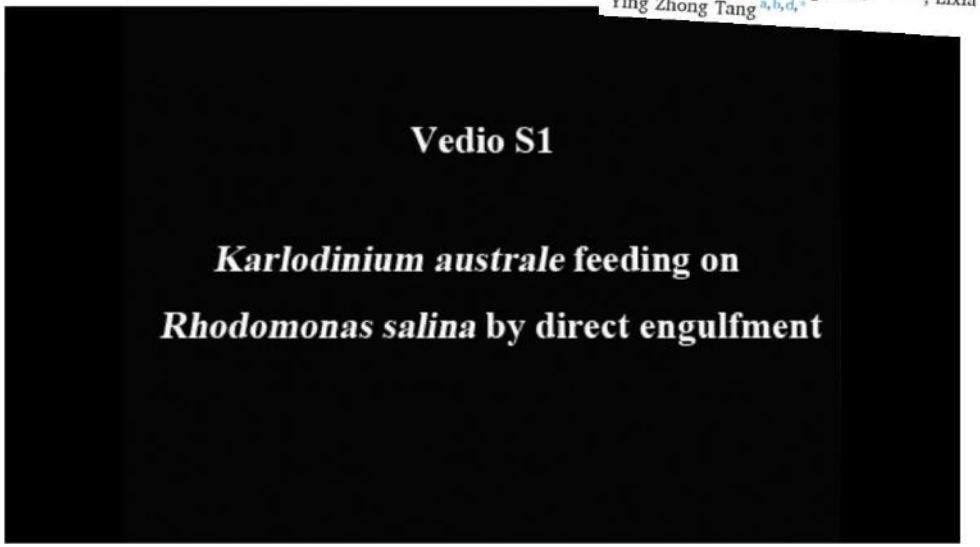
Contents lists available at ScienceDirect

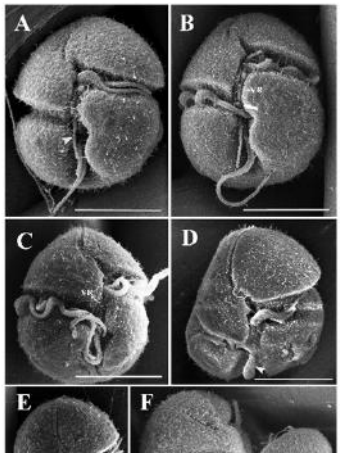
Harmful Algae

journal homepage: www.elsevier.com/locate/hal

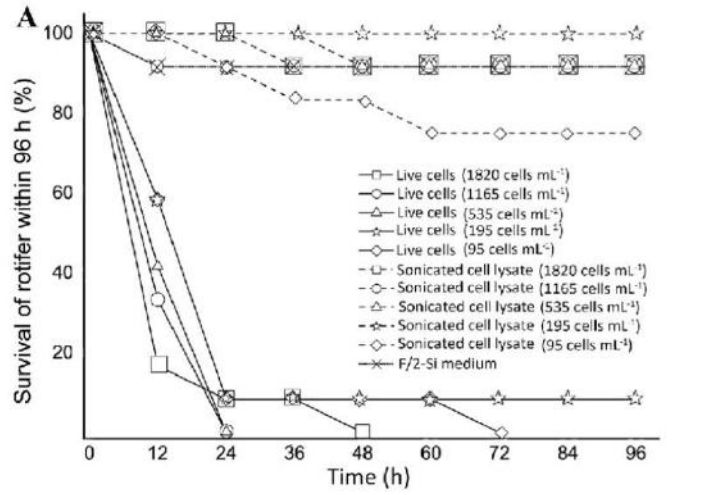
Contact micropredation may play a more important role than exotoxicity does in the lethal effects of *Karlodinium australe* blooms: Evidence from laboratory bioassays

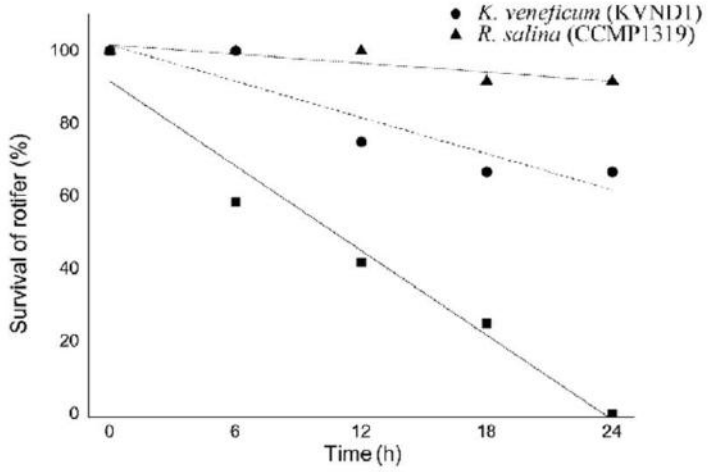
Xiaoying Song [a,c], Zhangxi Hu [a,b,d,**], Lixia Shang [a,b,d], Chui Pin Leaw [e], Po Teen Lim [e], Ying Zhong Tang [a,b,d,*]





Phagotrophic/mixotrophic dinoflagellates





Lethal effects on zooplankton

Vedio S5

***Karlodinium australe* feeding on rotifer *Brachionus plicatilis* by tube feeding**

Song et al. 2020 (*Harmful Algae*)

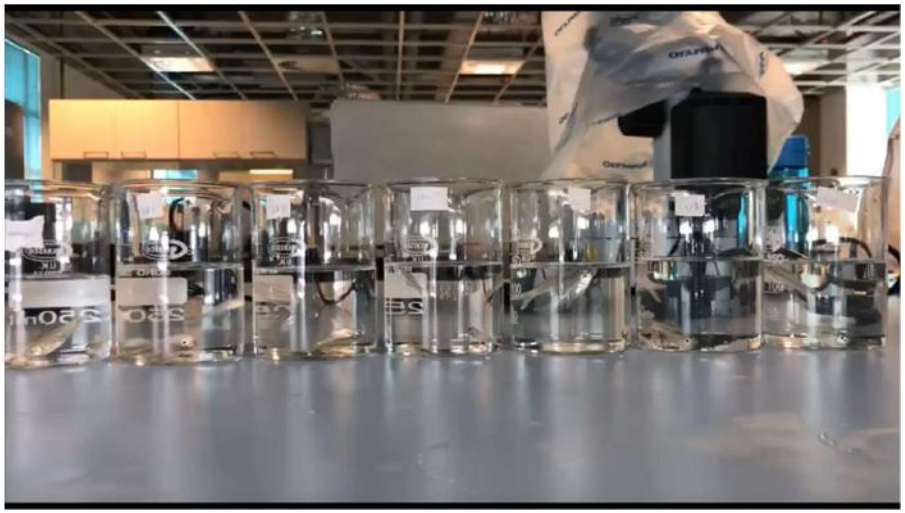
4. Ichthyotoxins + Micropredation

Fish killing mechanisms by *K. australe*

Table. 2
Fish bioassay using culture plate with inserts showing fish mortality as affected by contact with, or separation from live or freeze-thaw cells of *K. australe*. The DO level measured immediately after fish death was 8.438 ± 0.112 mg L^{-1}.

Treatment		Number of fish died within 120 h ($n = 6$) Test 1	Test 2	Average mortality
Live cells (1,700 cells mL^{-1})	Outside insert (with cell contact)	5/6	4/6	75%
	Inside insert (no cell contact)	0/6	0/6	0
Freeze-thaw lysate (equivalent to 1,700 cells mL^{-1})	Outside insert (no cell contact)	2/6	1/6	25%
	Inside insert (no cell contact)	3/6	2/6	42%

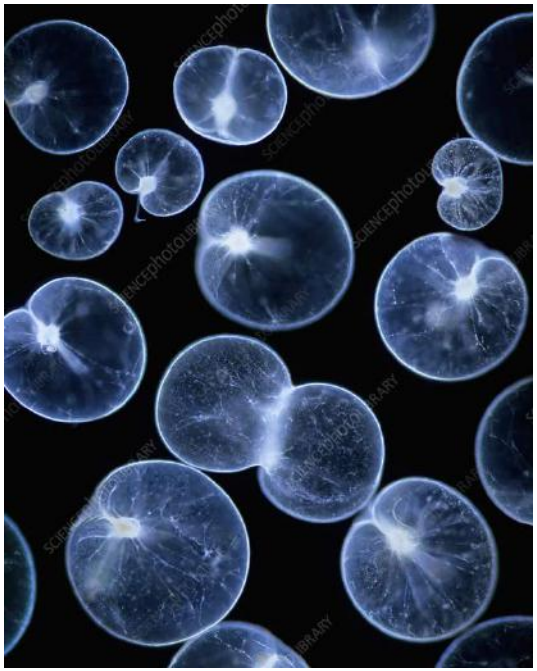
Song et al. 2020 (*Harmful Algae*)



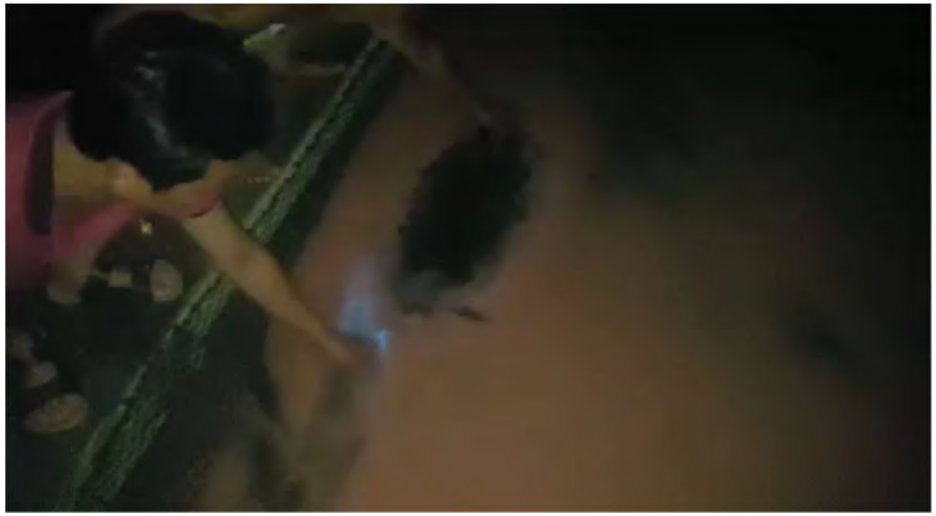
Teng et al. unpublished data

5. Ammonia production

Noctiluca scintillans



Noctiluca bloom in Perak (2016)



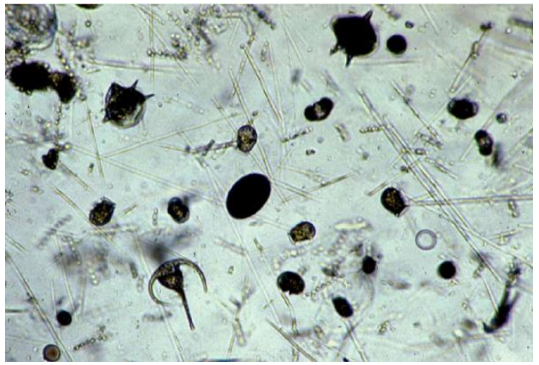
34

HAB MANAGEMENT AND MITIGATION

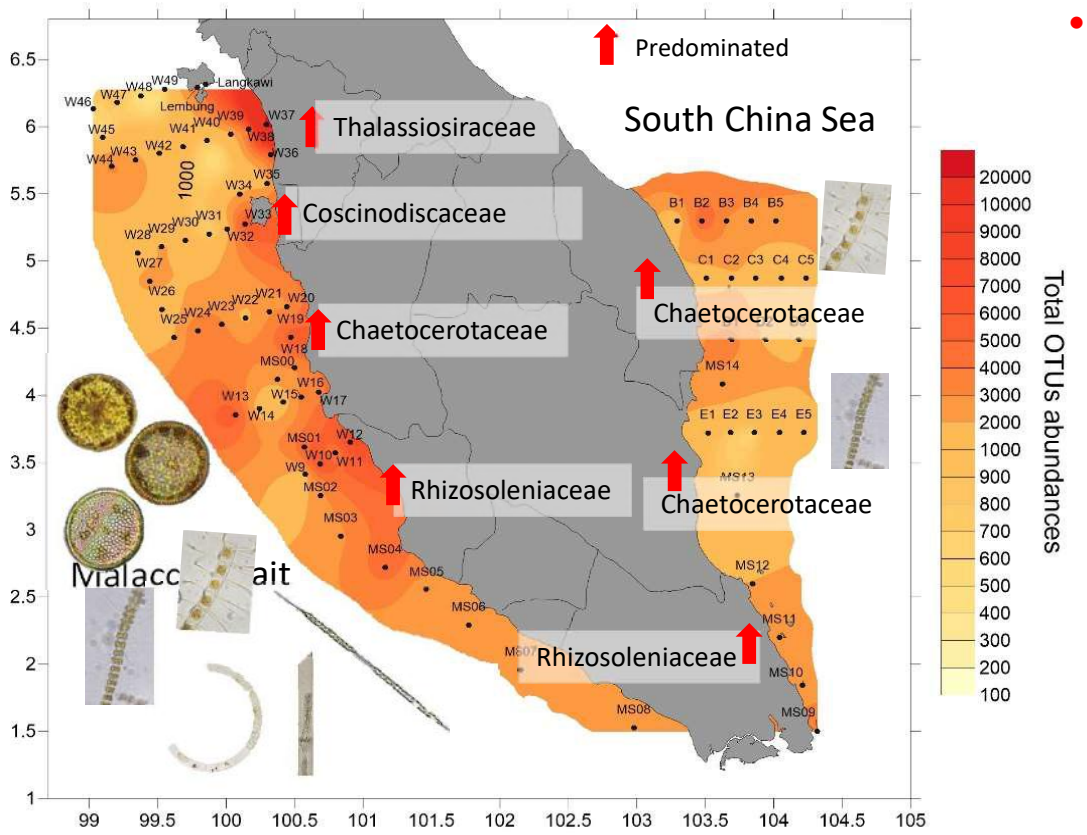
Aquaculture site selection

- Carrying capacity (e.g. Guide for the Sustainable Development of Mediterranean Aquaculture)
- Water quality, affect from other anthropogenic activities (e.g. poultry farm, industries waste etc.)

HAB risk assessment ? The use of metabarcoding of environmental DNA?



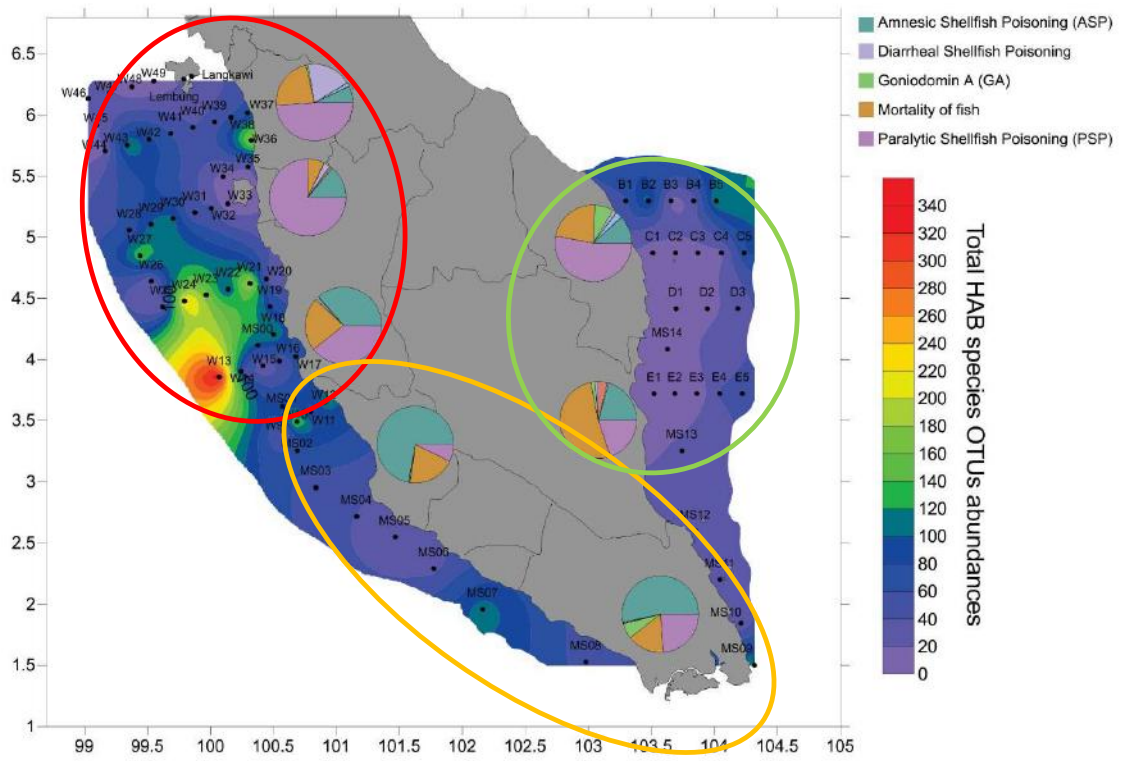
OTUs Abundance of phytoplankton



- High OTU abundances of phytoplankton were found at shore sampling stations of Malacca Strait.
  - This was likely influenced by high nutrient loading in the region.

Hii et al., Unpublished data

Harmful algal bloom species and its threats



- A total of 28 harmful algal bloom (HAB) species was annotated from OTU, with 7 new records in Malaysian waters.
- High OTU abundance of HAB species were mainly found in Malacca strait.

What to monitor in mariculture operation?

We need to know what to monitor “regular basis” and for what “purpose”

- Blooms forming species – to prevent fish mortality? (economical losses)
- Toxin producers- to warn of shellfish contamination (public health)

- Capacity building-technical know how
- Modernization of aquaculture infrastructures and operation

- HABs species have been recognized as one of the most unwanted species (IAS) that has been introduced to various regions of the world via discharge of ships' ballast water.
- IMO has established a guideline in 1991, and the international convention for the control and management of ship's ballast water (WM) was adopted in 2004 (IMO, 2004).

Biological control

(seaweed, algicidal bacteria, or species specific viruses)

Strategies and ecological roles of algicidal bacteria

s Meyer, Arite Bigalke, Anett Kaulfuß, Georg Pohnert

MS Microbiology Reviews, Volume 41, Issue 6, November 2017, Pages 880–899,
ps://doi.org/10.1093/femsre/fux029

blished: 22 August 2017 **Article history**

PLOS ONE

OPEN ACCESS PEER-REVIEWED
RESEARCH ARTICLE

Selective Algicidal Action of Peptides against Harmful Algal Bloom Species

Seong-Cheol Park, Jong-Kook Lee, Si Wouk Kim, Yoonkyung Park

Published: October 26, 2011 • https://doi.org/10.1371/journal.pone.0026733

1 **The algicidal activity and characteristics of the novel marine**
2 **algicidal bacterium *Paracoccus sp.* Y42 against a harmful algal**
3 **bloom causing dinoflagellate, *Prorocentrum donghaiense***
4 Fuxing Zhang[1#], Qian Ye[1#], Qiuliang Chen[2], Ke Yang[1], Danyang Zhang[1],
5 Zhangran Chen[1], Shasha Lu[1], Xueping Shao[1], Yongxiang Fan[1], Luming Yao[1],
6 Lina Ke[1], Tianling Zheng[2], Hong Xu[1,2*]

ELSEVIER

Science of The Total Environment
Volume 707, 10 March 2020, 135561

Kelp cultivation effectively improves water quality and regulates phytoplankton community in a turbid, highly eutrophic bay

Zhibing Jiang [a, b, d], Jingjing Liu [a], Shanglu Li [c], Yue Chen [a], Ping Du [a, b], Yuanli Zhu [a], Yibo Liao [a, d], Quanzhen Chen [a], Lu Shou [a], Xiaojun Yan [e], Jiangning Zeng [a, *], Jianfang Chen [a, d]

41

How to mitigate?

Eukaryotic Microbiology

Published by the International Society of Protistologists

Controlling Harmful Algal Blooms Through Clay Flocculation[1]

MARIO R. SENGCO, DONALD M. ANDERSON

First published: 11 July 2005 | https://doi.org/10.1111/j.1550-7408.2004.tb00541.x | Citations: 150

[1] Symposium presentation for a joint meeting of the Society of the Protozoologists and the Phyco Society of America. 14–19 June 2003, Gleneden Beach, Oregon.

Published: 31 October 2015

Flocculation of harmful algal cells using modified clay: effects of the properties of the clay suspension

Yang Liu, Xihua Cao, Zhiming Yu, Xiuxian Song & Lixia Qiu

Journal of Applied Phycology **28**, 1623–1633(2016) | Cite this article

493 Accesses | **11** Citations | Metrics

J. Mar. Sci. Eng. **2015**, *3*, 154-174; doi:10.3390/jmse3020154

OPEN ACCESS

Journal of *Marine Science and Engineering*

ISSN 2077-1312

www.mdpi.com/journal/jmse

Article

Mitigating Fish-Killing *Prymnesium parvum* Algal Blooms in Aquaculture Ponds with Clay: The Importance of pH and Clay Type

Andreas Seger [1,*], Juan José Dorantes-Aranda [1], Marius N. Müller [2], Adam Body [3], Anton Peristyy [4], Allen R. Place [5], Tae Gyu Park [6] and Gustaaf Hallegraeff [1]

42

Aquaculture Research

Effect of yellow loess on clearance rate in seven species of benthic, filter-feeding invertebrates

Sandra E Shumway, Dana M Frank, Lisa M Ewart, J Evan ward

First published: 10 December 2003 | https://doi.org/10.1111/j.1365-2109.2003.00958.x | Citations: 37

Correspondence: S E Shumway, Department of Marine Sciences, University of Connecticut, 1080 Shennecossett Road, Groton, CT 06340, USA. E-mail: sandrashumway@hotmail.com, sandra.shumway@uconn.edu

"……it may not necessarily be an environmentally advisable or responsible approach to dealing with HABs"

Marine Biology (2004) 144: 553–565
DOI 10.1007/s00227-003-1222-5

RESEARCH ARTICLE

Marie-Claude Archambault · V. Monica Bricelj
Jon Grant · Donald M. Anderson

Effects of suspended and sedimented clays on juvenile hard clams, *Mercenaria mercenaria*, within the context of harmful algal bloom mitigation

Received: 28 September 2002 / Accepted: 4 September 2003 / Published online: 5 November 2003

"These results suggest that repeated clay applications in the field are likely more detrimental to clams in a high-energy environment…."

www.harmfulalgae.info

Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2016.0346

59 (2017) 65–71
January

Ozone-based advanced oxidation processes for the removal of harmful algal bloom (HAB) toxins: a review

Kavithaa Loganathan
Qatar Environment and Energy Research Institute (QEERI), Hamad bin Khalifa University (HBKU), Qatar Foundation, Doha, Qatar, Tel. +974 77968323, Fax +974 4454 1528, email: kloganathan@qf.org.qa

Received 27 March 2016; Accepted 12 June 2016

Bull Environ Contam Toxicol
DOI 10.1007/s00128-016-1742-6

Evaluation of the Destruction of the Harmful Cyanobacteria, *Microcystis aeruginosa*, with a Cavitation and Superoxide Generating Water Treatment Reactor

Victor F. Medina[1] · Chris S. Griggs[1] · Catherine Thomas[1]

toxins MDPI

Toxins (Basel). 2014 Sep; 6(9): 2657–2675.
Published online 2014 Sep 9. doi: 10.3390/toxins6092657

PMCID: PMC4179153
PMID: 25208009

REVIEWS IN Aquaculture

Review

A critical review on control methods for harmful algal blooms

Juan J. Gallardo-Rodríguez, Allisson Astuya-Villalón, Alejandra Llanos-Rivera, Veronica Avello-Fontalba, Viviana Ulloa-Jofré

First published: 17 May 2018 | https://doi.org/10.1111/raq.12251 | Citations: 15

Application of Hydrogen Peroxide to the Control of Eutrophic Lake Systems in Laboratory Assays

Letizia Bauzá,[1] Anabella Aguilera,[2] Ricardo Echenique,[3] Darío Andrinolo,[1] and Leda Giannuzzi[1,*]

44

RAS as an alternative solution

Aquaculture in coastal urbanized areas: A comparative review of the challenges posed by Harmful Algal Blooms

Aurore Trottet, Christaline George, Guillaume Drillet & Federico M. Lauro

Published online: 17 Mar 2021

Download citation https://doi.org/10.1080/10643389.2021.1897372

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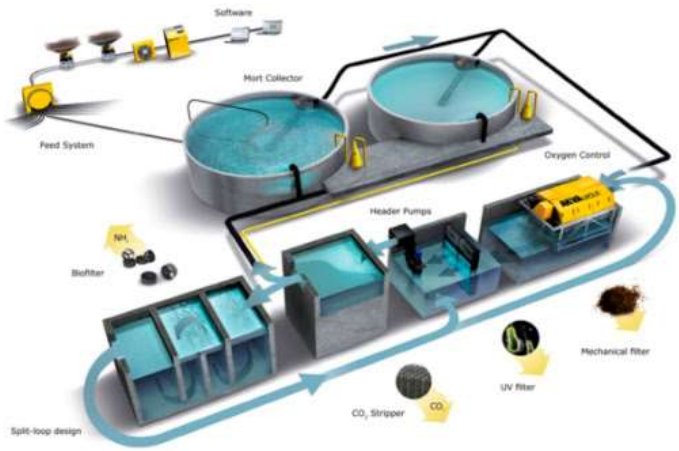
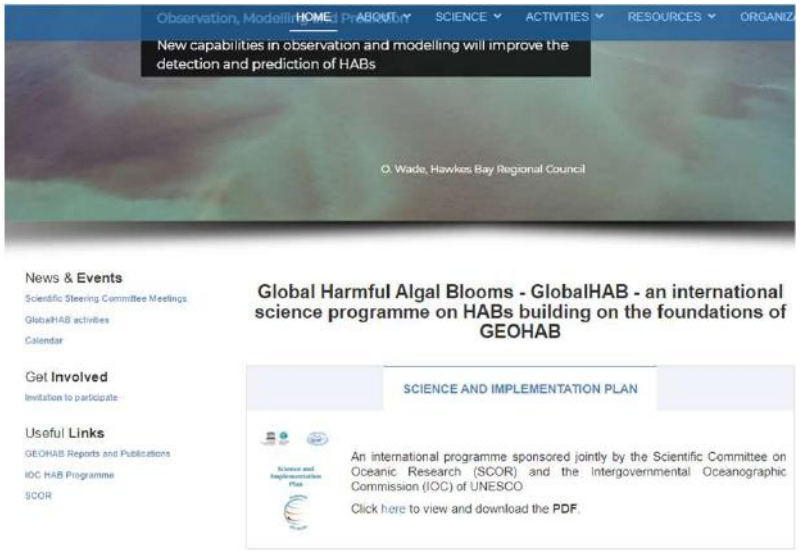
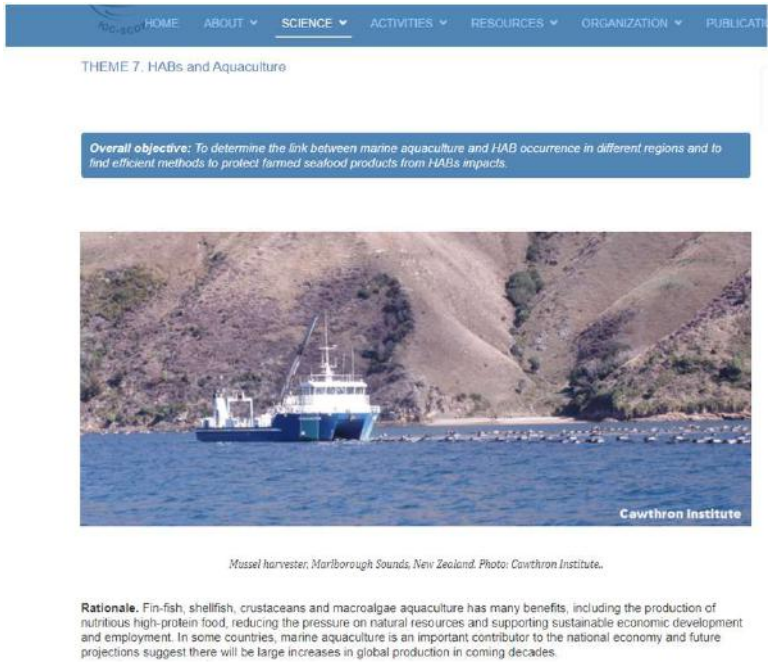


45

IOC SCOR GlobalHAB program



http://www.globalhab.info/



46

International collaboration

Joint Activities by GlobalHAB and other international programs:

Venue: Puerto Varas, Chile
Dates: 8th – 11th October, 2019
Funding: GlobalHAB (IOC & SCOR) and Gobierno de Chile
Organizing Committee: L. Guzmán, J. Mardones. O. Espinoza, A. Cembella and the IPHAB Task Team on Fish Killing Algae

TOPICS and Coordinators:
1. Climate change and fish-killing algae. *G. Hallegraeff, Australia*
2. Taxonomy and molecular characterization of fish-killing algae. *M. Iwataki, Japan*
3. Current knowledge of ichthyotoxins produced by fish-killing microalgae. *T.O. Larsen, Denmark*
4. Mechanisms of algal-induced fish-killing syndromes. *P.J. Hansen, Denmark*
5. Development and validation of current fish- or cell-based bioassay methods for assessing ichthyotoxicity. *H. Hégaret, France and J. Mardones, Chile*
6. Impact of fish-killing algal events on other components of coastal marine ecosystems. *L. Mackenzie, New Zealand*
7. Assessment of mitigation strategies and their effectiveness. *D.M. Anderson, USA*

White Paper (in prep) See presentation by the IPHAB Task Team on Fish Killing Algae

Concluding remarks

- Impact of HABs on the socio-economy (food safety and security) has been recognized as a global issues and required collective efforts by both national and international partners.
- Understanding the bloom dynamics of existing and emerging harmful species is crucial to provide more holistic HAB management and monitoring programs.
- Advancement of technologies in monitoring and mitigation of HABs will help to minimize the impact of HABs and ensure sustainable development of mariculture industries

49

50