Harmful Algal Blooms & Ocean Climate Change

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UTAS

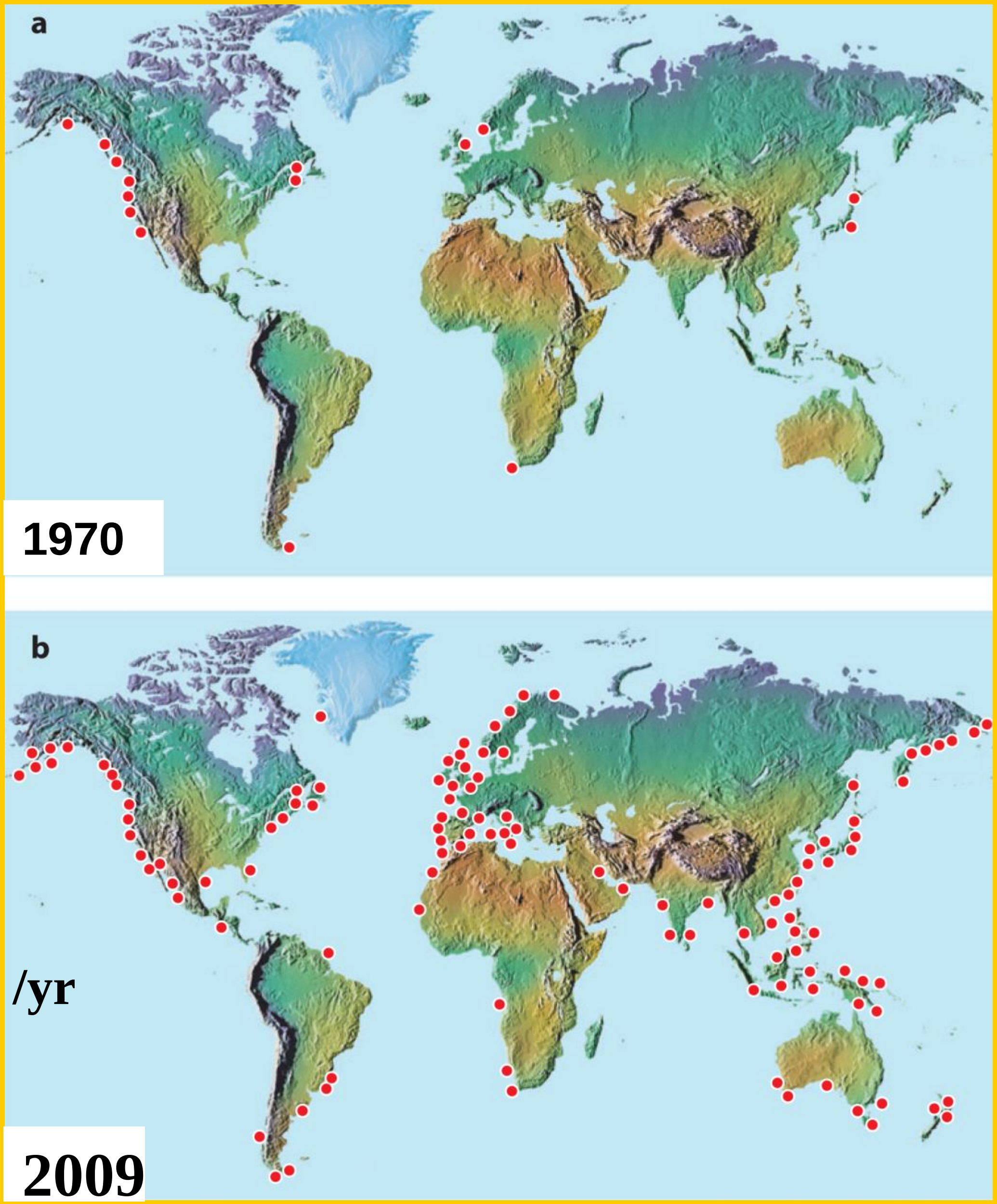
IMAS
INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

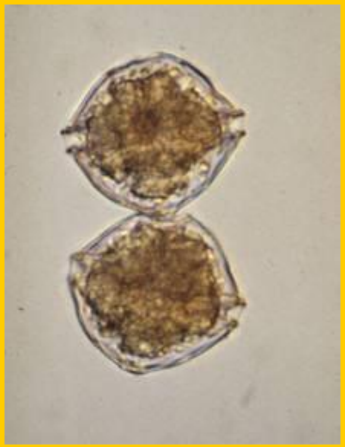

Shellfish danger
Red tide kills children, alert
WHO
Killer algae found in waters off Tasmania
FAO
FIAT PANIS
Algal toxin hits crays
IMO
UNESCO
HABs
Harmful Algal Blooms
Monographs on Oceanographic Methodology
Manual on Harmful Marine Microalgae
Edited by
UNESCO PUBLISHING
BEACH HEALTH DANGER
Tuna industry in shock
BELGIQUE

Increased Global Distribution Paralytic Shellfish Poisoning

Captain Vancouver

Poison Cove 1793

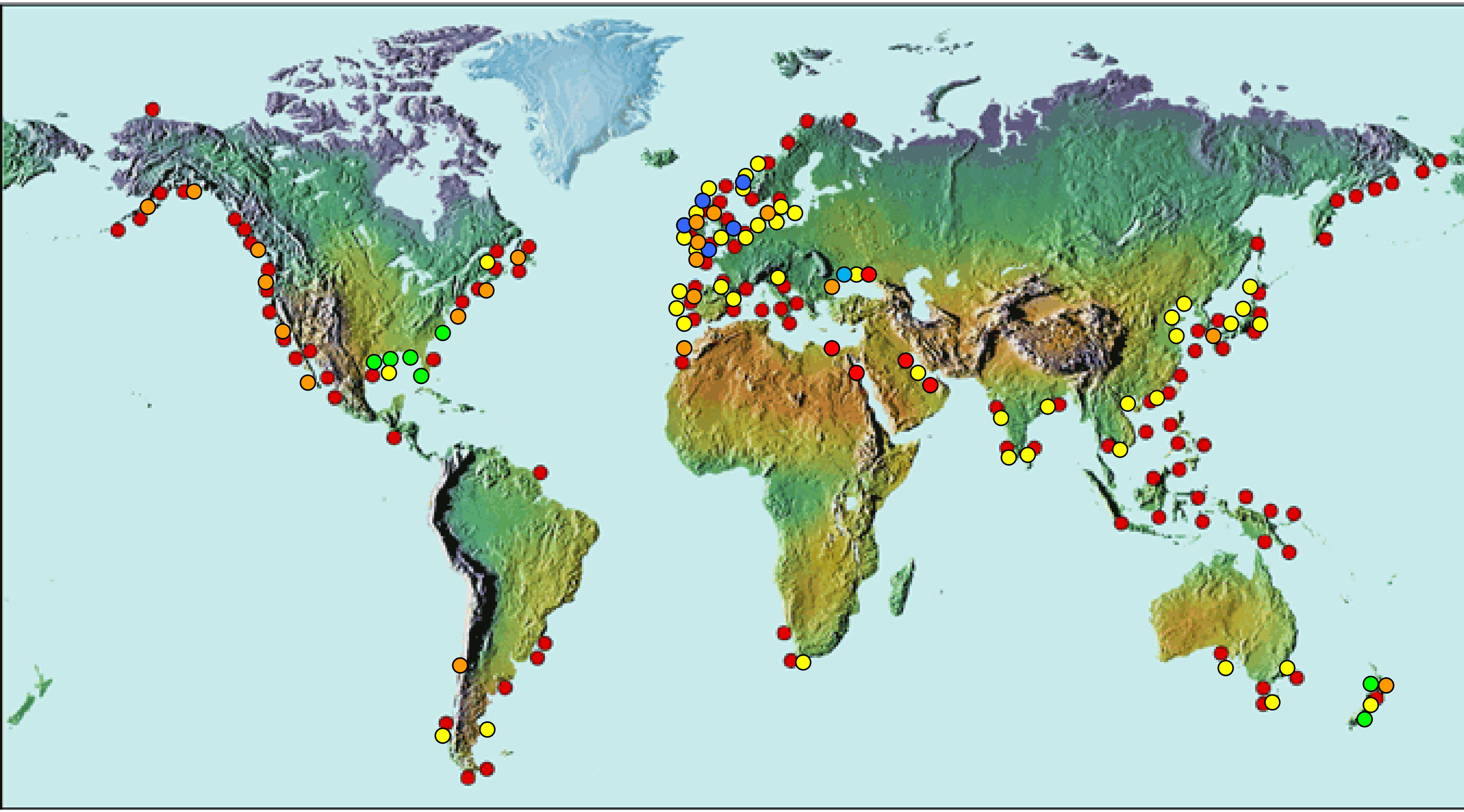




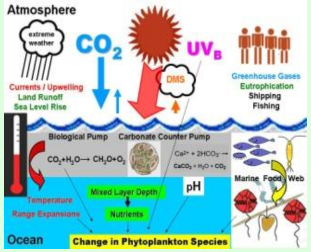
2000 poisonings /yr
(15% fatal)

Increased Awareness of Shellfish Biotoxins

ASP NSP AZP DSP PSP

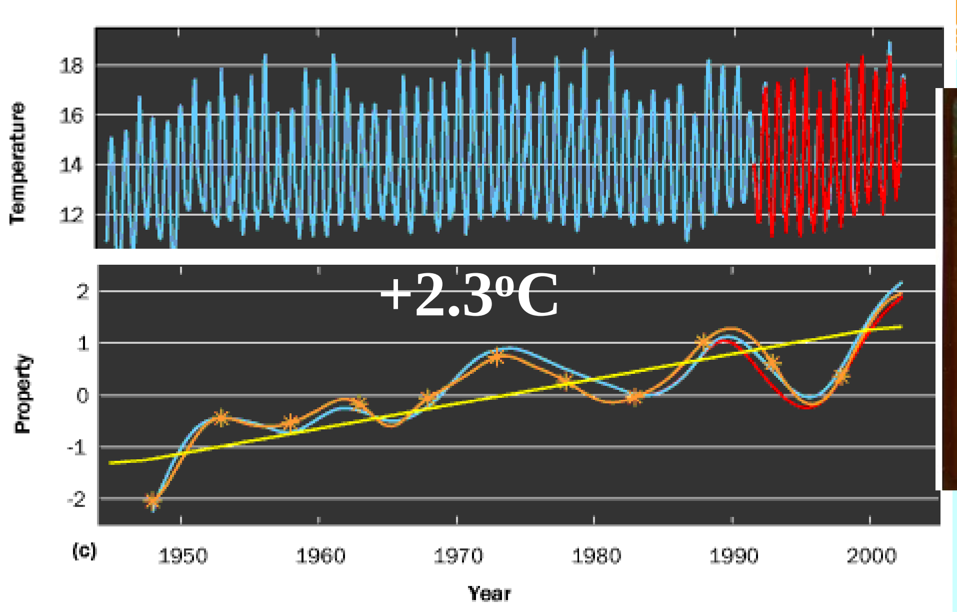


Environmental and Human Societal Drivers of increase in Harmful Algal Blooms



1.	Increased scientific **awareness** of toxic species.
2.	Increased utilisation of coastal waters for **aquaculture**
3.	Stimulation of plankton blooms by cultural **eutrophication**
4.	Transport in ships' **ballast water** or associated with translocation of shellfish stocks
5.	Stimulation by unusual **climate** conditions

WINNERS



LOSERS

EXTREME EVENTS

Increased Bush Fires

Sydney Dust Storm

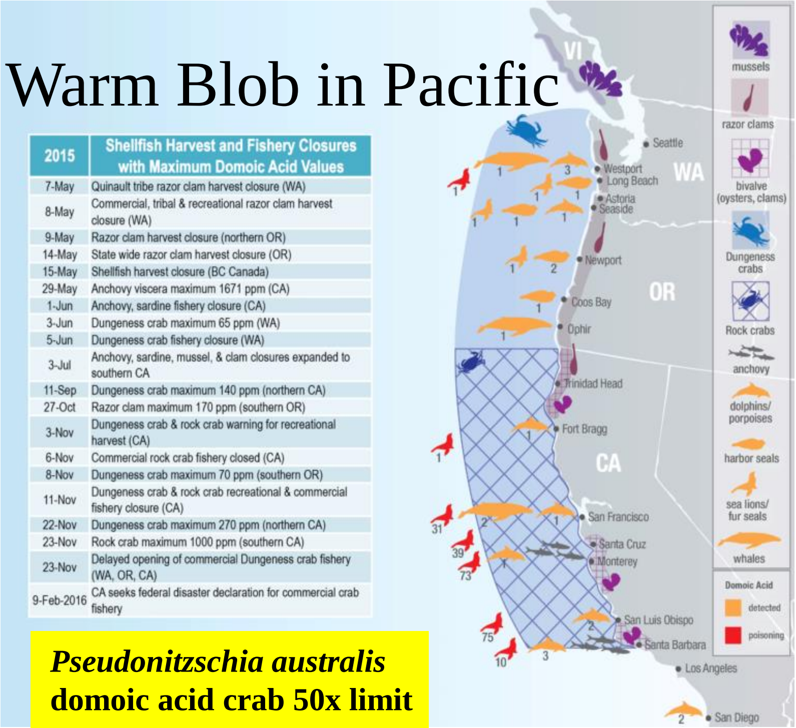
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP

WGII AR5
Ch 6 & 30

Brisbane 1:100 yr flood

California 1:100 yr drought

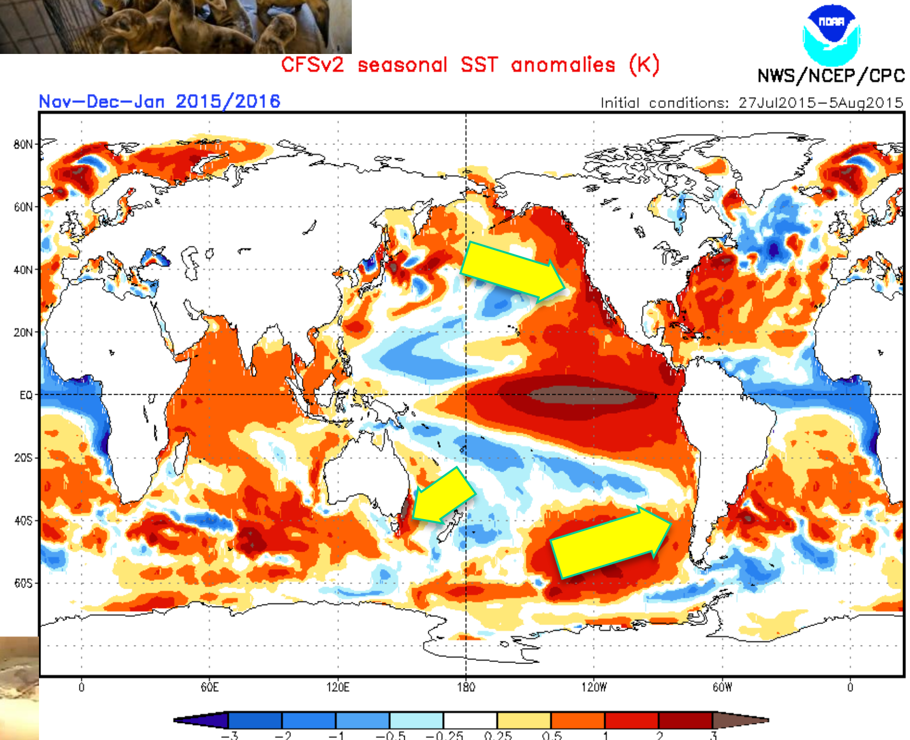
Warm Blob in Pacific



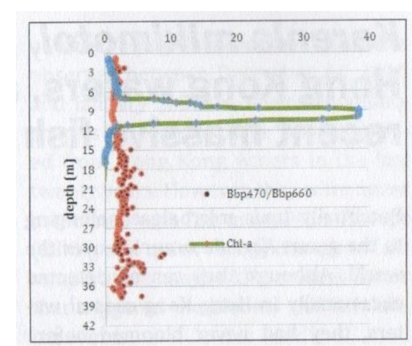
2015	Shellfish Harvest and Fishery Closures with Maximum Domoic Acid Values
7-May	Quinault tribe razor clam harvest closure (WA)
8-May	Commercial, tribal & recreational razor clam harvest closure (WA)
9-May	Razor clam harvest closure (northern OR)
14-May	State wide razor clam harvest closure (OR)
15-May	Shellfish harvest closure (BC Canada)
29-May	Anchovy viscera maximum 1671 ppm (CA)
1-Jun	Anchovy, sardine fishery closure (CA)
3-Jun	Dungeness crab maximum 65 ppm (WA)
5-Jun	Dungeness crab fishery closure (WA)
3-Jul	Anchovy, sardine, mussel, & clam closures expanded to southern CA
11-Sep	Dungeness crab maximum 140 ppm (northern CA)
27-Oct	Razor clam maximum 170 ppm (southern OR)
3-Nov	Dungeness crab & rock crab warning for recreational harvest (CA)
6-Nov	Commercial rock crab fishery closed (CA)
8-Nov	Dungeness crab maximum 70 ppm (southern OR)
11-Nov	Dungeness crab & rock crab recreational & commercial fishery closure (CA)
22-Nov	Dungeness crab maximum 270 ppm (northern CA)
23-Nov	Rock crab maximum 1000 ppm (southern CA)
23-Nov	Delayed opening of commercial Dungeness crab fishery (WA, OR, CA)
9-Feb-2016	CA seeks federal disaster declaration for commercial crab fishery

***Pseudonitzschia australis* domoic acid crab 50x limit**

El Nino 2016

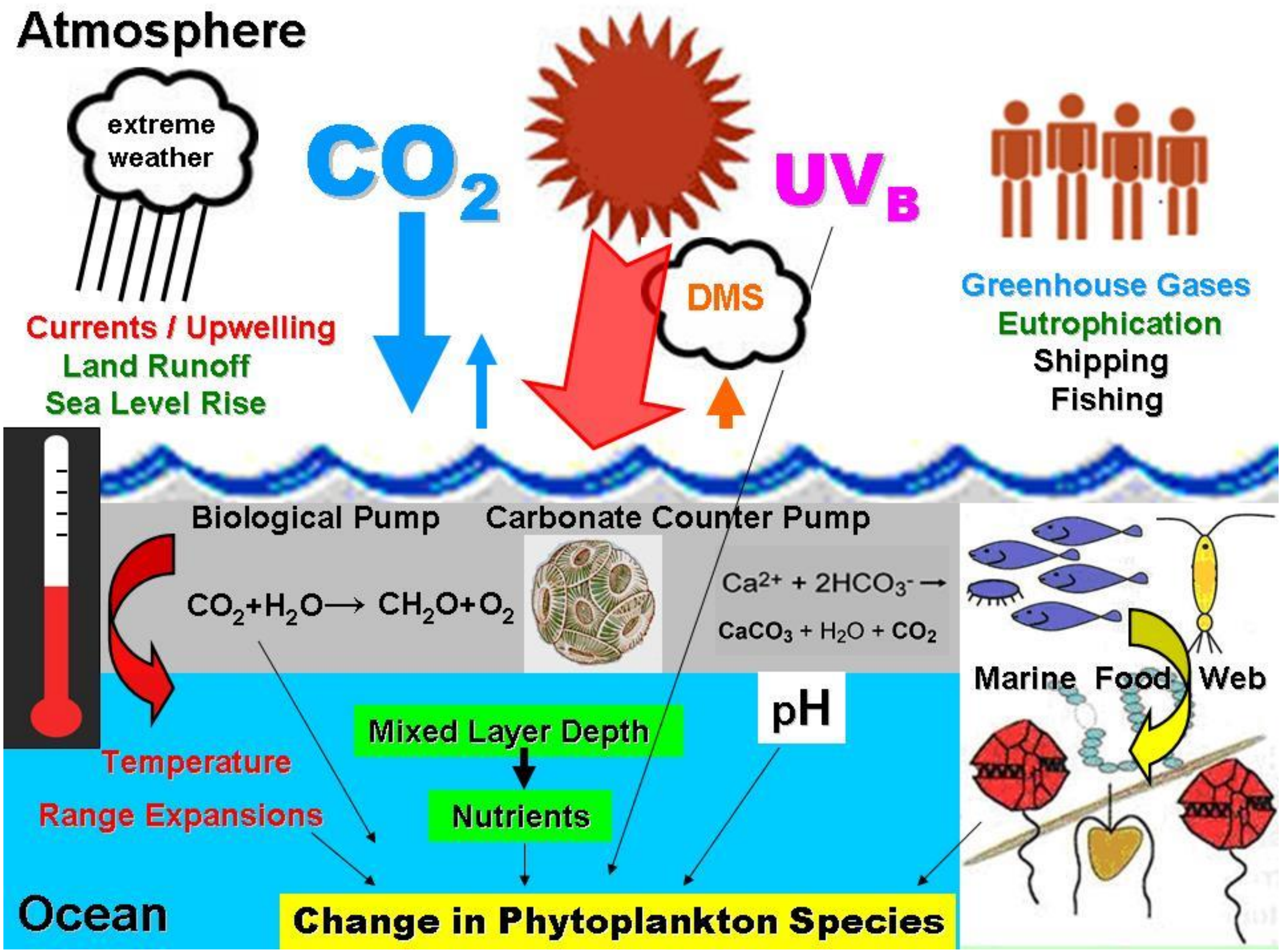


Chile March 2016 $800M



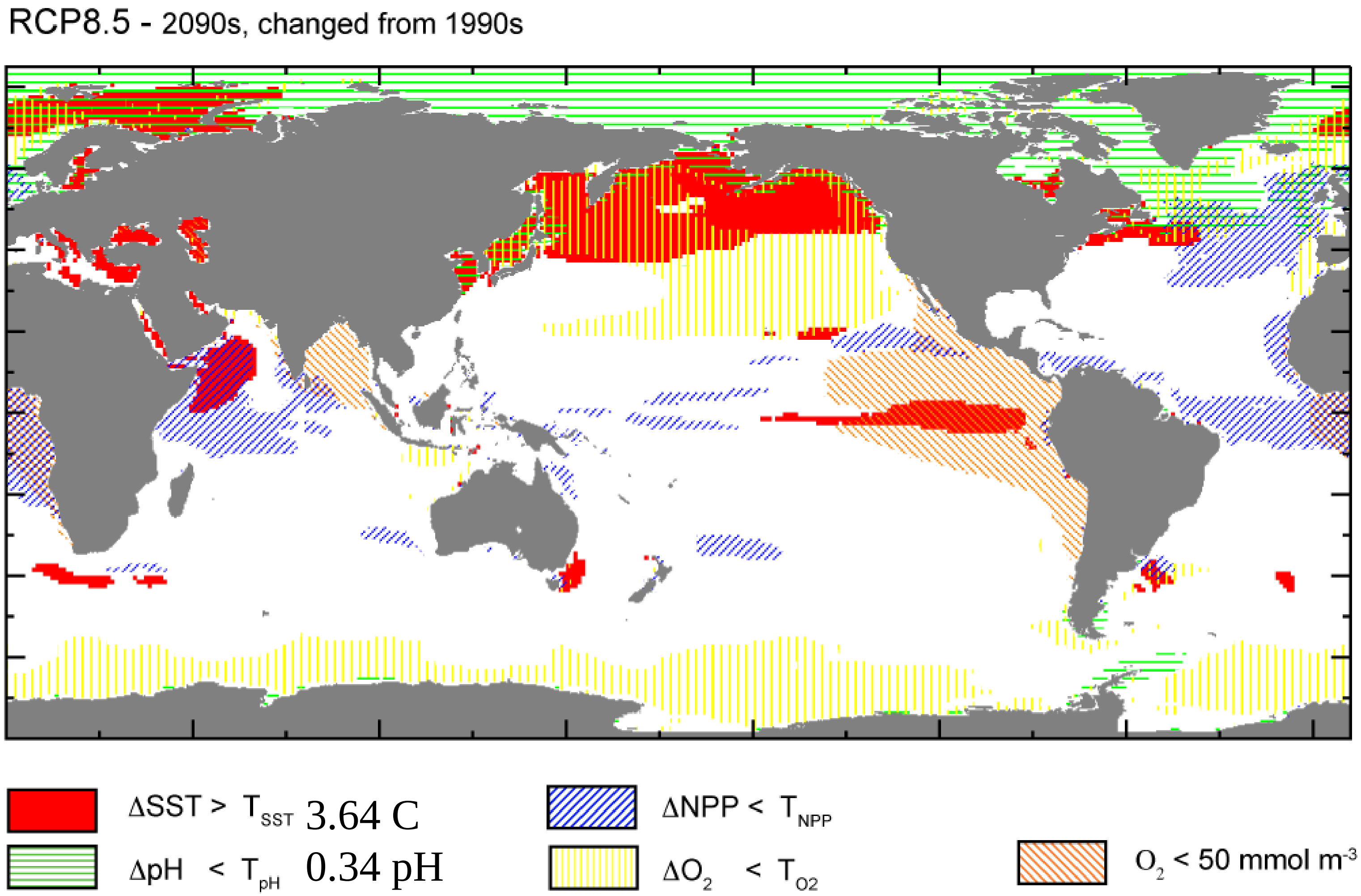
Pseudochattonella/ Alexandrium catenella

Climate Change is Multifactorial: Warming, Stratification, Light, Nutrients, Ocean Acidification, Grazing



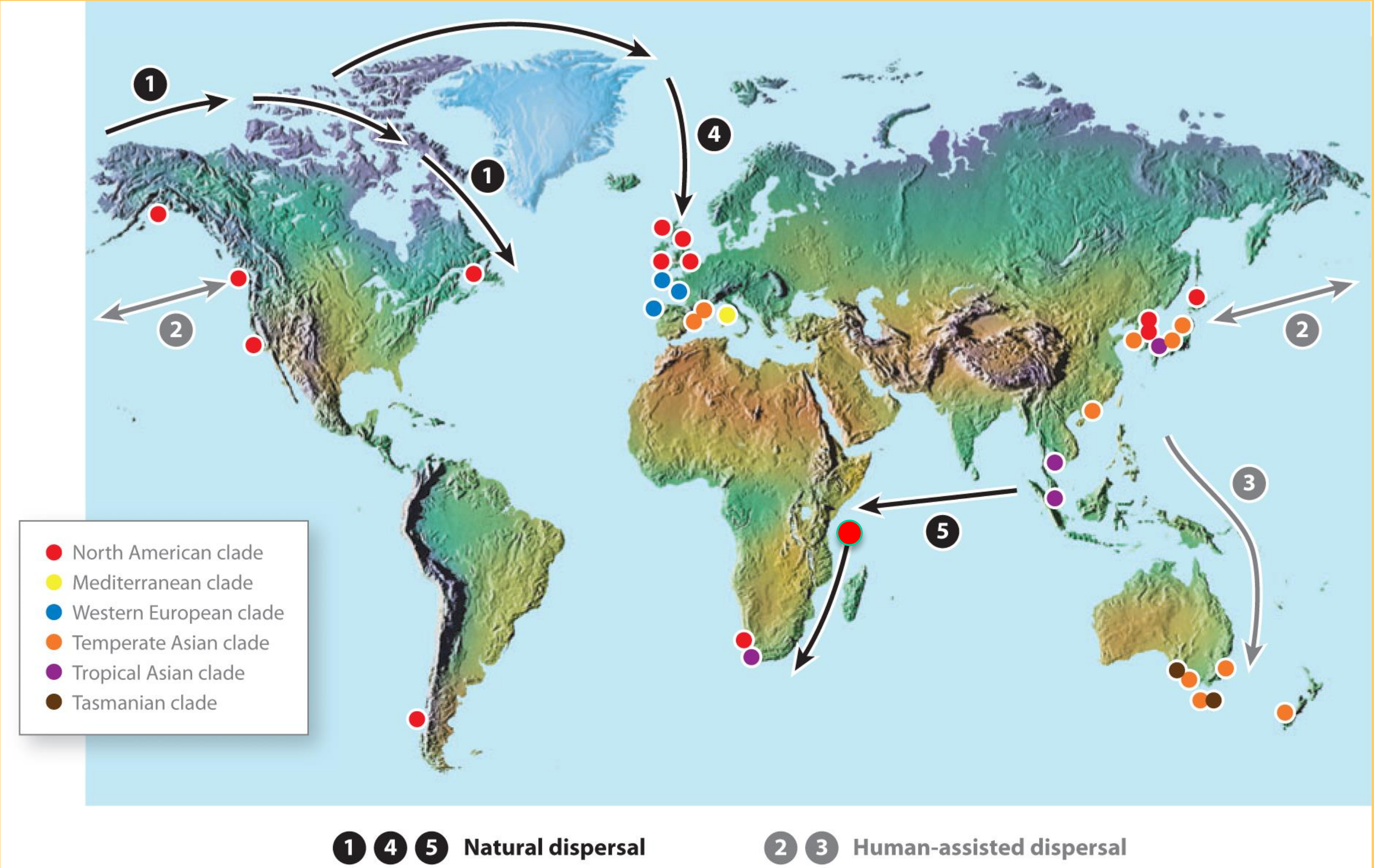
Different ocean regions change at different rates

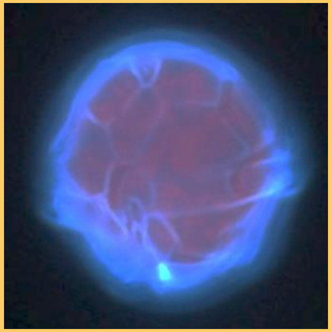
Boyd. *Nature Clim. Ch.* **5**, 71–79 (2015); Bopp. *Biogeosc. Disc.*10, 6225-45 (2013)



We need consensus on agreed observer hotspots for pH, T, N,P, O_2

A single culture strain is NOT representative of global population!

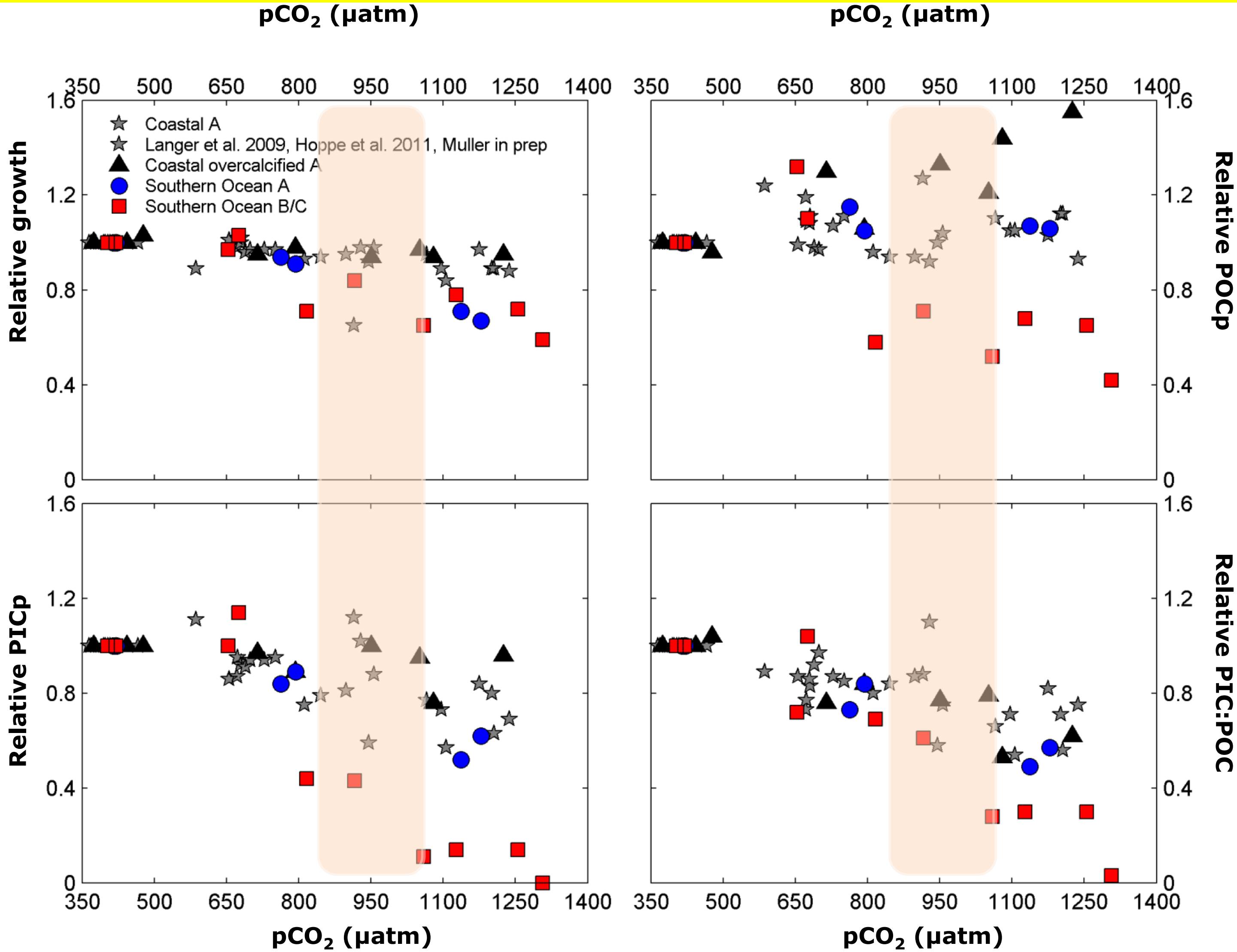




Alexandrium tamarense-species complex

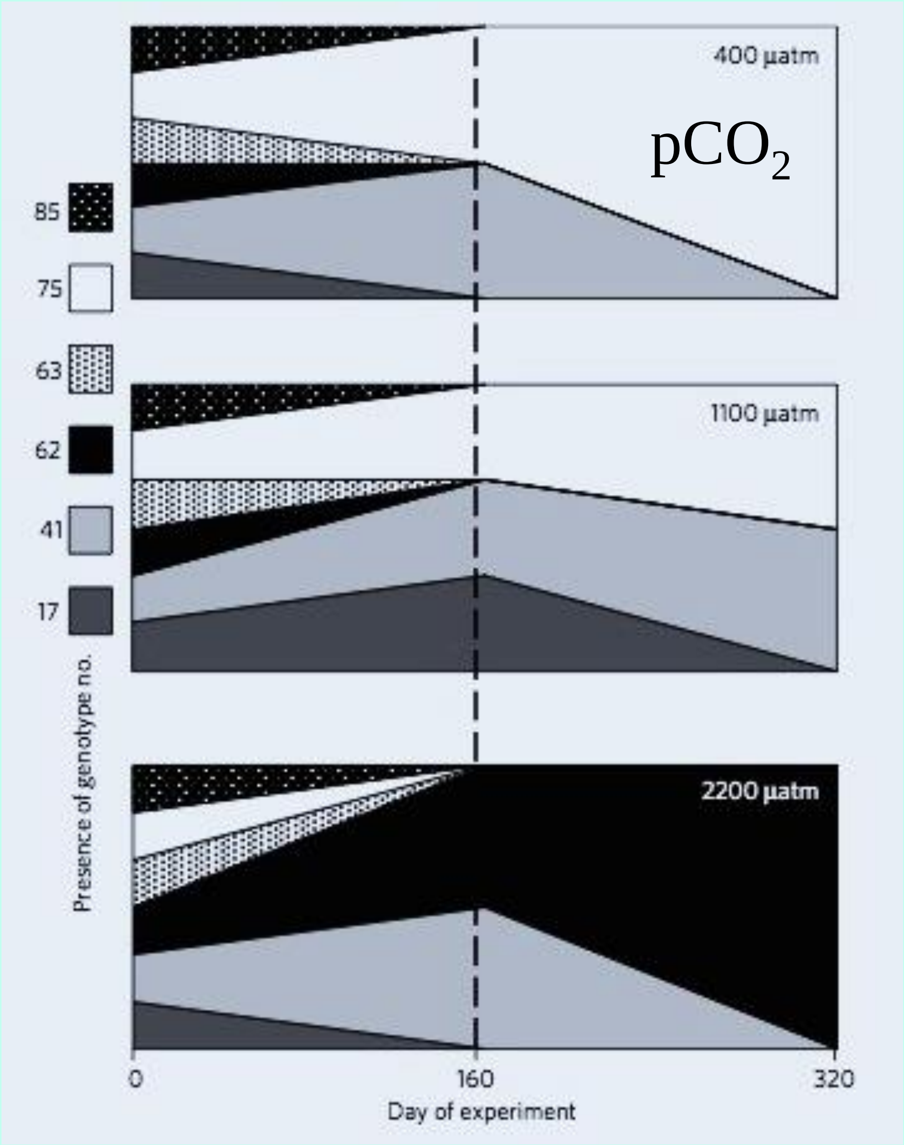
We need to work on agreed keystone species & well-defined strains

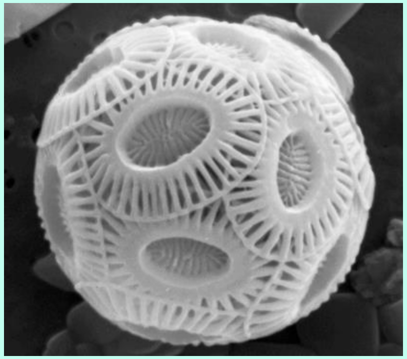
Differing responses of 3 Southern Ocean *Emiliania huxleyi* ecotypes to ocean acidification



Műller, Trull & Hallegraeff, MEPS 531, 81-90 (2015).

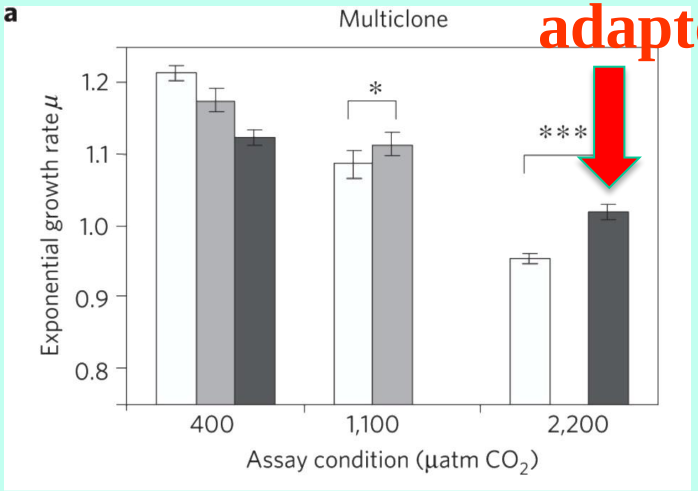
Multiclonal culture (6 genotypes)





Genetic shifts in multiclonal cultures over 500 generations

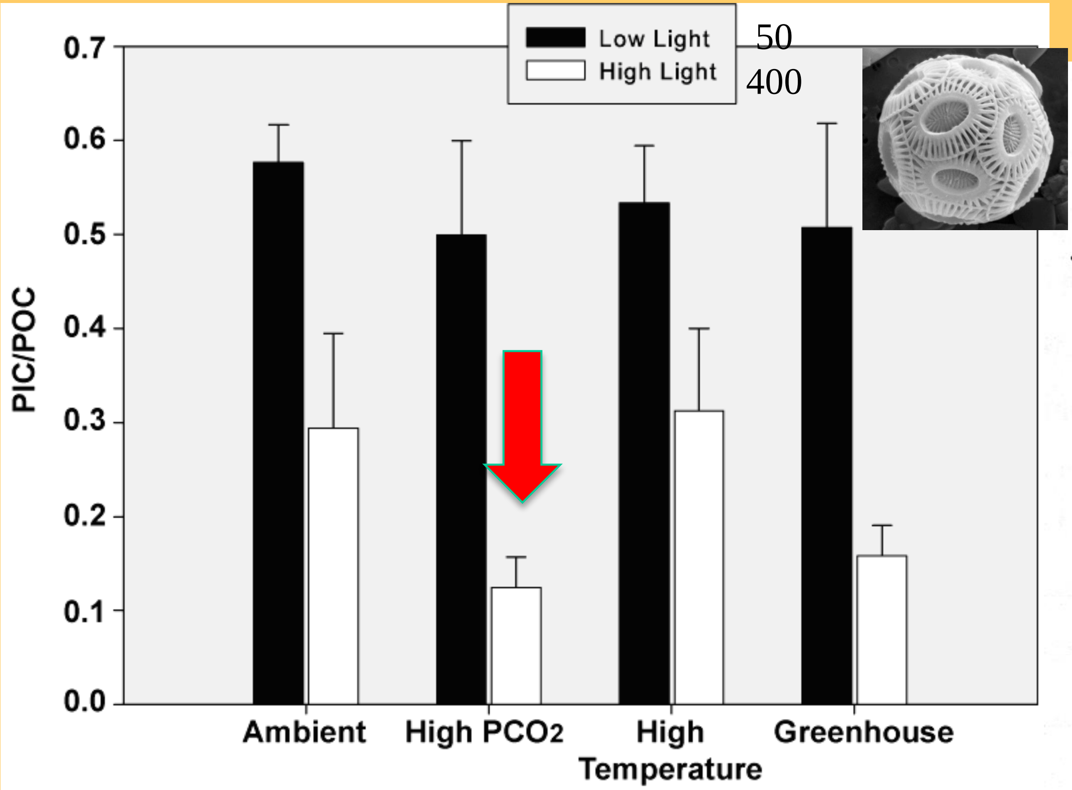
Lohbeck, Riebesell, Reusch. 2012



Microorganisms with short generation times may be able to respond to environmental alterations through adaptive evolution

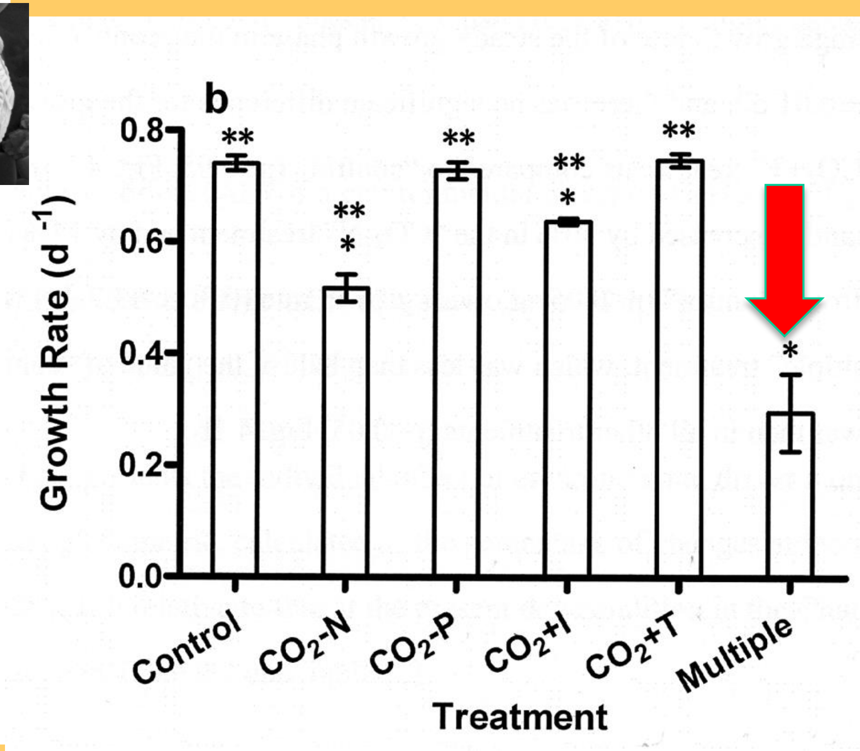
FACTOR INTERACTIONS *Emiliania huxleyi* x pCO_2

CO_2 ; Temp x light interaction



20C;375ppm 20;750 24; 375 24; 750

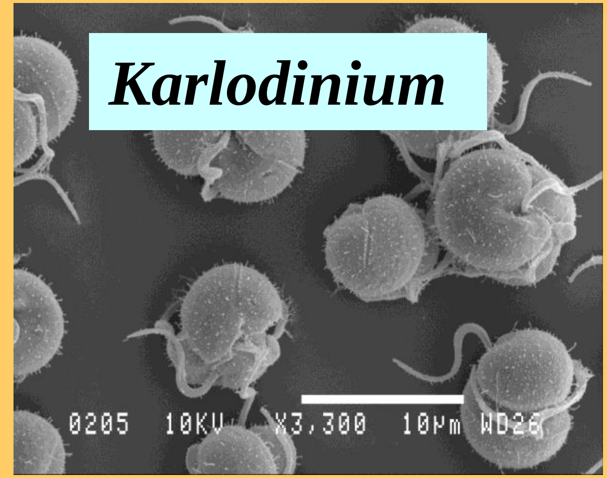
Lowest growth when changing **Multiple Drivers (N-,P-, I+,T+,CO_2+)**

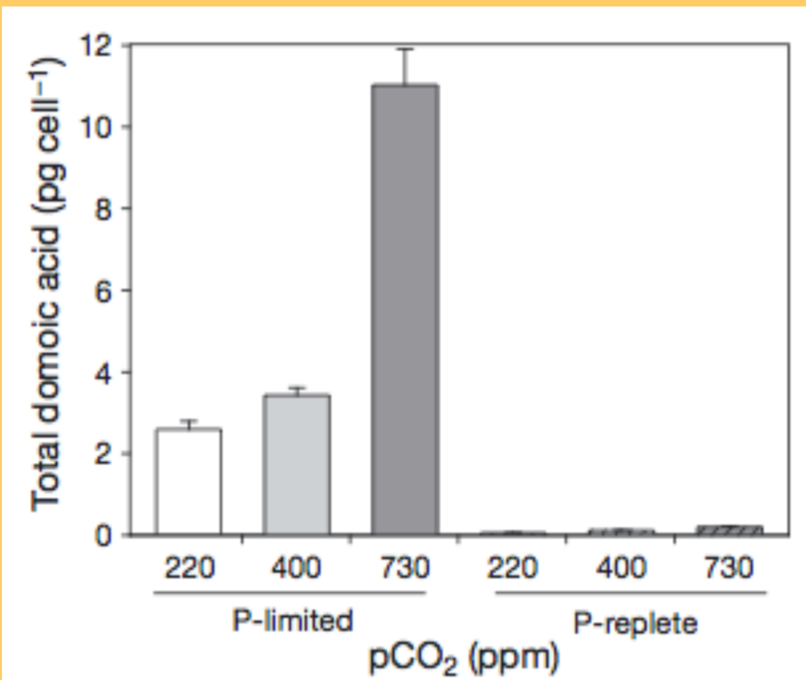


Feng 2017 Limnol.Oceanogr. 62: 519-540

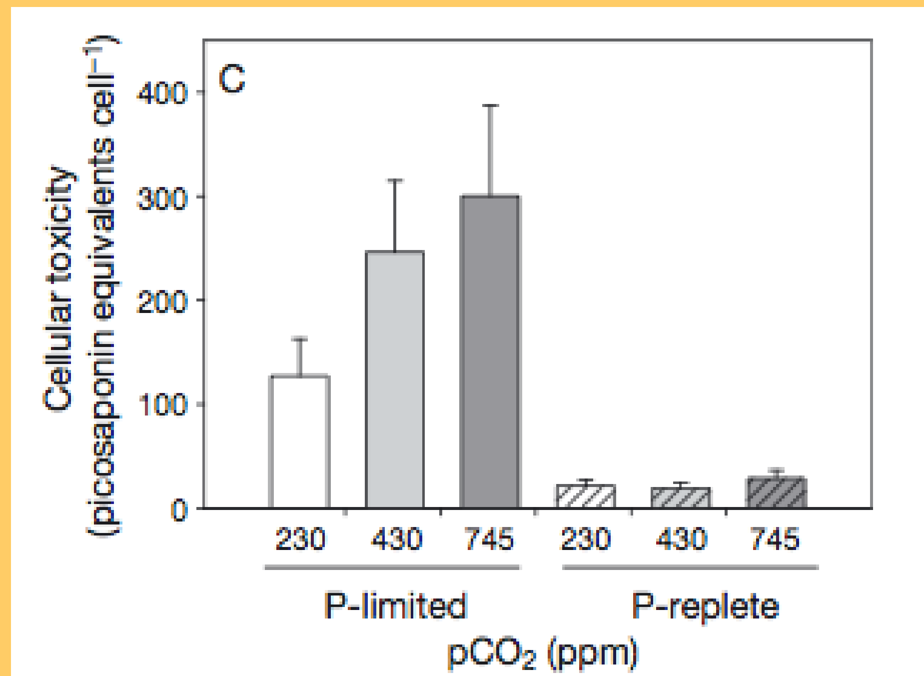
Feng et al. 2008. Eur. J. Phycol. 43:87–98.

Ocean Acidification + P limitation can alter Toxicity



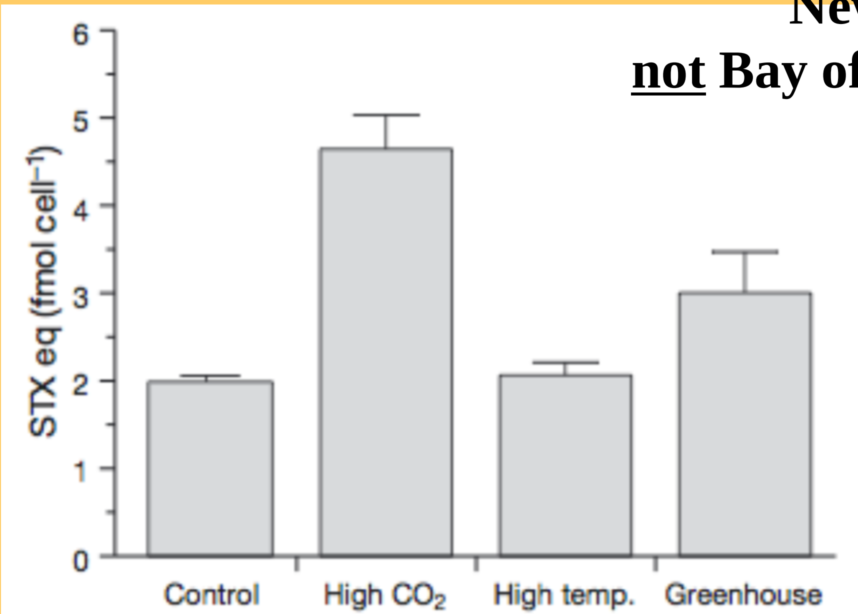


Sun et al. 2011. Limnol.Oceanogr.56:829-840



Fu et al. 2010. Aquat.Microb.Ecol.59:55-65

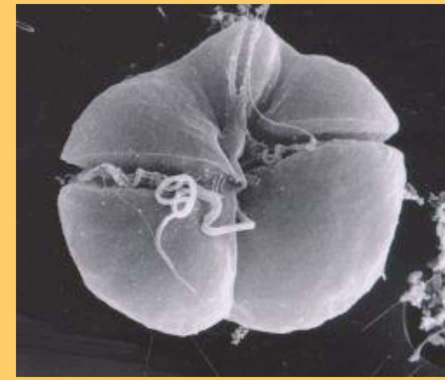
Alexandrium : more PST California strain
New York strain
<u>not</u> Bay of Fundy strain

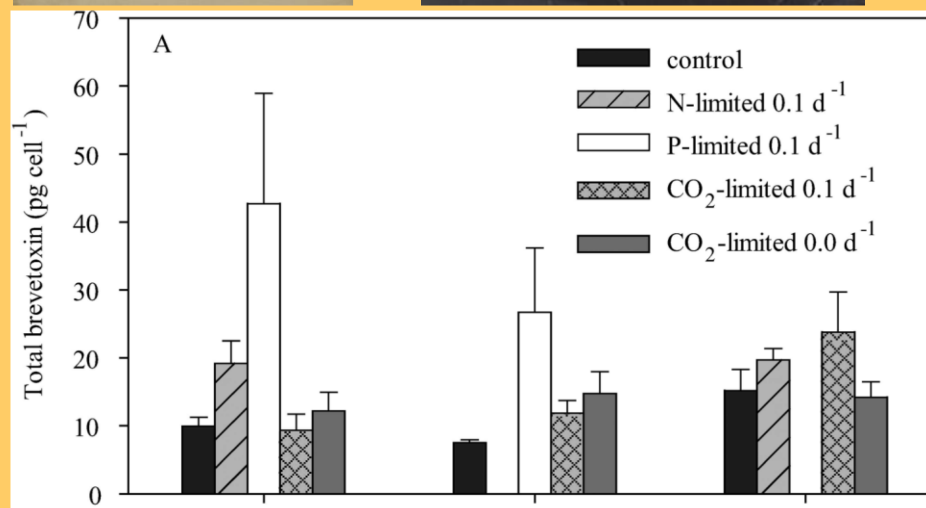


800 ppm; 15C

Tatters et al. 2013
Hattenrath-Lehmann 2014

Karenia brevis



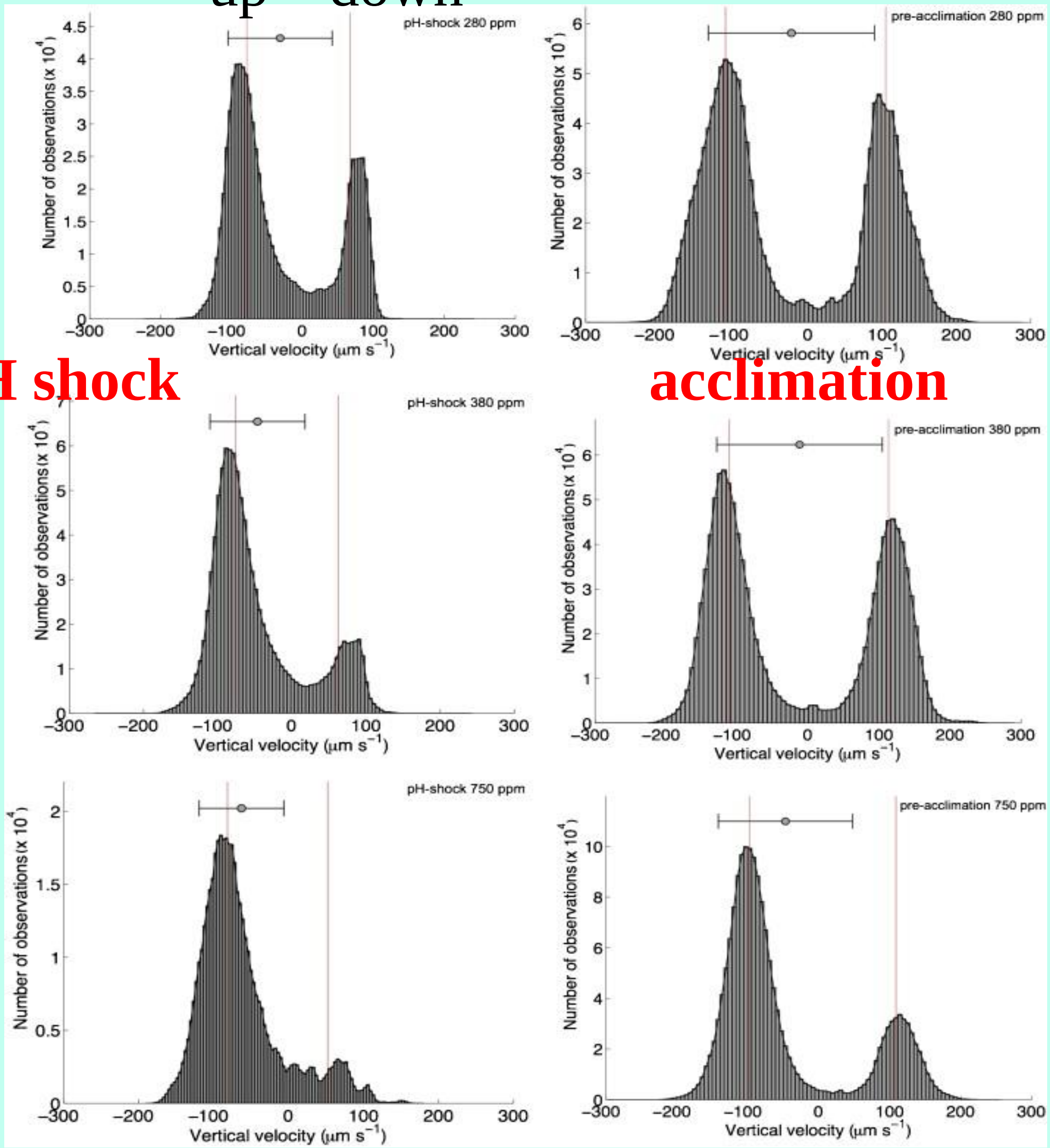


P deficiency strongest driver **BTX**
Hardison 2014

up down

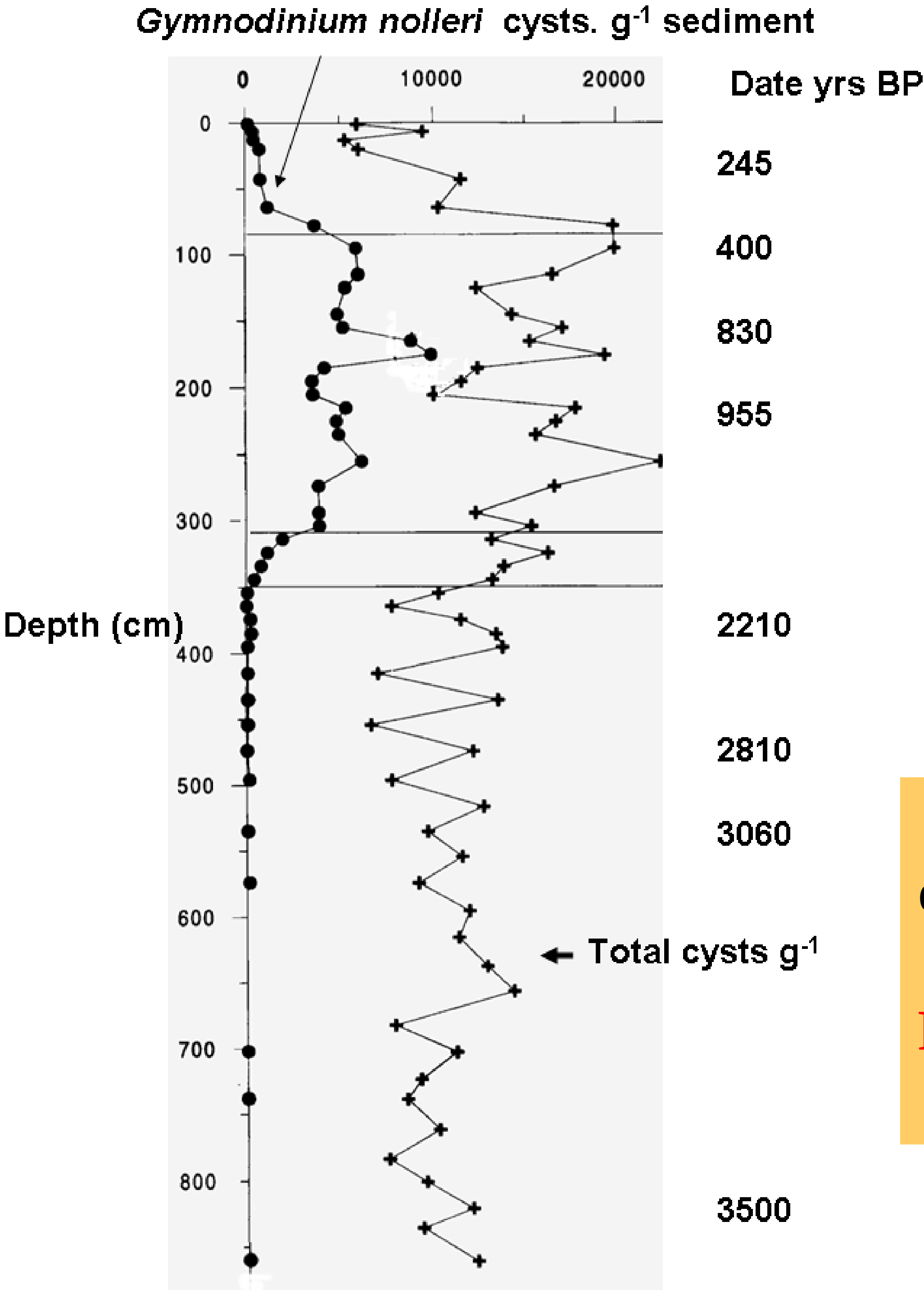
pH shock

acclimation

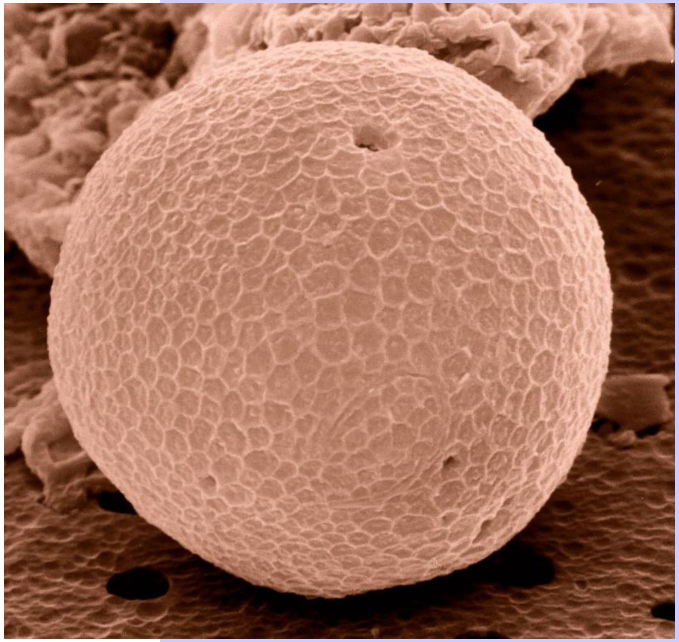


pH alters swimming behaviour of *Heterosigma* .

Kim et al. HARALG 2013



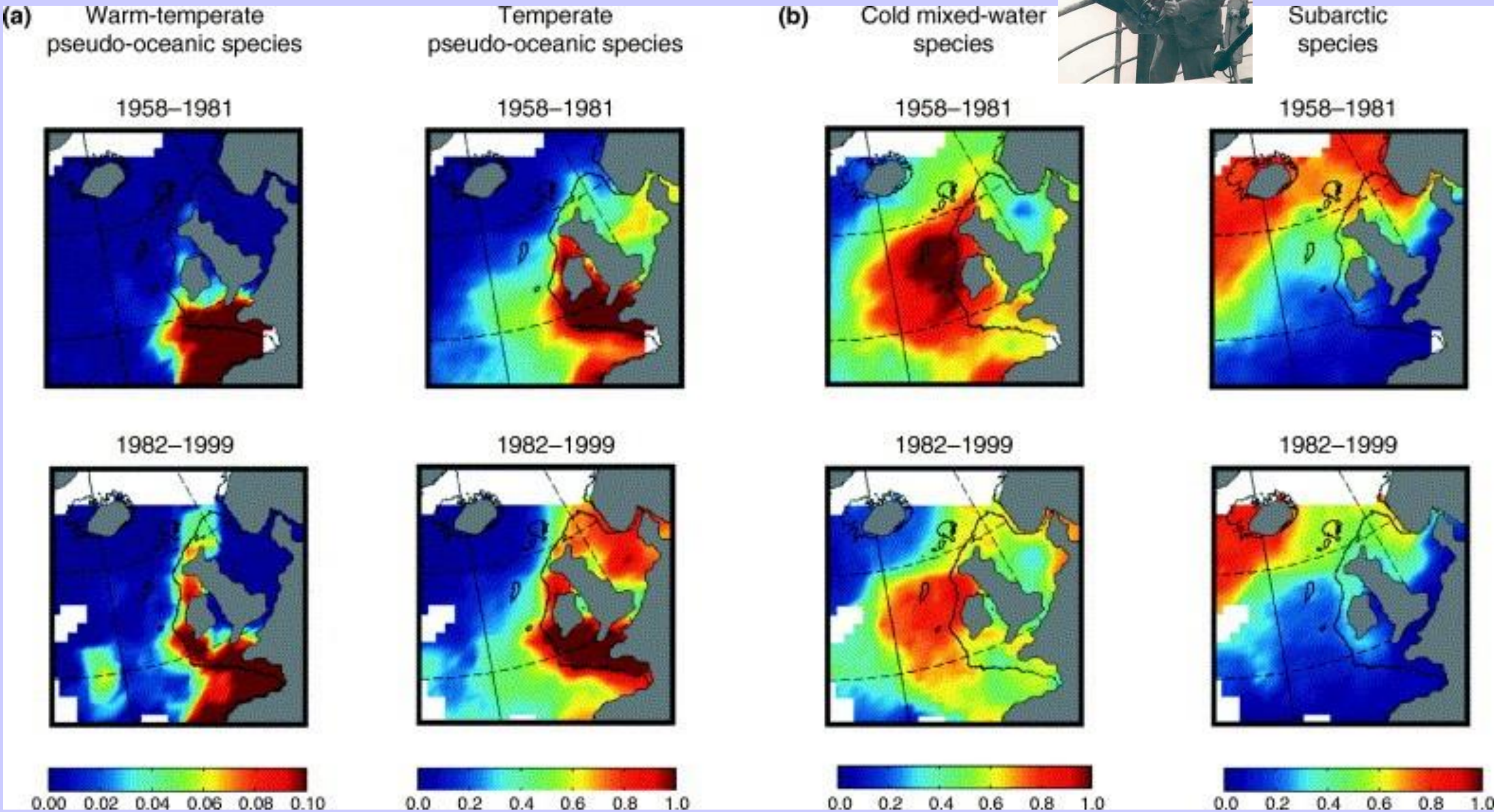
Kattegat



We can learn from the dinoflagellate cyst record

Resurrection Biology

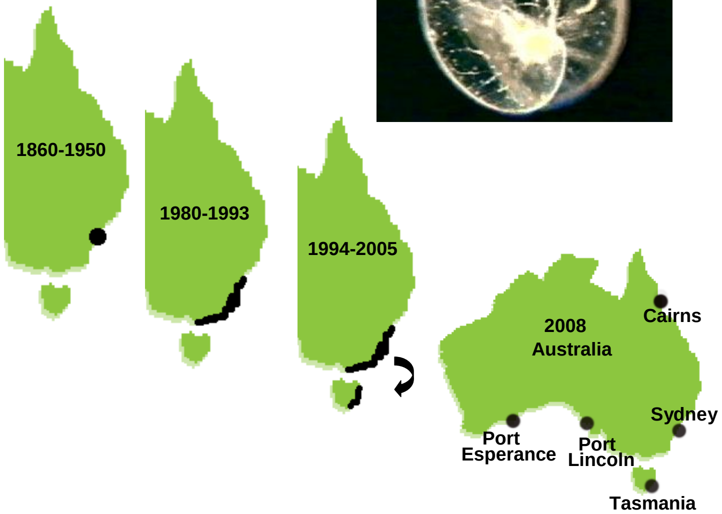
We need long-term (>30 yrs) Plankton Records

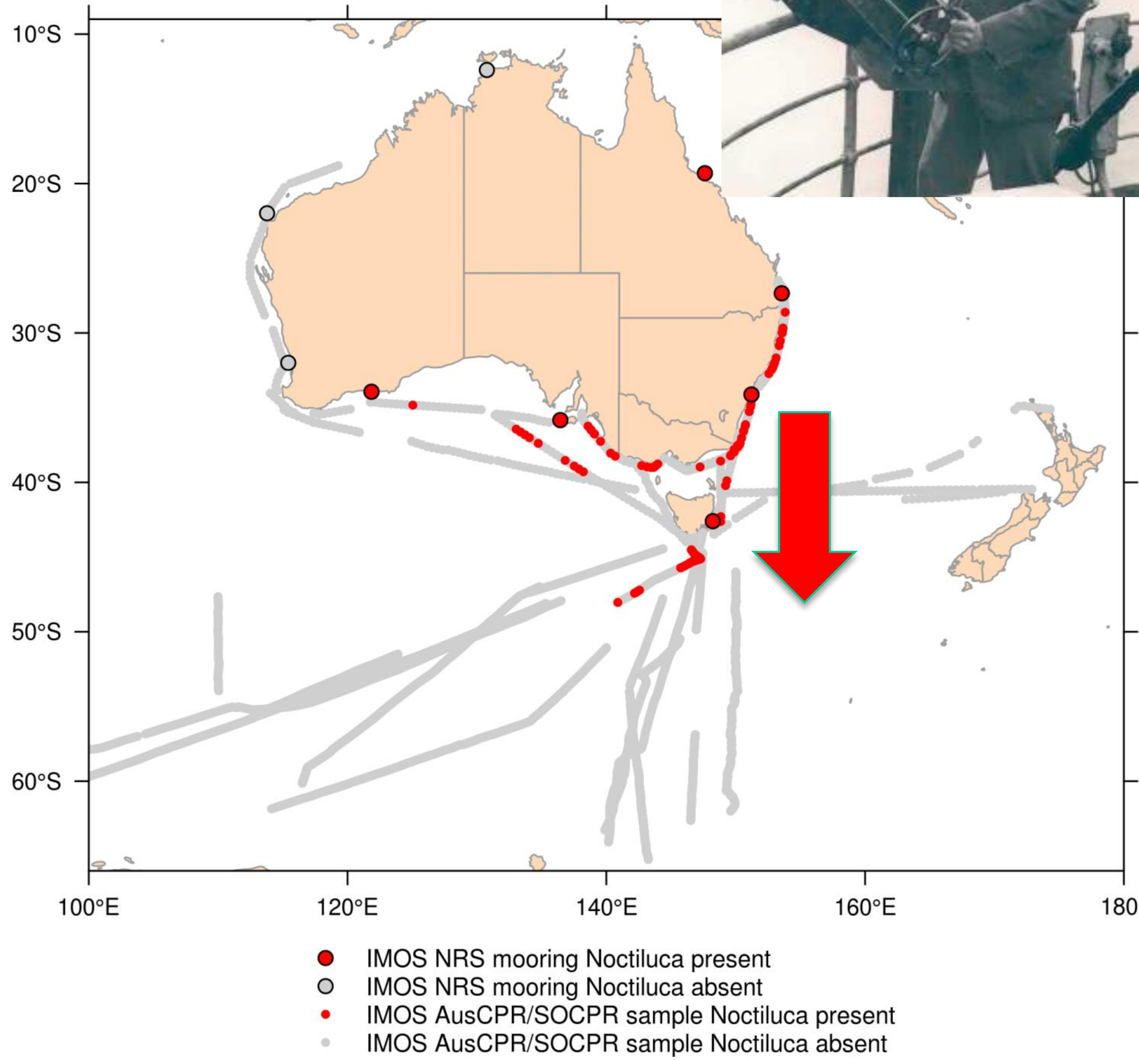


North Atlantic Zooplankton (CPR)

Pole-ward shift warm-water species; Cold-water species contract

Range Expansion Red-tide Dinoflagellate *Noctiluca*

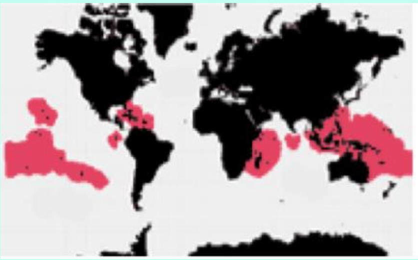




Grazing impact?

- Mediterranean and Eastern Atlantic

Is *Gambierdiscus* expanding to new areas



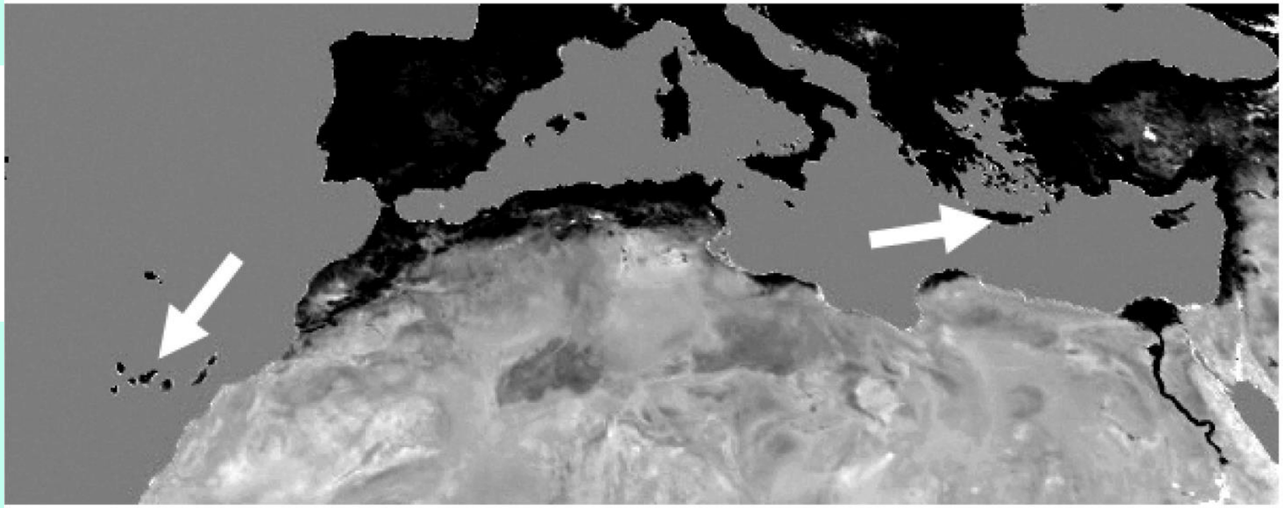
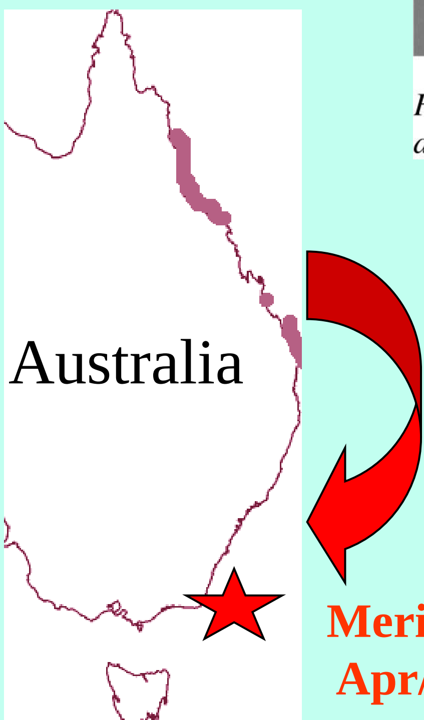
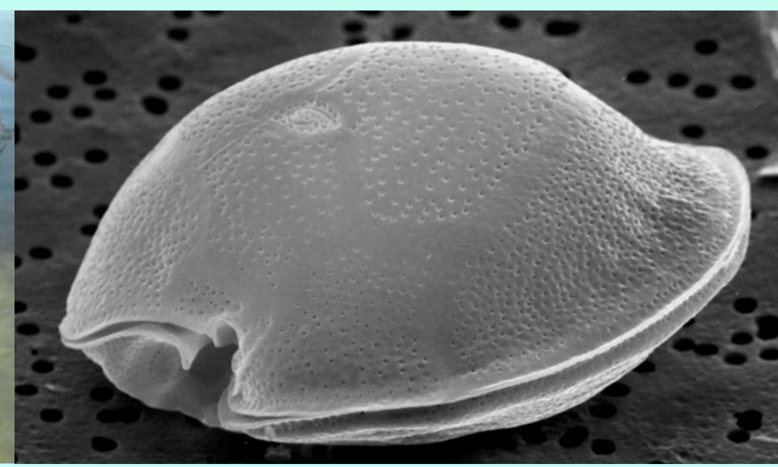


Fig. 1. Map indicating (arrows) the locations of Gambierdiscus *sp. records (Canary Islands, Spain and Crete, Greece).*

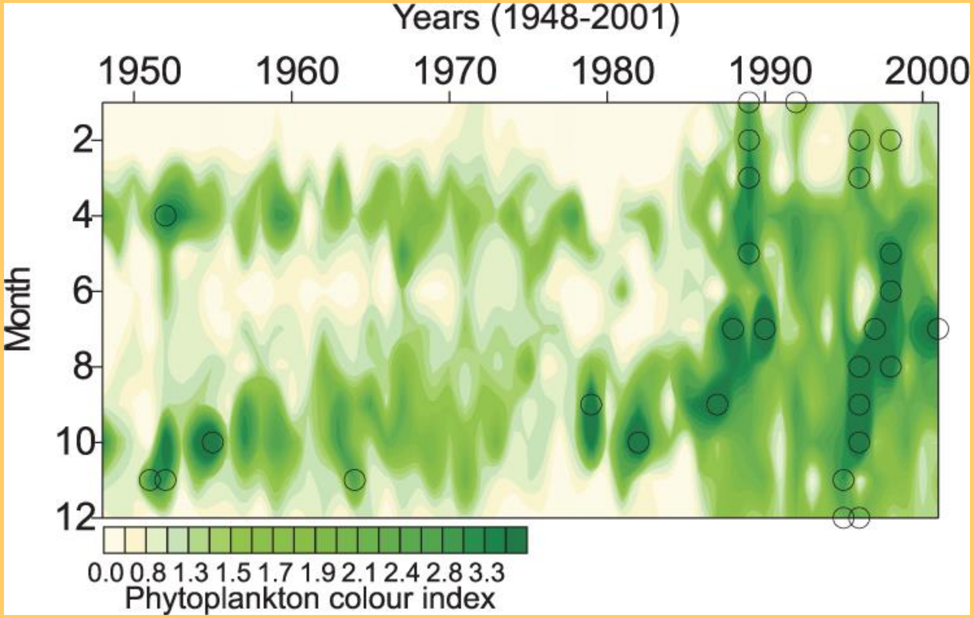


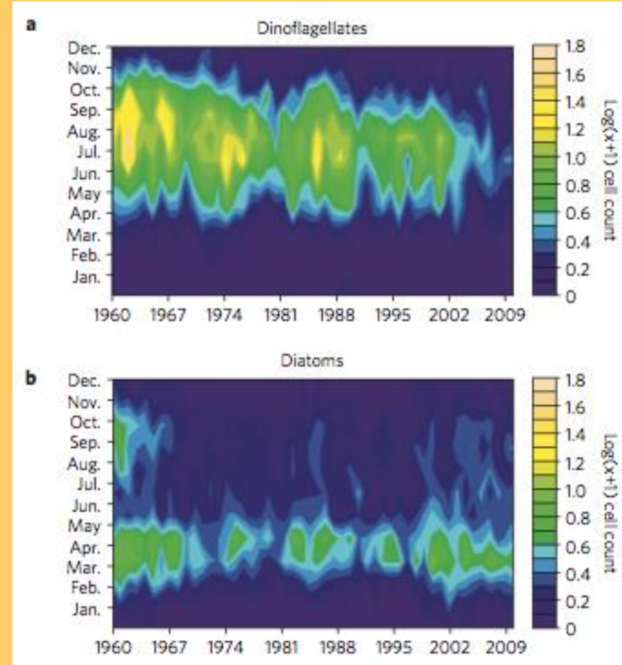
Merimbula, Apr/May 2006-2013



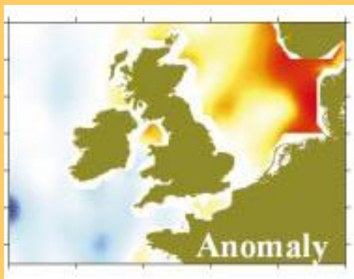
new coastal fisheries unexpectedly at risk

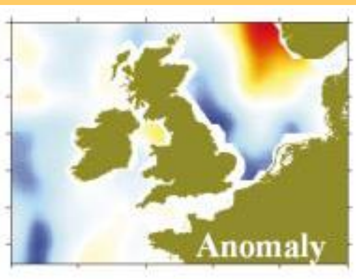
Earlier spring /autumn phytoplankton blooms in North Sea

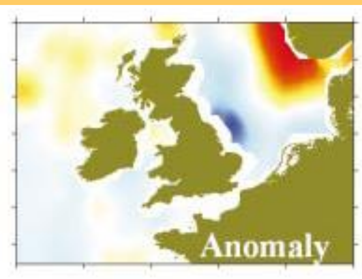


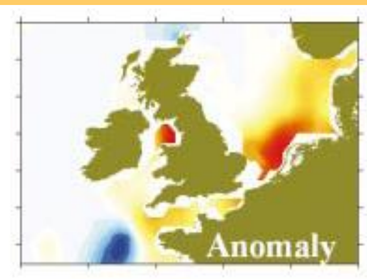


Shifts in selected HAB species in North Atlantic





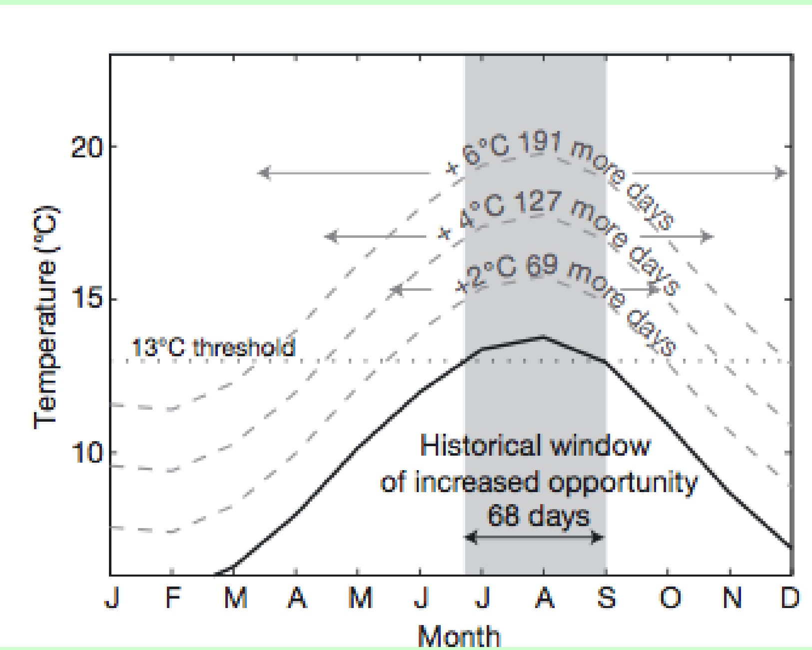




1960-1989

vs

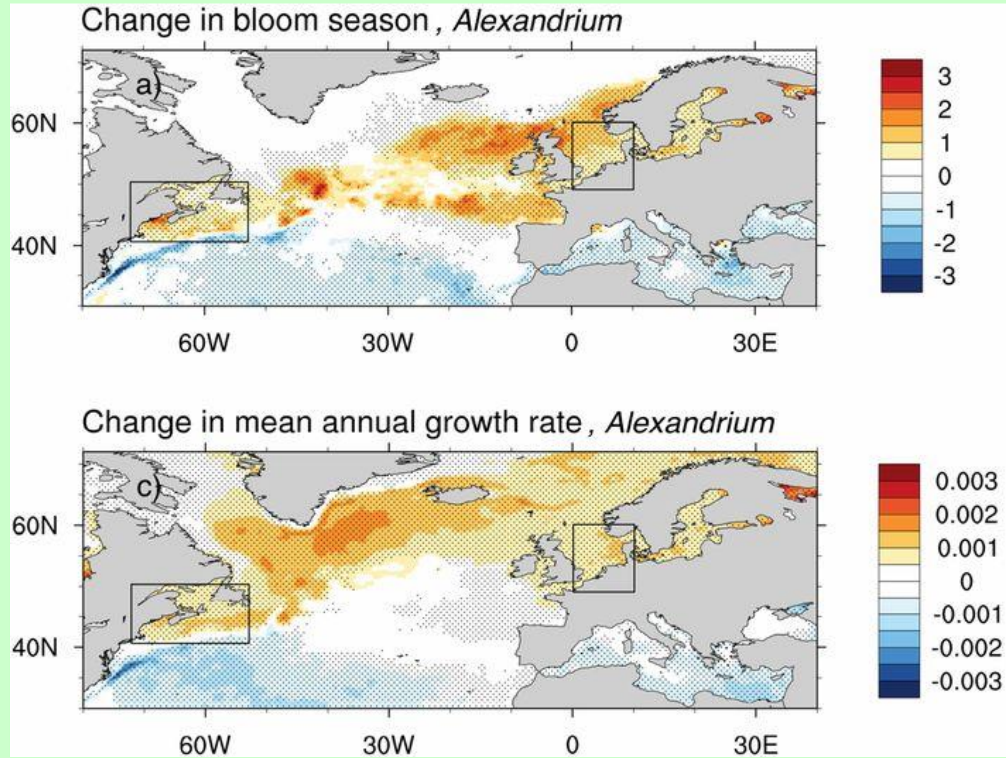
1990-2002



Moore et al. 2010

Wider Bloom Window

Modeled changes in North Atlantic 1982-2016



Gobler et al. PNAS 2017

We can expect

- Range expansion of warm-water at expense of cold-water species

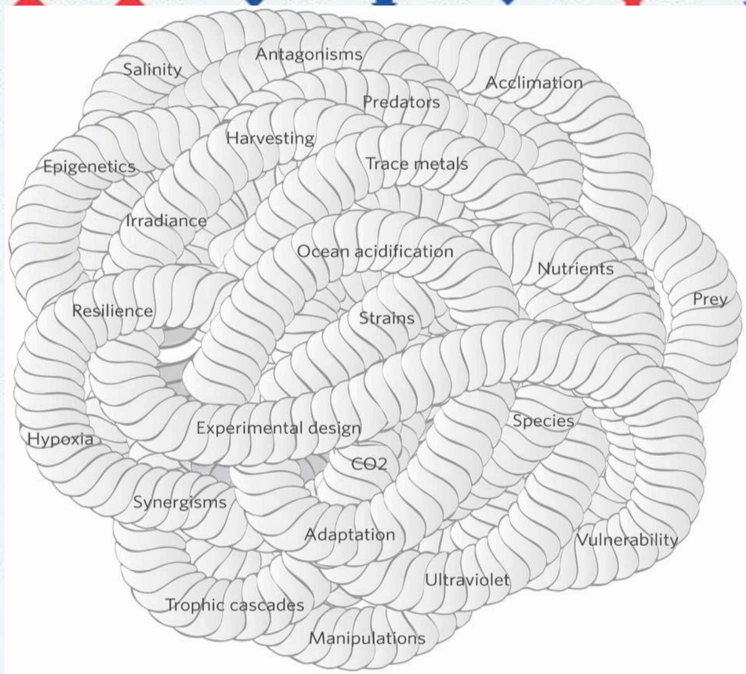
•Changes in abundance & seasonal window of growth

•Knock-on effects for marine foodwebs when individual zooplankton/fish are differentially impacted (match/mismatch)

•Ocean acidification combined with nutrient limitation or temperature changes may increase toxicity of HABs

•Increased vigilance for unexpected species invasions & food web alterations

	Physical variables							Biogeochemical variables				CO_2- system			
	Temp. (°C)	Salinity (psu)	Ice fraction –	Log_{10} MLD (cm)	PAR ($W m^{-2}$)	Windstress ($dyn cm^{-2}$)	Pot. density ($kg m^{-3}$)	Log_{10} SiO_3 ($mmol m^{-3}$)	Log_{10} PO_4 ($mmol m^{-3}$)	Log_{10} Fe ($mmol m^{-3}$)	Log_{10} NO_3 ($mmol m^{-3}$)	Alkalinity ($meq m^{-3}$)	CO_3^{2-} ($\mu mol kg^{-1}$)	pH –	p_{CO_2} (ppmv)
Global mean	2.50	−0.10	−0.03	−0.02	0.43	0.00	−0.73	−0.13	−0.31	0.07	−0.25	−6.52	−82.5	−0.33	486
SSO	1.51	−0.30	−0.19	−0.03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.01	−2.7	−51.3	−0.3	440
NSO	2.96	0.02	0.00	−0.03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.18	−4.1	−73.8	−0.3	493
SSPO	2.41	−0.02	0.00	−0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.44	−6.8	−96.2	−0.3	488
WEPO	2.53	−0.48	0.00	−0.03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.65	−9.1	−98.7	−0.3	482
EEPO	2.80	−0.16	0.00	−0.04	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.36	−7.2	−73.1	−0.3	447
NSPO	2.44	−0.17	0.00	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.46	−7.8	−96.6	−0.3	493
NPO	3.22	−0.45	0.00	−0.03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.11	−7.3	−66.2	−0.3	491
SIO	2.62	−0.20	0.00	0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.25	−4.7	−96.1	−0.3	494
NIO	2.70	−0.19	0.00	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.19	−7.8	−96.6	−0.3	483
SAO	2.38	0.08	0.00	−0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.27	−6.9	−93.3	−0.3	482
NSAO	2.37	0.55	0.00	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0.19	−5.18	−96.0	−0.3	494
NAO	1.94	−0.19	−0.04	−0.08	1.49	−0.06	−0.57	−0.16	−0.20	0.05	−0.16	−12.0	−81.9	−0.4	495
AO	1.51	−0.30	−0.19	−0.03	3.67	0.18	−0.35	−0.08	−0.01	0.01	−0.01	−16.3	−48.8	−0.3	440



Red arrows denote an increase, and blue arrows denote a decrease in an ocean property. The arrows are scaled according to the regional deviation from the global mean; larger arrows indicate a stronger regional anomaly relative to the global mean anomaly, and smaller arrows a weaker regional anomaly. Together, these regional deviations, across ocean properties, drive distinctive patterns in multi-stressors. The acronyms for the regions are defined in Fig. 2 and Supplementary Fig. 1.

Regional anomalies

Largest regional anomaly   Global mean   Smallest regional anomaly

Multiple Stressors/ Feedbacks

Major Departure from current HAB approaches

LAB

- **Study <u>multiple strains</u>**
- **Best practices experimental techniques (<u>adaptation</u>)**
- **<u>Multifactorial</u> experiments should be norm**
- **Hypotheses why OA etc impact on cellular toxicity**
- **<u>Global</u> extrapolations via mathematical modelling**

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

GEOHAB

FIELD

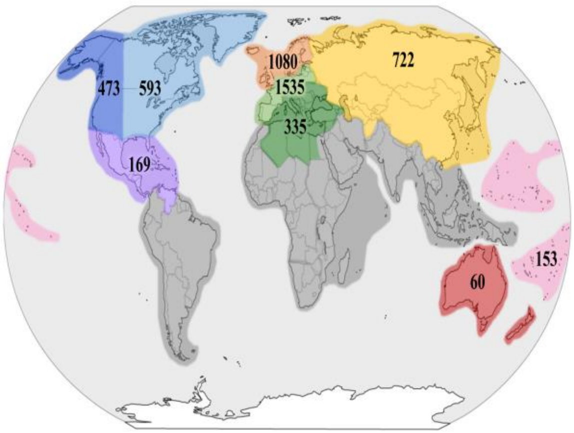
- **High quality long-term time series (CPR, micropaleontology)**
- **Recommended <u>hot spot observer sites</u>**
- **Study HABs as part of total phytoplankton**
- **Learn from unusual Climate Events (eg. El Ñino)**
- **Better collaborate & partition this formidable task!**

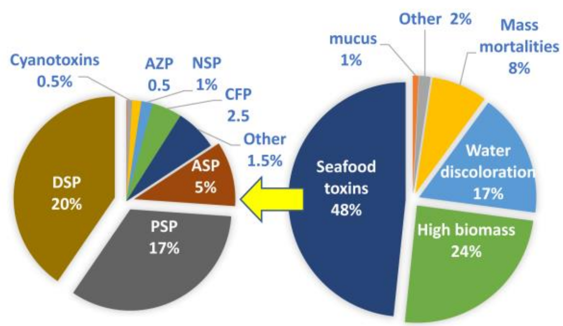
United Nations Educational, Scientific and Cultural Organization

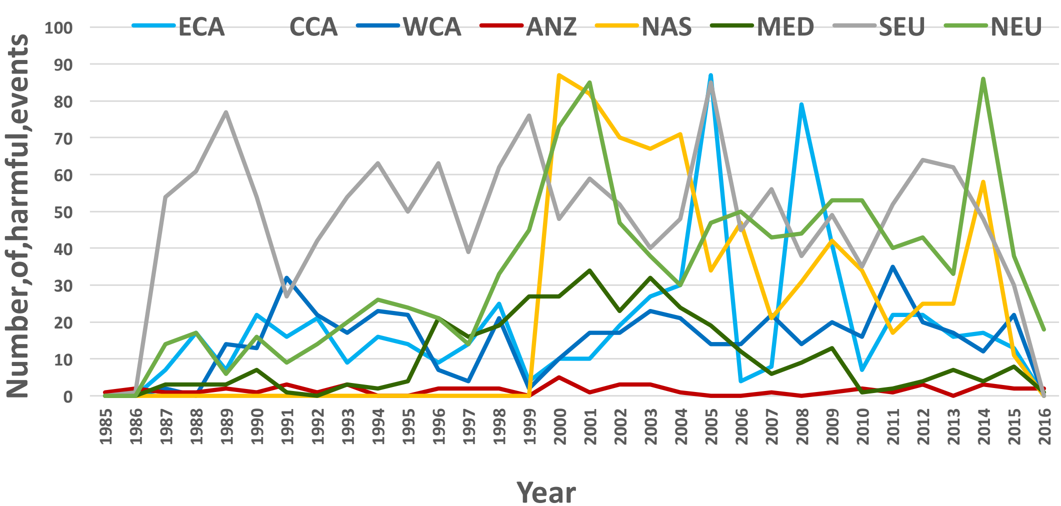
Intergovernmental Oceanographic Commission

Global HAB Status Reports

HAEDAT

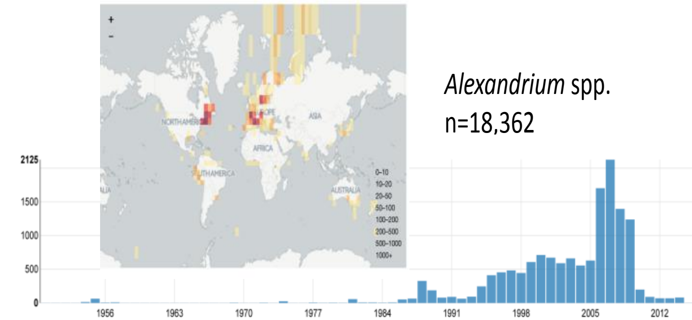




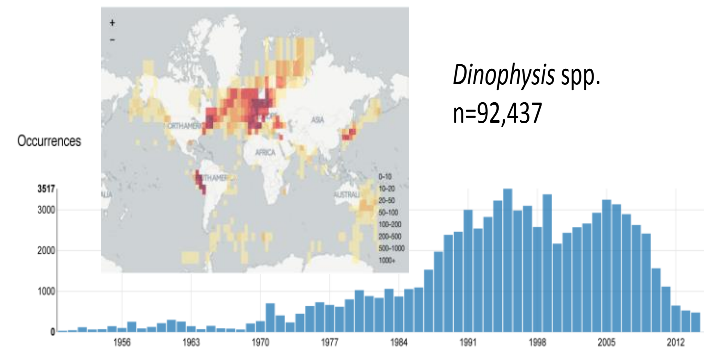


Ines Sunesen (South America minus Venezuela (Pat Tester)

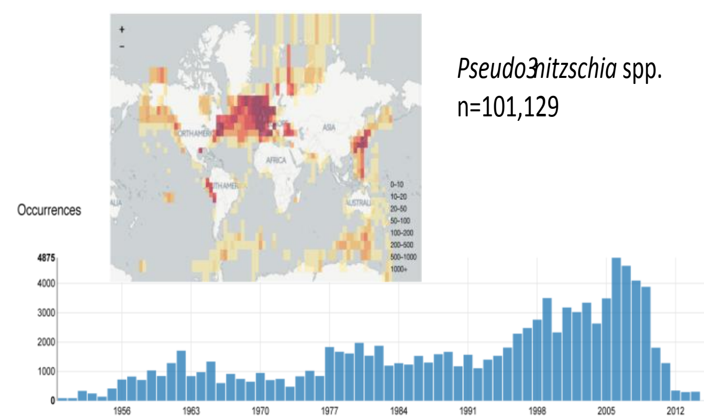
OBIS



Alexandrium spp.
n=18,362



Dinophysis spp.
n=92,437



Pseudo3nitzschia spp.
n=101,129