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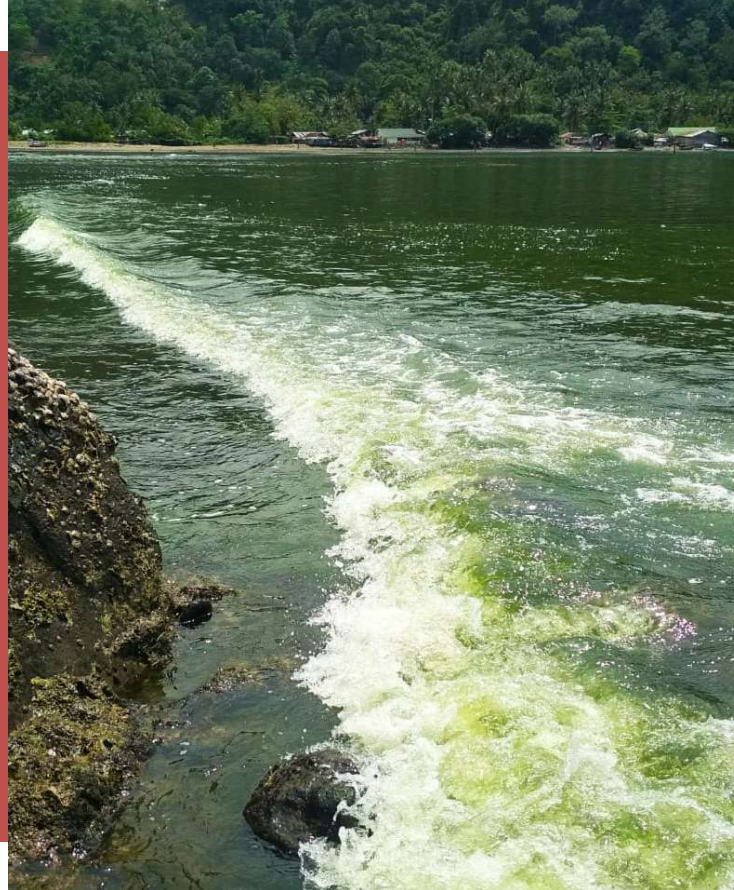
Harmful Algal Blooms (HABs) and Ciguatera Indonesia Studies in Lombok

Indonesian Ciguatera Science Team

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Harmful Algal Blooms (HABs)

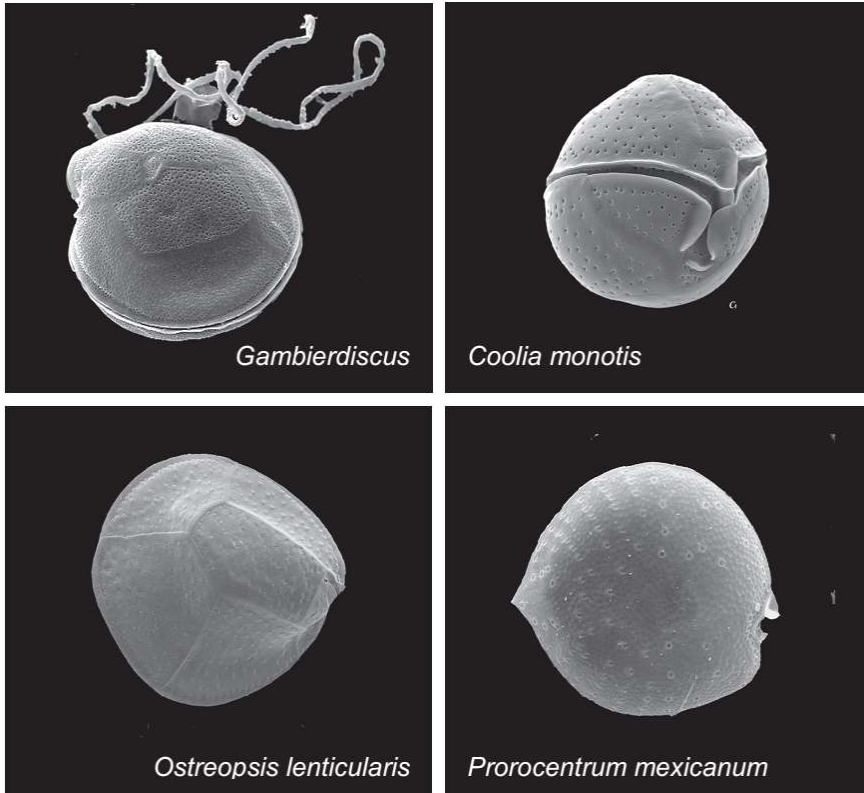
- Harmful Algal Blooms (HABs) → rapid and uncontrolled growth of microalgae species in the water that could damage the aquatic ecosystems → one of the 10 Plagues of the Seas
- The occurrence of HABs → could threaten the ecosystem balance and the life of coastal communities (Duarte et al., 2014)



Harmful effects of algal blooms (GEOHAB, 2000)

- Ocean discoloration
- Mass fish mortality/fish kill
- Toxin contamination of seafood products
- Altering/disrupting the balance of the ecosystem
- Danger to the health of humans (poisoning cases could lead to death)
- Damages to the economy of coastal communities

Ciguatera Fish Poisoning (CFP)



(Faust et al. 2009)

Four benthic dinoflagellate genus are commonly associated with CFP cases: *Gambierdiscus*, *Ostreopsis*, *Prorocentrum*, *Coolia*

- Ciguatera Fish Poisoning → poisoning disease in human or marine mammals due to consumption of reef fishes that are contaminated by ciguatoxin (CTX) produced by several species of benthic dinoflagellates → *Gambierdiscus toxicus* and other associated species → *Ostreopsis ovata*, *Prorocentrum lima*, *P. concavum*, *P. mexicanum (rhathymum)*, and *Amphidinium carterae* (Burkholder 1998; Lehane and Lewis 2000)
- Known symptoms of CFP (deSylva 1994; Lehane dan Lewis 2000) :
 - diarrhea
 - nausea
 - vomitting
 - stomachache
 - reversal of cold-hot sensation
 - muscles and joints pain
 - tingling (often painful)
 - numbness on lips and tongue
 - itch
 - hypotension (low blood pressure)

Records of benthic dinoflagellate species associated with CFP

Benthic dinoflagellates which could potentially caused CFP → *Amphidinium* sp., *G. toxicus*, *O. ovata*, *O. siamensis*, *P. lima*, *P. concavum*, dan *P. rathymum*, *Gambierdiscus* sp., *Ostreopsis* sp → have been reported and studied from several places in Indonesia:

- Seribu Island
- Belitung Island
- Bali coastal waters
- West coast of South Sumatera
- Bintan Island
- Padang coastal waters
- Lampung Bay
- Weh Island coastal waters
- Gili Matra



Compiled by: Widiarti 2020

Widiarti 2002, Widiarti 2010, Skinner et al. 2011, Widiarti 2011, Thamrin 2014, Dwivayana 2015, Eboni et al. 2015, Oktavian et al. 2015, Seygita et al. 2015, Widiarti & Pudjiarto 2015, Widiarti et al. 2016a, Widiarti et al. 2016b, Widiarti & Adi 2016, Widiarti et al. 2019

bHABs and CFP → not yet considered as a major threat to Indonesian coastal communities or ecosystems (no formal report or huge cases) → lack of awareness and studies



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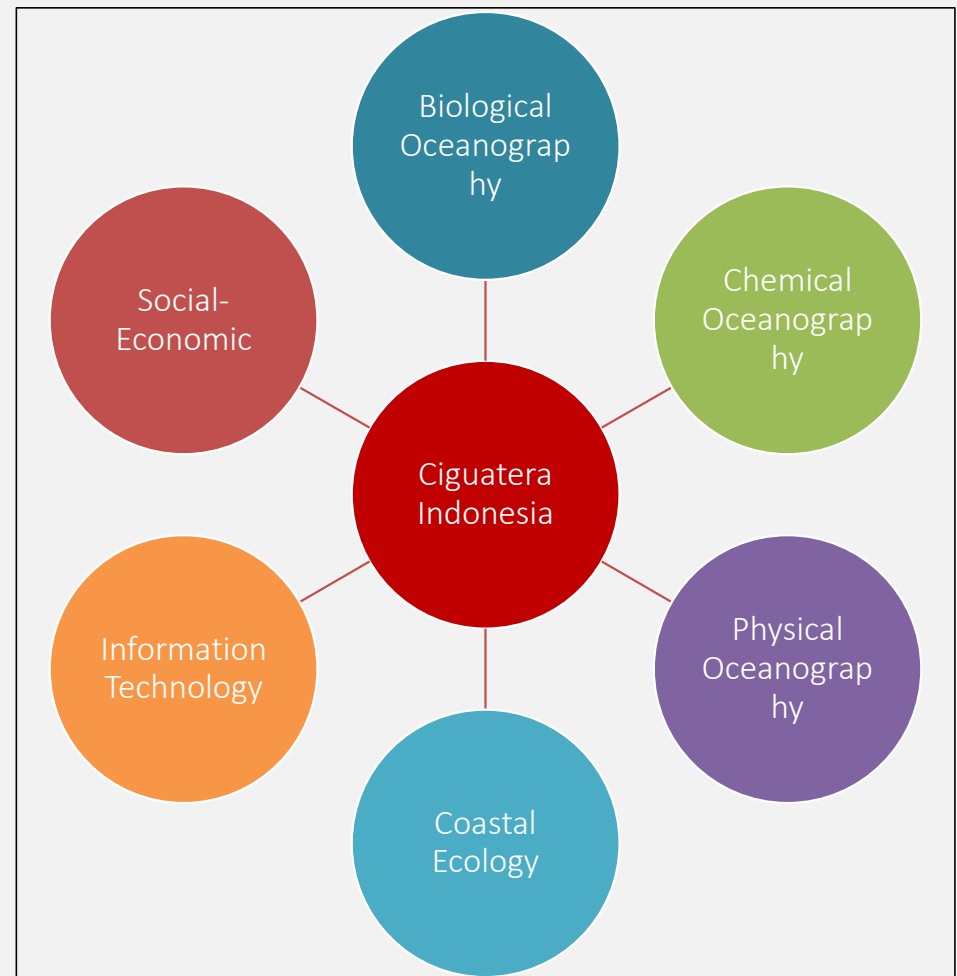
Potential threats of harmful algal blooms (HABs) and ciguatera fish poisoning (CFP) in the marine tourism park of Gili Matra islands, Indonesia

A part of the **Ciguatera Indonesia** project 2022 - 2023



“Multidiscipline and beyond borders”

“Ciguatera Indonesia” → research collaboration beyond institutional and country borders which involving researchers, academics, experts, and university students from many different disciplines



HABs and CFP study of the Ciguatera Indonesia

Identify the potentially harmful phytoplankton and benthic dinoflagellate species which could cause HABs and CFP along with their relationship with habitat condition

Estimate the level of anthropogenic pressures and potential economic loss that might be caused by HABs and/or CFP

Disseminate information and increase the local public awareness on the potential danger of HABs and CFP

Gili Matra Marine Tourism Park (Taman Wisata Perairan/TWP) → Gili Trawangan, Gili Meno, Gili Air

- An important conservation and tourism area to the local people and marine biota in the coastal area of West Lombok

Conservation area → 2.273,56 ha

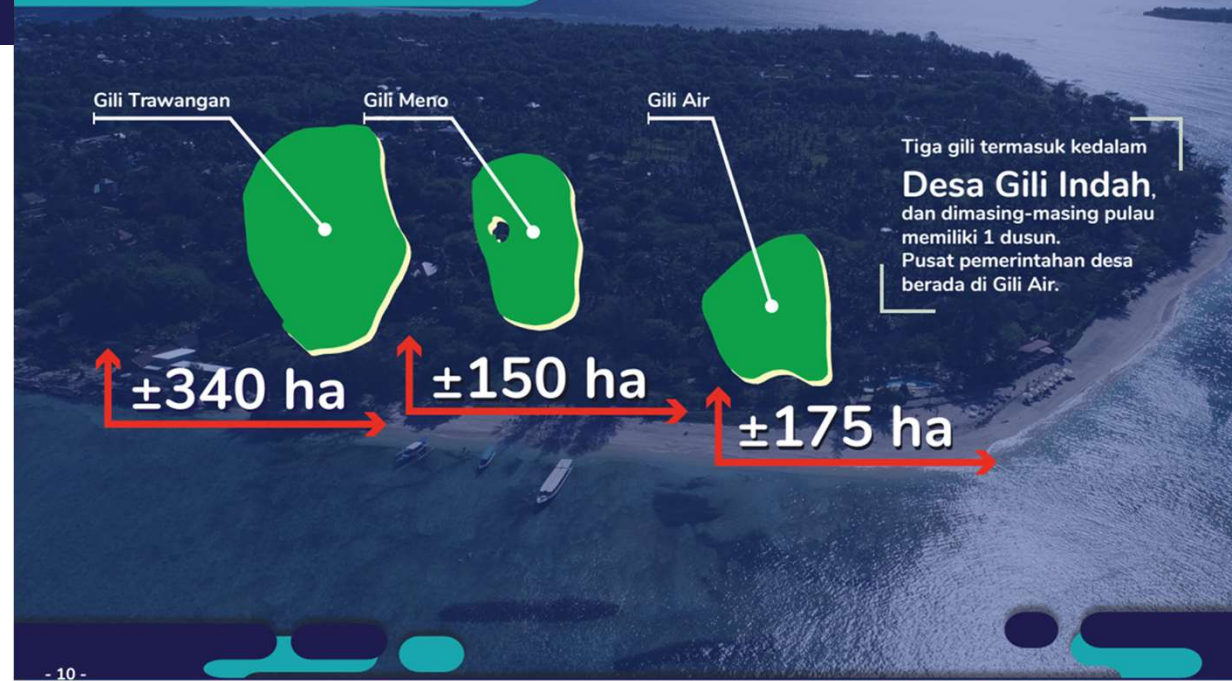
Important coastal ecosystems:

- Mangrove
- Coral Reef
- Seagrass

- Ecologically vital to some protected and charismatic rare species, such as :

- Hiu Sirip Hitam (Blacktip reef shark)
- Hiu Sirip Putih (Whitetip reef shark)
- Penyu (Sea turtle)
- Kima (Giant clam)
- Pari Manta (Manta rays)

Island Profile



Source: Balai Kawasan Konservasi Perairan Nasional Kupang Wilker TWP Gili Matra, 2018



Blacktip and whitetip reef sharks



Giant clams



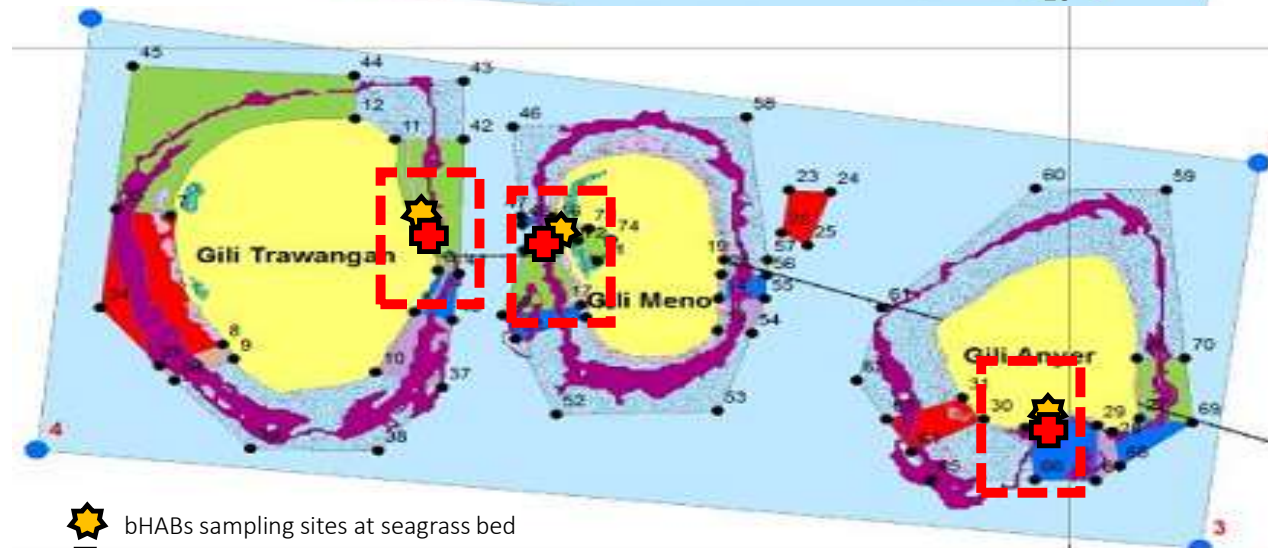
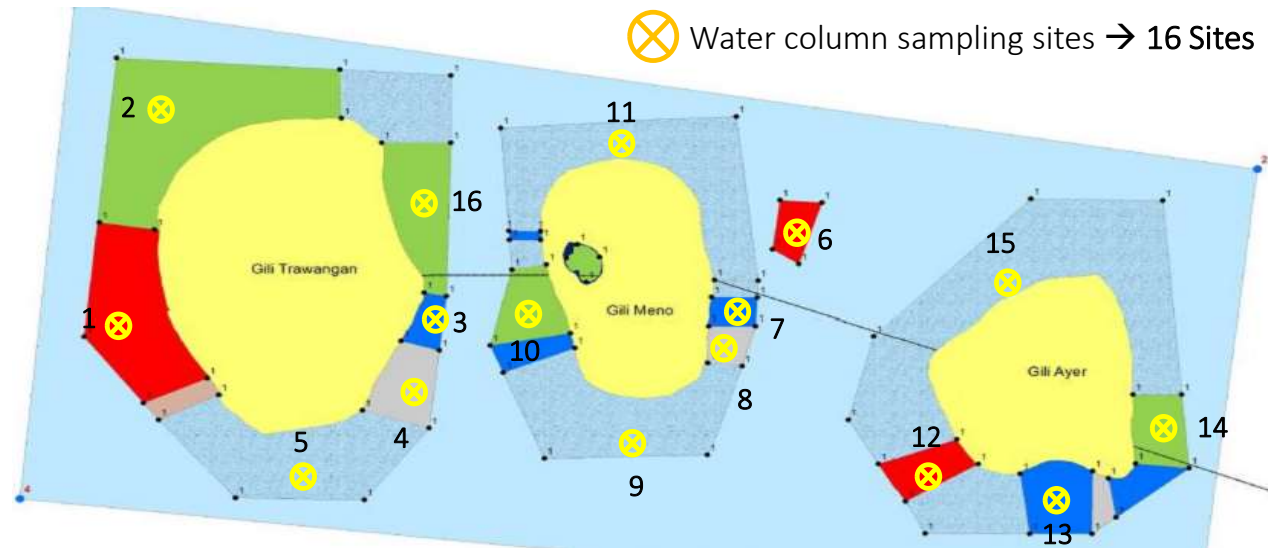
Sea turtles



Manta rays

Sampling Sites

- Gili Matra Marine Tourism Park (Taman Wisata Perairan/TWP) → Gili Trawangan, Gili Meno, Gili Air
- An important conservation and tourism area to the local people and marine biota in the coastal area of West Lombok
- 16 water column sites → plankton, water physical-chemical properties
- 6 permanent sites → benthic dinoflagellates from macroalgal and seagrass beds (natural and artificial)



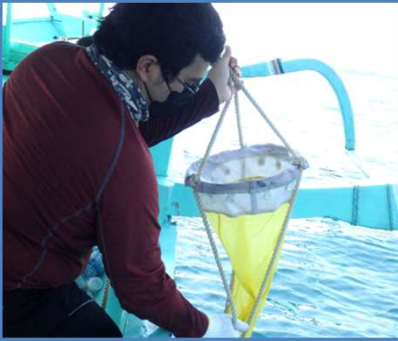
- ★ bHABs sampling sites at seagrass bed
- bHABs sampling sites at coral reef (macroalgal substrate)

Legenda:

● Koordinat Batas Kawasan	● Koordinat Zonasi Kawasan
— Batas Kawasan	— Jalur Pipa Dan Kabel

Ekosistem Pesisir	Zonasi
■ Karang	■ Zona Inti
■ Lamun	■ Zona Perikanan Berkelanjutan
■ Mangrove	■ Sub Zona Perikanan Berkelanjutan Karang
Administrasi	■ Zona Pemanfaatan
■ Provinsi NTB	■ Zona Pelabuhan
	■ Zona Perlindungan
	■ Zona Rehabilitasi

Field Sampling in Gili Matra and Lombok



Plankton
sampling &
water column
parameters
measurement

Benthic
dinoflagellate
sampling



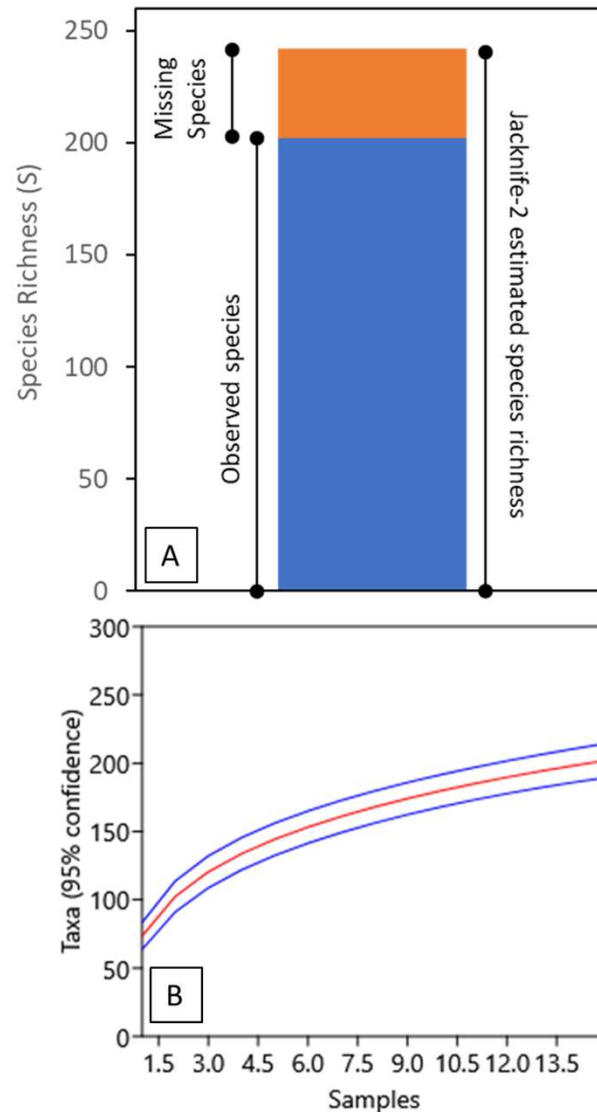
Socio-
economics
sampling

Fish tissue
sampling

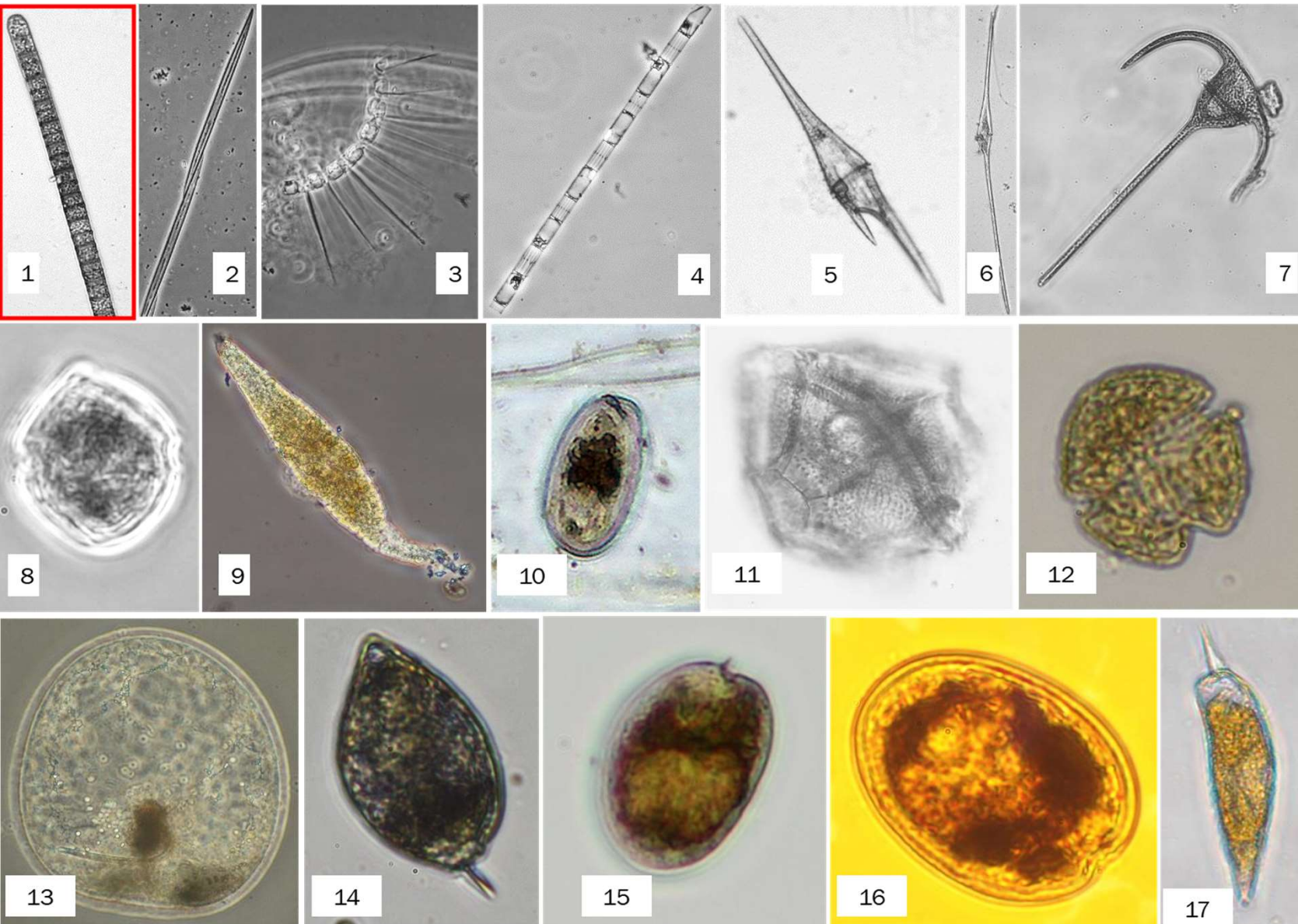


Phytoplankton density & diversity

- In total → 202 species of phytoplankton has been identified from the Core, Harbour, and Sustainable Fisheries zones of Gili Meno at two seasons (n =15) → 17 potentially harmful species
- Jackknife-2 species estimator with 1000 permutation → estimated 215-242 species at the current sampling effort → at least 40 missing species
- Species Accumulation Curve (SAC) → indicating that the number of identified species was representative to the estimated real species assemblages in Gili Meno

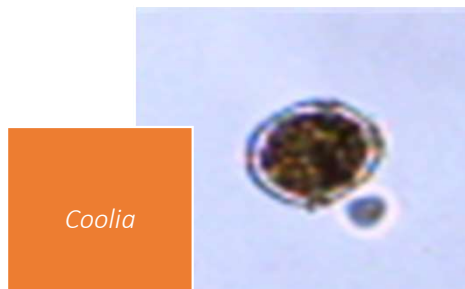
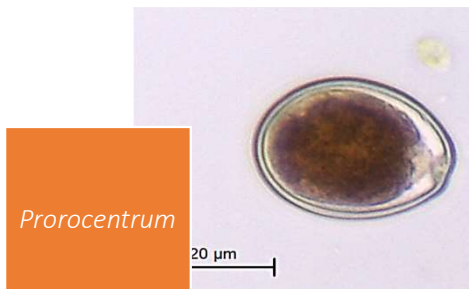
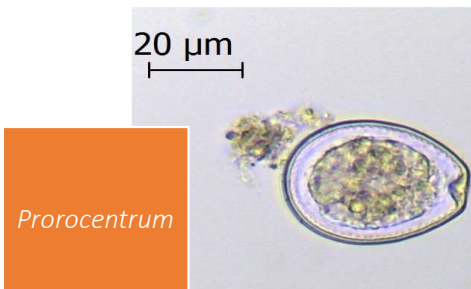
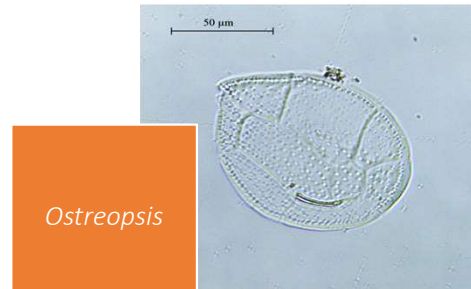
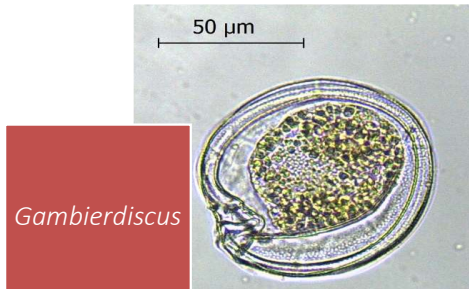


Cyanobacteria	Hemiaulus membranaceus	Dinoflagellate
<i>Lyngbya</i> sp.	<i>Hemiaulus sinensis</i>	<i>Amphidinium</i> sp.
<i>Trichodesmium erythraeum</i>	<i>Hemidiscus cuneiformis</i>	<i>Amphisolenia bidentata</i>
Diatomae	<i>Lampriscus cf. shadbolianum</i>	<i>Ceratium azoricum</i>
<i>Amphiprora</i> spp.	<i>Lauderia annulata</i>	<i>Ceratium breve</i>
<i>Amphisolenia bidentata</i>	<i>Leptocylindrus danicus</i>	<i>Ceratium candelabrum</i>
<i>Amphora laevis</i>	<i>Leptocylindrus mediterraneus</i>	<i>Ceratium cf. karstenii</i>
<i>Asterionellopsis glacialis</i>	<i>Licmophora abbreviata</i>	<i>Ceratium cantortum</i>
<i>Asterolampra marylandica</i>	<i>Licmophora</i> sp.	<i>Ceratium dens</i>
<i>Bacillaria paxillifera</i>	<i>Lioloma elongatum</i>	<i>Ceratium furca</i>
<i>Bacteriastrium delicatulum</i>	<i>Lioloma pacificum</i>	<i>Ceratium fusus</i>
<i>Bacteriastrium furcatum</i>	<i>Lioloma</i> sp.	<i>Ceratium gibberum</i>
<i>Bacteriastrium hyalinum</i>	<i>Lioloma</i> sp.2	<i>Ceratium inflatum</i>
<i>Bacteriastrium minus</i>	<i>Melosira maniliformis</i>	<i>Ceratium kofoidi</i>
<i>Bellerophon malleus</i>	<i>Meuniera membranacea</i>	<i>Ceratium macroceros</i>
<i>Biddulphia pulchella</i>	<i>Navicula directa</i>	<i>Ceratium massiliense</i>
<i>Cerataulina dentata</i>	<i>Navicula</i> spp.	<i>Ceratium teres</i>
<i>Cerataulina pelagica</i>	<i>Nitzschia bicapitata</i>	<i>Ceratium trichoceros</i>
<i>Chaetoceros aequatorialis</i>	<i>Nitzschia longissima</i>	<i>Ceratium tripas</i>
<i>Chaetoceros affinis</i>	<i>Nitzschia longissima var. reversa</i>	<i>Ceratocorys armata</i>
<i>Chaetoceros anastomosans</i>	<i>Nitzschia lorenziana</i>	<i>Ceratocorys goretii</i>
<i>Chaetoceros atlanticus</i>	<i>Nitzschia marina</i>	<i>Ceratocorys horrida</i>
<i>Chaetoceros coarctatus</i>	<i>Nitzschia rectilonga</i>	<i>Chattonella</i> sp.
<i>Chaetoceros compressus</i>	<i>Nitzschia sigma</i>	<i>Cladopyxis brachiolata</i>
<i>Chaetoceros costatus</i>	<i>Nitzschia</i> sp.	<i>Dinophysis caudata</i>
<i>Chaetoceros curvisetus</i>	<i>Nitzschia</i> sp.2	<i>Dinophysis miles</i>
<i>Chaetoceros dadayi</i>	<i>Nitzschia</i> sp.3	<i>Dinophysis odiosa</i>
<i>Chaetoceros danicus</i>	<i>Nitzschia</i> sp.4	<i>Diplopelta bomba</i>
<i>Chaetoceros decipiens</i>	<i>Nitzschia</i> sp.	<i>Diplopelta lenticula</i>
<i>Chaetoceros denticulatus</i>	<i>Odontella mobilensis</i>	<i>Diplopelta steinii</i>
<i>Chaetoceros didymus</i>	<i>Odontella sinensis</i>	<i>Diplopsalid</i> sp.1
<i>Chaetoceros didymus var. protuberans</i>	<i>Palmeria hardmaniana</i>	<i>Diplopsalis lenticula</i>
<i>Chaetoceros distans</i>	<i>Planktoniella sol</i>	<i>Dictyocha speculum</i>
<i>Chaetoceros diversus</i>	<i>Pleurosigma elongatum</i>	<i>Goniadoma polyedricum</i>
<i>Chaetoceros eibenii</i>	<i>Pleurosigma</i> sp.	<i>Gonyaulax</i> sp.
<i>Chaetoceros gracilis</i>	<i>Proboscia alata</i>	<i>Gymnodinium</i> sp.
<i>Chaetoceros laciniatus</i>	<i>Proboscia indica</i>	<i>Gymnodinium</i> sp.2
<i>Chaetoceros lauderi</i>	<i>Pseudo-nitzschia</i> spp.	<i>Gymnodinium</i> sp.3
<i>Chaetoceros lorenzianus</i>	<i>Pseudosolenia calcar-avis</i>	<i>Gyrosigma</i> spp.
<i>Chaetoceros messanensis</i>	<i>Rhabdonema adriaticum</i>	<i>Karenia</i> spp.
<i>Chaetoceros paradoxus</i>	<i>Rhizosolenia bergonii</i>	<i>Noctiluca scintillans</i>
<i>Chaetoceros peruvianus</i>	<i>Rhizosolenia castracanei</i>	<i>Ornithocercus magnificus</i>
<i>Chaetoceros radicans</i>	<i>Rhizosolenia debyana</i>	<i>Ornithocercus</i> sp.
<i>Chaetoceros tenuissimus</i>	<i>Rhizosolenia decipiens</i>	<i>Ornithocercus thumii</i>
<i>Chaetoceros teres</i>	<i>Rhizosolenia hebetata f. semispina</i>	<i>Peridinium quinquecorne</i>
<i>Chaetoceros tortissimum</i>	<i>Rhizosolenia hebetata</i>	<i>Phalacroma doryphorum</i>
<i>Chaetoceros wighamii</i>	<i>Rhizosolenia hyalina</i>	<i>Podolampas bipes</i>
<i>Climacodinium frauenfeldianum</i>	<i>Rhizosolenia imbricata</i>	<i>Prorocentrum compressum</i>
<i>Corethron crispipilum</i>	<i>Rhizosolenia robusta</i>	<i>Prorocentrum micans</i>
<i>Coscinodiscus granii</i>	<i>Rhizosolenia setigera</i>	<i>Prorocentrum rathymum</i>
<i>Coscinodiscus lineatus</i>	<i>Skeletonema costatum</i>	<i>Prorocentrum sigmoides</i>
<i>Coscinodiscus oculus-iridis</i>	<i>Stephanopyxis palmeriana</i>	<i>Protoperidinium curtipes</i>
<i>Coscinodiscus radiatus</i>	<i>Stephanopyxis turris</i>	<i>Protoperidinium depressum</i>
<i>Cylindrotheca closterium</i>	<i>Stigmaphora rastrata</i>	<i>Protoperidinium divergens</i>
<i>Dactylosolen phuketensis</i>	<i>Striatella unipunctata</i>	<i>Protoperidinium elegans</i>
<i>Detonula cf. confereacea</i>	<i>Thalassionema javanicum</i>	<i>Protoperidinium oceanicum</i>
<i>Ditylum sol</i>	<i>Thalassionema nitzschioides</i>	<i>Protoperidinium pentagonum</i>
<i>Eucampia cornuta</i>	<i>Thalassionema nitzschioides var. parva</i>	<i>Protoperidinium quarnense</i>
<i>Eucampia zodiacus</i>	<i>Thalassionema nitzschioides</i>	<i>Protoperidinium steinii</i>
<i>Gossilieria tropica</i>	<i>Thalassiosira</i> spp.	<i>Pyrocystis fusiformis</i>
<i>Guinardia cylindrus</i>	<i>Thalassiothrix longissima</i>	<i>Pyrocystis hamulus</i>
<i>Guinardia delicatula</i>	<i>Triceratium alternans</i>	<i>Pyrocystis lunula</i>
<i>Guinardia flaccida</i>	<i>Triceratium favus</i>	<i>Pyrophacus horologium</i>
<i>Guinardia striata</i>	<i>Triceratium revale</i>	<i>Pyrophacus steinii</i>
<i>Gyrosigma</i> spp.	<i>Triceratium</i> sp.	<i>Naked dinoflagellate</i>
<i>Haslea gigantea</i>	<i>Unknown diatom</i>	<i>Naked flagellates</i>
<i>Helicotheca tamesis</i>	<i>Unknown diatom sp.2</i>	<i>Unknown dinoflagellate</i>
<i>Hemiaulus hauckii</i>	<i>Unknown diatom sp.3</i>	<i>Unknown dinoflagellate sp.2</i>
<i>Hemiaulus indicus</i>		<i>Unknown dinoflagellate sp.3</i>



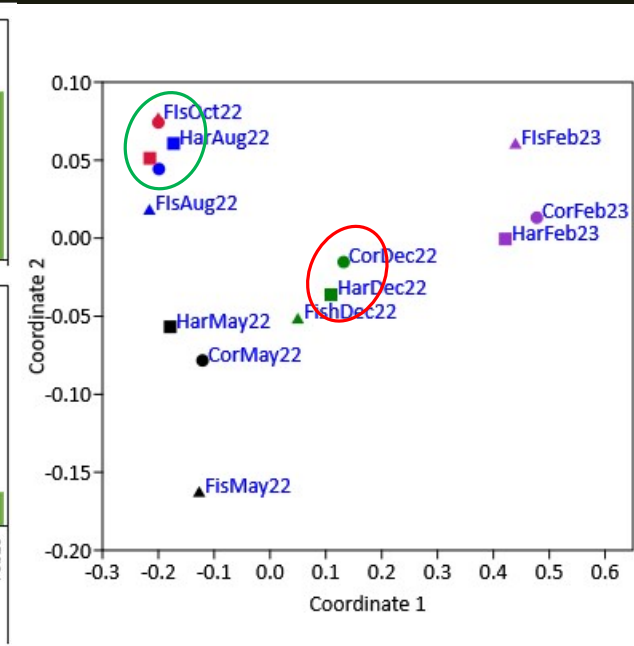
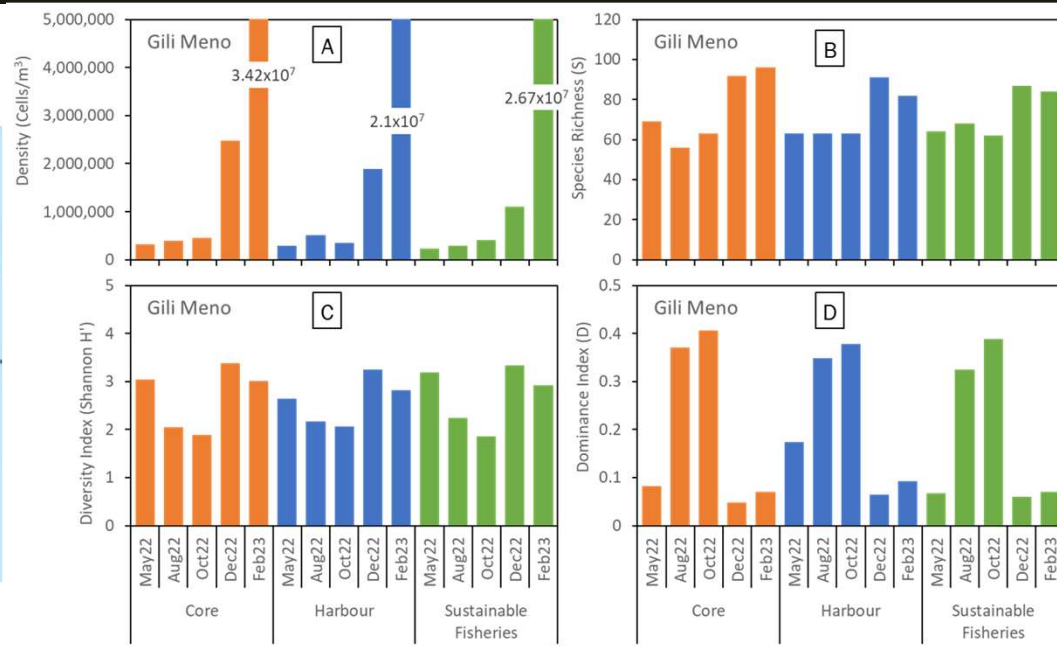
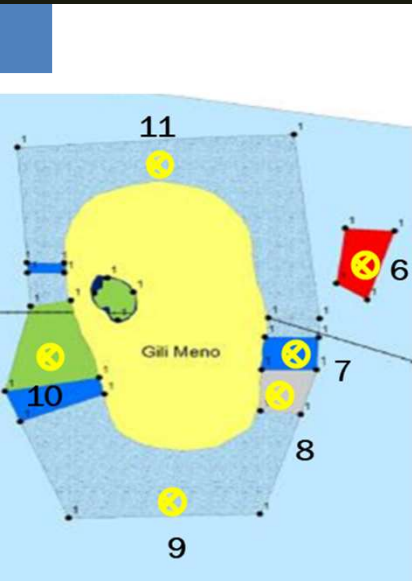
17 potentially harmful species of Gili Matra

1. *Trichodesmium erythraeum* → often blooms in Seribu Islands
2. *Pseudo-nitzschia* spp. → Some species produced Domoic Acid, causing Amnesic Shellfish Poisoning (ASP)
3. *Chaetoceros curvisetus* → several blooms cases recorded in Jakarta Bay
4. *Skeletonema costatum* → blooms in Jakarta Bays, particularly in wet season
5. *Tripos furca* → often blooms in Lampung Bay
6. *Tripos (Ceratum) fusus*
7. *Tripos muelleri (Ceratum tripos)*
8. *Scrippsiella trochoidea*
9. *Chattonella* spp. → Fish Killer
10. *Amphidinium* spp.
11. *Gonyaulax* spp. → some species cause recent blooms in Ambon Bay
12. *Karenia* spp. → some species produces Brevetoxin, causing Neurotic Shellfish Poisoning (NSP)
13. *Noctiluca scintillans* → often blooms in Jakarta Bay, Lampung Bay, fish killer
14. *Prorocentrum micans*
15. *Prorocentrum rathymum*
16. *Prorocentrum compressum*
17. *Prorocentrum sigmoides*



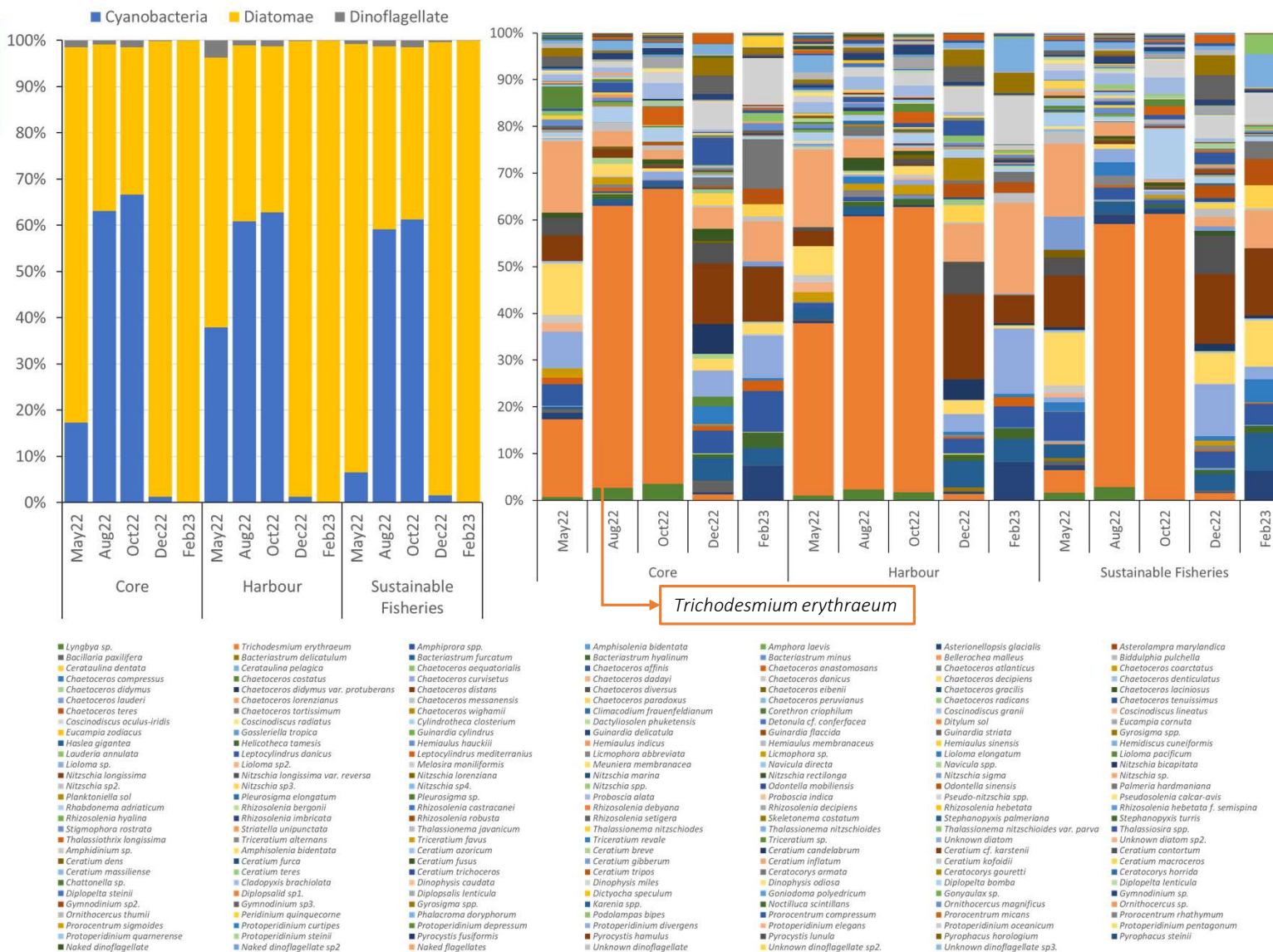
The six genera of benthic dinoflagellates found on both natural (macroalgae, seagrass) and artificial (screen) substrates in Gili Matra

Seasonal variation in one Gili Matra island (example: Gili Meno)



- Drastic increase in phytoplankton cell density and diversity during the start of wet season in December 2022 to February 2023
- At the same time → dominance indeks decrease significantly → no overdomination of certain species of phytoplankton
- Seasonal differences in phytoplankton communities → indicated in nMDS analysis
- Phytoplankton community in Gili Meno relatively similar during the Dry Season (Aug) and Transitional Season II (Oct) → caused by dominance of Cyanobacterial species, *Trichodesium erythraeum*
- Sustainable Fisheries (Fis) zone in Gili Meno → have unique phytoplankton community structure which differs from Harbour (Har) and Core (Cor) zones

SEASON → DRIVES THE CHANGES IN PHYTOPLANKTON COMMUNITY STRUCTURES IN GILI MATRA

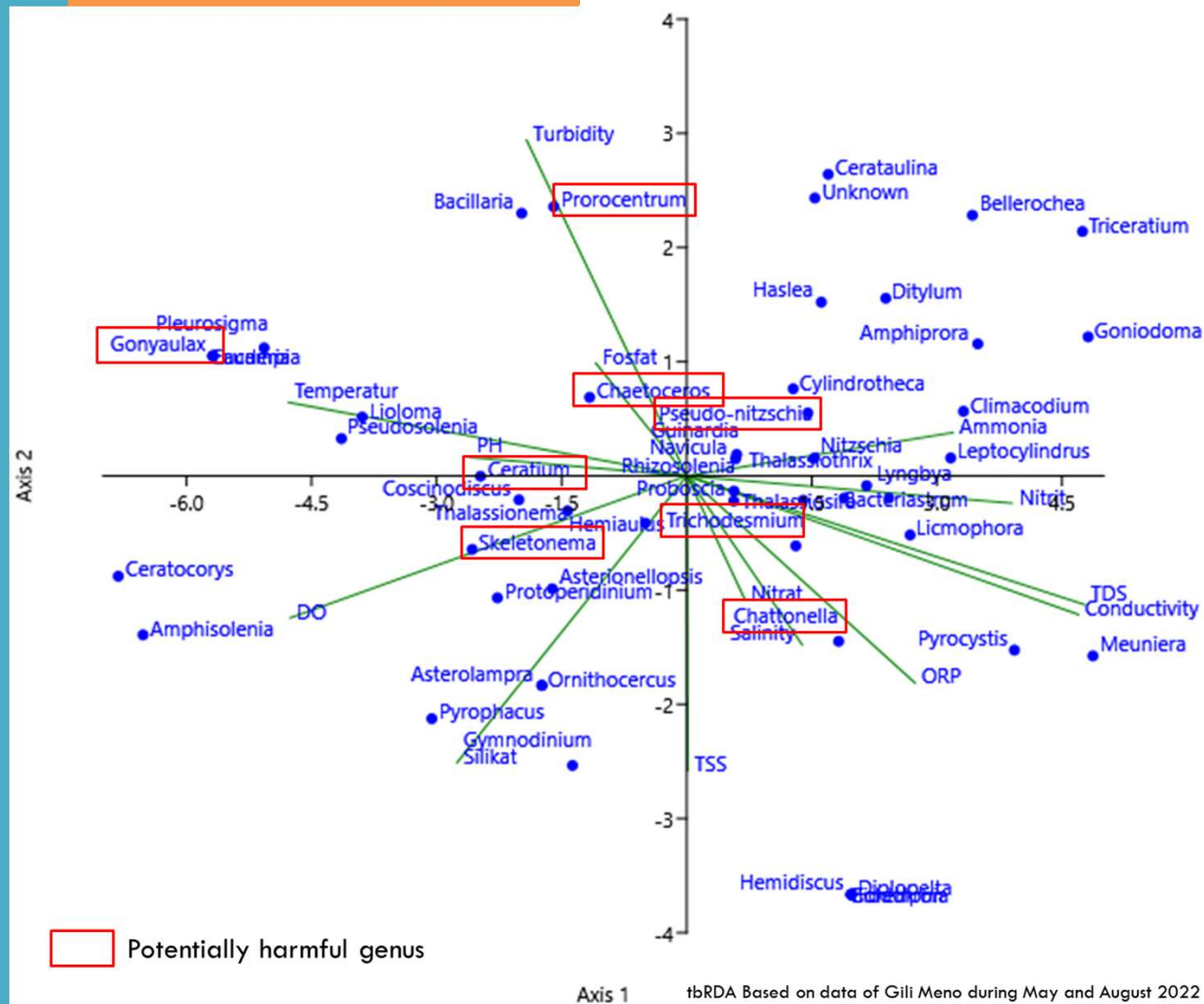


Community Structure

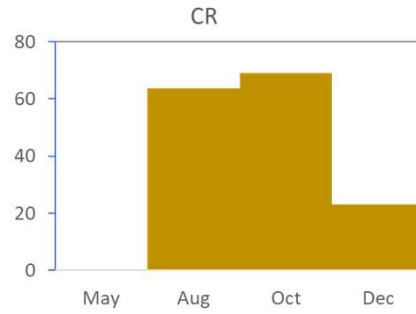
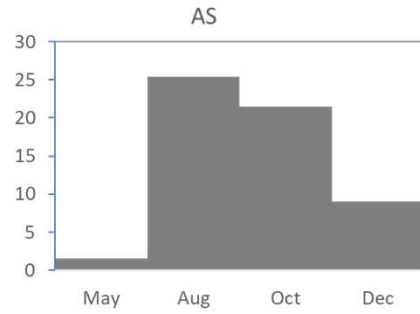
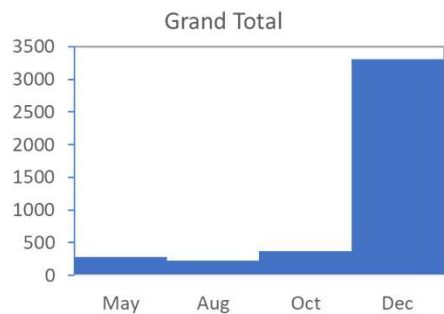
- Evidence of cyanobacterial dominance in Gili Matra (Meno) → *Trichodesmium erythraeum* dominating the marine ecosystems during Dry Season (Aug) and Transitional Season II (Oct)
- T. erythraeum* is categorized HABs species → have recorded blooms in highly eutrophic area such as Jakarta Bay and Seribu Island.
- Seasonal changes influence the shift in dominance → diatom-dominance in Wet and Transitional Season I followed by cyanobacterial-dominance in Dry and Transitional Season II

Parameters affecting the density of phytoplankton genera in Gili Matra

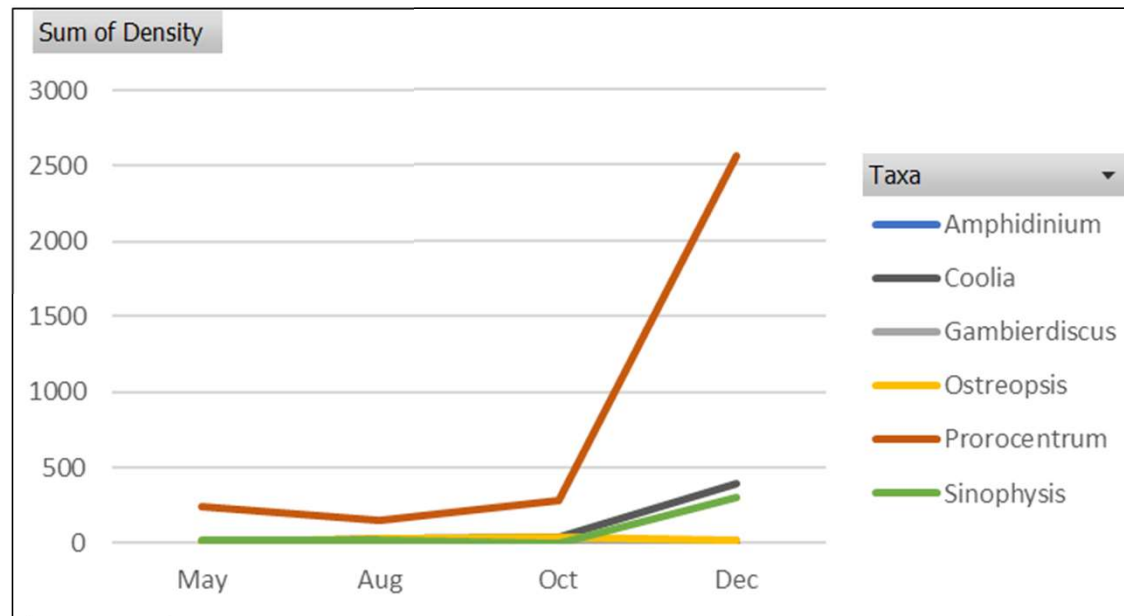
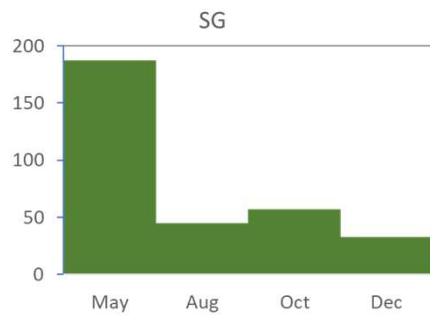
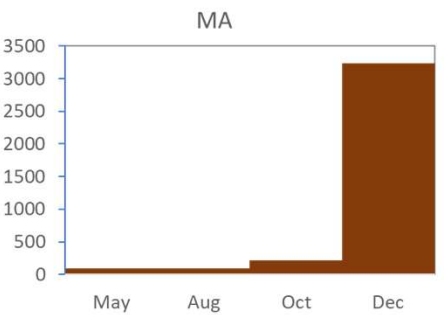
- Most dominant genus → *Trichodesmium* → abundant at waters with higher salinity and nitrates concentration
- Common and abundant diatoms → *Chaetoceros* → more abundant at warmer and turbid water, which rich in phosphate
- Some potentially harmful genus:
 - *Ceratium/Triplos* → more abundant at higher temperature and pH and did not strongly affected by any nutrient concentration
 - *Chattonella* → prefer nitrate-rich high salinity water, similar with *Trichodesmium*
 - *Pseudo-nitzschia* → more abundant at ammonia-rich waters
 - *Prorocentrum* → more abundant at turbid waters, which also rich with phosphate



Benthic dinoflagellate population dynamics



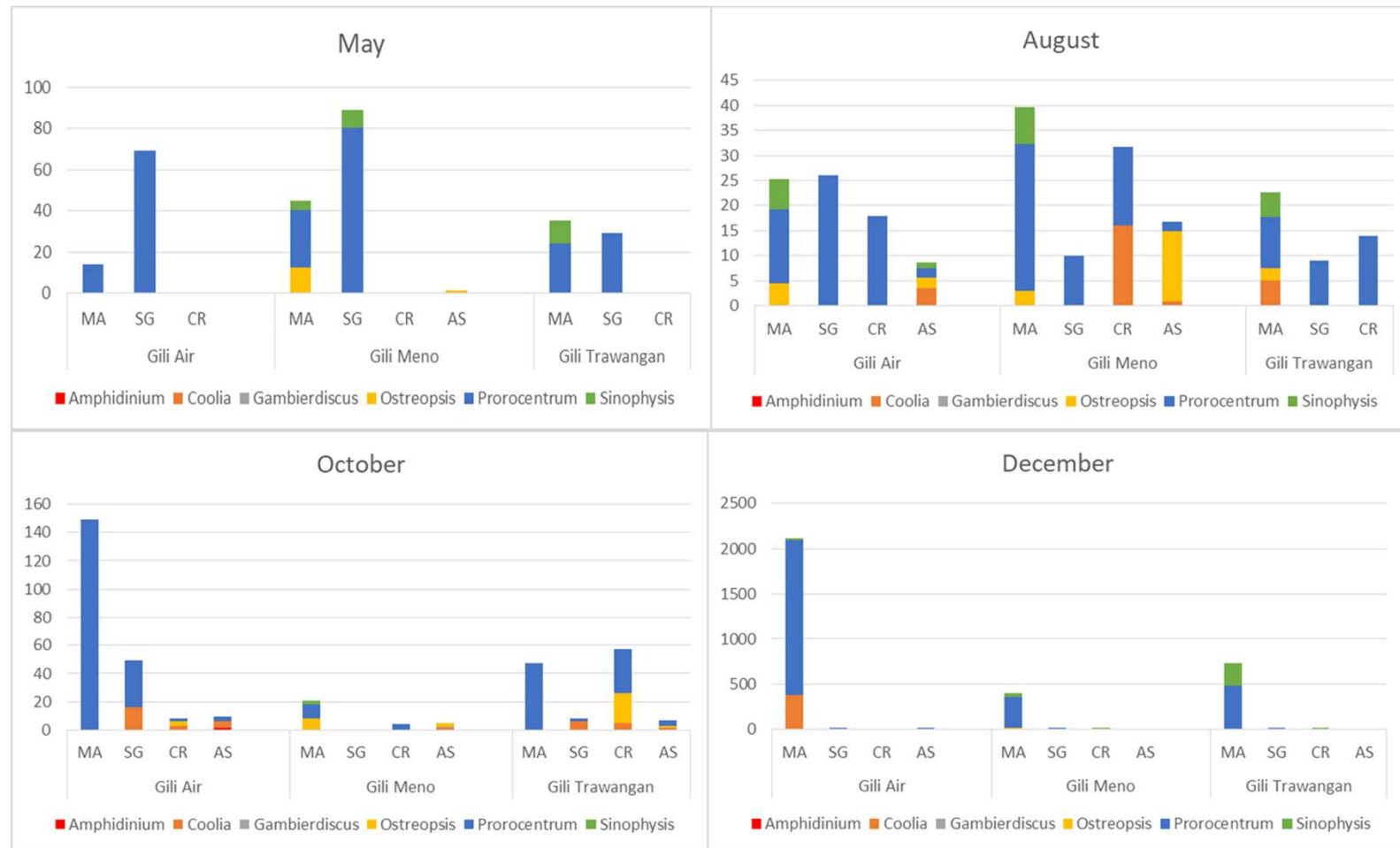
- Similar to phytoplankton → drastic increase in benthic dinoflagellate cell density in macroalgal (MA) substrate also observed in wet season (December 2022)
- Opposite trends → observed in benthic dinoflagellates on seagrass (SG)
- Trends in benthic dinoflagellates in artificial substrate (AS) and coral rubble (CR) → similar



- In general → cell density for all benthic dinoflagellates genus → increased during wet season (December 2022)
- The density of potentially toxic genera *Gambierdiscus* → very low
- The most common and abundant genera → *Prorocentrum* → also known to commonly abundant in macroalgal substrates in other area, such as Seribu Island

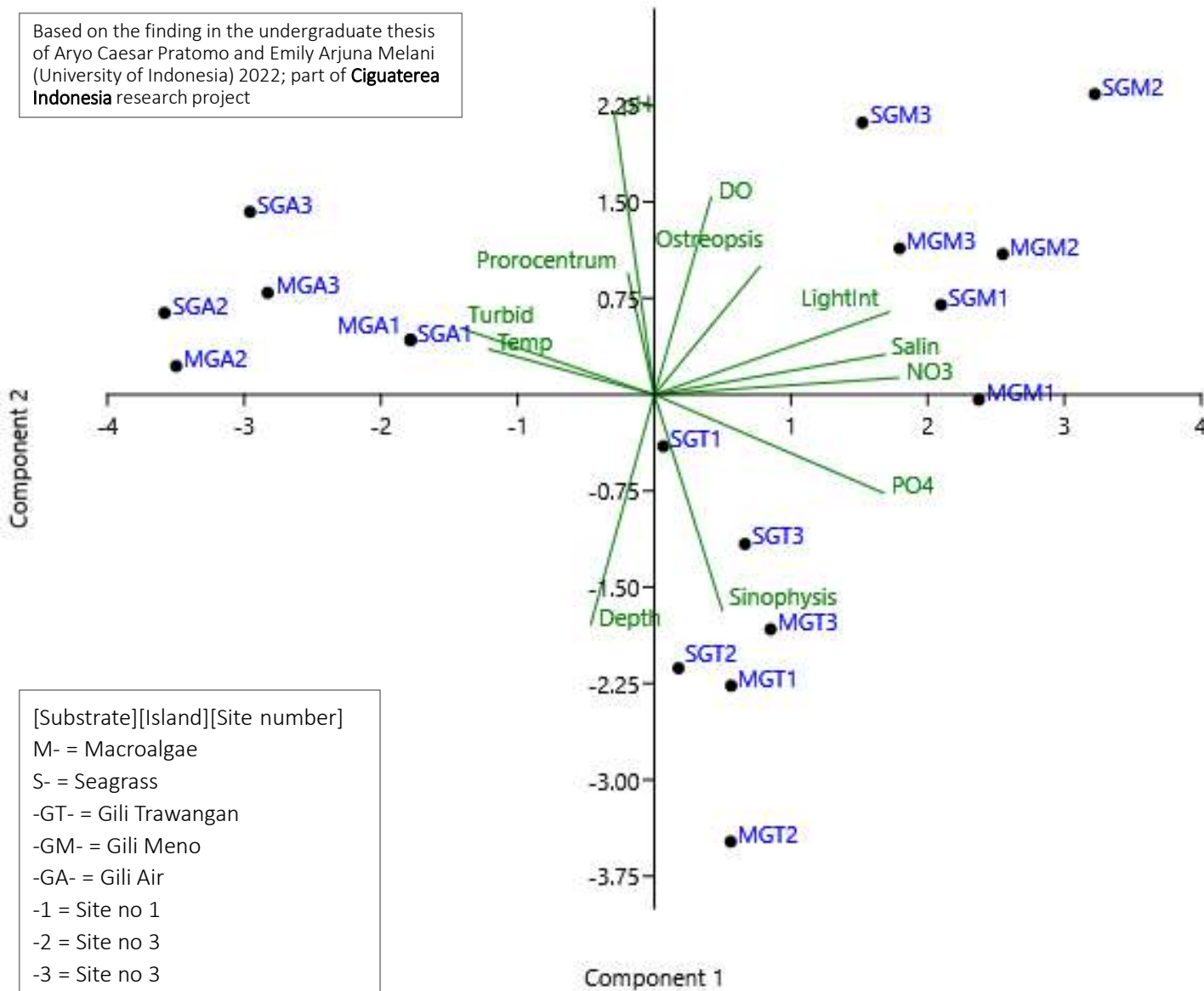
Substrate preference

- Benthic dinoflagellates were found in any kind of substrates
- *Prorocentrum* → the most abundance dinoflagellate → especially on macroalgae and sea grass substrates → usually together with *Sinophysis*.
- *Ostreopsis* and *Coolia* → were often found on non-living substrates → coral rubble and artificial substrate.
- *Gambierdiscus* and *Amphidinium* density → were the lowest among all targeted genera



MA: Macro Algae, SG: Sea grass, CR: Coral Rubble, AS: Artificial Substrate

Based on the finding in the undergraduate thesis of Aryo Caesar Pratomo and Emily Arjuna Melani (University of Indonesia) 2022; part of **Ciguatera Indonesia** research project



[Substrate][Island][Site number]
M- = Macroalgae
S- = Seagrass
-GT- = Gili Trawangan
-GM- = Gili Meno
-GA- = Gili Air
-1 = Site no 1
-2 = Site no 3
-3 = Site no 3

Relationship of target benthic dinoflagellate genera with water parameters in the Transitional Season I (May)

- The three islands of Gili Matra → have distinct and different water physical-chemical characteristics → affecting the density of target benthic dinoflagellate genera in Transitional Season I (May)
- *Sinophysis* → generally associated with deeper sites in Gili Trawangan which also contain more nutrients, particularly phosphate
- *Prorocentrum* → tend to be more abundant at Gili Air which have higher temperature, pH, and more turbid water
- *Ostreopsis* → tend to be more abundant in Gili Meno which have higher salinity and higher light intensity
- *Amphidinium* and *Gambierdiscus* → were not present in the Transitional Season I (May)

Ciguatoxin analysis (mouse bioassay)

- Ciguatoxin → was NOT DETECTED with mouse bioassay analysis from 31 fish samples → 13 from May 2022, 6 from August 2022, and 12 from February 2023 sampling
- Ciguatoxin concentration → might be below the concentration that required for the laboratory mice to show observable symptoms or lethality
- However → we can't rule out the possibility of low (or very low) concentration of ciguatoxin exist in the reef fish tissue → could be accumulate over time in higher trophic level organisms (particularly, fish and later, human)
- More detailed chemical based analysis → such as ELISA → needed to quantify the concentration of ciguatoxin (if there are any)

Analyzed fish:

- Rabbitfish (Siganidae)
- Parrotfish (Scaridae)
- Barracuda (Sphyraenidae)
- Island Mackerel (Scombidae)
- Grouper (Serranidae)
- Longtail Tuna (Scombridae)



Kakatua – Parrotfish (Scaridae)



Baronang hitam - Rabbitfish (Siganidae)



Kembang – Island Mackerel (Scombidae)



Barakuda –Barracuda (Sphyraenidae)

What to do when HABs occurred?

Check the water quality
(Hydrocolor)

Mark the location/coordinate
(Fish-GIS)

Observe the species
composition
(Planktoscope/Foldscope)

Collect the samples
(Plankton Net / Water Sampler)

Inform and send the data anr/or
sample the local academics/experts



Report the findings to the
local government

Inform those closest to you
(families, friends) → **DO NOT
CONSUME SHELLFISH
AND/OR DEAD FISH
COLLECTED FROM THE
HABs IMPACTED AREA**

Awas ada **HAB!**

Hikmah Thoha, Tumpak Sidabutor,
Nurul Fitriya, Brief Rachman,
Vishnu Aditya, Rsep Koswara



- 1) Waspadai perubahan warna air dan (atau) kematian massal ikan di perairan sekitar kita. Bila hal tersebut terjadi, mungkin perairan sedang mengalami fenomena *Harmful Algal Blooms* (HABs) atau marak alga.
- 2) Segera laporkan kemunculan fenomena tersebut ke instansi terkait kelautan atau lingkungan.



- 3) Pemerintah daerah dan (atau) instansi terkait kelautan atau lingkungan dapat mengirimkan tim untuk mengambil contoh air dan gumpalan mikroalga, kemudian melakukan pengujian di laboratorium.
- 4) Ketika hasil pengujian selesai, instansi yang melakukan pengujian mengadakan koordinasi dengan instansi pembuat kebijakan atau pemerintah daerah yang terkena HABs.



- 5) Pemerintah daerah yang terkena dampak HAB mengambil langkah-langkah untuk mencegah munculnya dampak negatif atau mengurangi dampak negatif yang telah muncul akibat fenomena HABs. Beberapa langkah yang bisa diambil adalah mengeluarkan kebijakan untuk melarang masyarakat memanen kerang-kerangan, berenang, dan atau menggunakan air untuk keperluan minum/masakan sampai perairan dinyatakan kembali aman/bebas dari HAB.

Community Preparedness (Compress)
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Conclusions

There were 17 potentially harmful phytoplankton species found in Gili Matra, with *Trichodesmium erythraeum* dominates the ecosystem in Dry Season and Transitional Season II

The 6 targeted benthic dinoflagellates were found, with *Prorocentrum* as the most abundant genera, particularly on macroalgae and seagrass

The potentially toxic *Gambierdiscus* was found in very low density, thus currently possess small risk to cause CFP, unless coral reef and environmental deterioration progress to provide more suitable condition for bloom

Seasonal changes heavily influenced the shift in phytoplankton community structure, with dry season generally characterized with dominance of cyanobacteria and wet season with dominance of diatoms

No ciguatoxin was detected in the mouse bioassay of the coral reef fishes collected from Gili Matra and Northern Lombok, indicating no risk of CFP in Lombok so far

Increasing turbidity, nutrient concentration, and disturbances to the ecosystem could trigger rapid growth of HABs species, which usually well adapted to low water quality



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Thank you

Scribo ergo sum