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Harmful Algal Blooms –
biological and chemical diversity in a changing climate and emerging risks for food safety and security

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Chair of Intergovernmental Panel on HABs (IOC-UNESCO)

19 June 2024

- Harmful Algal Blooms & climate change
- Fish- and shellfish-poisoning
- Fish-kills and shellfish mortalities
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- IPHAB – GlobalHAB – HAB-Solution

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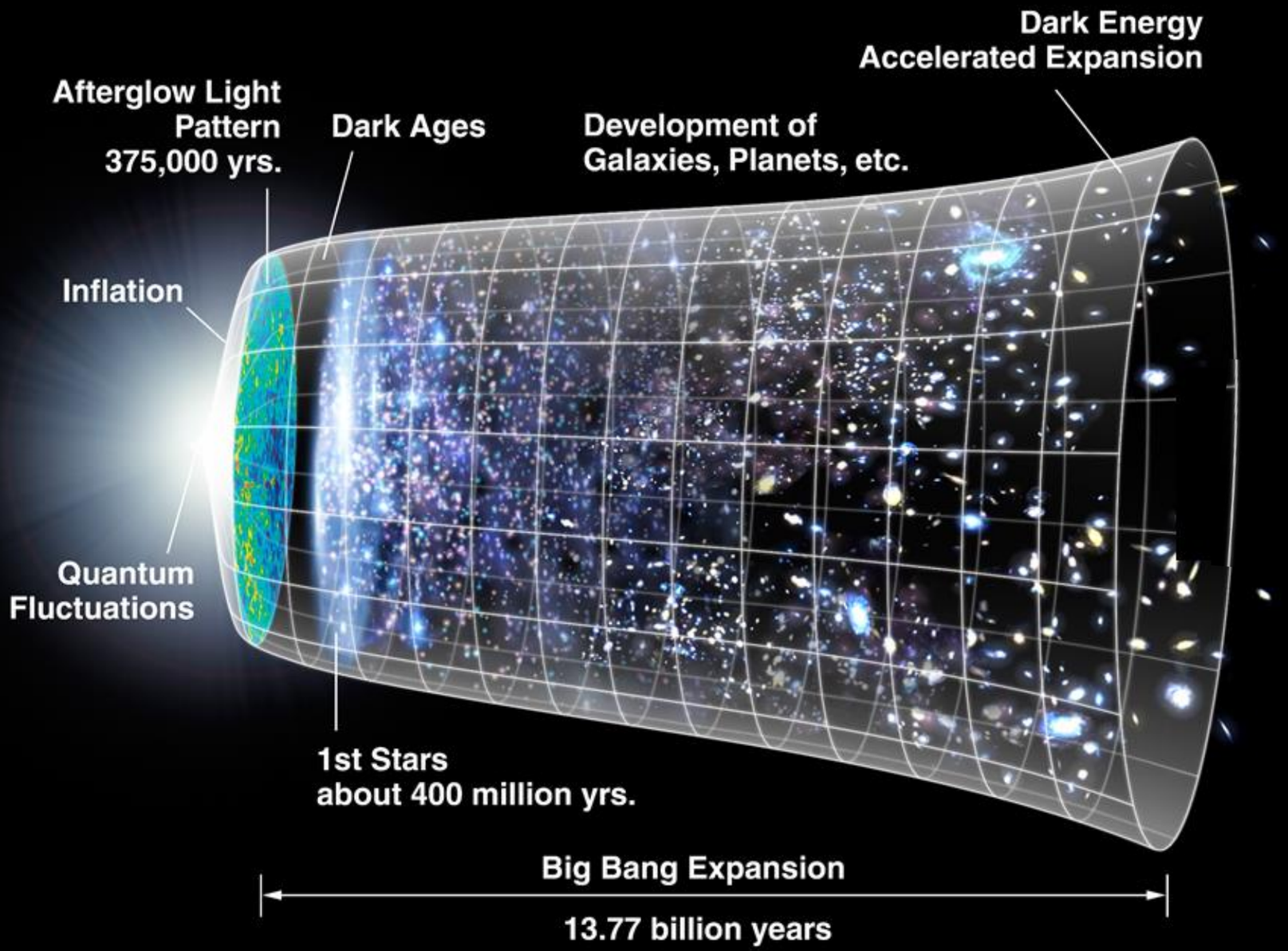
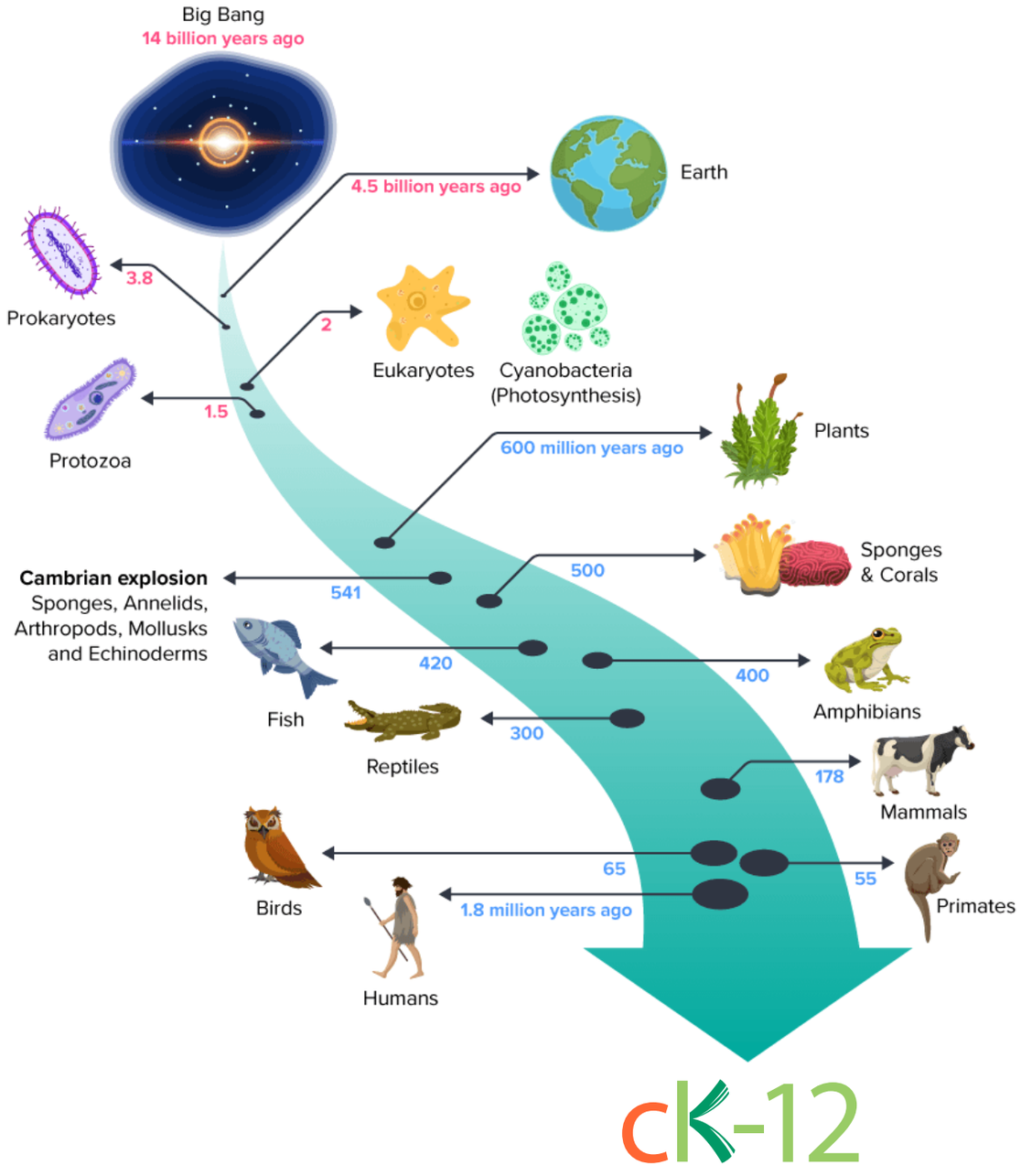
Microlgae are microscopic, photosynthetic unicellular organisms vs. macroalgae

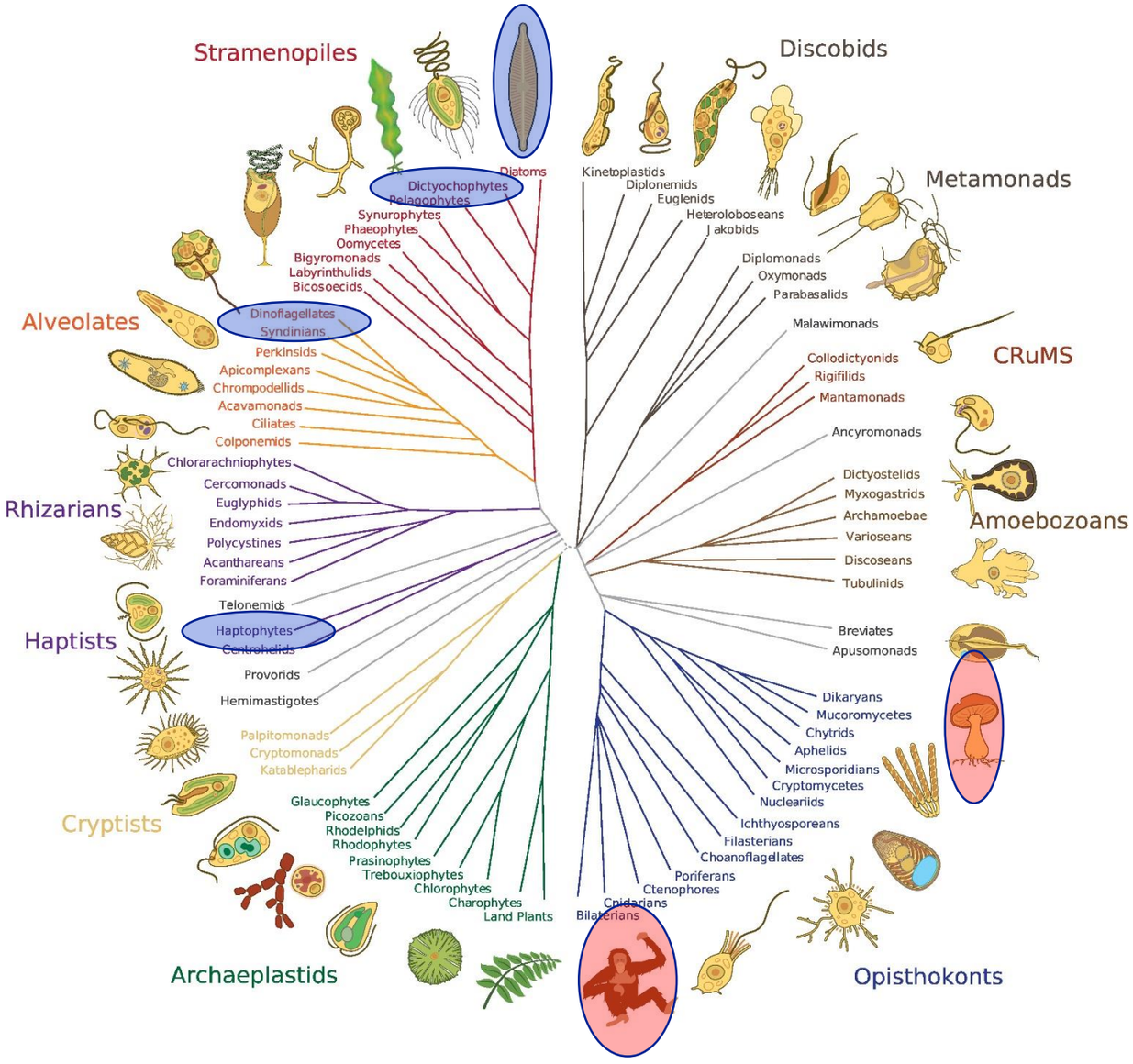
≠

Macro-algaeBaie de La Forêt, 2018. Western France

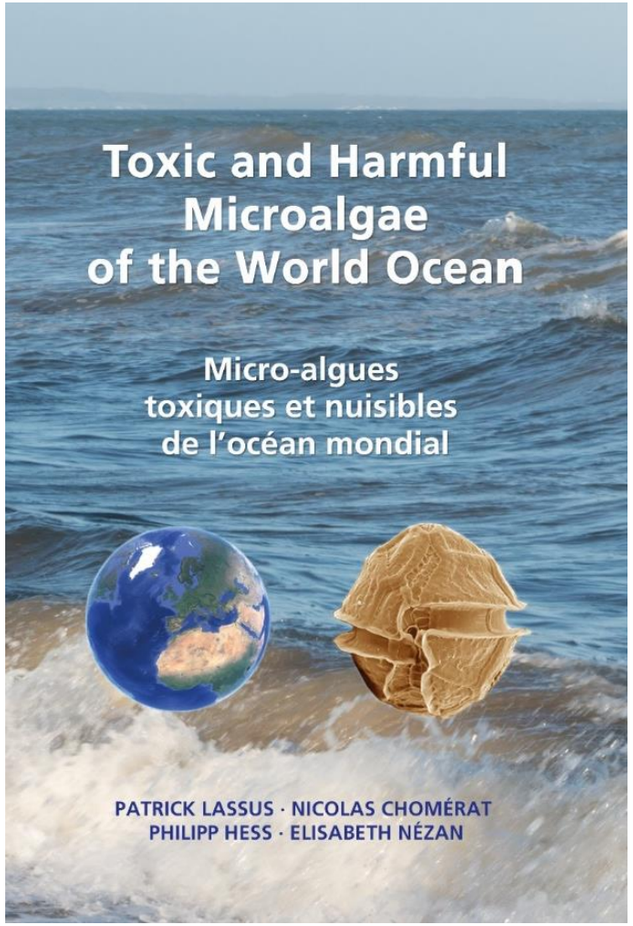
Densities may exceed 10^6 cells / L and blooms are then visible to the naked eye


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years


Big Bang
14 billion years ago
4.5 billion years ago
Earth
3.8
Prokaryotes
2
Eukaryotes
Cyanobacteria
(Photosynthesis)
1.5
Protozoa
600 million years ago
Plants
Cambrian explosion
Sponges, Annelids,
Arthropods, Mollusks
and Echinoderms
541
500
Sponges
& Corals
420
400
Fish
Amphibians
300
Reptiles
178
Mammals
65
55
Birds
Primates
1.8 million years ago
Humans
cK-12


Stramenopiles
Diatoms
Dictyochophytes
Pelagophytes
Synurophytes
Phaeophytes
Oomycetes
Bigyromonads
Labyrinthulids
Bicosoecids
Alveolates
Dinoflagellates
Syndinians
Perkinsids
Apicomplexans
Chrompodellids
Acavamonads
Ciliates
Colponemids
Rhizarians
Chlorarachniophytes
Cercomonads
Euglyphids
Endomyxids
Polycystines
Acanthareans
Foraminiferans
Telonemids
Haptists
Haptophytes
Centrohelids
Provorids
Hemimastigotes
Cryptists
Palpitomonads
Cryptomonads
Katablepharids
Glaucophytes
Picozoans
Rhodelphids
Rhodophytes
Prasinophytes
Trebouxiophytes
Chlorophytes
Charophytes
Land Plants
Archaeplastids
Discobids
Kinetoplastids
Diplonemids
Euglenids
Heterolobosseans
Jakobids
Metamonads
Diplomonads
Oxymonads
Parabasalids
Malawimonads
CRuMS
Collodictyonids
Rigifilids
Mantamonads
Ancyromonads
Dictyostelids
Myxogastrids
Archamoebae
Varioseans
Discoseans
Tubulinids
Amoebozoans
Breviates
Apusomonads
Dikaryans
Mucoromycetes
Chytrids
Aphelids
Microsporidians
Cryptomycetes
Nucleariids
Ichthyosporeans
Filasterians
Choanoflagellates
Poriferans
Ctenophores
Cnidarians
Bilaterians
Opisthokonts

175 HAB species of 5 000 – 100 000 microalgae



Shellfish poisoning

High Biomass Bloom anoxia

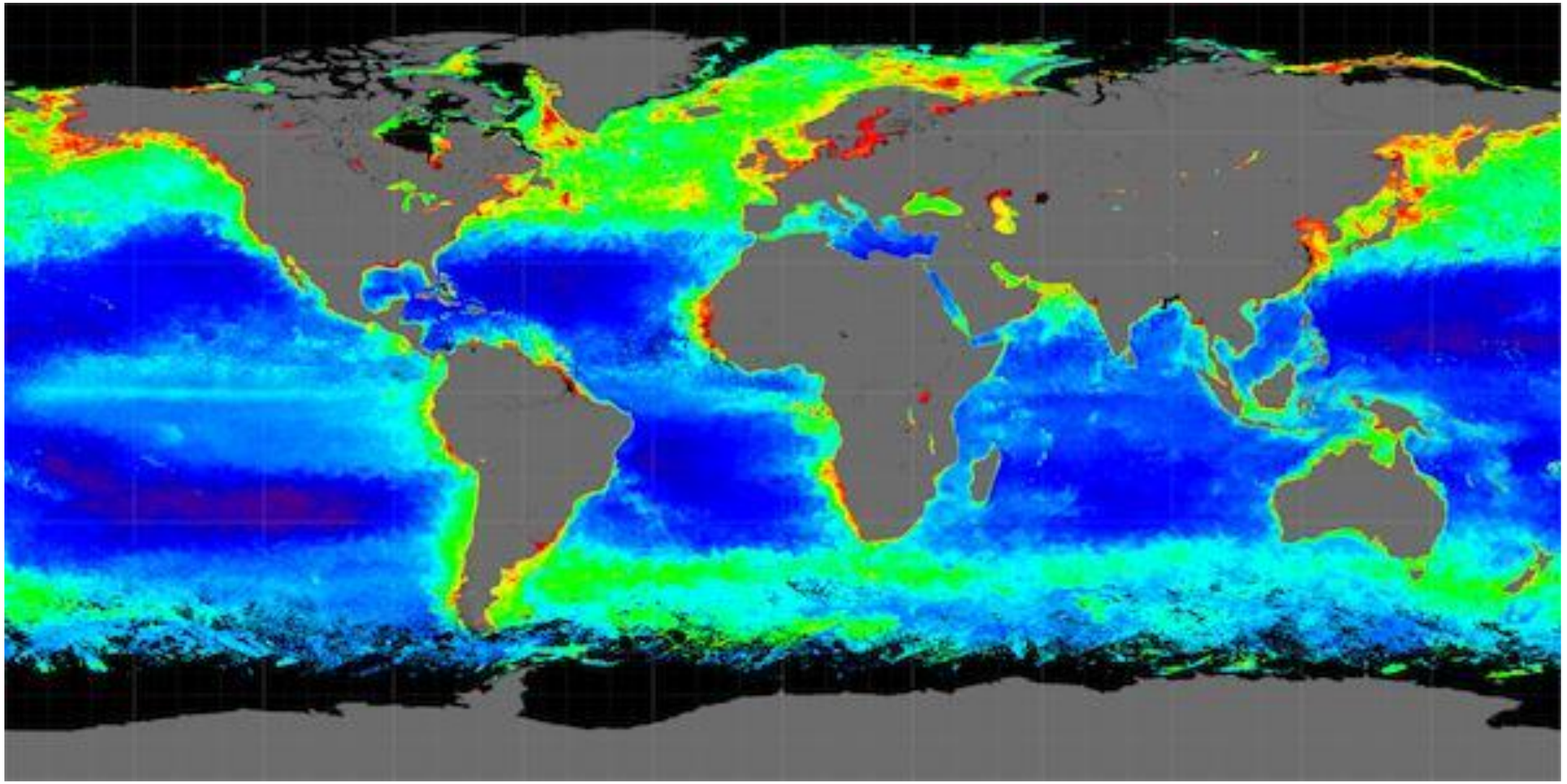
Fish killing blooms

Aerosol blooms

Contact toxicity

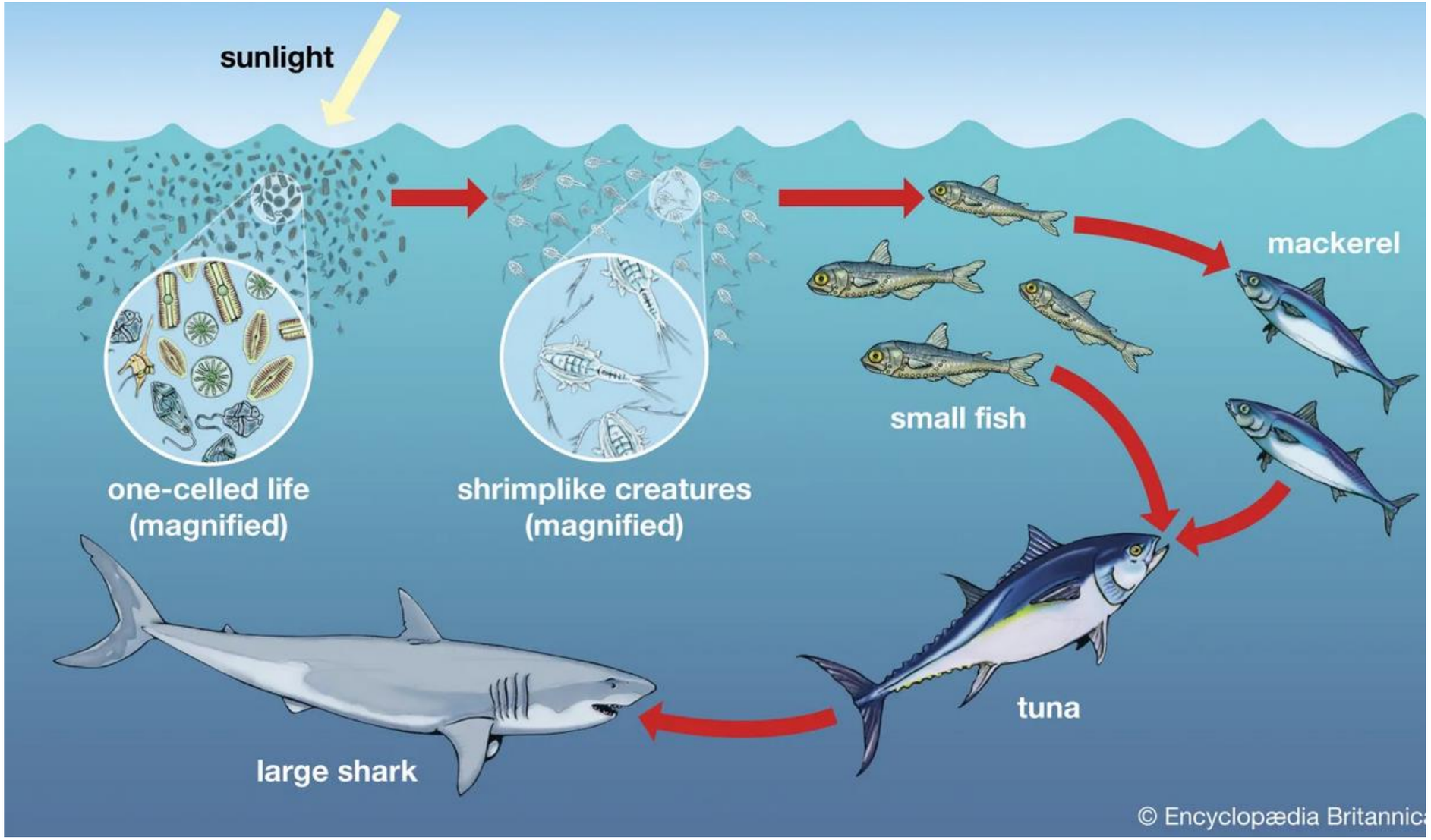
https://unesdoc.unesco.org/ark:/48223/pf0000247767

Phytoplankton produces half the oxygen on the planet

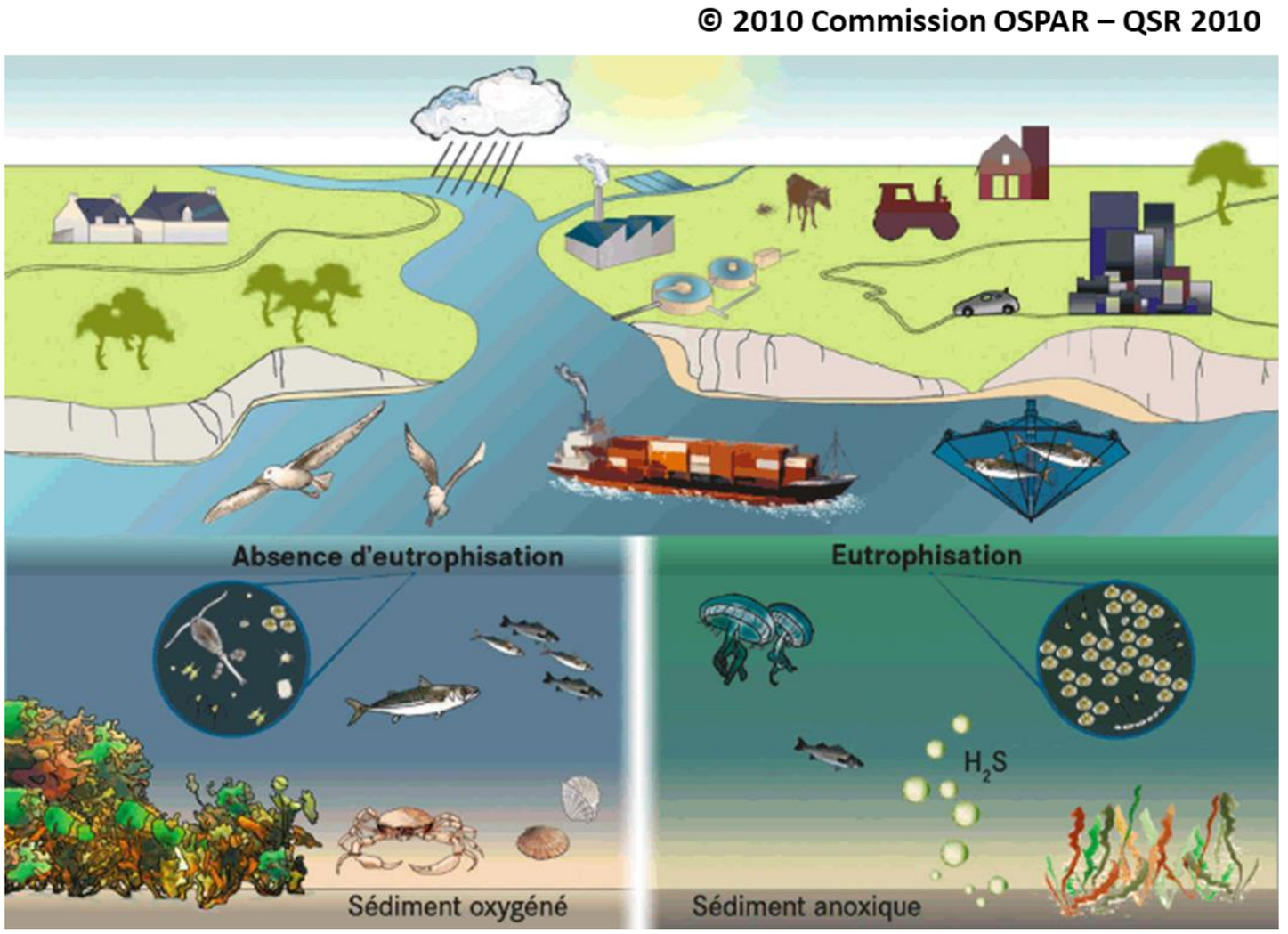


Concentration of chlorophyll “a” (in mg/L

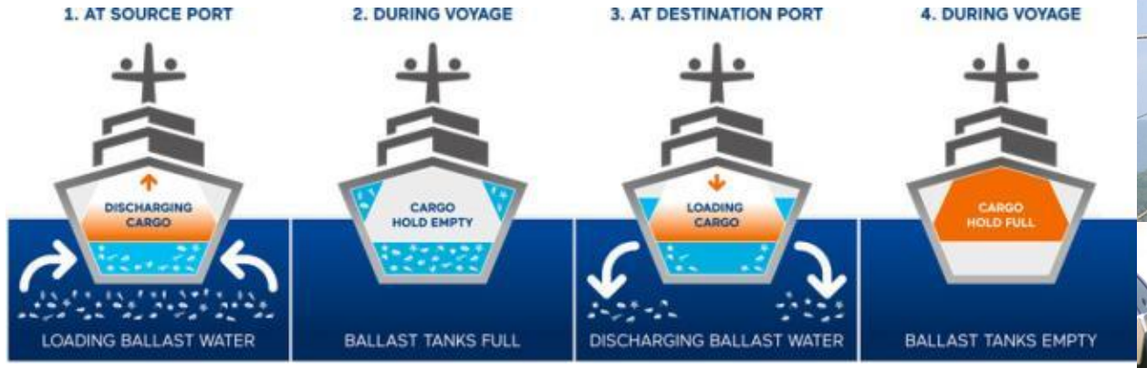
Phytoplankton feeds marine food chains



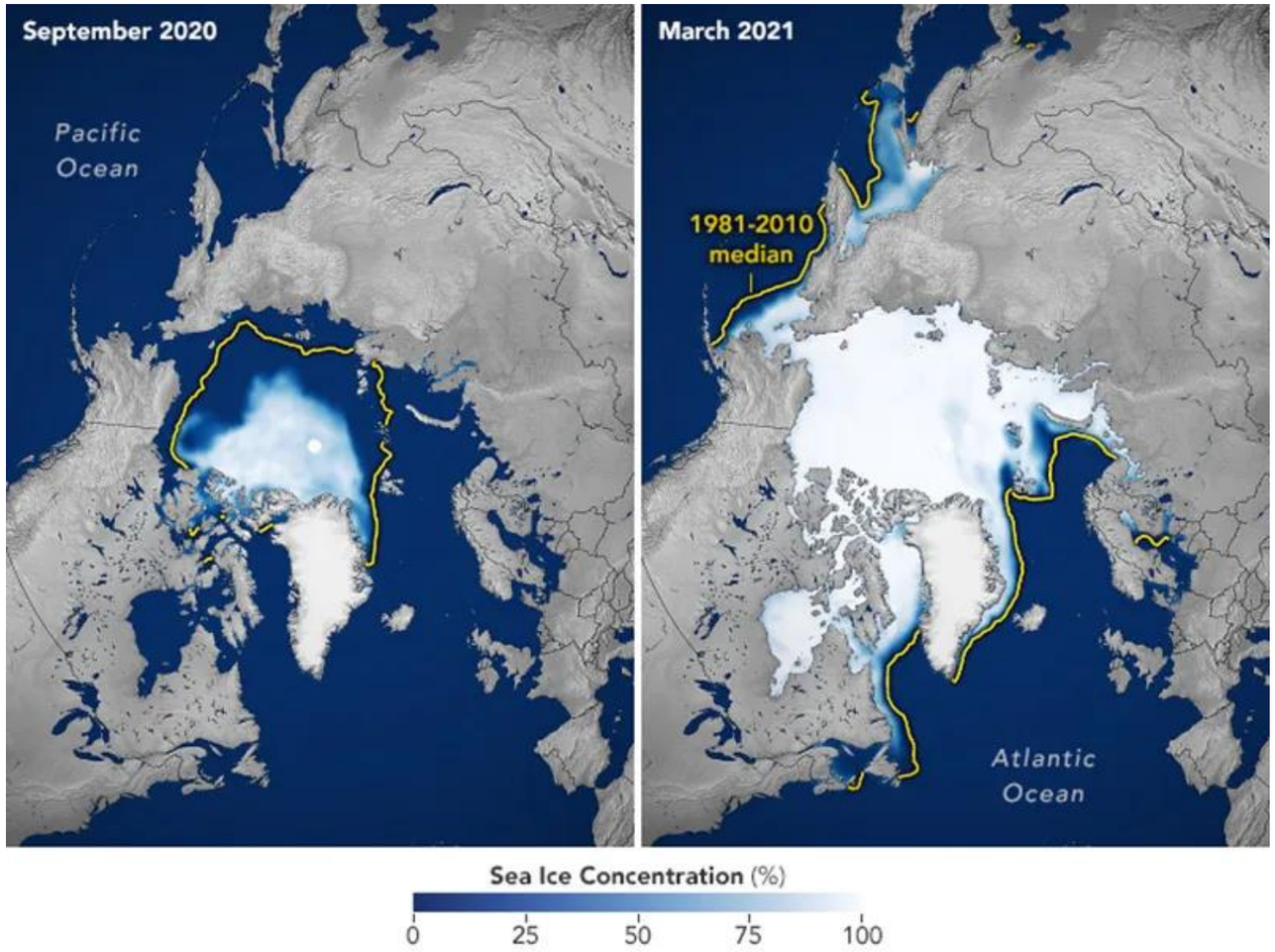
Nutrient & chemical pollution affect natural diversity



Ballast water and hull fouling may transport HABs



Melting arctic – climate change :
remixing of oceans & novel shipping routes



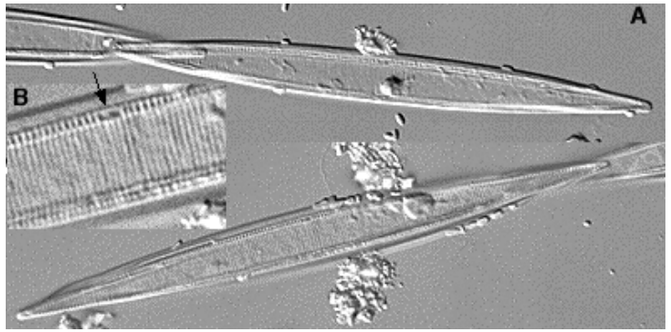
Extreme weather events will increase

Xynthia : an unexpectedly strong storm hits the French Atlantic coast 27-28/2/2010

Domoic Acid producer Pseudo-nitzschia bloomed

50-100 times > than before

Pseudo-nitzschia



2 years closure of scallop fisheries!

•Increased temperature

•Enhanced surface stratification

•Alteration of ocean currents/nutrient upwelling

•Stimulation of photosynthesis by elevated CO_2

•Ocean acidification ("the other CO_2 problem")

•Heavy precipitation/ storm events

Complex factor interactions /feedback mechanisms exists

Laboratory simulations rarely allow for sufficient **acclimation**

Organism responses will be species - or even **strain-specific**

There will be winners and losers!

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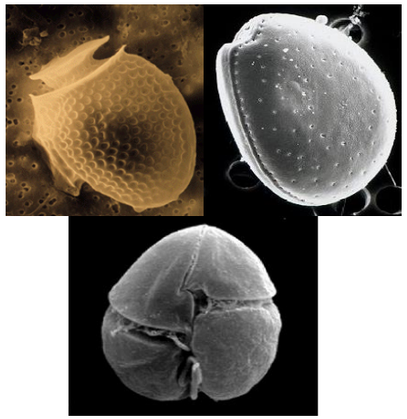
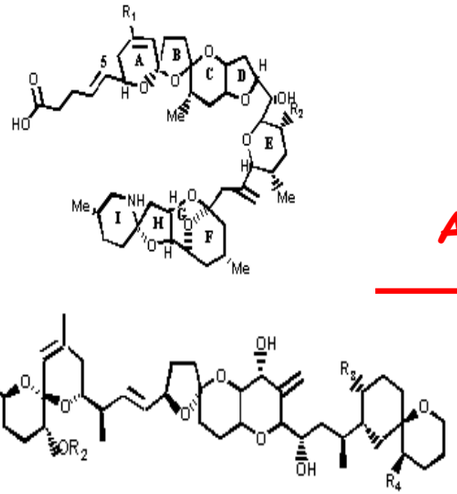
Shellfish poisoning:

Production



Microalgal cells



Marine biotoxins

Accumulation

Filter-feeding bivalves

Processing, cooking etc.

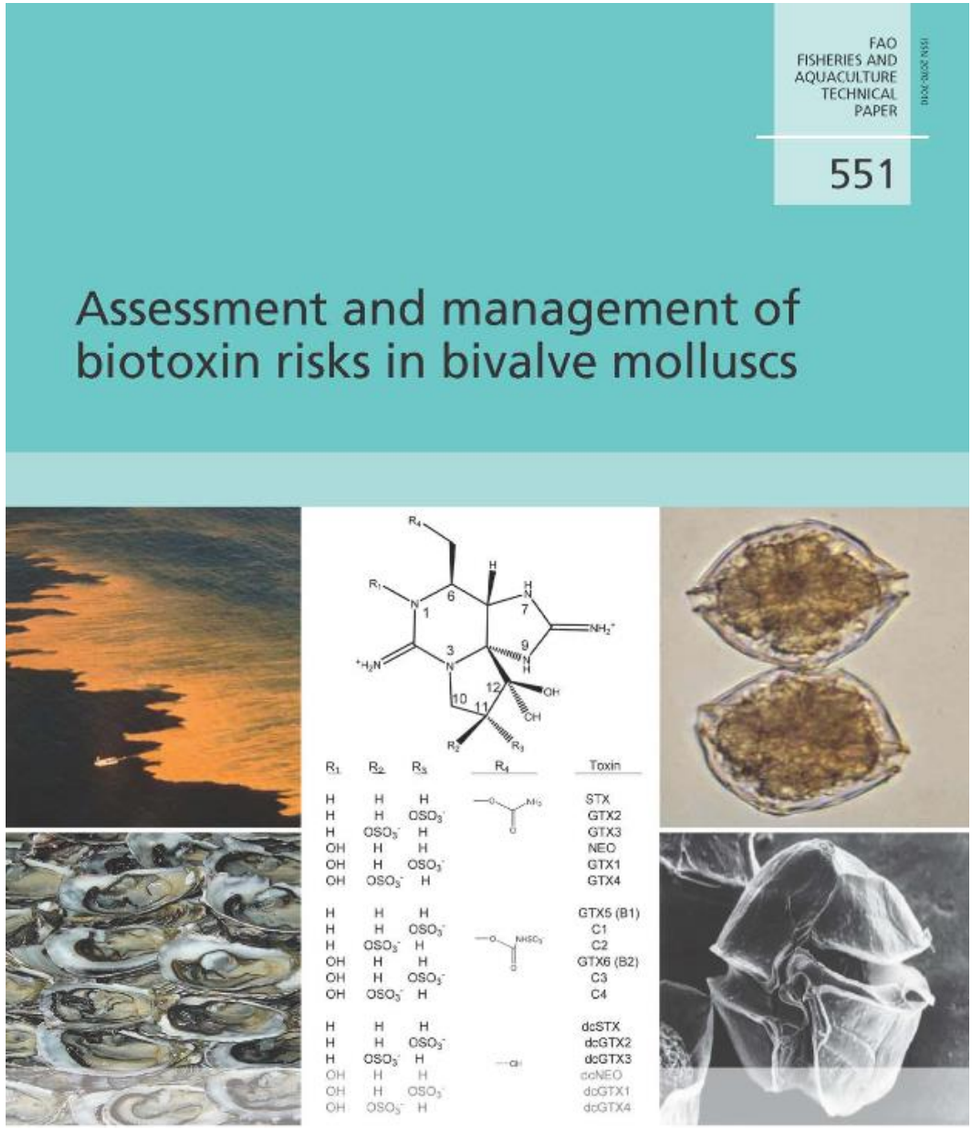
Food poisoning

Combatting shellfish poisoning

Codex Standard for live and raw bivalve molluscs (CODEX STAN 292-2008)

I-5.2 The following provisions apply to the edible parts of live bivalve mollusc (the whole part or any part intended to be eaten separately).

Name of biotoxin groups	Maximum level/kg of mollusc flesh
Saxitoxin (STX) group	≤0.8 milligrams (2HCL) of saxitoxin equivalent
Okadaic acid (OA) group	≤0.16 milligrams of okadaic equivalent
Domoic acid (DA) group	≤20 milligrams domoic acid
Brevetoxin (BTX) group	≤200 mouse units or equivalent
Azaspiracid (AZP) group	≤0.16 milligrams

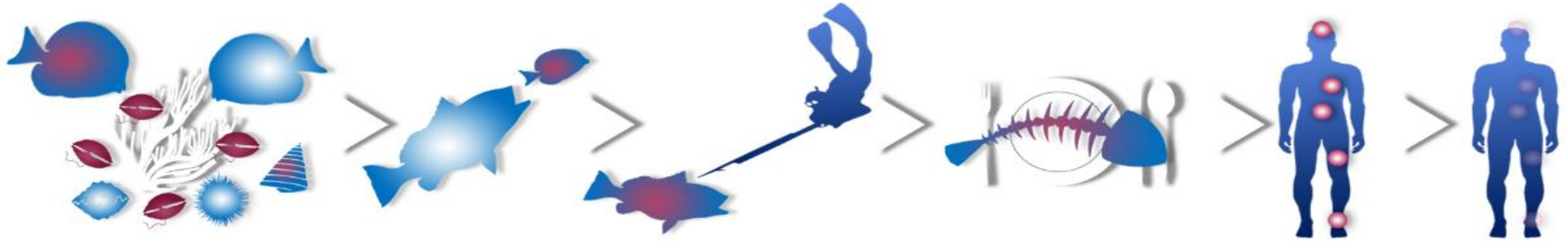


Countries with surveillance systems in place for HABs

Number of countries is increasing but still big gaps in

- Africa
- Middle East
- India
- Far East
- Central and South Amercia
- Pacific Island states

Ciguatera poisoning and symptoms



Micro-algue toxique / *Toxic microalgae*

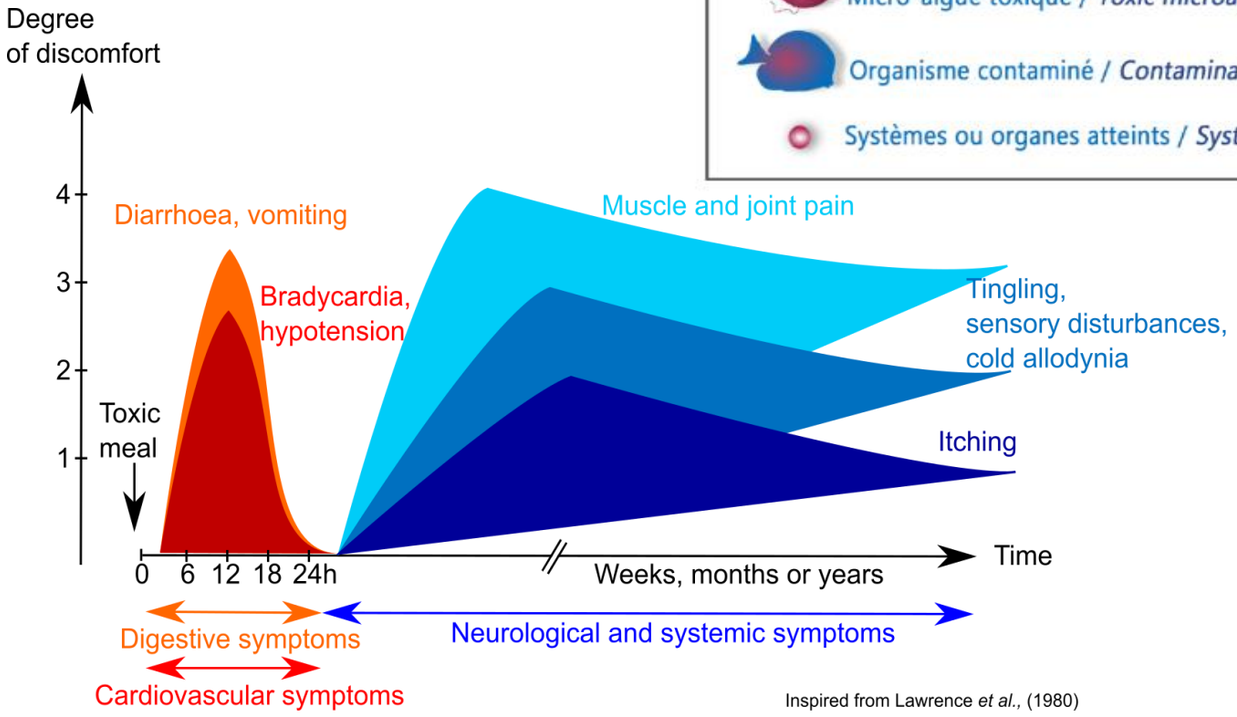
Organisme contaminé / *Contaminated organism*

Systèmes ou organes atteints / *Systems or organs affected*

Delai moyen d'apparition des symptômes
Onset of symptoms
2h-12h

Rémission / *Recovery*
Semaines / Weeks
Mois / Months
Années / Years

(image credit: Louis Malardé Institute)



Inspired from Lawrence *et al.*, (1980)

> 50 000 patients / year

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Fish-kills in open waters and caged fish (recent events)

- ***Chattonella*** **in the Western Pacific**
- ***Alexandrium catenella & Pseudochattonella*** **in Chile**
- ***Chrysochromulina*** **in Norway**
- ***Prymnesium parvum*** **in Germany/Poland**
- ***Karenia selliformis*** **in Hokkaido (Japan) and Kamtchatka (Russia)**

Shellfish mortalities often not registered by public at large but by shellfishermen and -farmers

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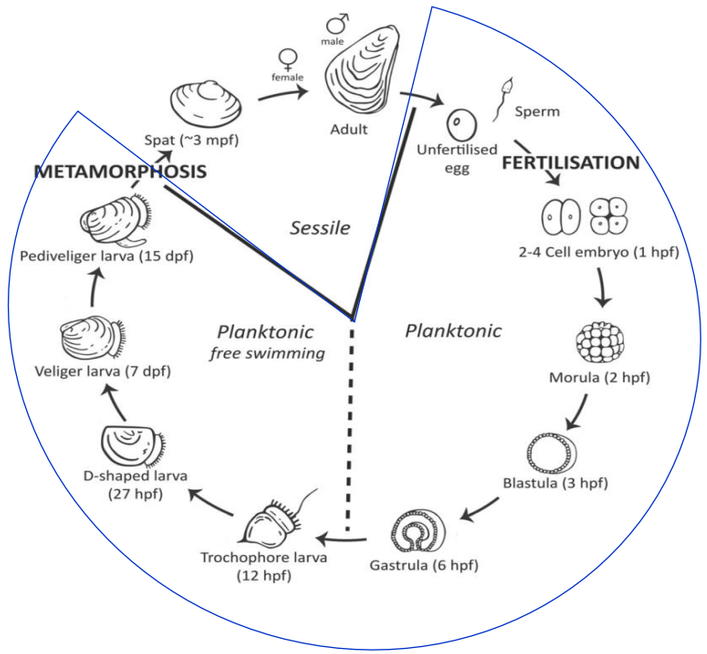
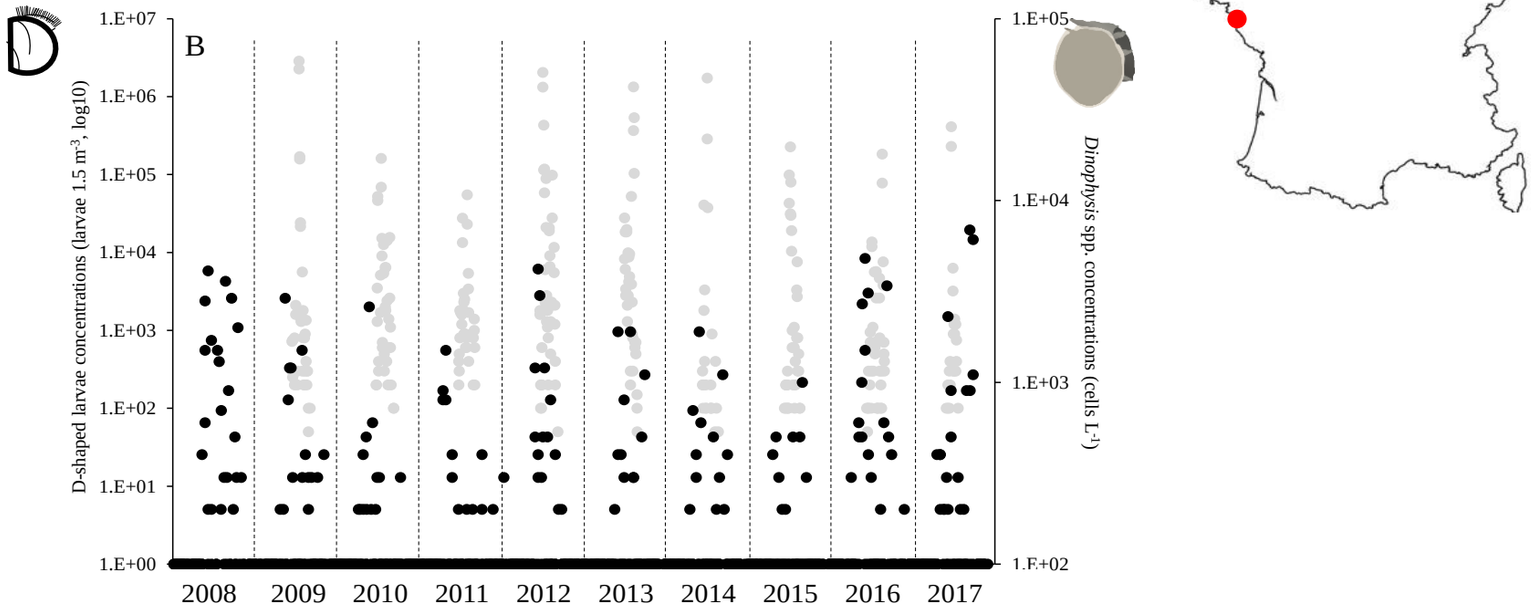
Effects of *Dinophysis* and its toxins towards bivalves

- OA or *Dinophysis* (bloom) towards bivalve hemocytes: cytotoxicity, genotoxicity… (Pinto-Silva et al., 2003; Mello et al., 2010)
- *D. caudata* towards adult bivalves: pathology and mortality (Basti et al., 2015)

- Lack of study on critical early life stages – Environmental co-occurrence



Life stages of the Pacific oyster, *Crassostrea gigas*

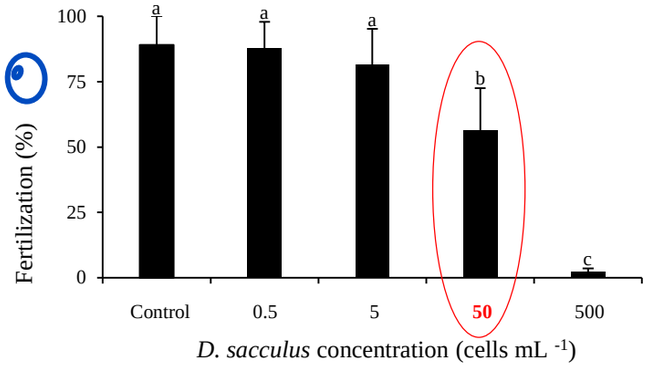


Environmental occurrences of D-shaped larvae (from Velyger database) and *Dinophysis* spp. (REPHY database) at Bourgneuf Bay

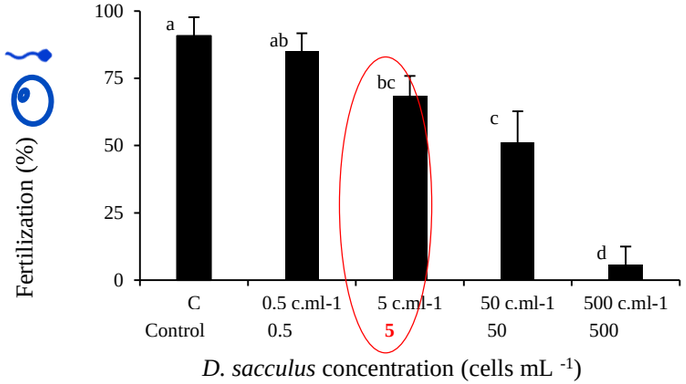
How are gametes and fertilization of the Pacific oyster affected by *Dinophysis* and their toxins?

Exposure of gametes to *D. sacculus*

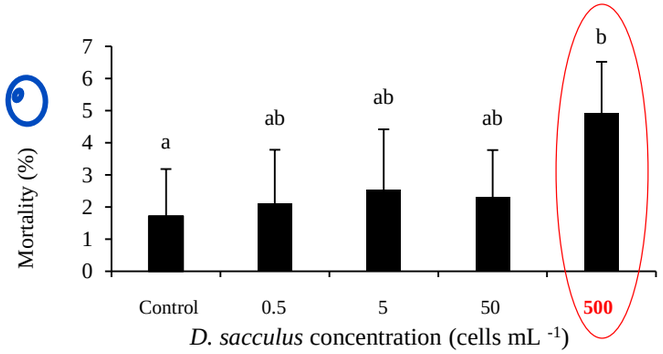
D. sacculus **PTX2** (80 pg cell^{-1}) and OA (5 pg cell^{-1}) total producer



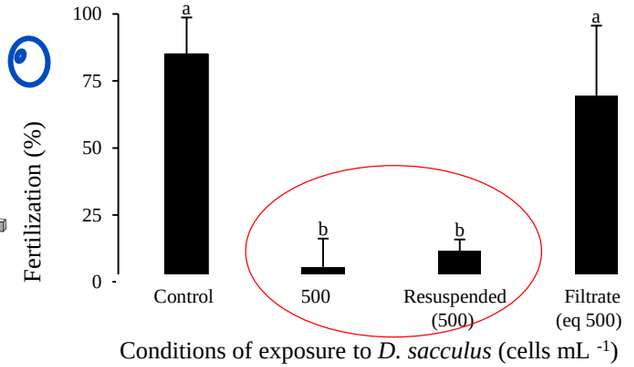
↘ Fertilization success



Cumulative effect



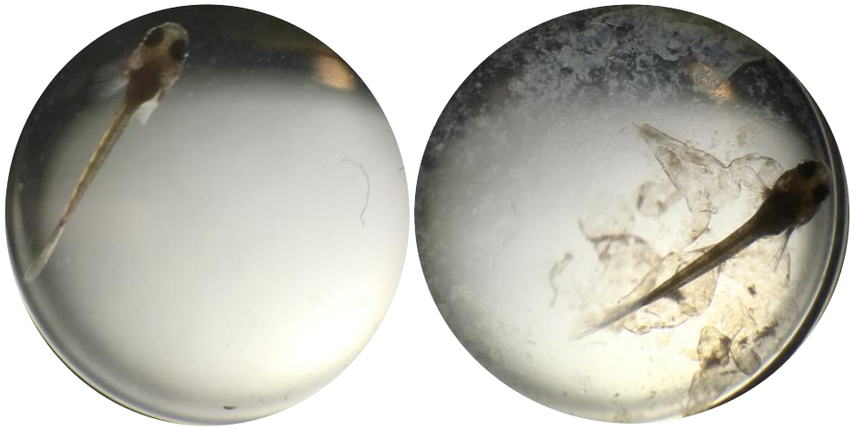
↗ Oocyte **mortality**



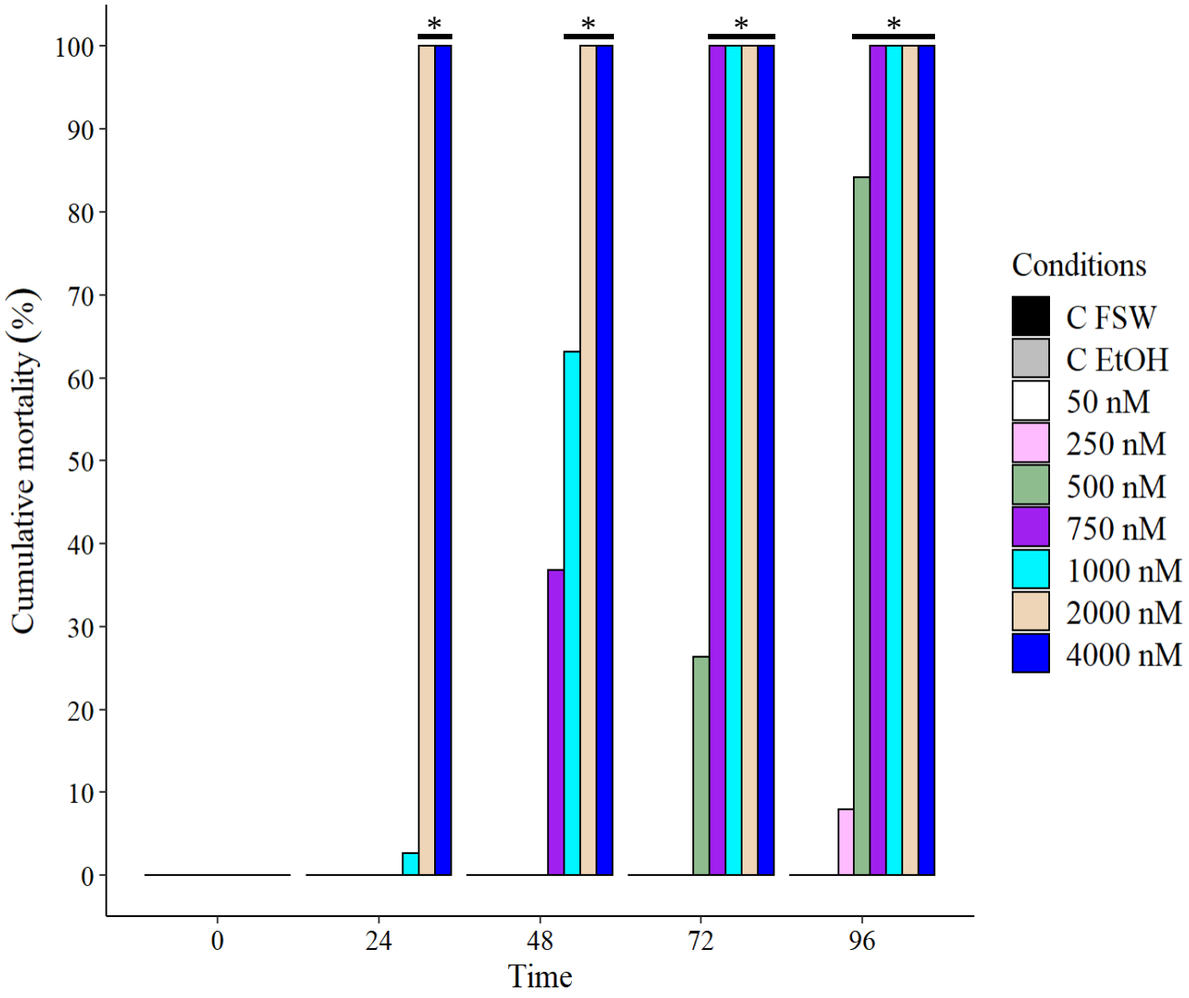
No effects of supernatant

Gaillard et al., 2020. Cultures of Dinophysis sacculus, D. acuminata and pectenotoxin 2 affect gametes and fertilization success of the Pacific oyster, Crassostrea gigas. Environ. Pollut. 265, 10.

Mortality of fish larvae exposed to PTX2



Control fish larvae High [PTX2]



Gaillard et al. 2023. Mortality and histopathology in sheepshead minnow (*Cyprinodon variegatus*) larvae exposed to pectenotoxin-2 and D. acuminata. Aquat Toxicol 257, 106456.

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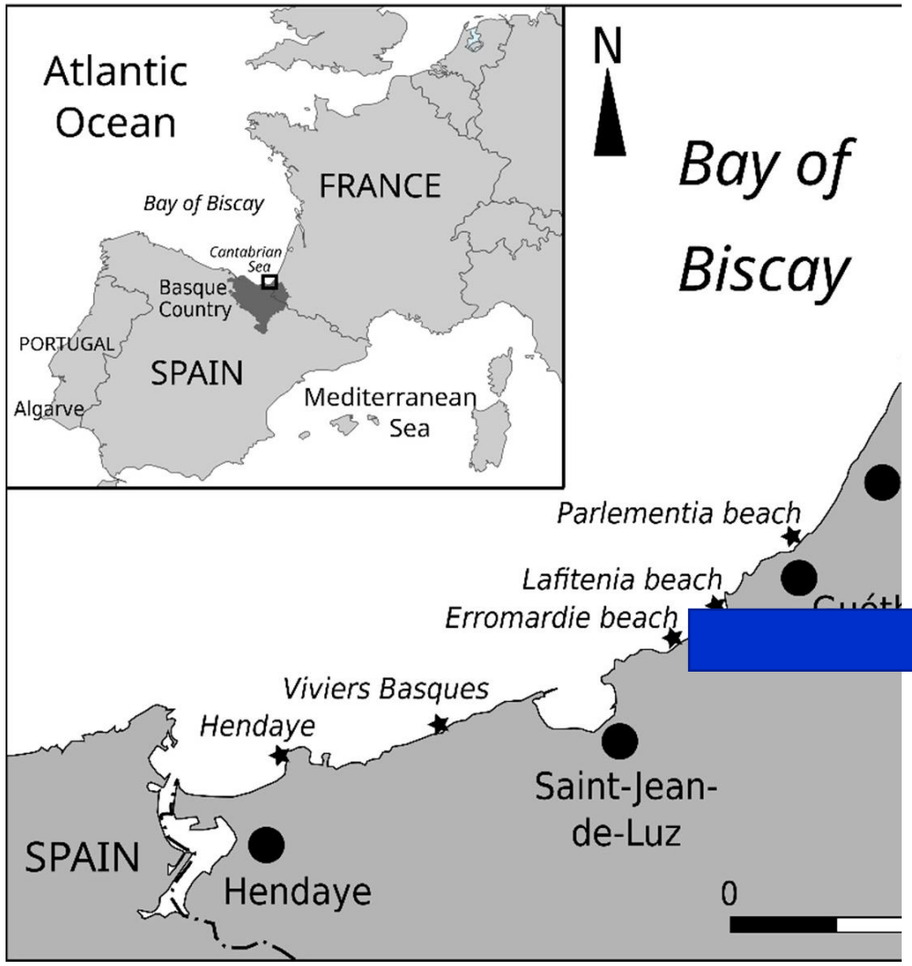
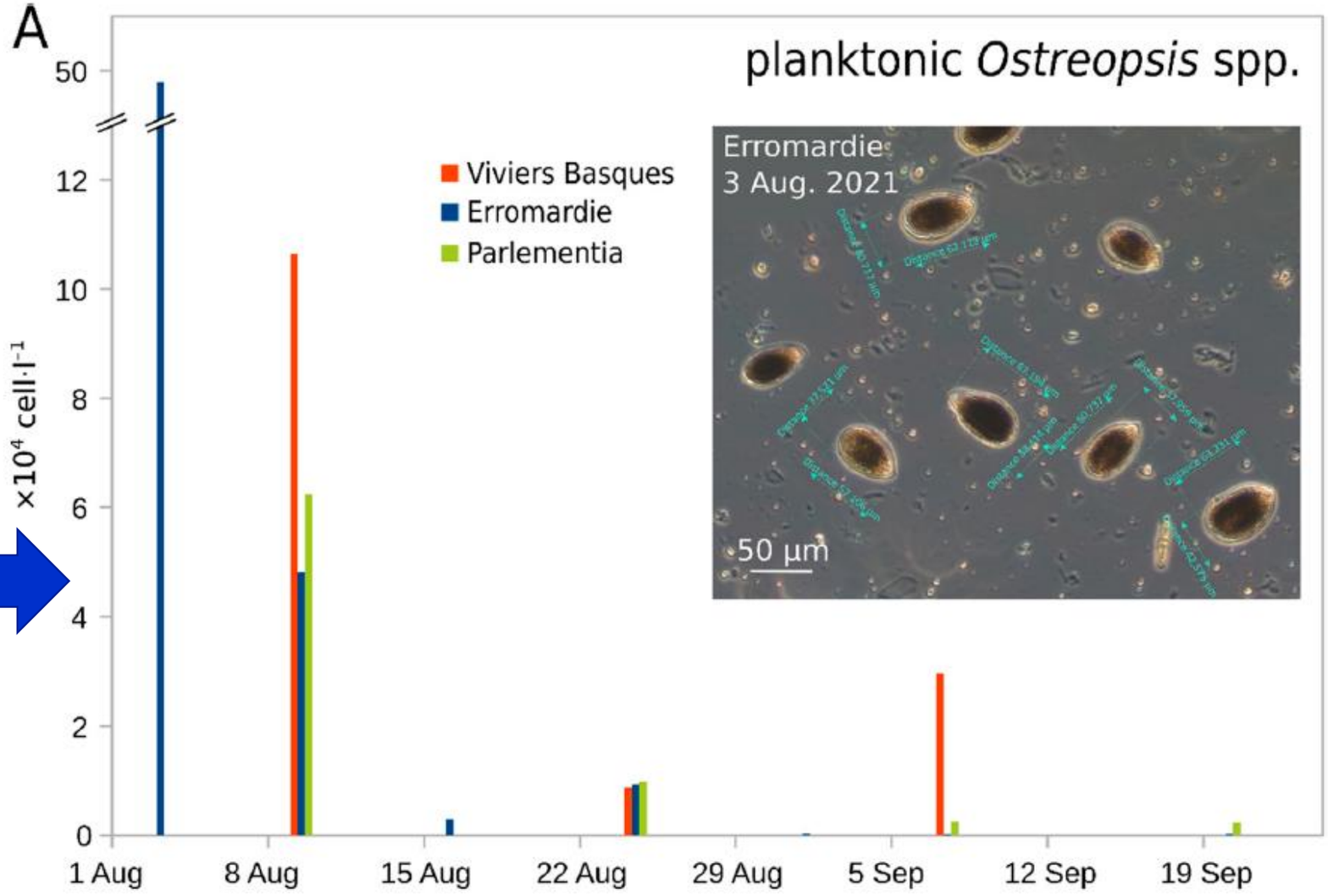
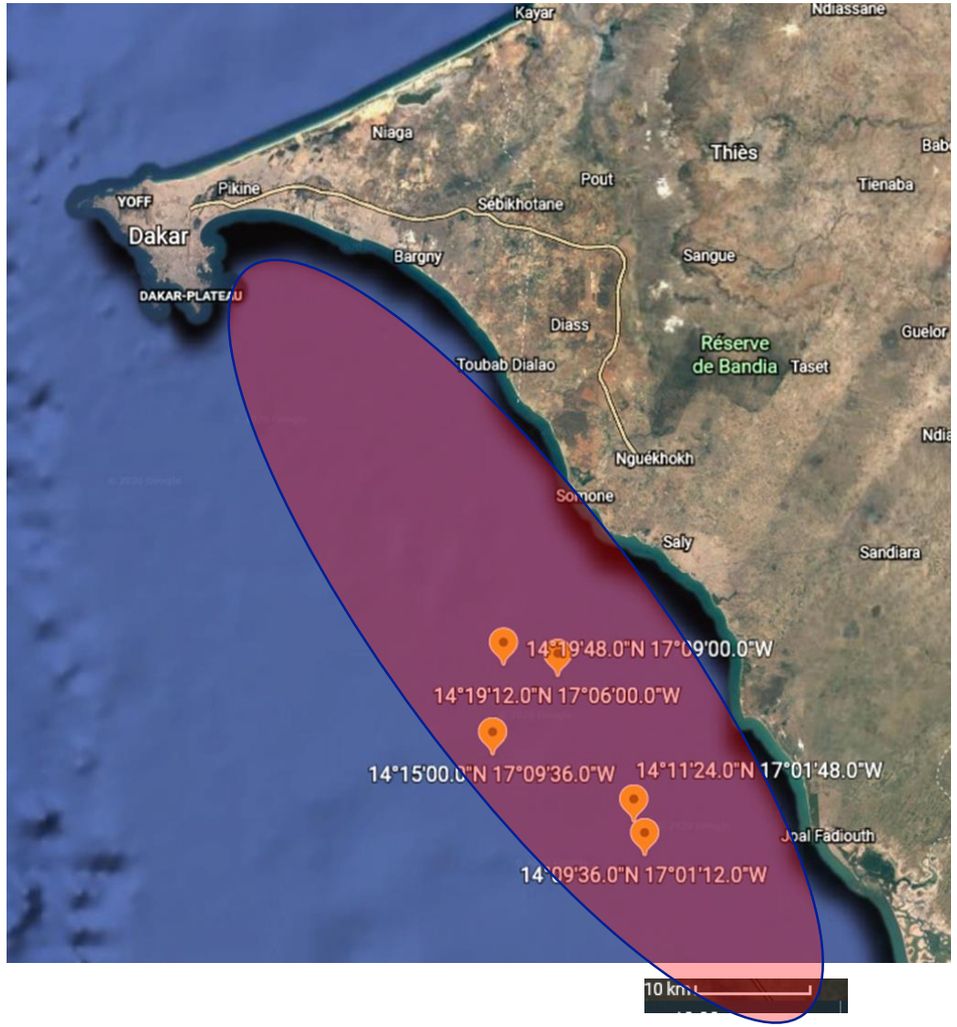
2021 Event of *O.* cf. *ovata* discovered through surf competition



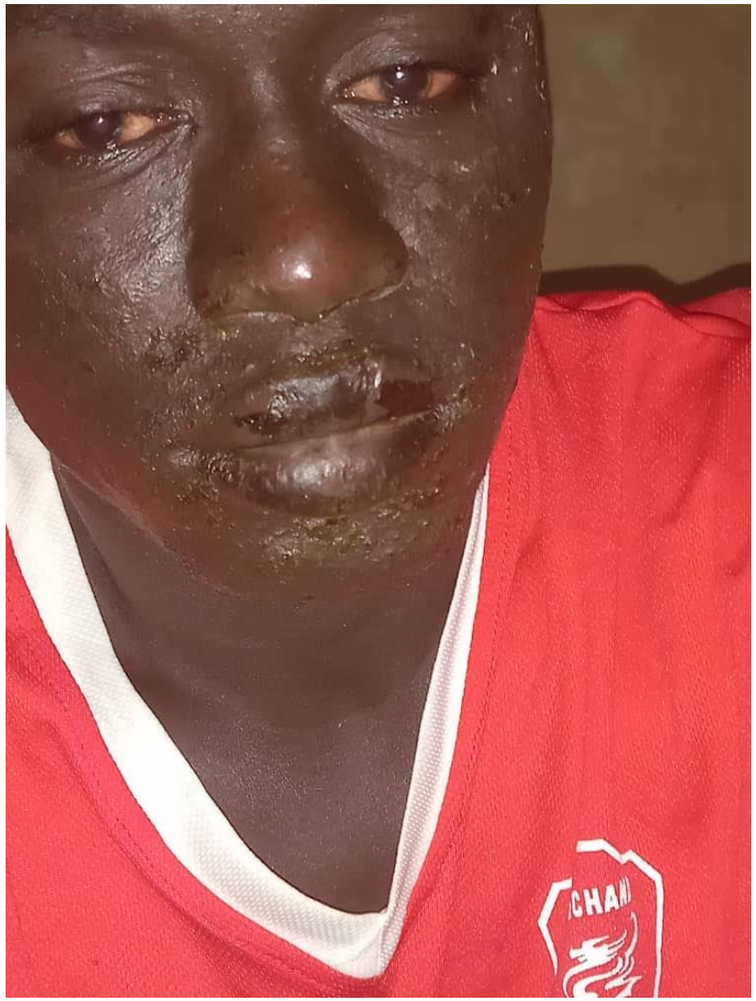


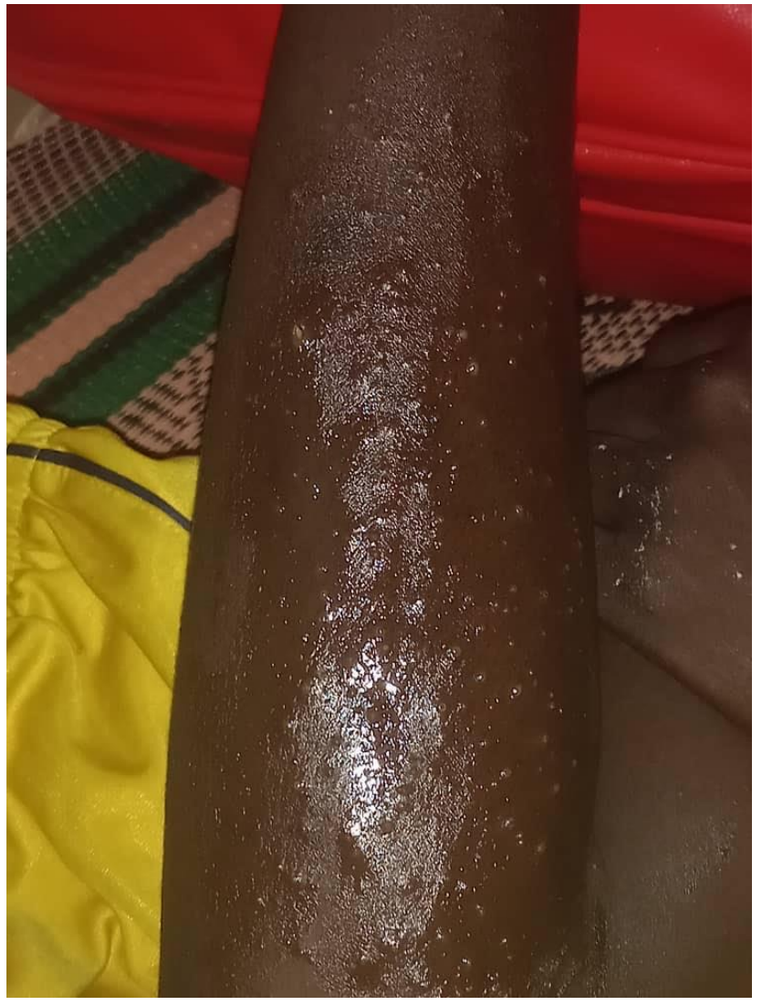
(Chomérat et al., 2022)

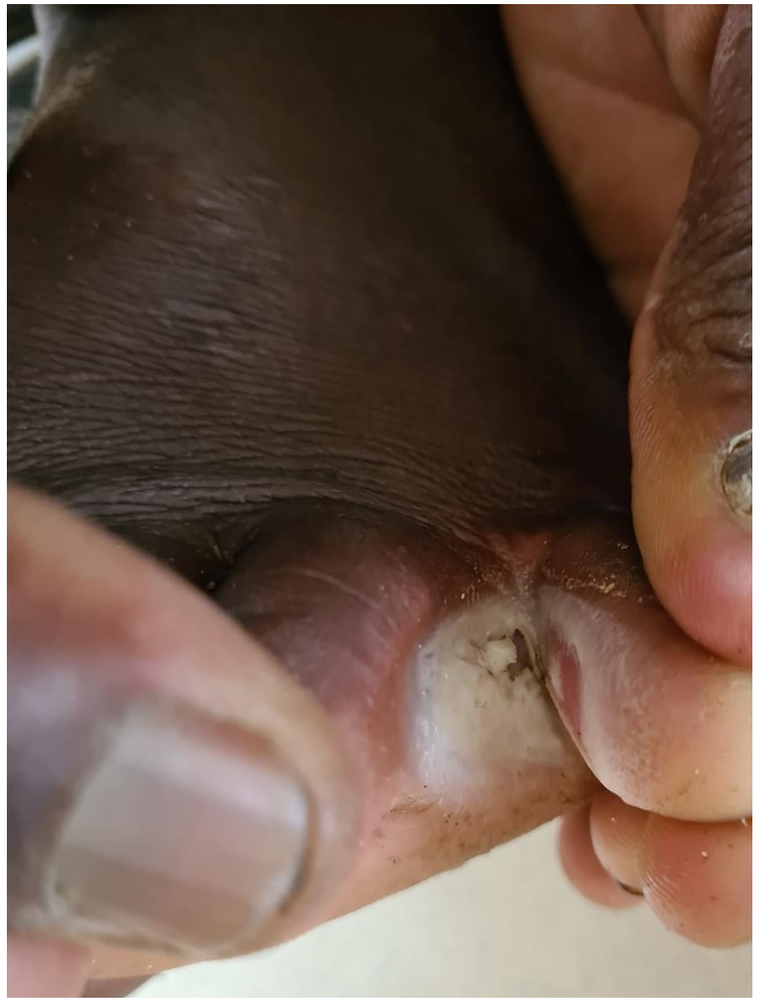
Senegal: 16 000 fishing canoes for artisanal drift-net fishing



Senegal event – November 2020

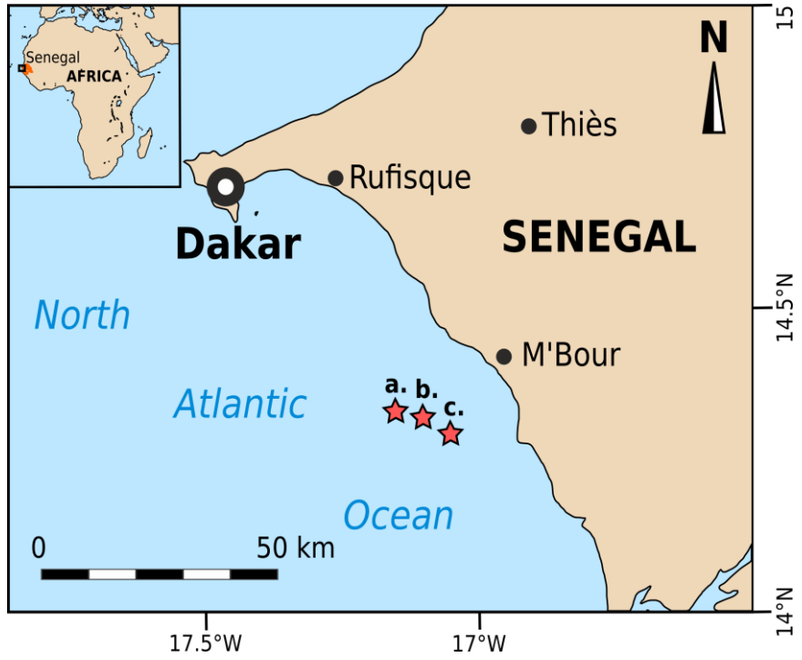






Vulcanodinium rugosum bloom in Senegal causes acute dermatitis in fishermen

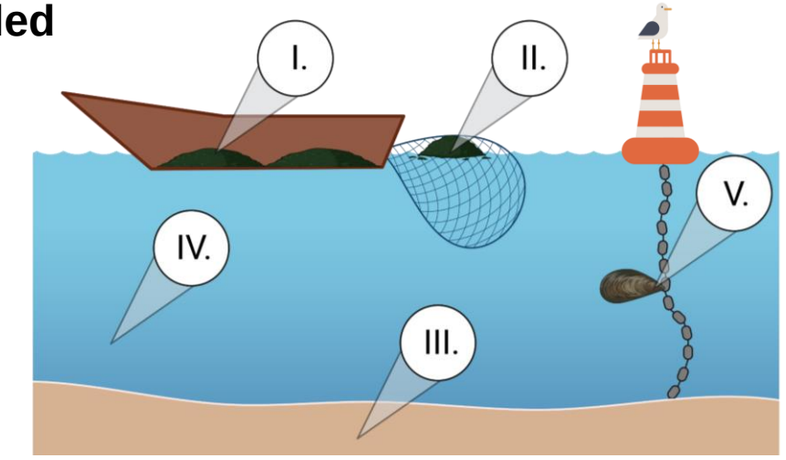
A



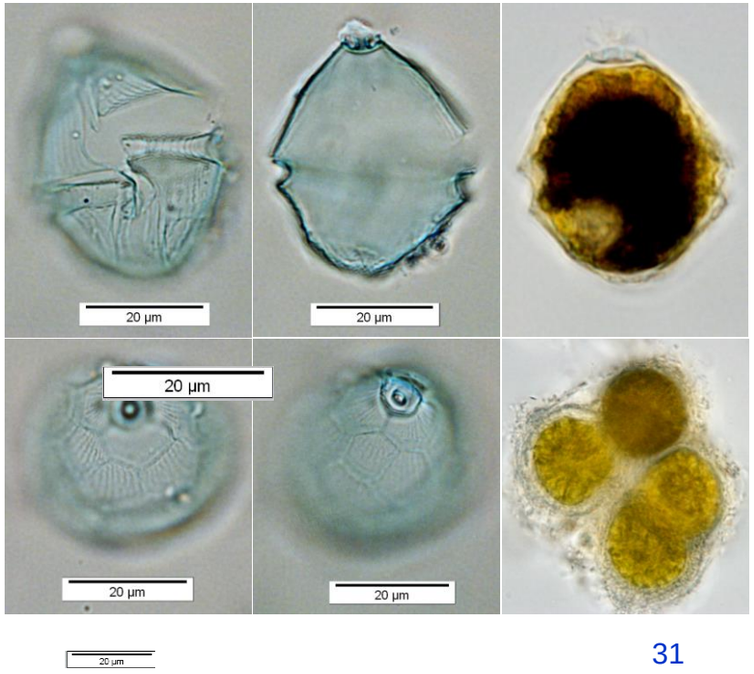
B

C

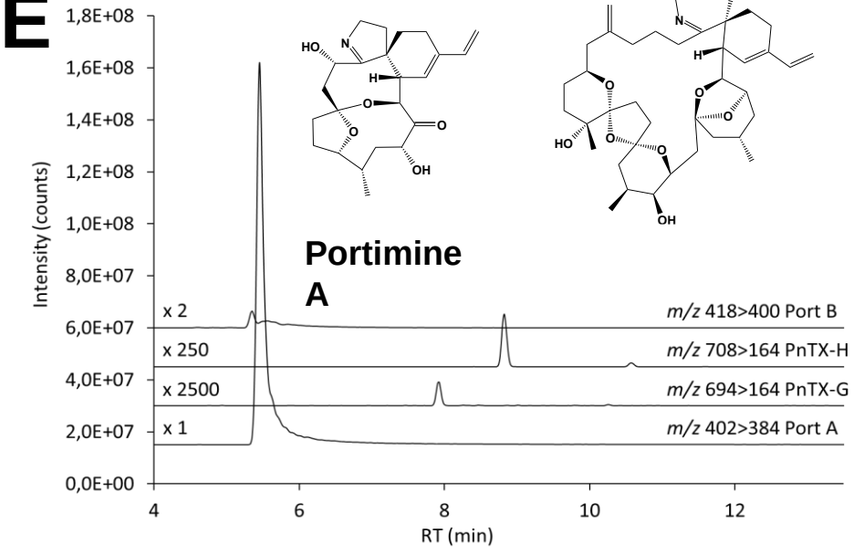
Environmental compartments sampled



D



E



F

Features common to Senegalese biomass and *V. rugosum*

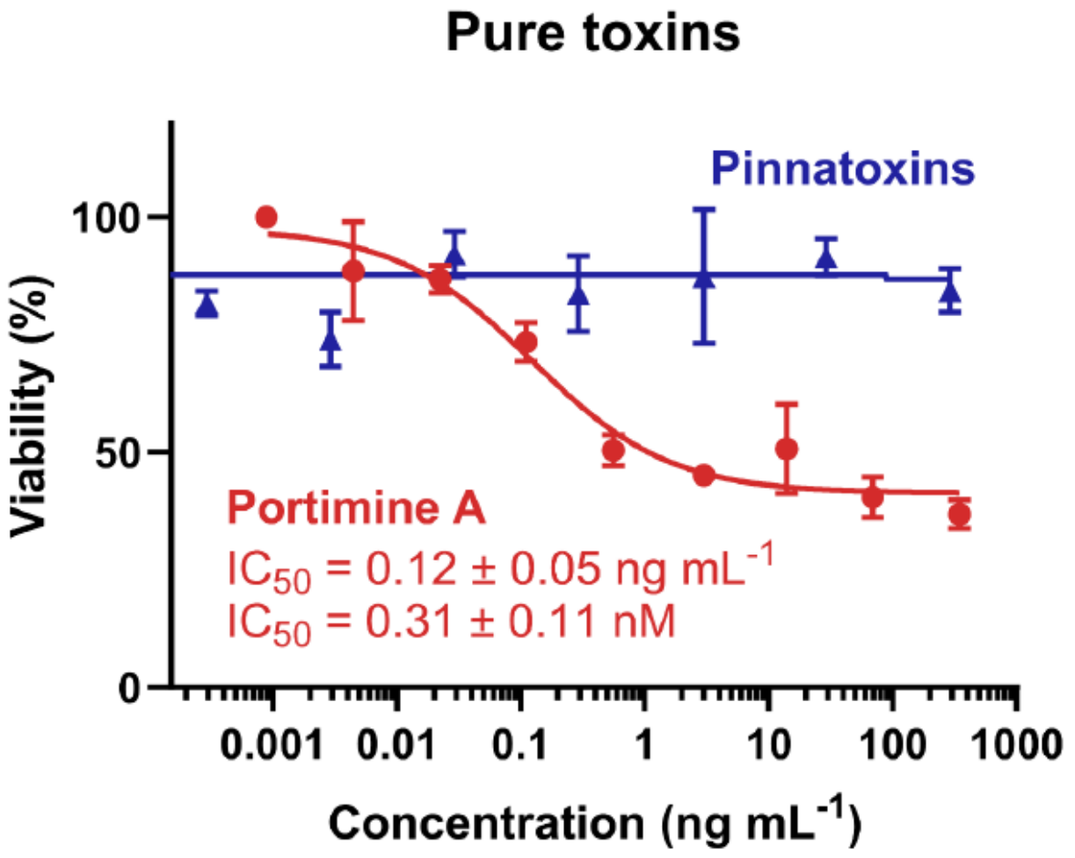
Net biomass (II.)

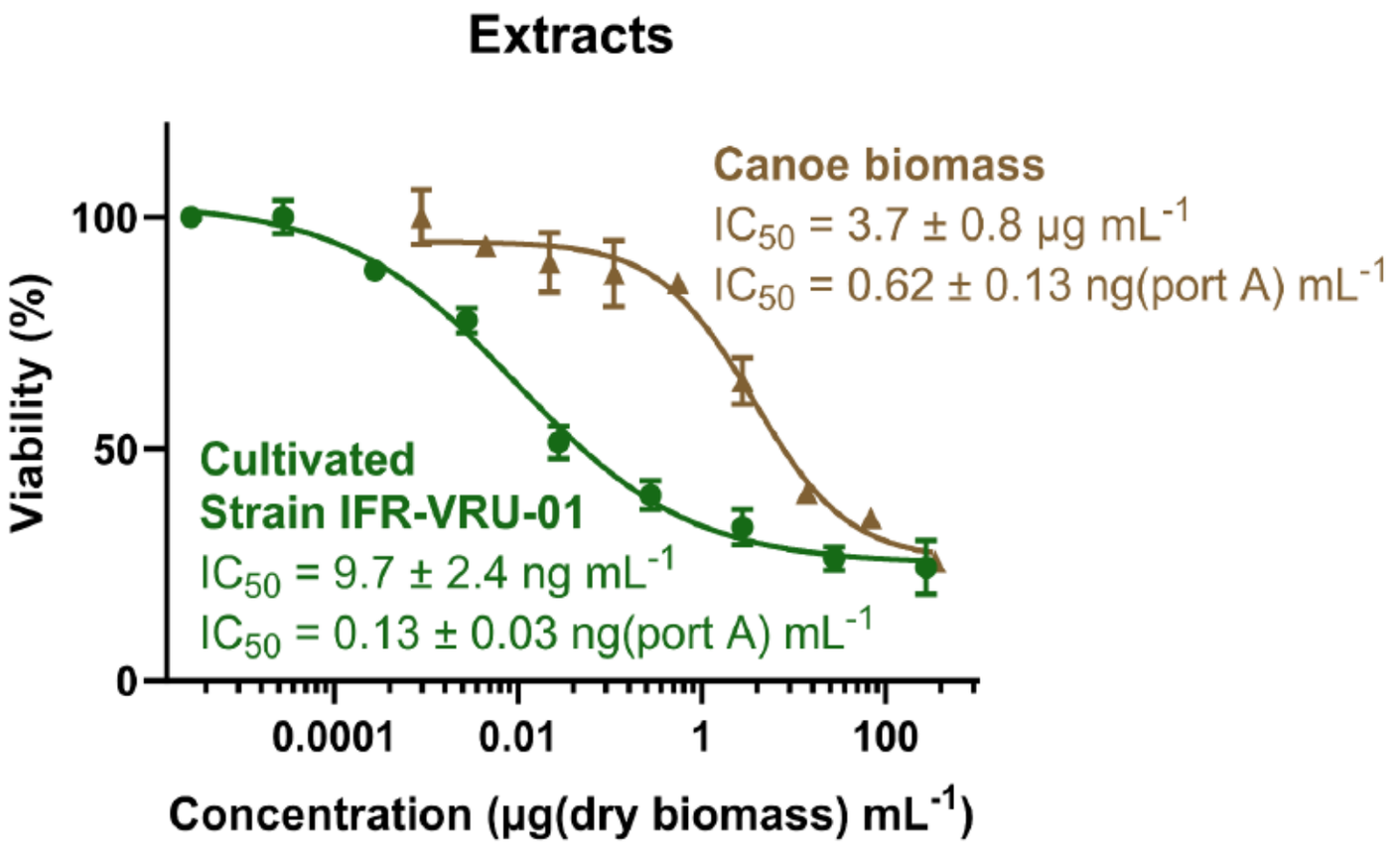
***V. rugosum* cultured cells**

G

Sample		Site	Portimine A	Portimine B	PnTX-H	PnTX-G	PnTX-H Iso	
Canoe biomass	(I.)	b.	224 361	4 906	228	10	17	µg kg^{-1}
Net biomass	(II.)	b.	177 324 460*	6 458 n.d.*	109 2*	14.1 0.8*	11.5 0.1*	µg kg^{-1}
Sediment	(III.)	b.	3 861 94*	79 n.d.*	17 0.009*	0.6 0.014*	7.7 n.d.*	µg kg^{-1}
Sea water	(IV.)	a.	28.6	0.8	n.d.	n.d.	n.d.	ng filter^{-1}
Mussel	(V.)	c.	42.7*	n.d.*	1.7*	0.6*	n.d.*	µg kg^{-1}

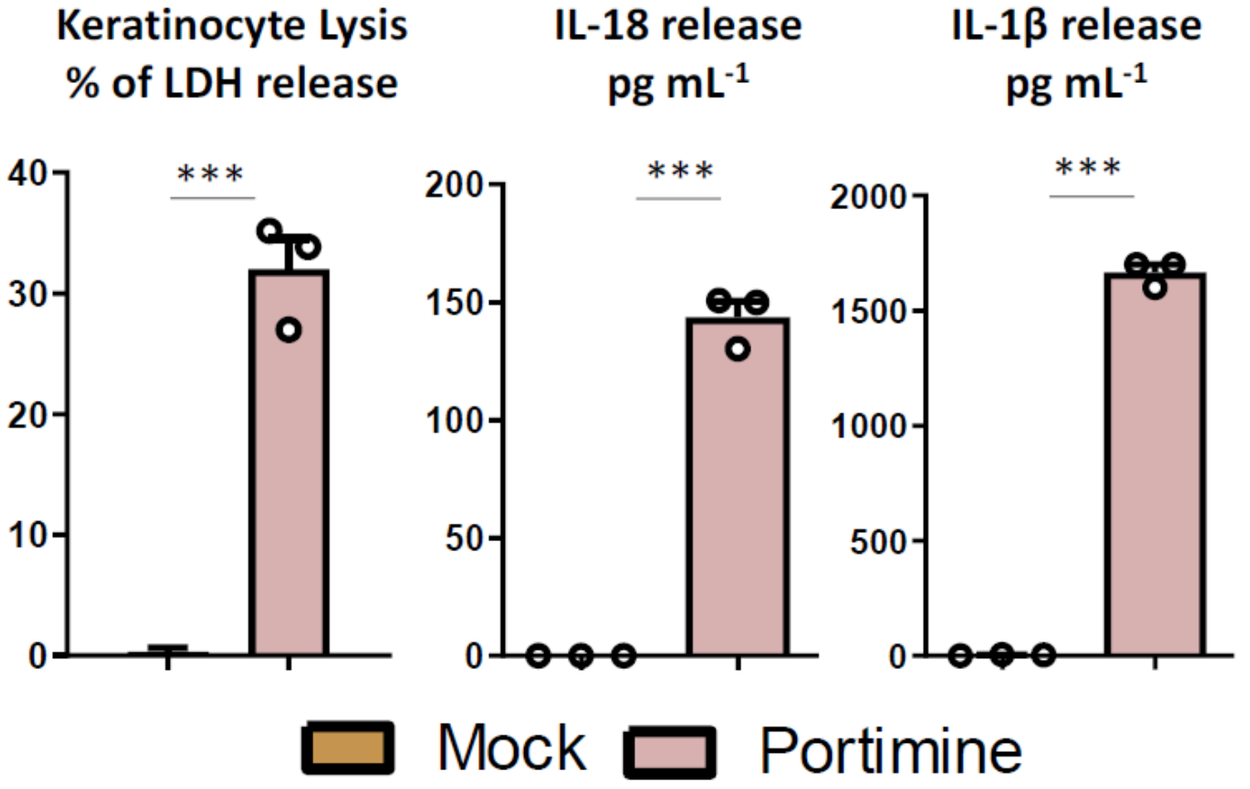
Cytotoxicity on HaCaT keratinocytes

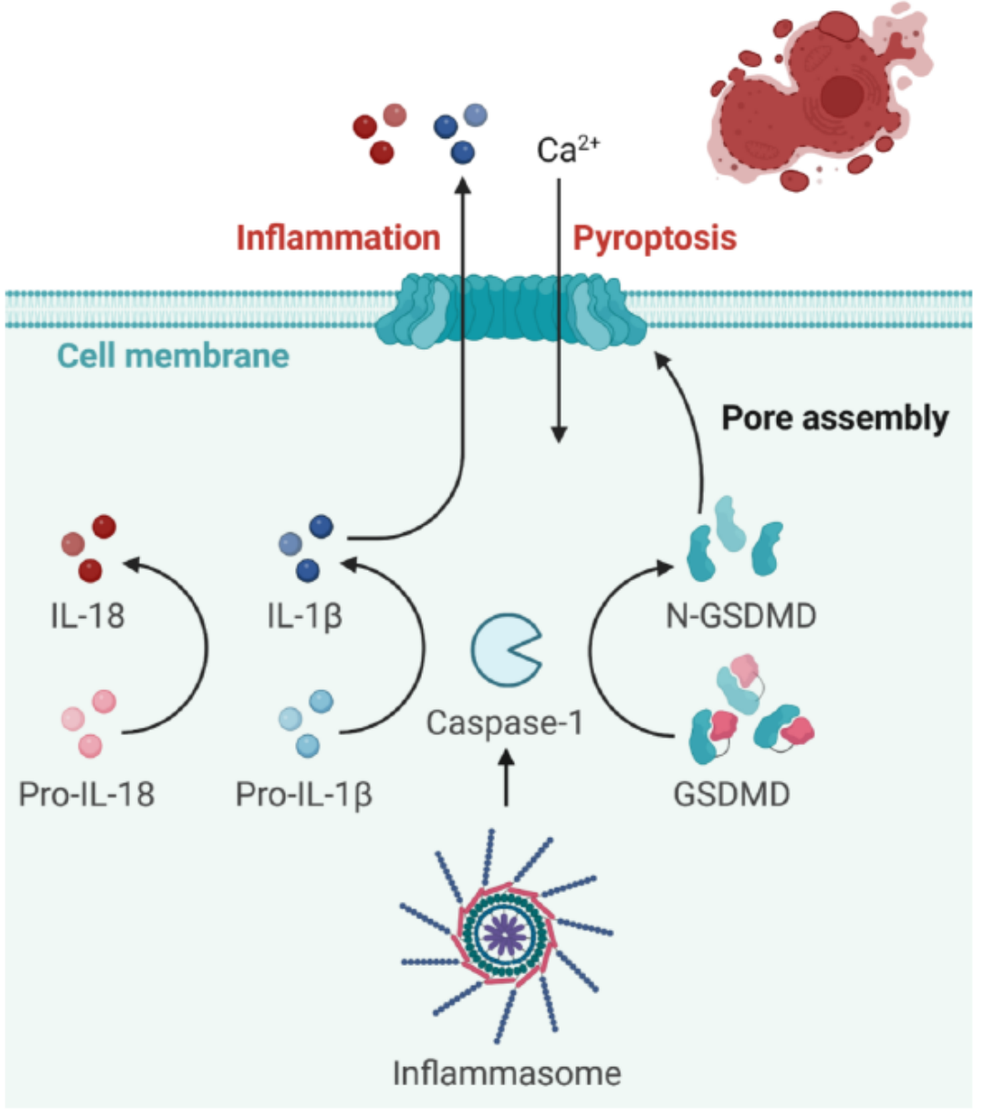




- **Portimine A is highly cytotoxic on keratinocytes down to sub-nanomolar concentrations**

Portimine triggers an inflammatory response in skin cells





IL-18 & IL-1β release → **Caspase-1 involved** → **Inflammasome(s) involved**

Broz and Dixit (2016) "Inflammasomes: mechanism of assembly, regulation and signaling", *Nat Rev Immunol*

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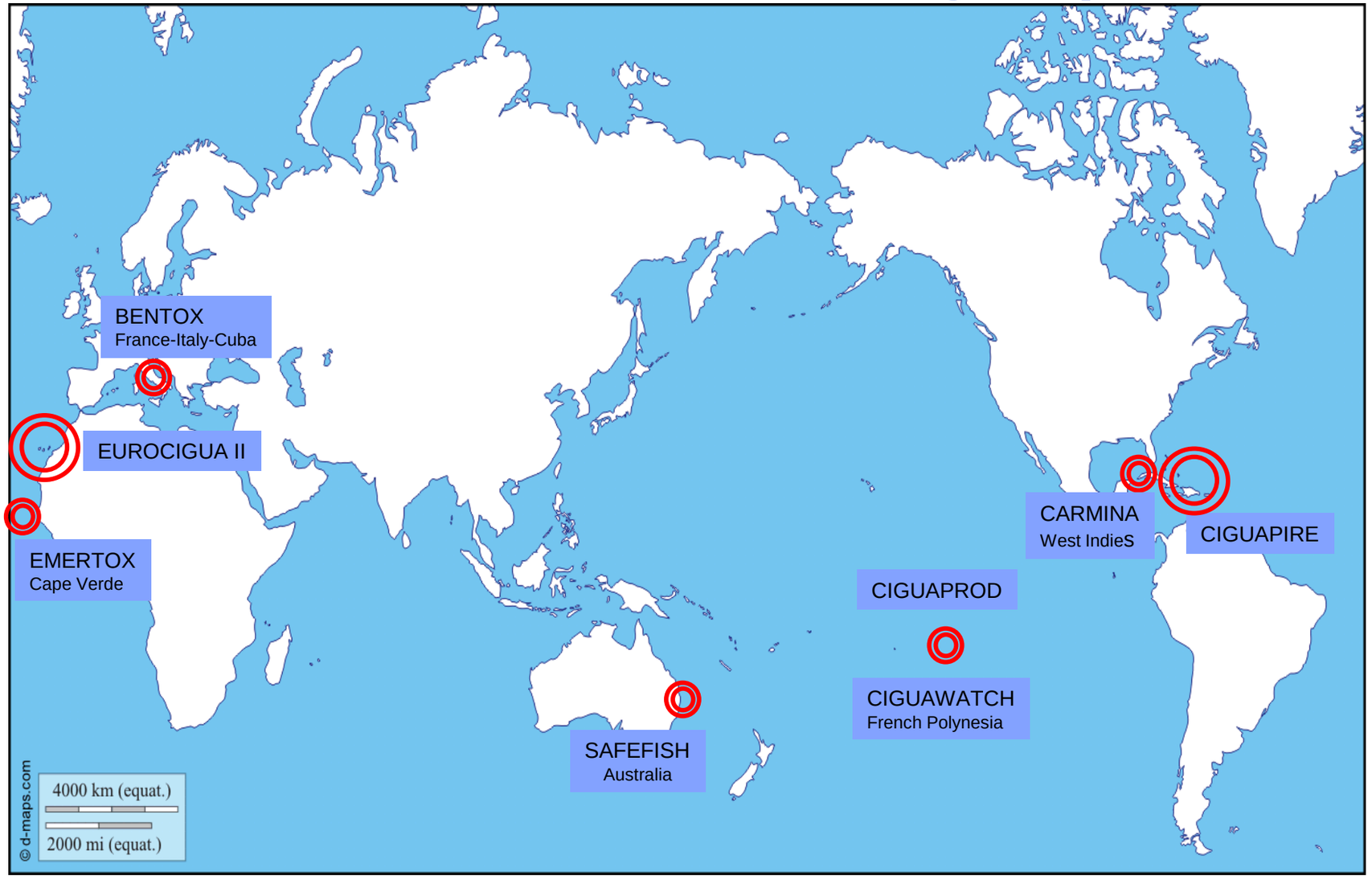
Task Team on a Global Inter-Agency Ciguatera Strategy for Improved Research and Management

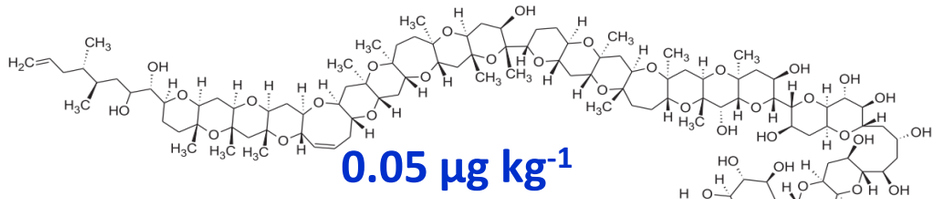
1. Improved detection & monitoring of CTX-producing organisms
2. Improved toxin detection & monitoring
3. Improved epidemiology, prevention and treatment

Research projects are progressing but concerted international efforts are direly required



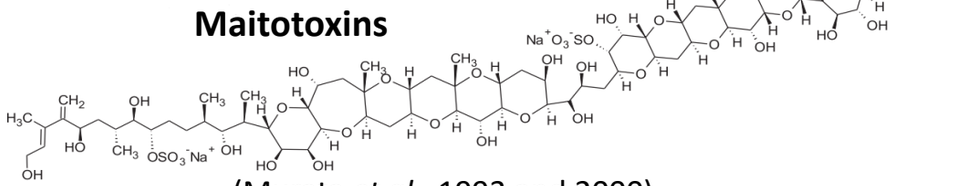
Known versus emerging risks – mapping the known ones globally

Toxicity of Gambierdiscus metabolites (LD_{50} i.p. in mice)



0.05 µg kg^{-1}

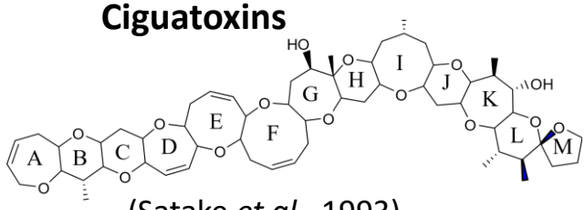
Maitotoxins



(Murata *et al.,* 1993 and 2000)

0.24-3.6 µg kg^{-1}

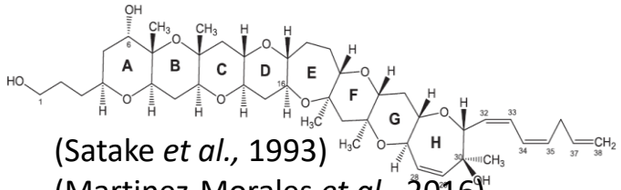
Ciguatoxins



(Satake *et al.,* 1993)
(FAO and WHO 2020)

50-80 µg kg^{-1}

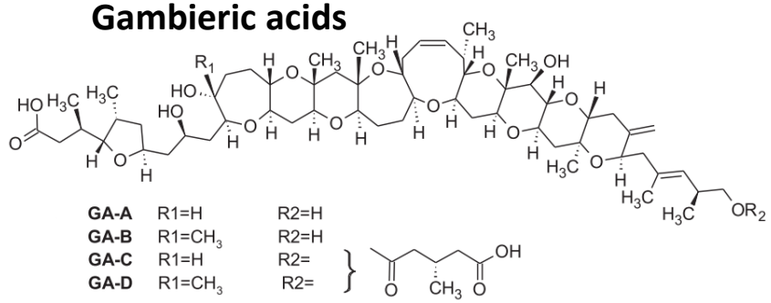
Gambierol



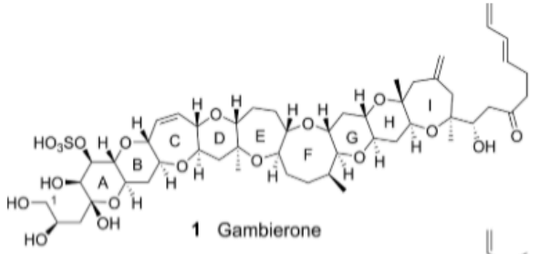
(Satake *et al.,* 1993)
(Martinez-Morales *et al.,* 2016)

Not toxic at 1mg kg^{-1}

Gambieric acids

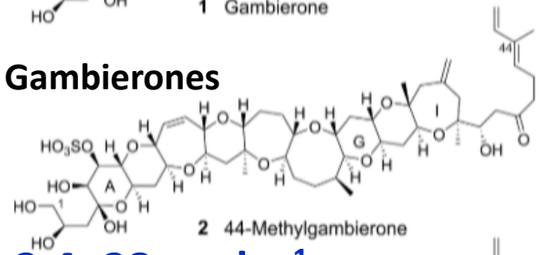


(Nagai *et al.,* 1992)
(Laza-Martinez *et al.,* 2016)



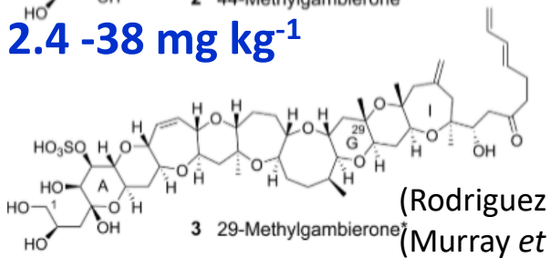
1 Gambierone

Gambierones



2 44-Methylgambierone

2.4 -38 mg kg^{-1}

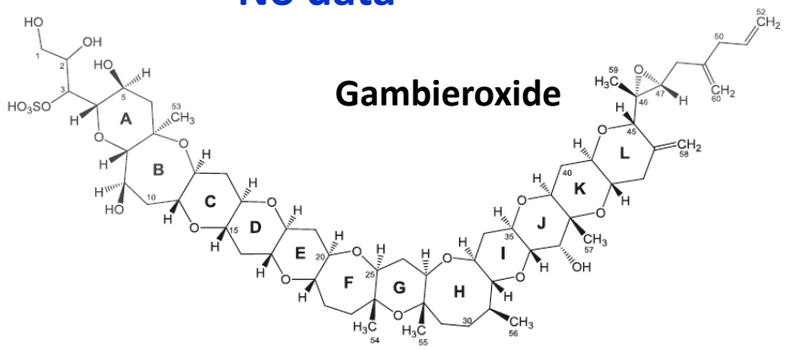


3 29-Methylgambierone*

(Rodriguez *et al.,* 2015)
(Murray *et al.,* 2020 and 2021)

No data

Gambieroxide



(Watanabe *et al.,* 2013)

IPHAB Toxins Home Export Login

IOC-UNESCO Toxins database

Welcome to the IOC-UNESCO Toxins database. This database contains reference information about toxins - some of which are associated with Harmful Algal Events.

Toxin: azaspiracid

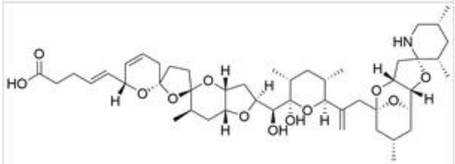
Progenitor or vector:

Search | More filters | Download JSON

15 Toxins

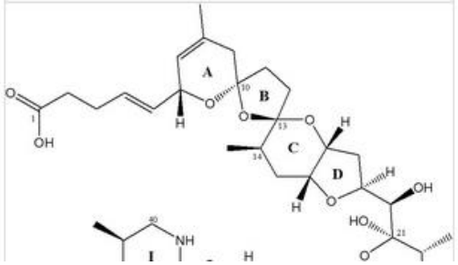
Azaspiracid
19 Toxins

Azaspiracid



Azaspiracid-1
C47H71NO12

Azaspiracid



Global Harmful Algal Blooms

Search ...

News & **Events**

Scientific Steering Committee Meetings

GlobalHAB activities

Calendar

Get **Involved**

Invitation to participate

Useful **Links**

GEOHAB Reports and Publications

IOC HAB Programme

SCOR

Global Harmful Algal Blooms - GlobalHAB - an international science programme on HABs building on the foundations of GEOHAB

SCIENCE AND IMPLEMENTATION PLAN

Science and Implementation Plan

An international programme sponsored jointly by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO

User **login**

Username

Password

Remember Me

Log In

Forgot your password?

Harmful Algal Bloom Solutions (HAB-S)

unesco
Intergovernmental Oceanographic Commission

Food and Agriculture Organization of the United Nations

An Endorsed Action for the UN Decade of Ocean Science for Sustainable Development led by the FAO-IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB)

HAB-S initiatives will **co-create transformative region-specific solutions** for:

1) Preventing, controlling & mitigating HAB events
2) Advancing HAB Observing tools & technologies
3) Making HAB Data equitable & accessible
4) Improving HAB Literacy

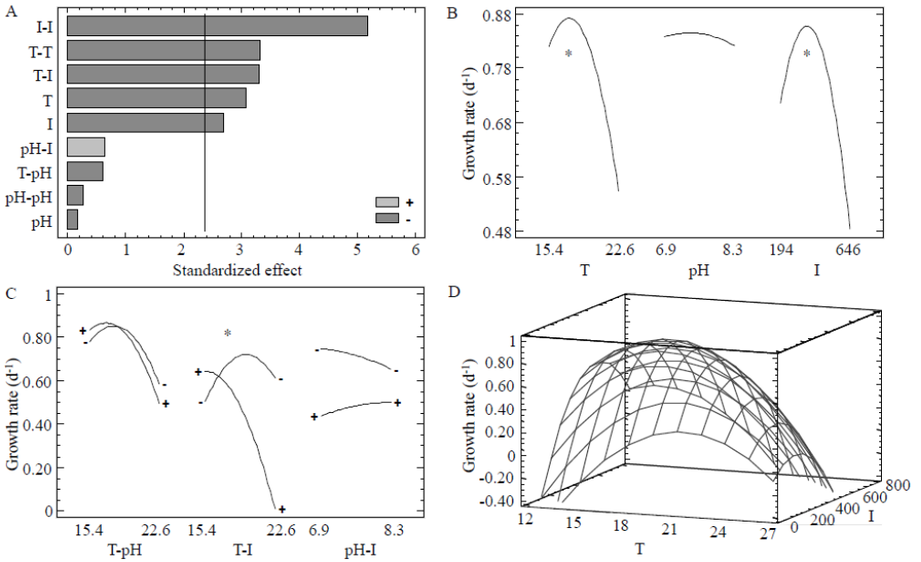
- **Sharing knowledge and improved integrated databases**
- **Breakthrough technologies in in situ-and satellite detection of HABs and toxins**
- **Improved understanding of HAB development and prediction**
- **Co-developed approaches to mitigate effects**

Breakthrough Technologies: Physiology

Evaluating multiple strains of microalgae

Simultaneous evaluation of multiple strains in environmental stress conditions to understand toxin-production as specialized metabolism

Factorial design to understand the complex interactions Involved in climate change



Membrane Inlet Mass Spectrometer

Gas detection to understand HAB photosynthesis & respiration (O_2, CO_2, DMS…)

Functional genomics and flow-cytometry to understand HAB-mixotrophy

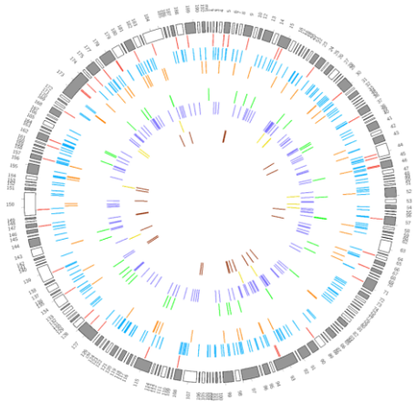
qPCR for improved rapid quantitation of toxic algae, ddPCR for improved rapid confirmation of emerging microalgae

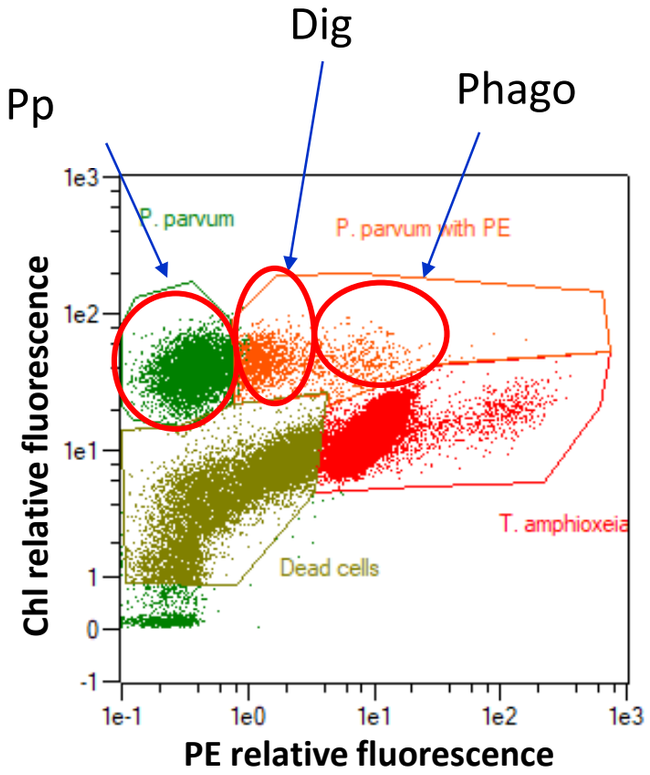
Miniaturized sequencing technology MinIon (Oxford Nanopore)

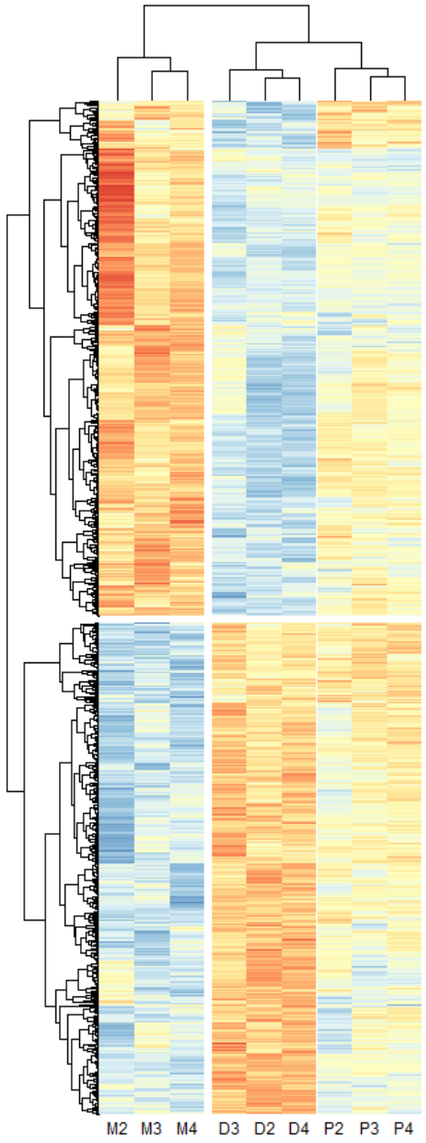
Flow cytometry for detection of popoluations in situ or in culture

Functional transcriptomics to understand mixotrophy

bioinfo Ifremer





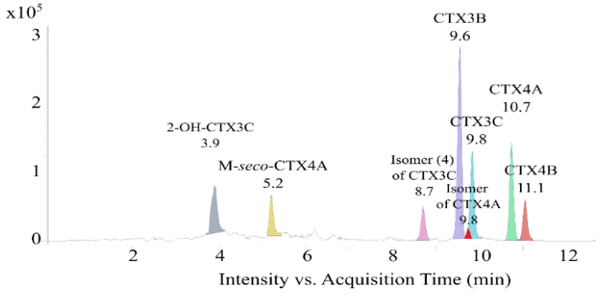


Philipp Hess – philipp.hess@ifremer.fr

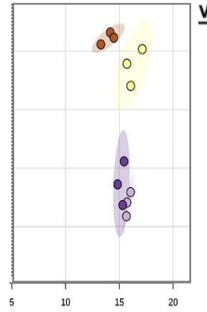
3 juin 2024

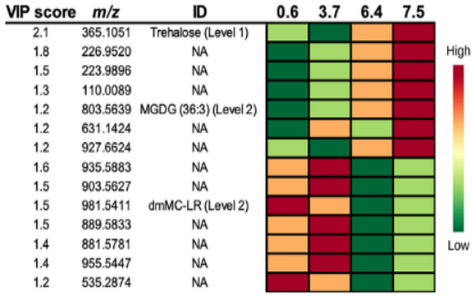
Breakthrough tecnology in detection of algal metabolites

Target analysis of known toxins and key metabolites



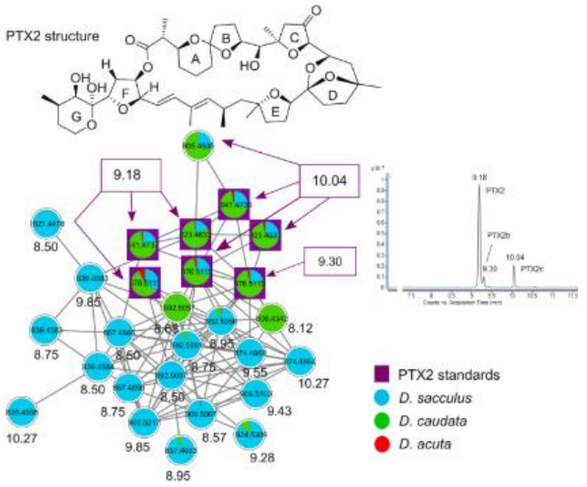
- **Toxins**
- **Pigments**
- **Fatty acids**
- **Osmolytes**
- **Photoprotective compounds**



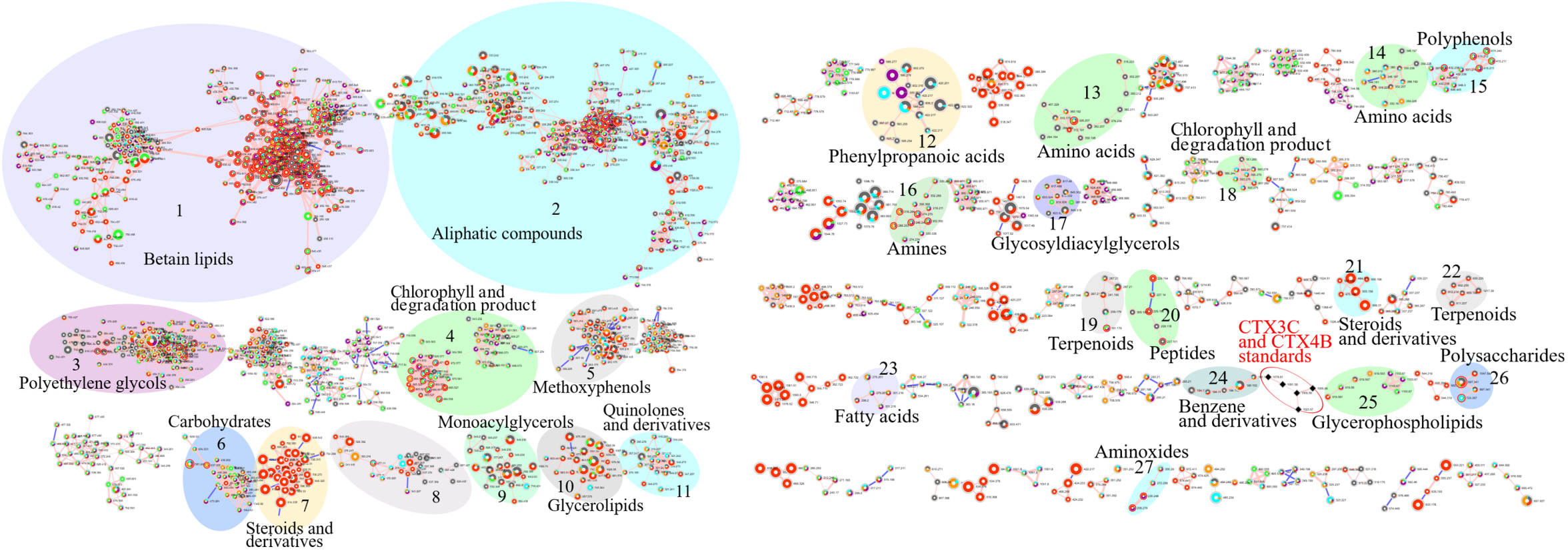


Untargeted analysis of emerging toxins

- **Déréplication + annotation (réseaux moléculaires, GNPS)**
- **Purification**
- **Identification**



Exploration of the chemical diversity of algal metabolomes aids in understanding their metabolic plasticity



Yon, T., Reveillon, D., Sibat, M., Holland, C., Litaker, R.W., Nascimento, S.M., Rossignoli, A.E., Riobo, P., Hess, P., Bertrand, S., 2024. Targeted and non-targeted mass spectrometry to explore the chemical diversity of the genus *Gambierdiscus* in the Atlantic Ocean. Phytochemistry, 114095.

Thanks

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