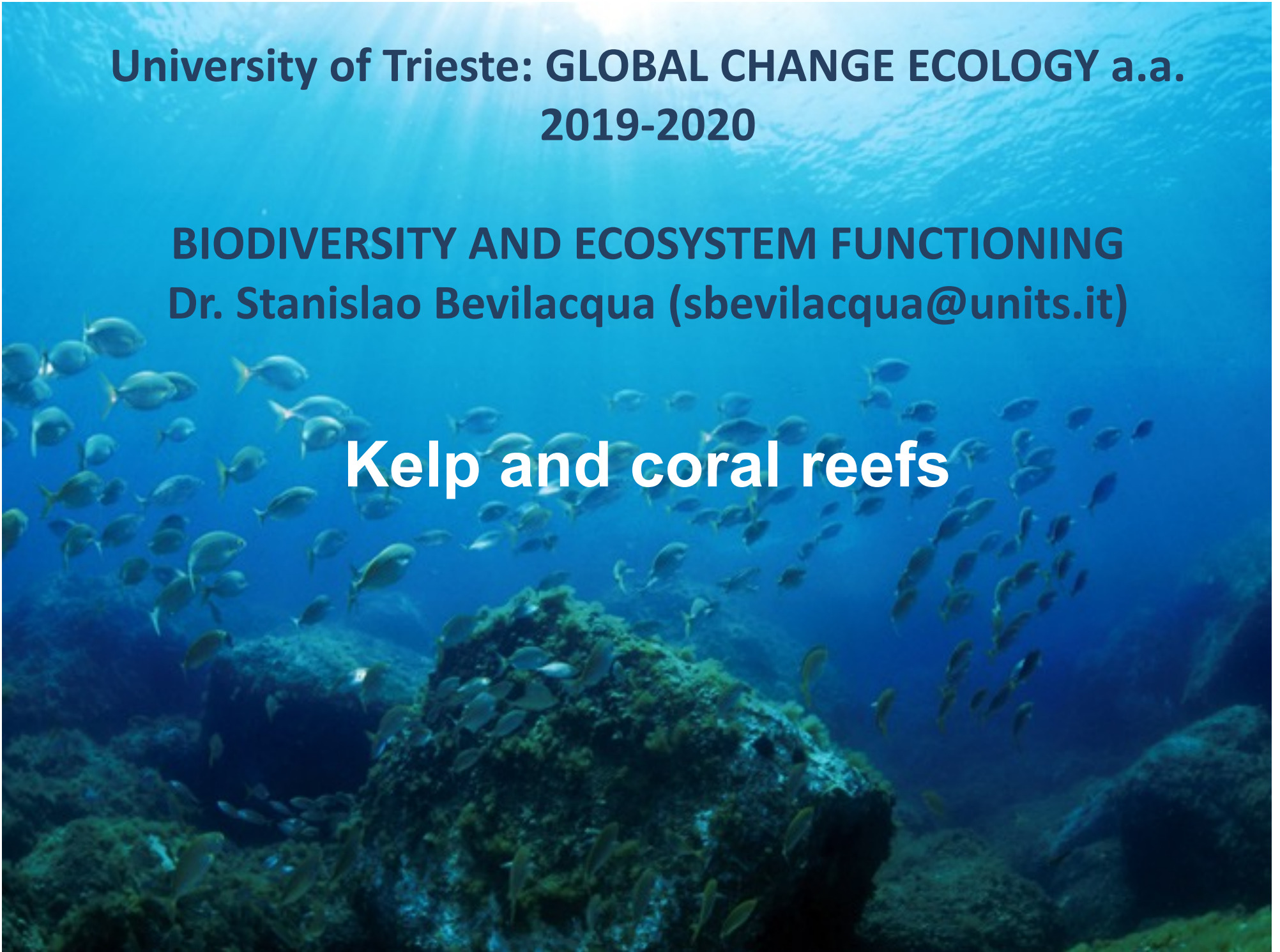


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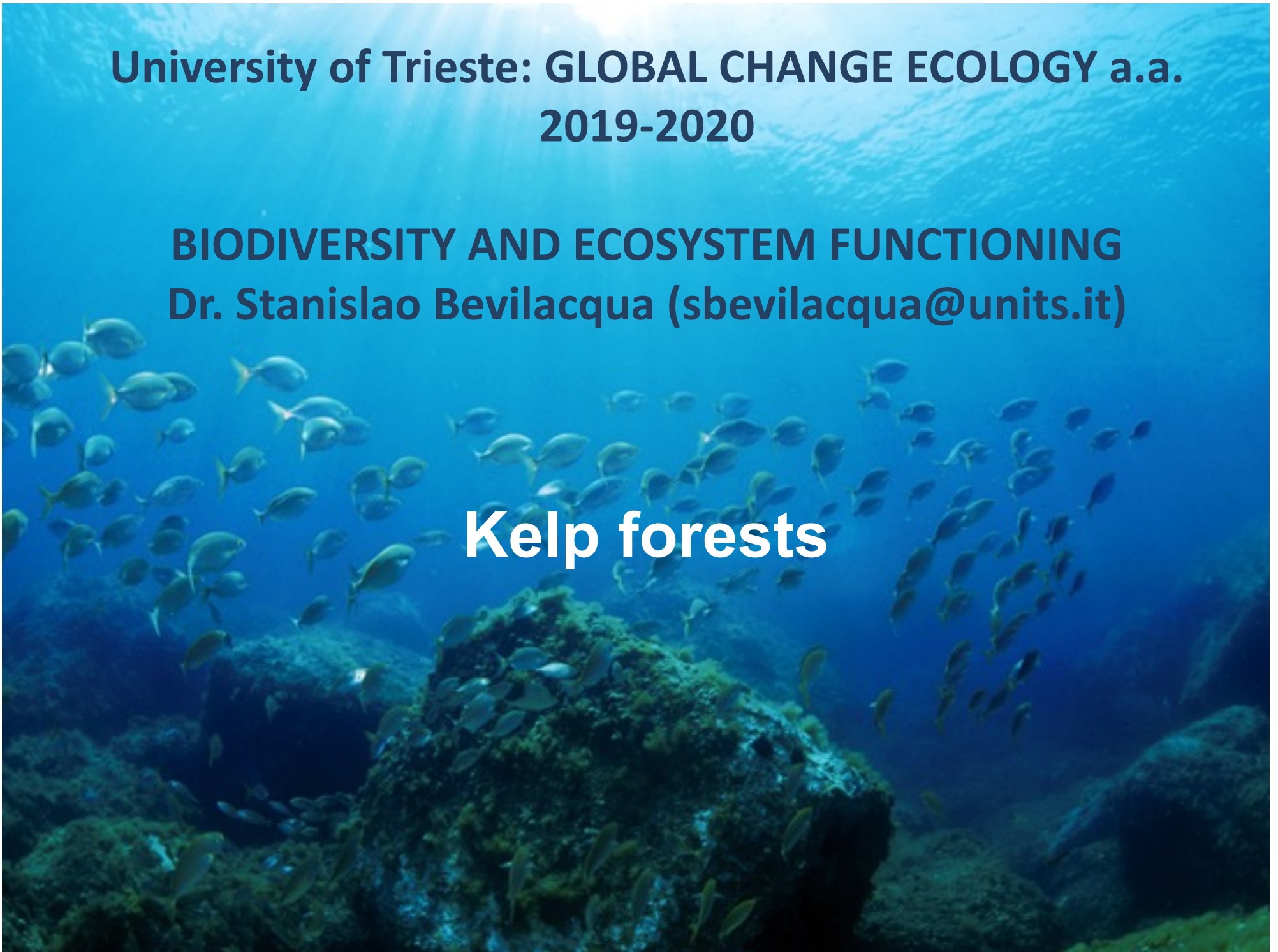
# **Kelp and coral reefs**



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**Kelp forests**





# Kelp

- Ochrophyta – Phaeophyceae – Order: Laminariales
- About 20 Mya
- Large marine brown algae
- Typical of cold-temperate areas and rocky substrates
- Depth 2->30 m
- Fast growth rates (up to 60 cm per day)

Kelp common name including >150 species complex

	LAMINARIALES	
	GENERE	SPECIE
<i>Emisfero Nord :</i>		
Artico	4	13
W-N Pacifico	16	50
E-N Pacifico	20	44
W-N Atlantico	5	13
E-N Atlantico	6	24
<i>Emisfero Sud:</i>		
Sud Africa	3	4
Australia S	4	5
Nuova Zelanda	4	7

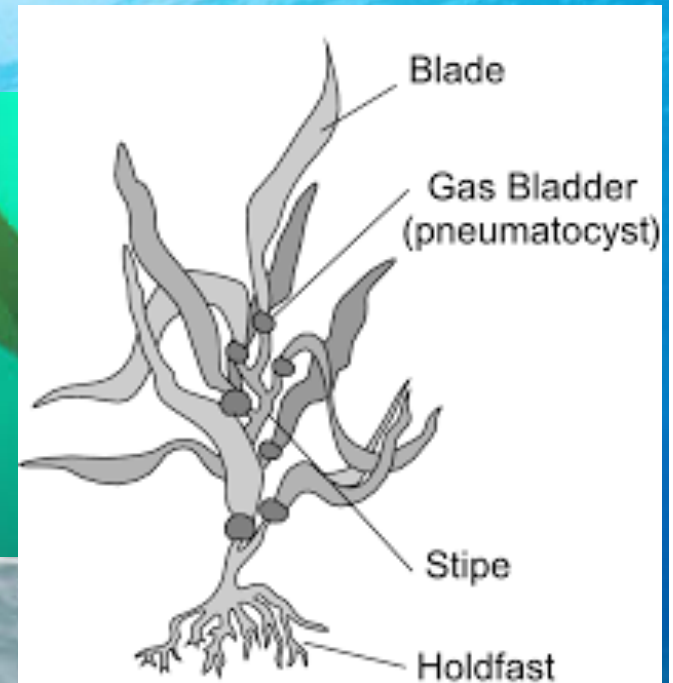
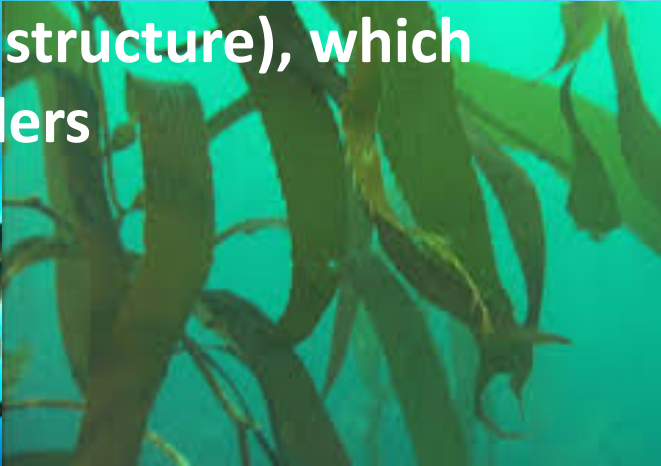
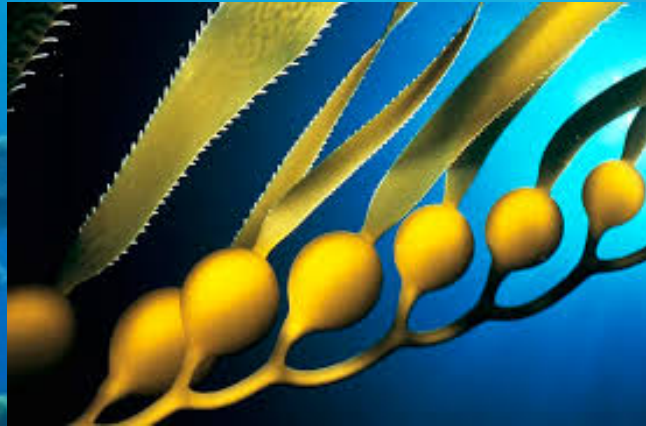




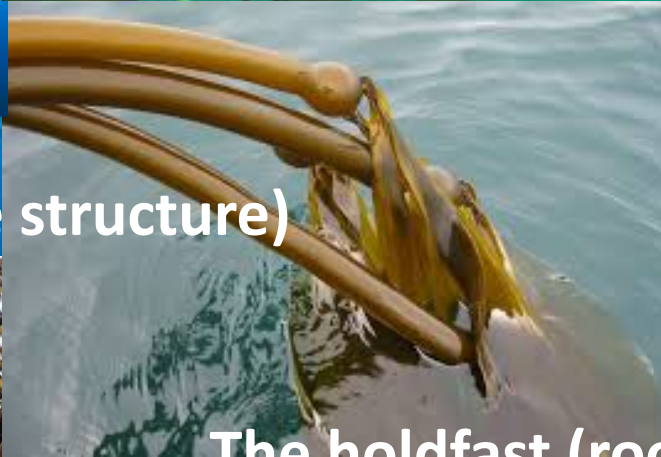
# Three-dimensional structure

Kelp has three parts:

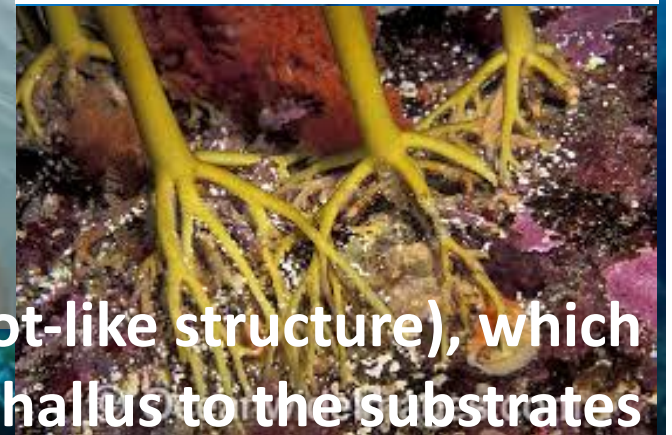
The blade (the leaf-like structure), which are buoyed by air bladders



The stipe (the stem-like structure)



The holdfast (root-like structure), which anchor the thallus to the substrates



Thalli do not dry up at low tide because cell walls contain a mucilaginous, water retaining material



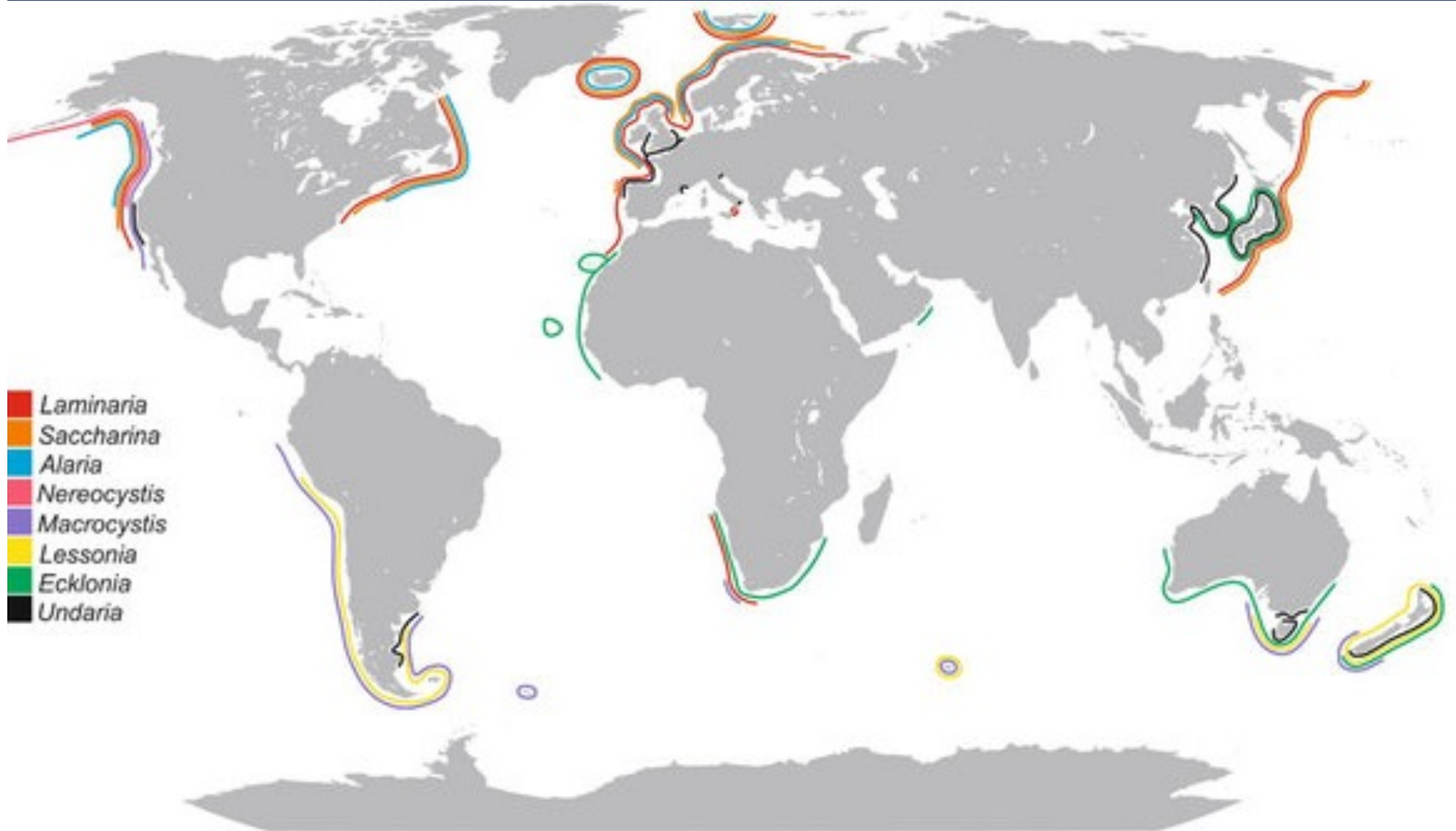
# Forests

They form large and dense underwater forests (thalli until 50 m height), similar to terrestrial ones, hosting a variety of species among their fronds and in the understory. Kelps are the most prominent constituents of the lower intertidal and subtidal of Atlantic and Pacific rocky shores of temperate regions of both the Northern and Southern Hemisphere.

As for terrestrial deciduous forests, kelp forests exhibit strong seasonality. Starting from late summer, kelp start to shed old blades. Winter storms and wave action drastically reduce kelp fronds. From late spring kelp renew from vegetative growth and new recruits.



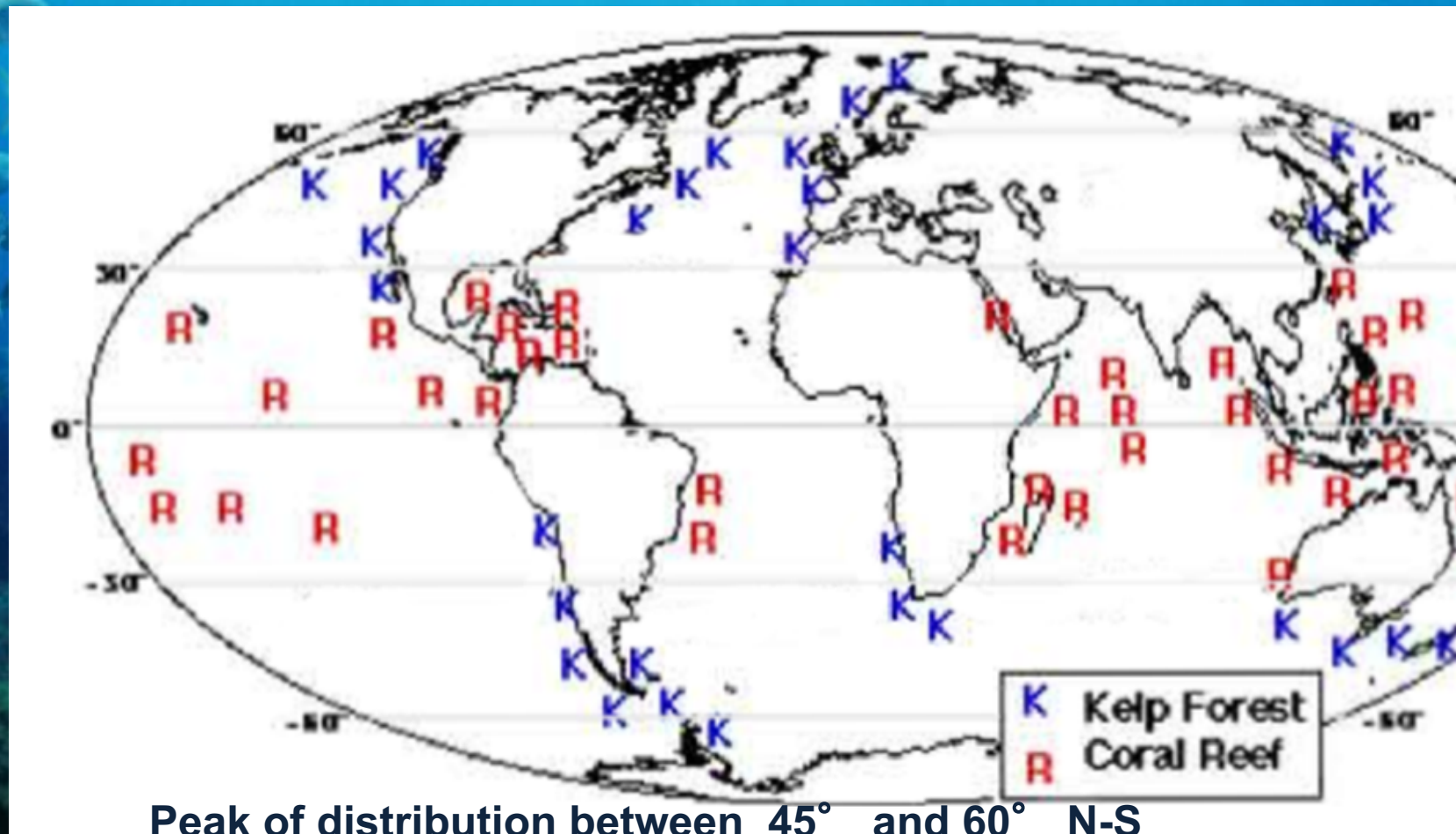
# Distribution





# Factors influencing distribution

Geographical distribution is limited by ice and light poleward and by water temperature and limited nutrient availability towards tropical zones  
Kelp require nutrient-rich water with temperatures between 6 and 14 ° C  
Most productive kelp areas in presence of upwelling, which provides cold currents and nutrient supply.





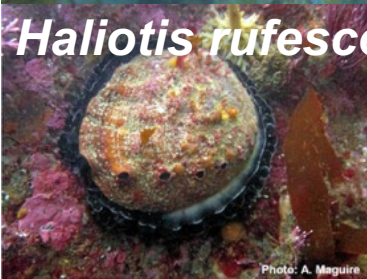
# Biodiversity

Kelp forests are structurally complex and highly productive components of cold-water rocky marine coastlines, hosting thousands species including algae, invertebrates and vertebrates

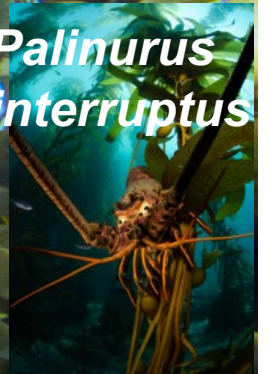


*Phoca vitulina*

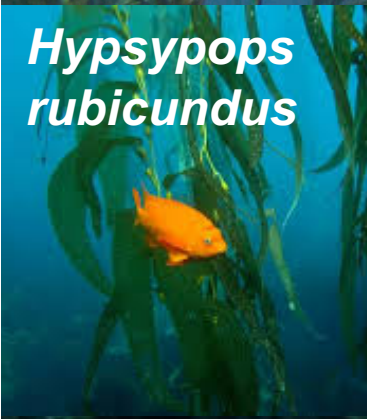
*Haliotis rufescens*



*Palinurus interruptus*



*Hypsypops rubicundus*



*Strongylocentrotus droebachiensis*



*Heterodontus francisci*



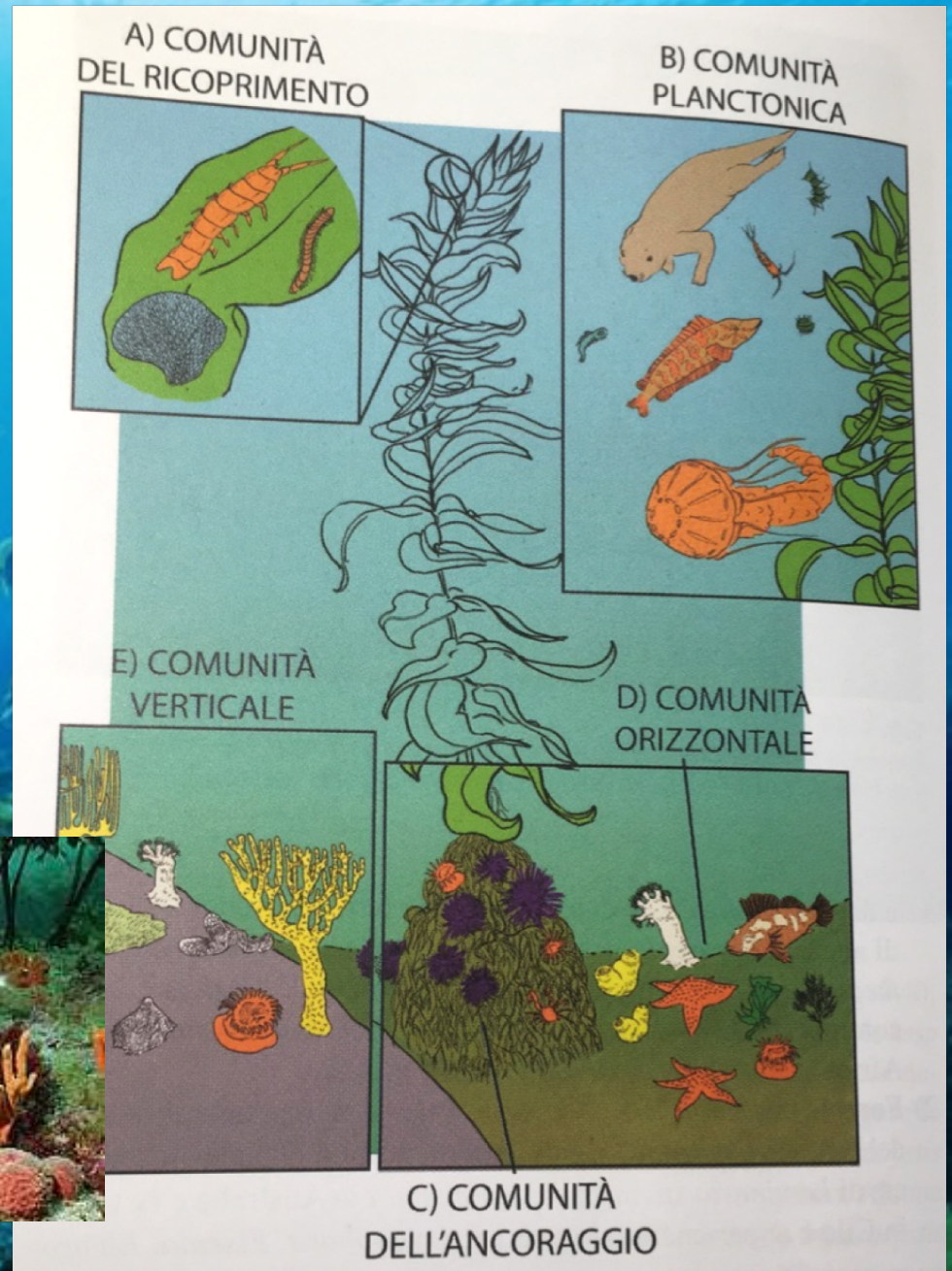
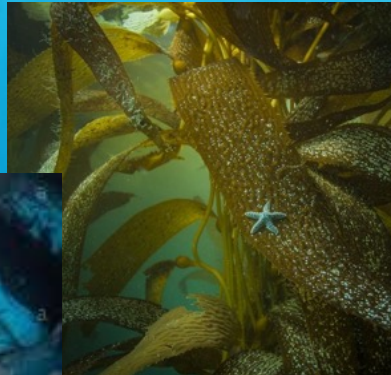
*Enhydra lutris*





# Ecological role and functioning

Size and 3-d structure modify the seascape and provide habitat for different assemblages and vertical stratification.





# Ecological role and functioning



**Habitat**  
**Refuge**  
**Nursery**  
**Secondary substrate**  
**Food**  
**Oxygen**  
**Primary production**  
**Hunting grounds**



# Ecological role and functioning



**Modify  
environmental  
conditions  
Light  
Hydrodynamism  
Coastal  
protection from  
erosion**

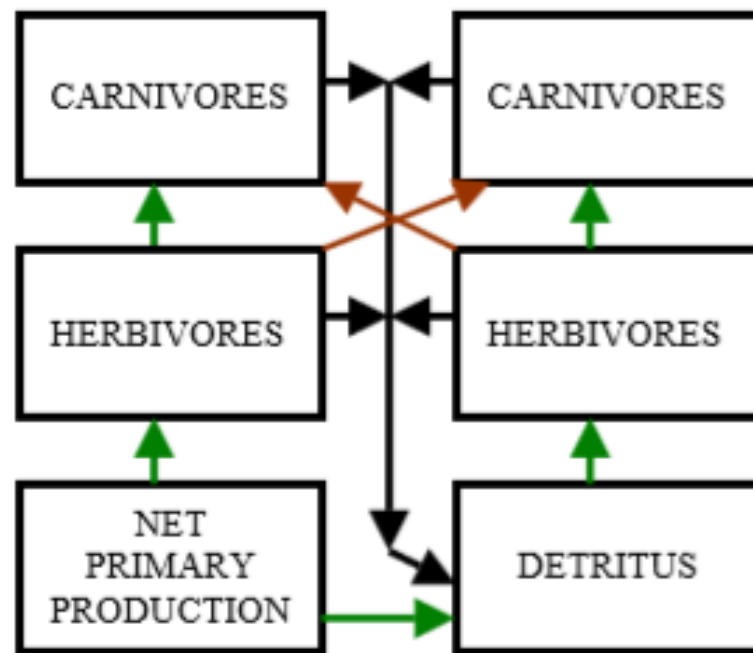




# Productivity

FOREST TYPE	ANNUAL NET PRODUCTION (dry kg / m <sup>2</sup> / yr)
Steneck, 2002	
Tropical rain forest	2.2
Tropical seasonal forest	1.6
Temperate evergreen forest	1.3
Temperate deciduous forest	1.2
Boreal forest	0.8
Giant kelp forest	2.2

Productivity is very high, comparable to most productive terrestrial forests. In contrast, however, low storage of biomass. Most of kelp biomass, as detritus, is decomposed, consumed, or exported. Therefore, kelp provide biomass for adjacent low-productivity habitats (e.g., deeper waters).

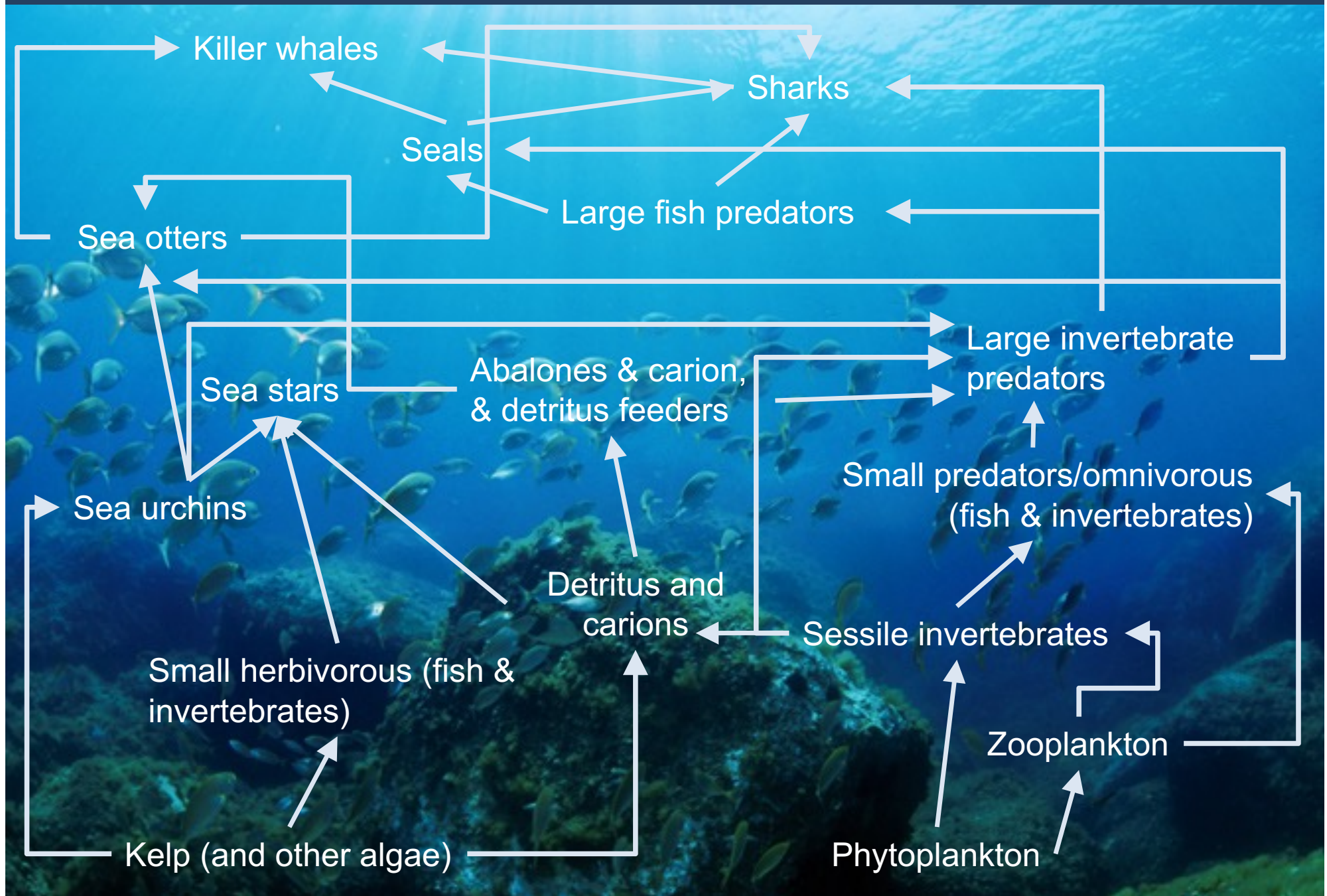


Kelly, 2005

**Figure 1** Simplified Food Chain.



# Trophic web





# Human impacts



**Kelp ash** (= sodium carbonate) obtained burning the algae. This practice since early XVII century for production of glass, soap, and fertilizer. XIX → Iodine extraction from ashes. XX → Alginate for food, pharmaceuticals  
Aquaculture



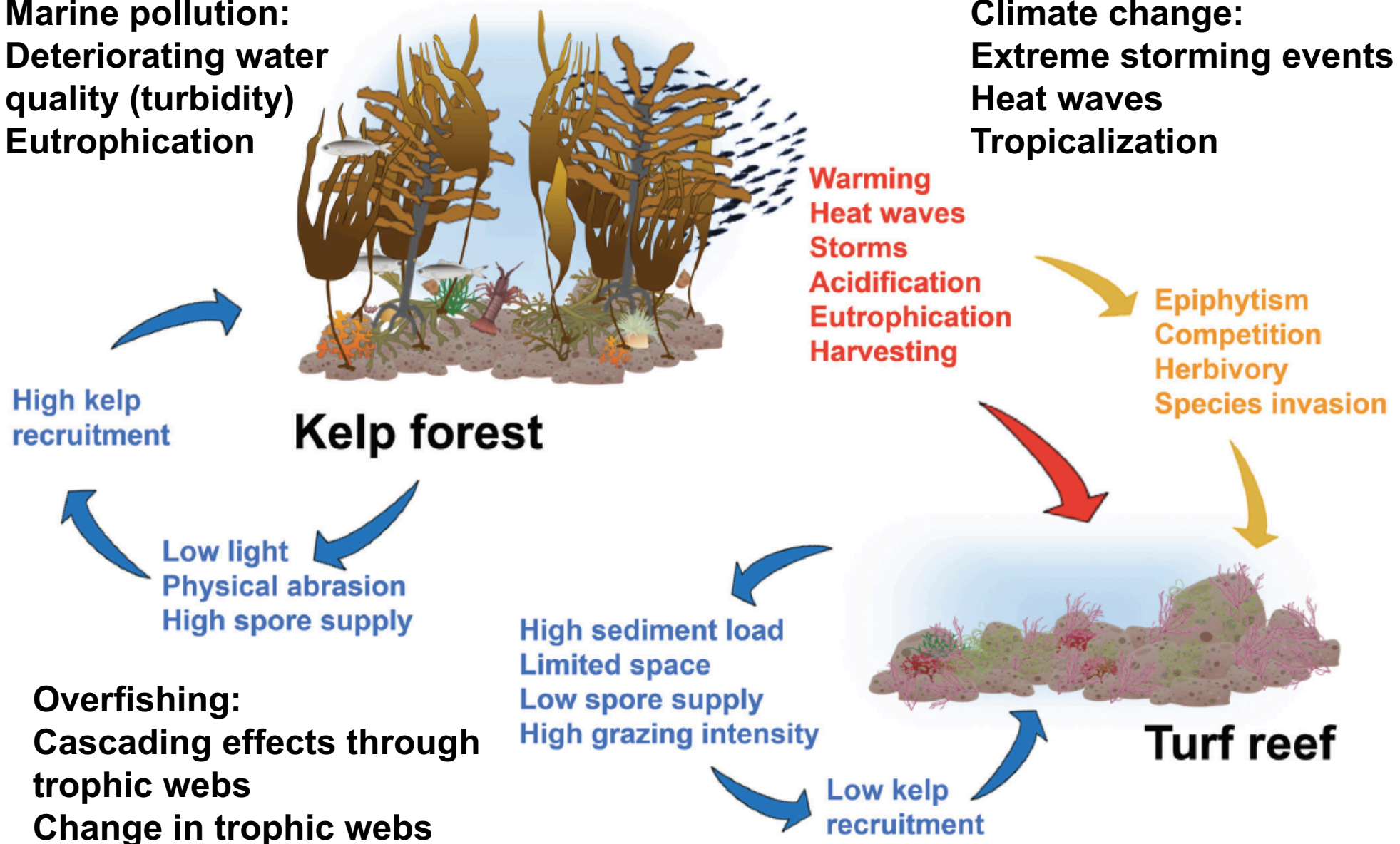
**overexploitation**



# Human impacts

**Marine pollution:**  
Deteriorating water  
quality (turbidity)  
Eutrophication

**Climate change:**  
Extreme storming events  
Heat waves  
Tropicalization





# Human impacts

Filbee-Dexter and Wernberg, 2018

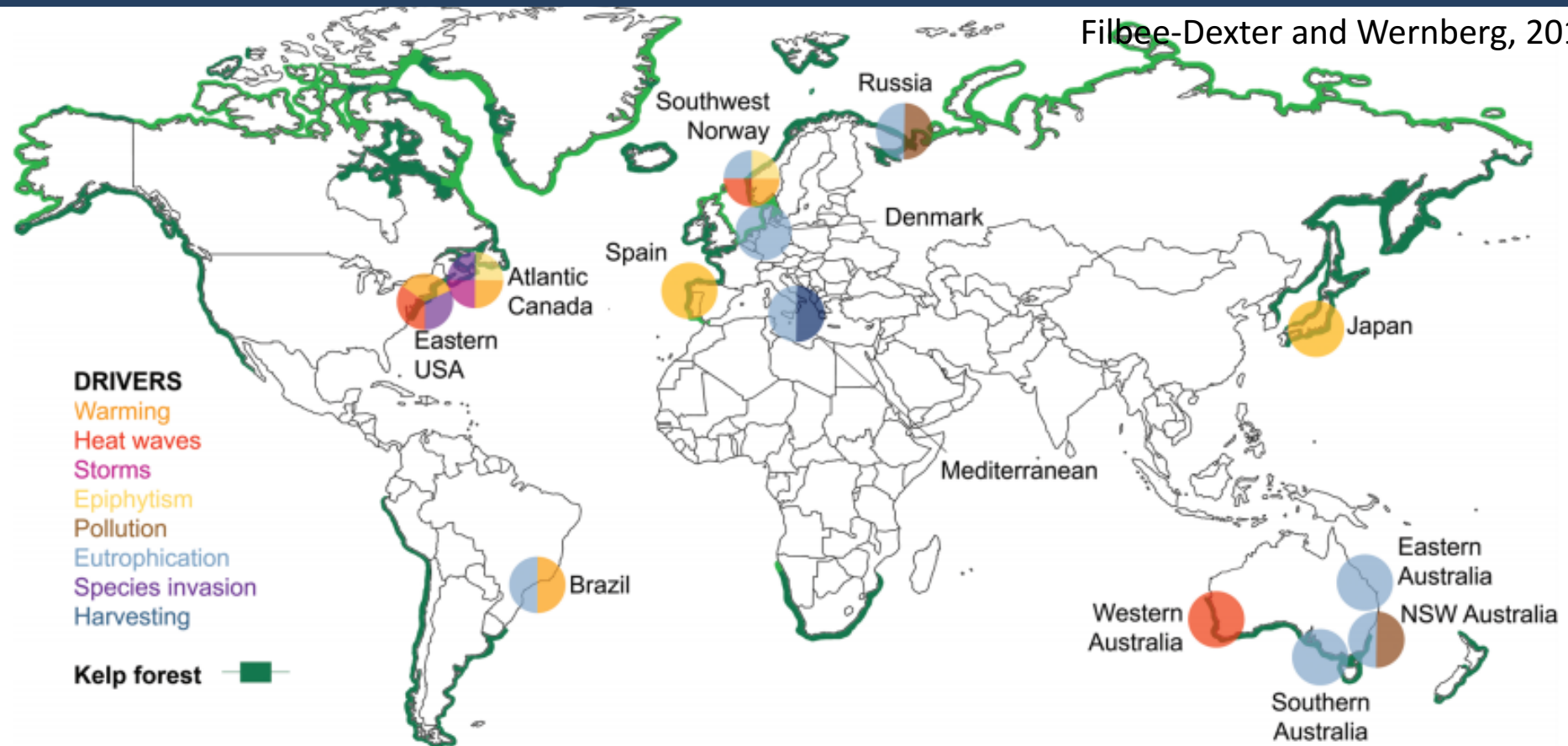


Figure 3. A global map showing the locations of shifts from habitat-forming macroalgae to turfs (circles) overlaid on the approximate distribution of global kelp forests (green; light green unknown but inferred from habitat requirements; Filbee-Dexter and Scheibling 2014). The slice colors of circles indicate different drivers implicated in the shift. See table 2 for further details.

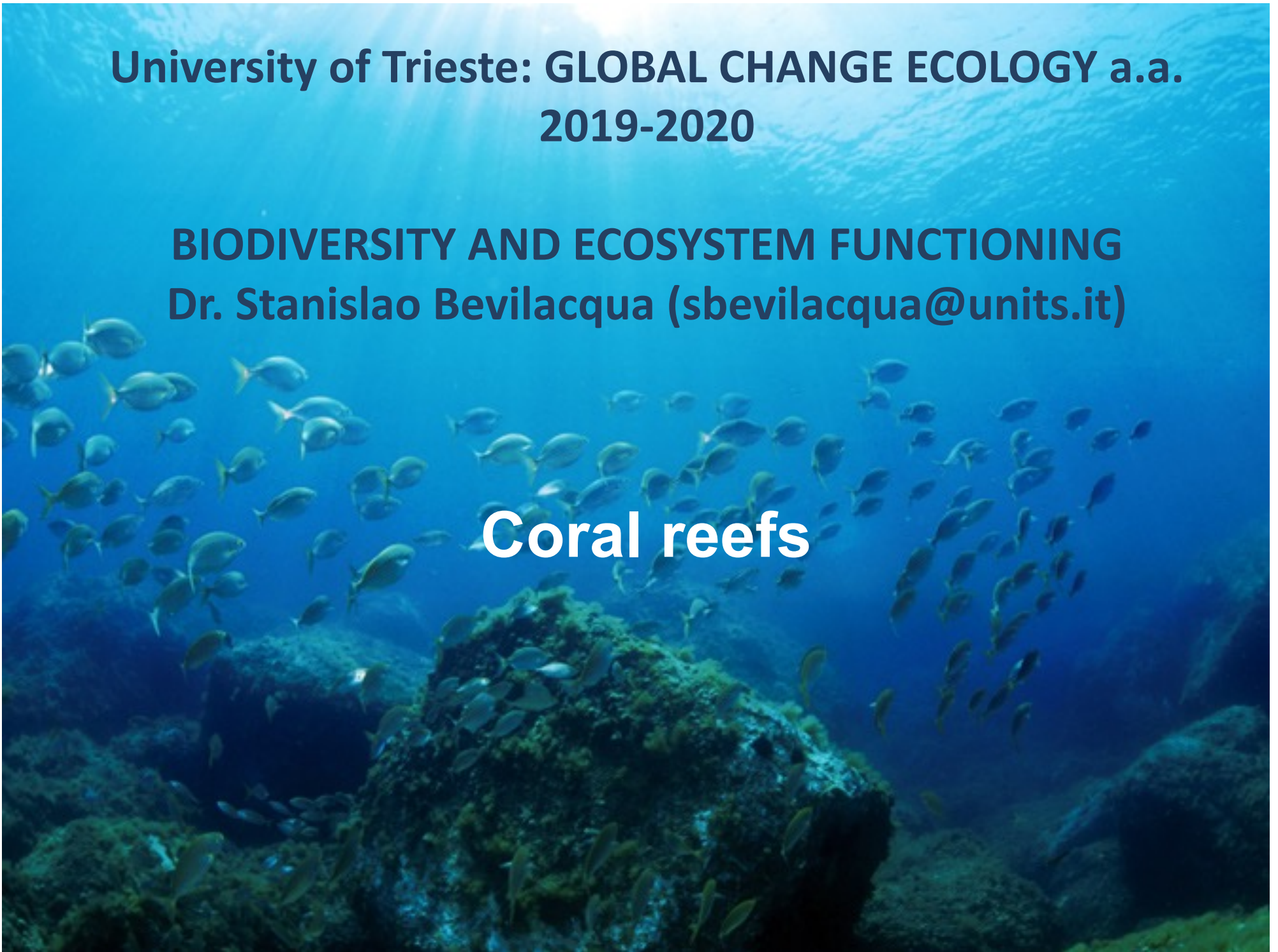
The numbers of living creatures of all Orders whose existence intimately depends on kelp is wonderful ... I can only compare these great aquatic forests of the southern hemisphere with the terrestrial ones in the intertropical regions. Yet if in any country a forest was destroyed, I do not believe as many species of animals would perish as would here from the destruction of kelp. (C. Darwin, 1839)



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**Coral reefs**





# Soft corals

## Octocorallia

8-fold symmetry,  
most of them symbionts  
calcium carbonate or protein skeleton  
Do not form reefs



**Corallium rubrum**



'True' Corals are Hexacorallia, Scleractina, also known as madreporarians or stony corals



# Reef-building corals

Cnidaria – Anthozoa – Hexacorallia – Order: Scleractinia (stony corals)

Hermatypic corals (reef-building)

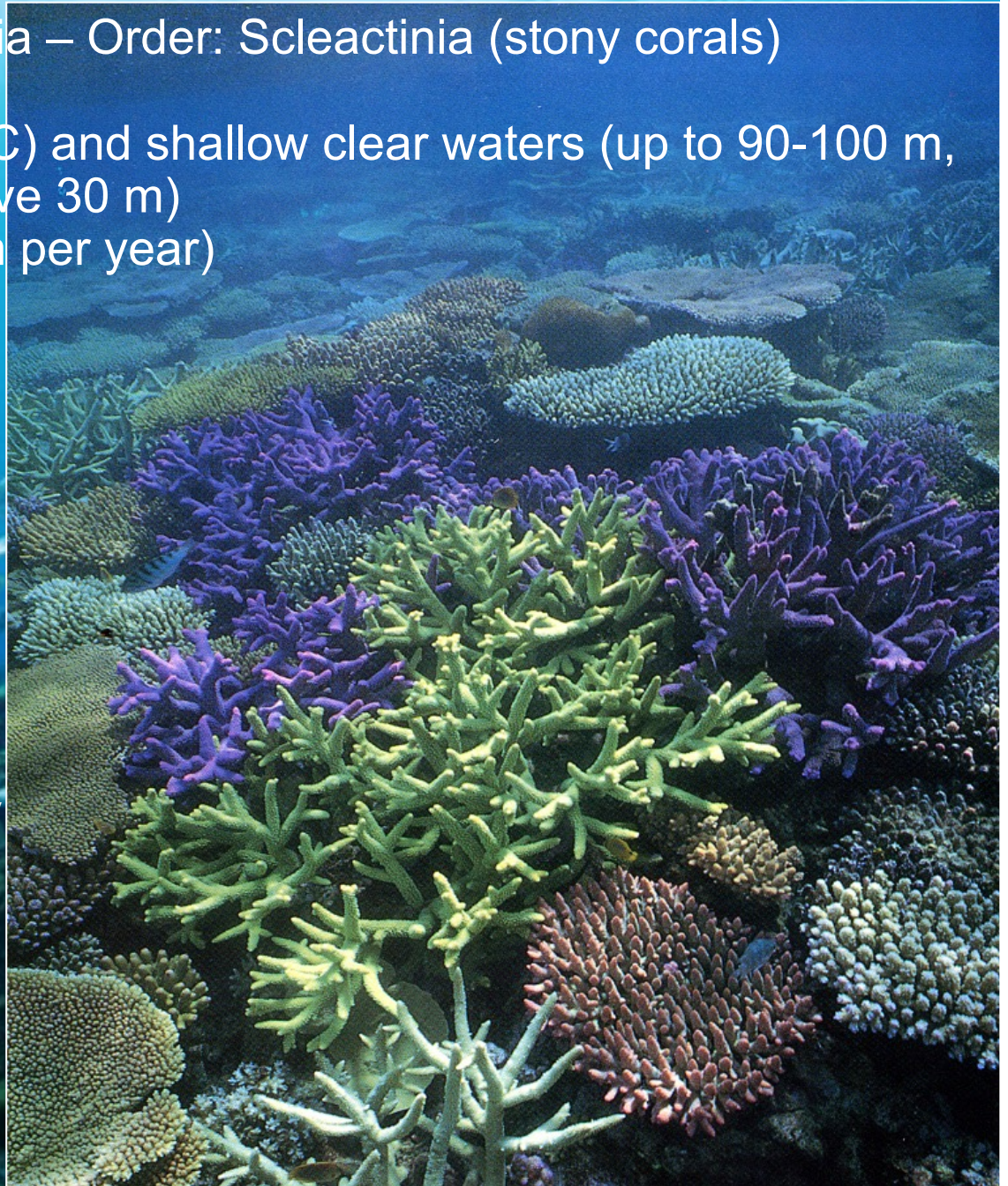
Typical of tropical areas (20-25° C) and shallow clear waters (up to 90-100 m, but their optimal for growth is above 30 m)

Low growth rates (0.5 up to 20 cm per year)

**Hermatypic corals** are those corals which build reefs by depositing hard calcareous material (calcium carbonate, aragonite) for their skeletons, forming the hard structure of the reef. Corals that do not contribute to reef development are referred to as **ahermatypic** (non-reef building) species.

Present day reefs have 5000-10000 y

**Coral reefs are among the most biodiverse marine ecosystems of the planet**





# Reef-building corals



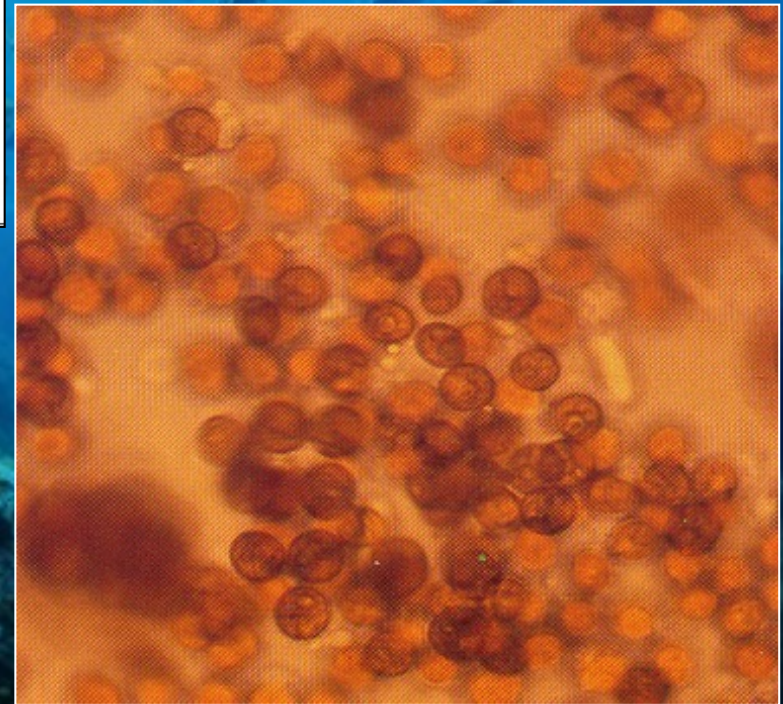
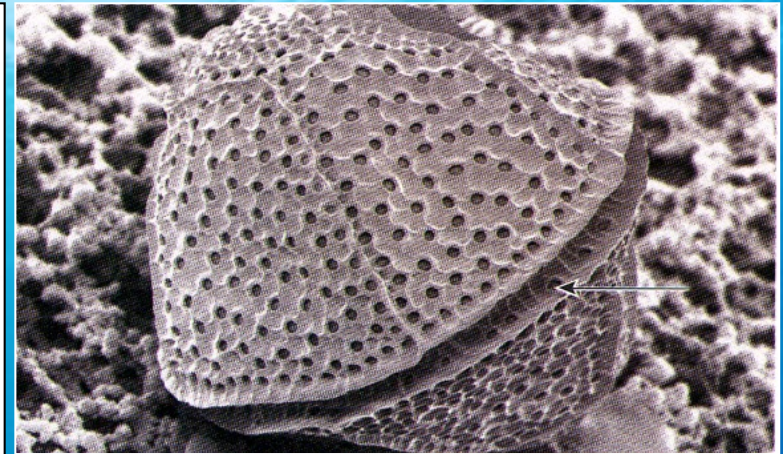
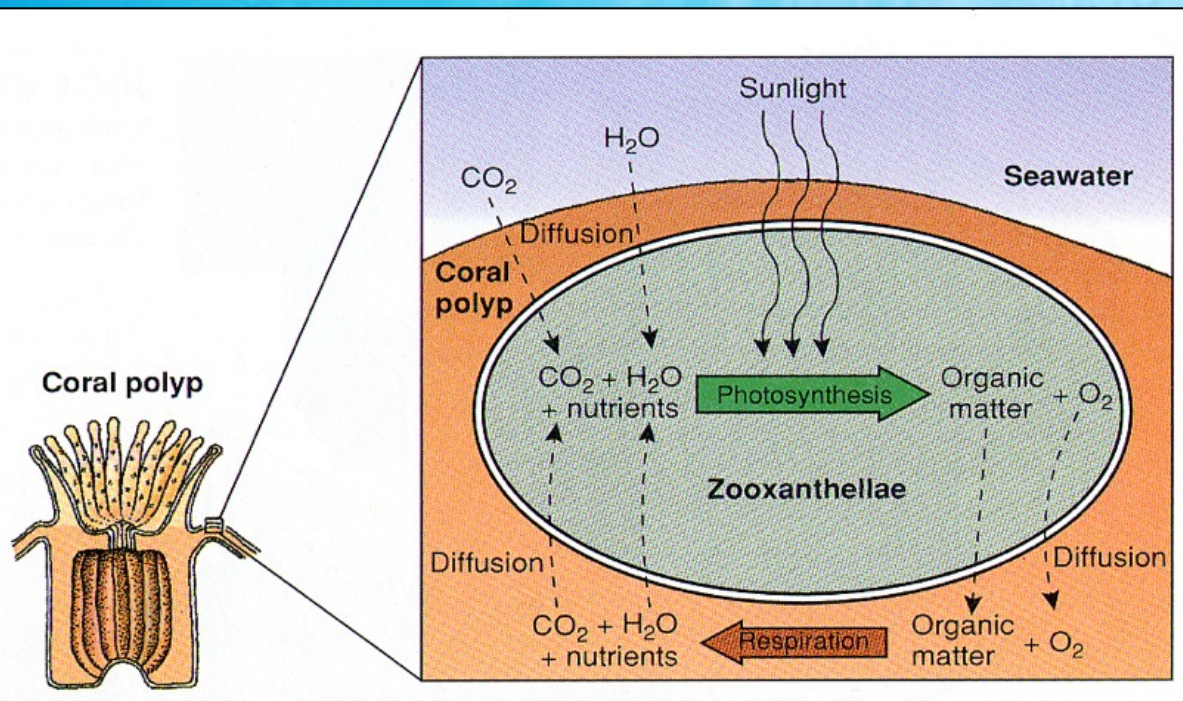
**Corals are covered by mucus allowing retaining humidity and avoiding desiccation during low tide periods**



**In the majority of cases corals host mutualistic symbionts (Protista: Dinoflagellata) allowing higher performance in nutrient-poor environments**



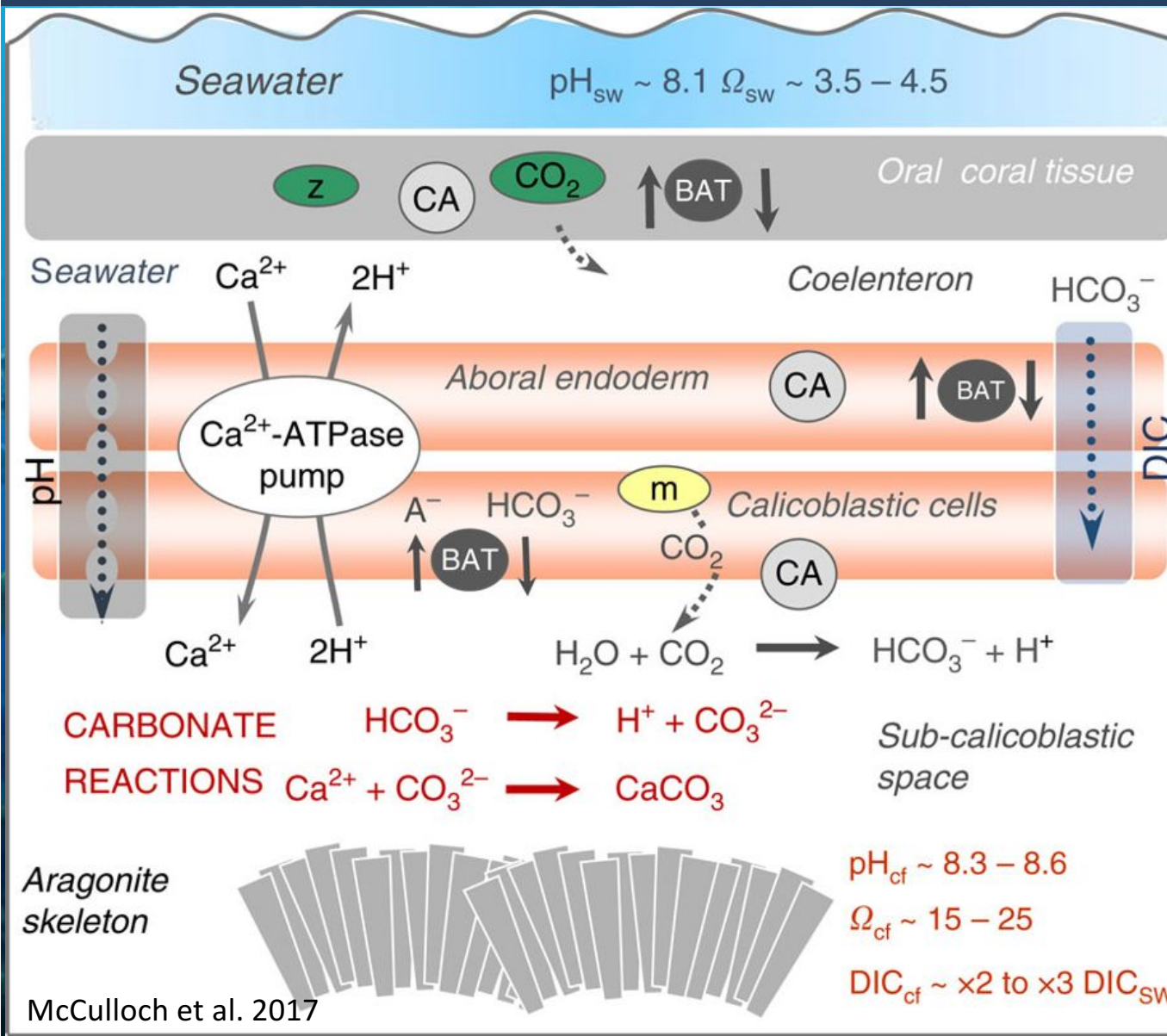
# Symbiosis



Zooxanthellae are dinoflagellates living in the *gastrodermis* (the inner layer of cells). They are photosynthetic organisms that exploit  $\text{CO}_2$  (dissolved and produced by coral respiration) to synthesize carbohydrates. There are millions zooxanthellae per  $\text{cm}^2$  in coral tissues. They provide energy to corals, allowing them to thrive and helping skeletogenesis. Corals in turn, provide shelter,  $\text{CO}_2$ , and nutrients to zooxanthellae.



# Skeletogenesis



Z: zooxanthellae  
CA: carbonic anhydrases  
BAT: bicarbonate anion transporters

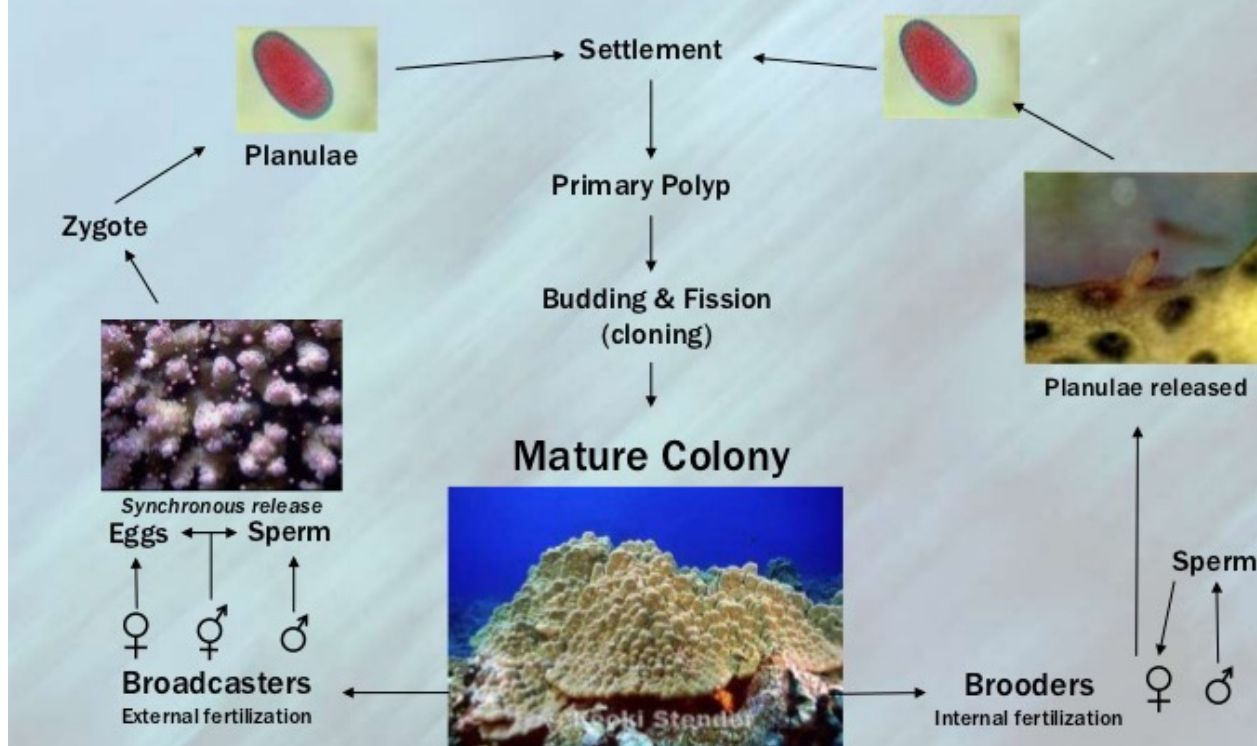
$\text{HCO}_3^-$  are transported by BAT in the calcification fluid between calicoblastic cells and skeleton. It is also produced by CA, from  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .  $\text{CO}_3^{2-}$  are formed and  $\text{Ca}^{++}\text{ATPase}$  pump  $\text{Ca}^{++}$  exchanging with  $2\text{H}^+$ . This increases pH and saturation of aragonite, which in turn allows formation and precipitation of  $\text{CaCO}_3$  adding aragonite crystal to the coral skeleton.

A comprehensive understanding of the mechanism is still to be achieved.

During daylight higher calcification speed, because photosynthesis helps providing energy for the process, and  $\text{Ca}^{++}\text{ATPase}$  is active.



# Reproduction



Corals are hermaphrodites. In most cases they spawn eggs and sperm in the seawater, often in synchrony. Others are brooders. In this case fertilization happens within the gastrovascular cavity, originating larvae (planulae) which are then released in the seawater.



# Mediterranean stony corals

*Cladocora caespitosa*



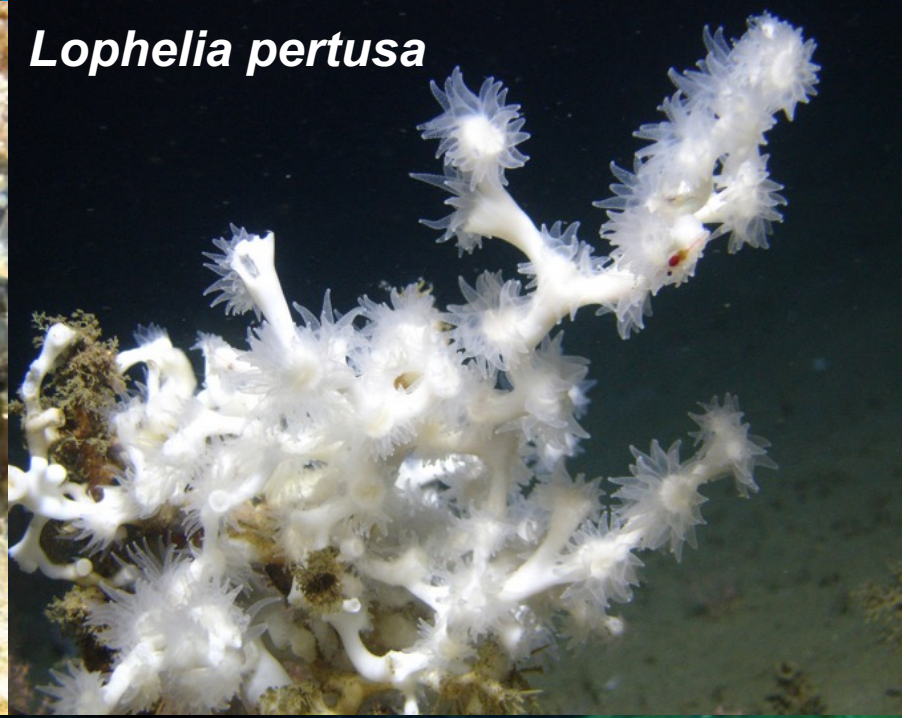
*Astroides calycularis*



*Balanophyllia europaea*



*Lophelia pertusa*



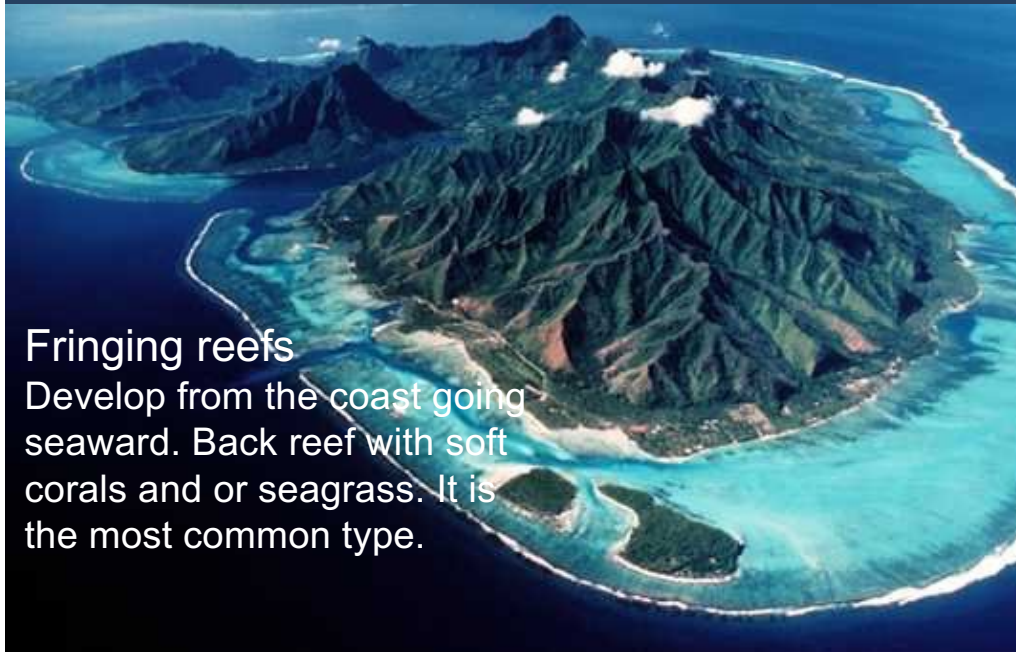


# Three-dimensional structure





# Types of coral reefs



## Fringing reefs

Develop from the coast going seaward. Back reef with soft corals and or seagrass. It is the most common type.

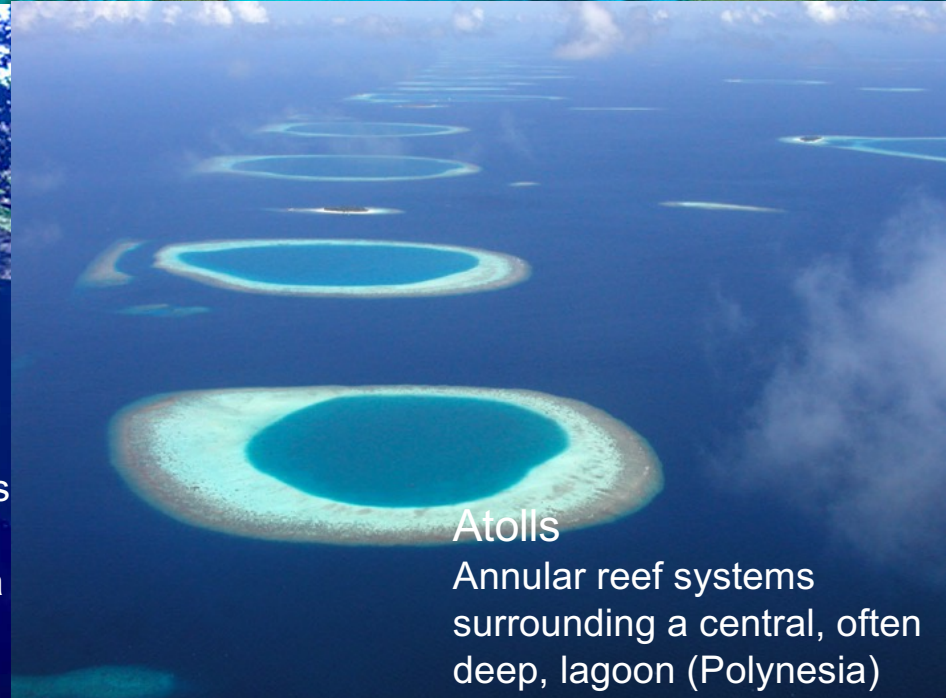
## Platform reefs

Isolated reefs developing from the island or continental shelf in sheltered areas, often surrounding very shallow lagoons (e.g. Bahamas).



## Barrier reefs

A complex of reefs formations that parallel the shoreline, and separated from land by a lagoon (The Great Barrier Reef).

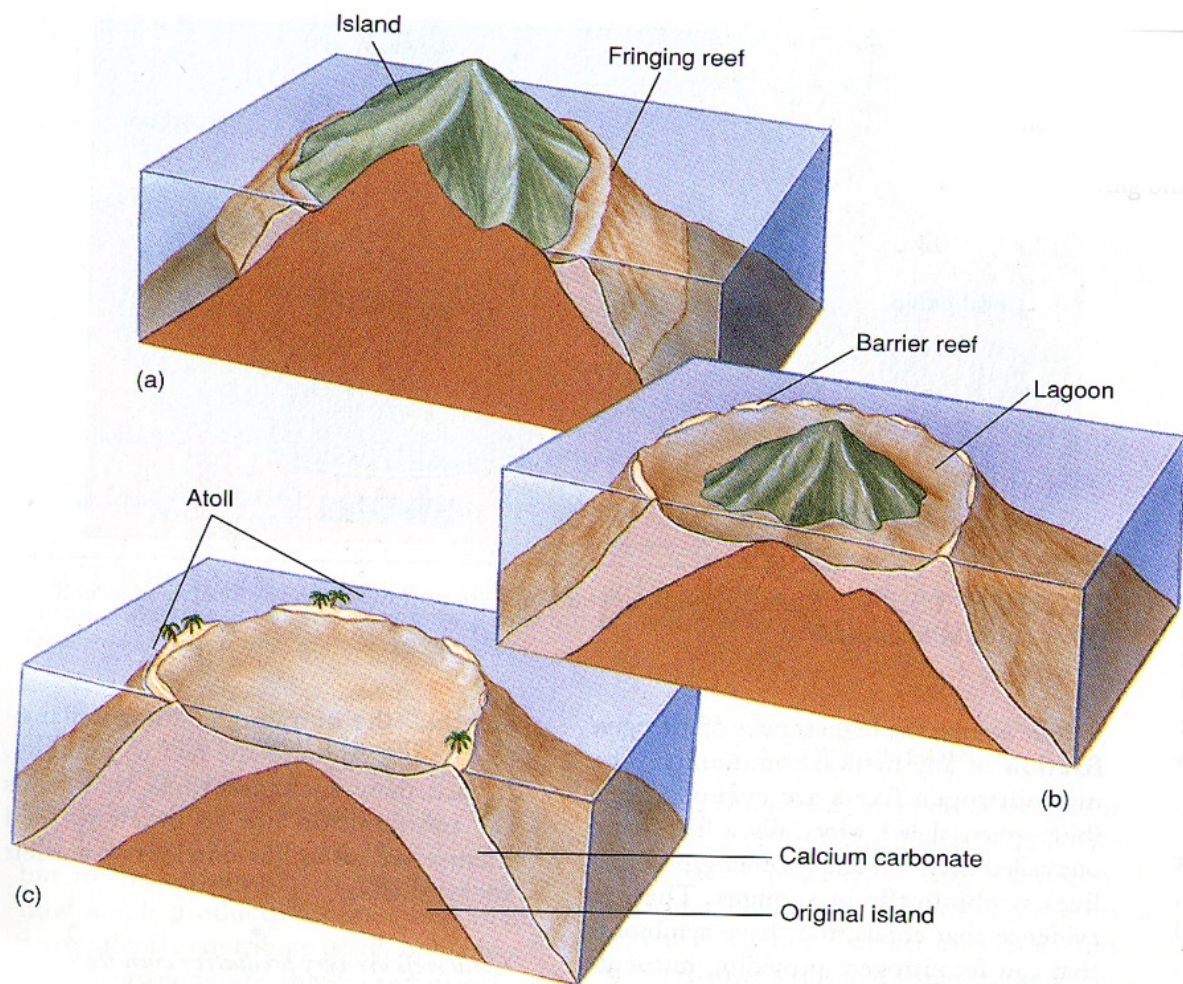


## Atolls

Annular reef systems surrounding a central, often deep, lagoon (Polynesia)



# Atolls formation



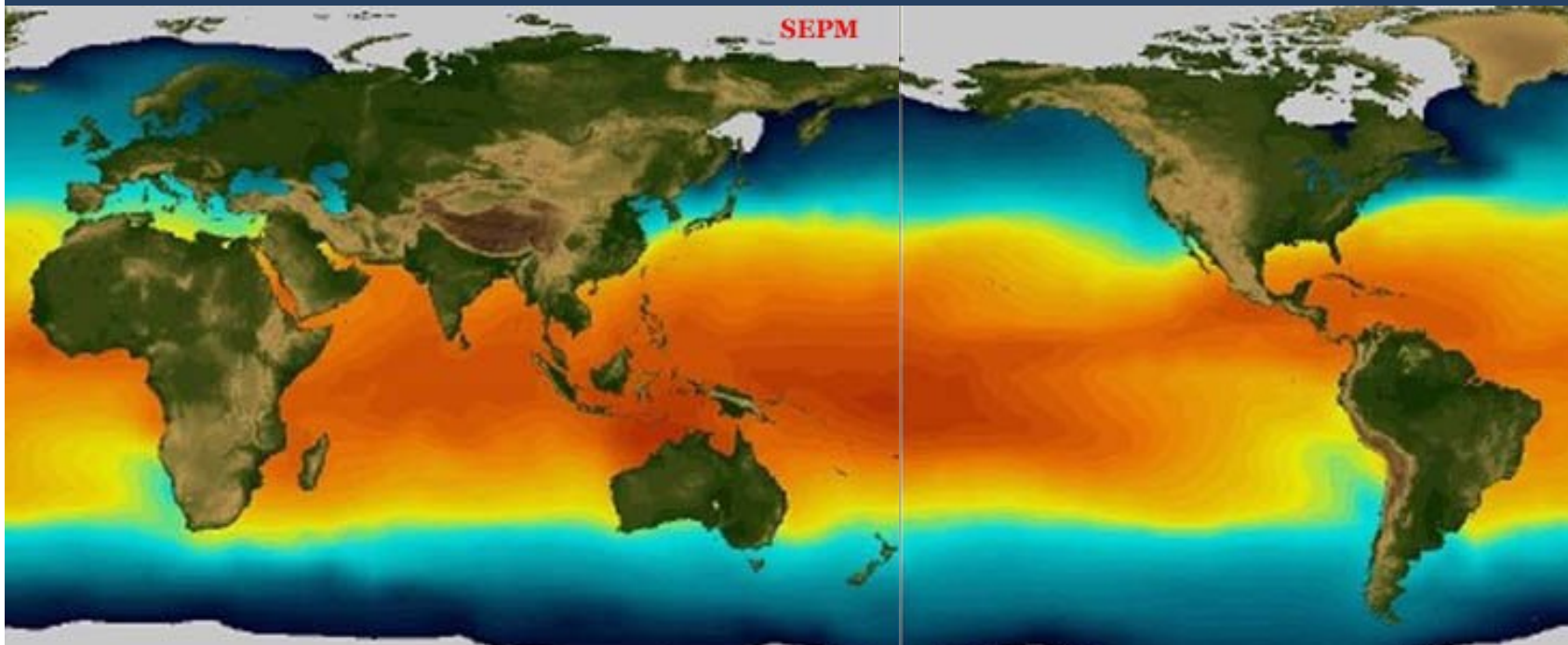
a. Volcanic islands rise from the sea bottom and begin to be colonized by corals forming a reef around them (fringing reefs).

b. Once activity has ceased, subsidence, and/or sea level rise, lead the island to sink, whereas corals continue to grow forming a barrier reef that surrounds a lagoon

c. Finally, the island completely sinks and is covered by carbonate deposit from corals that continue to grow towards the surface forming the atoll.



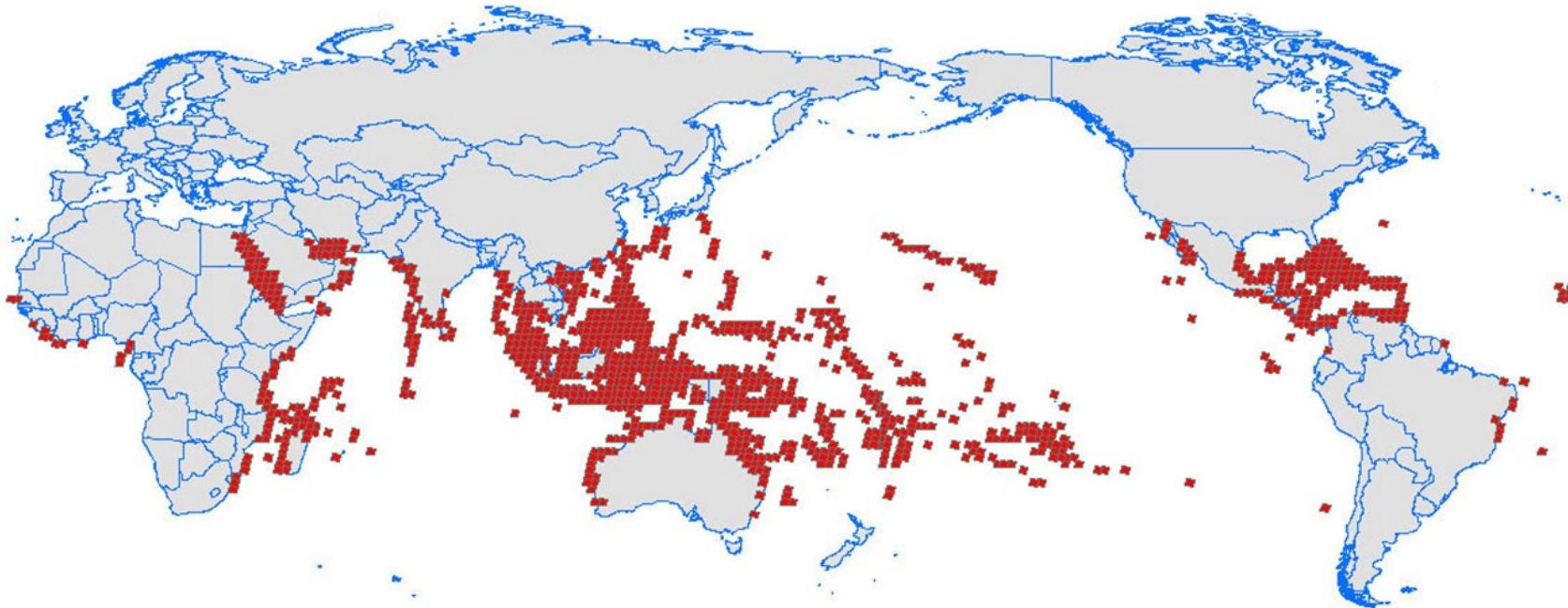
# Distribution



Global distribution of coral reefs is delimited northward and southward by the 20° C isotherm.

'Hotspots' of presence are the Indo-Pacific and the Caribbean.

Surface water temperature, therefore, is one of the most important factors limiting reef distribution at global scale





# Factors influencing distribution

Temperature (warm waters, 20° C)

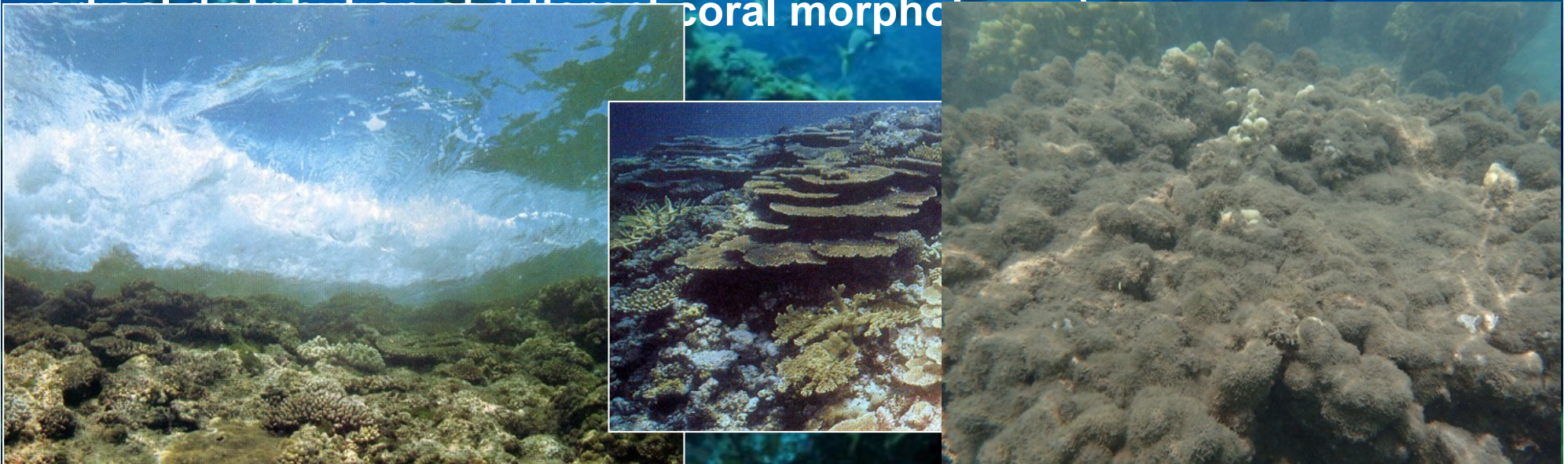
Light (appropriate irradiation for photosynthetic activity, 20° N-S, limiting depth, influencing vertical distribution of different coral morphologies)

Salinity (>32-35 ‰, no osmoregulation and higher salinity affect photosynthetic rates)

Sedimentation (increased turbidity affect photosynthesis by limiting light penetration, affect polyp predation, facilitate competing species such as turf algae)

Hydrodynamism (tide levels influence emersion time and therefore exposure to air, sunlight; wave action increase erosion and influence

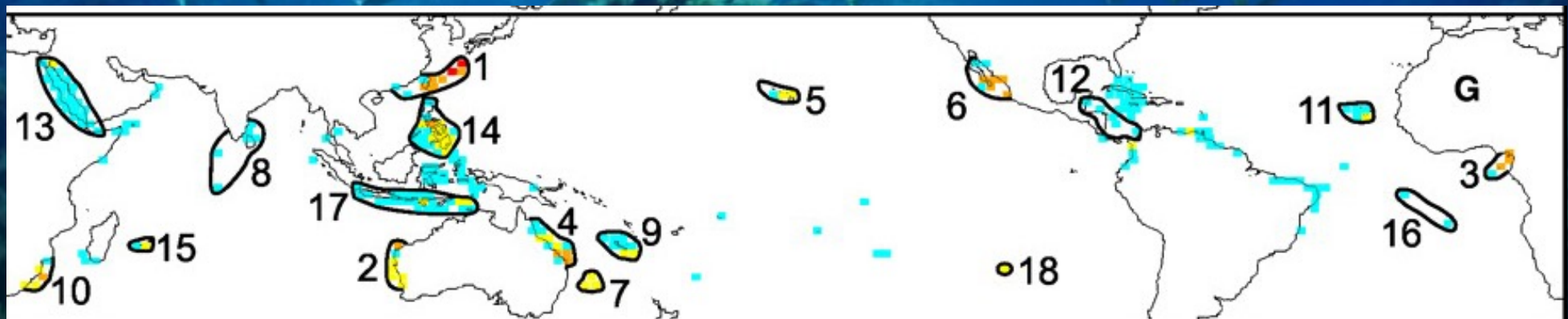
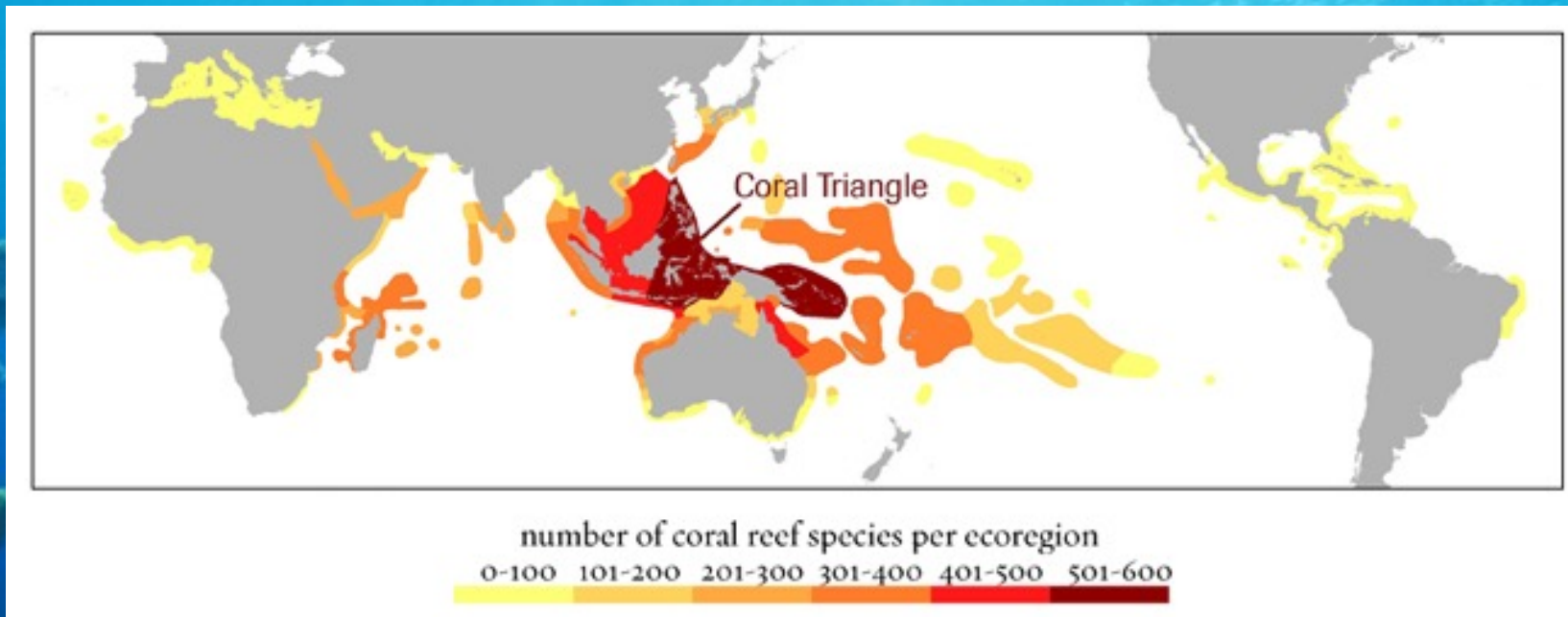
vertical distribution of different coral morphologies)





# Biodiversity

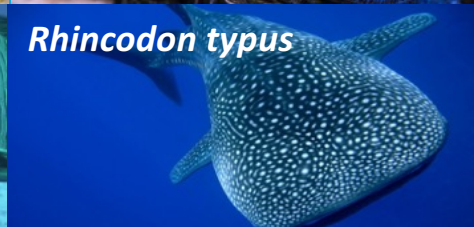
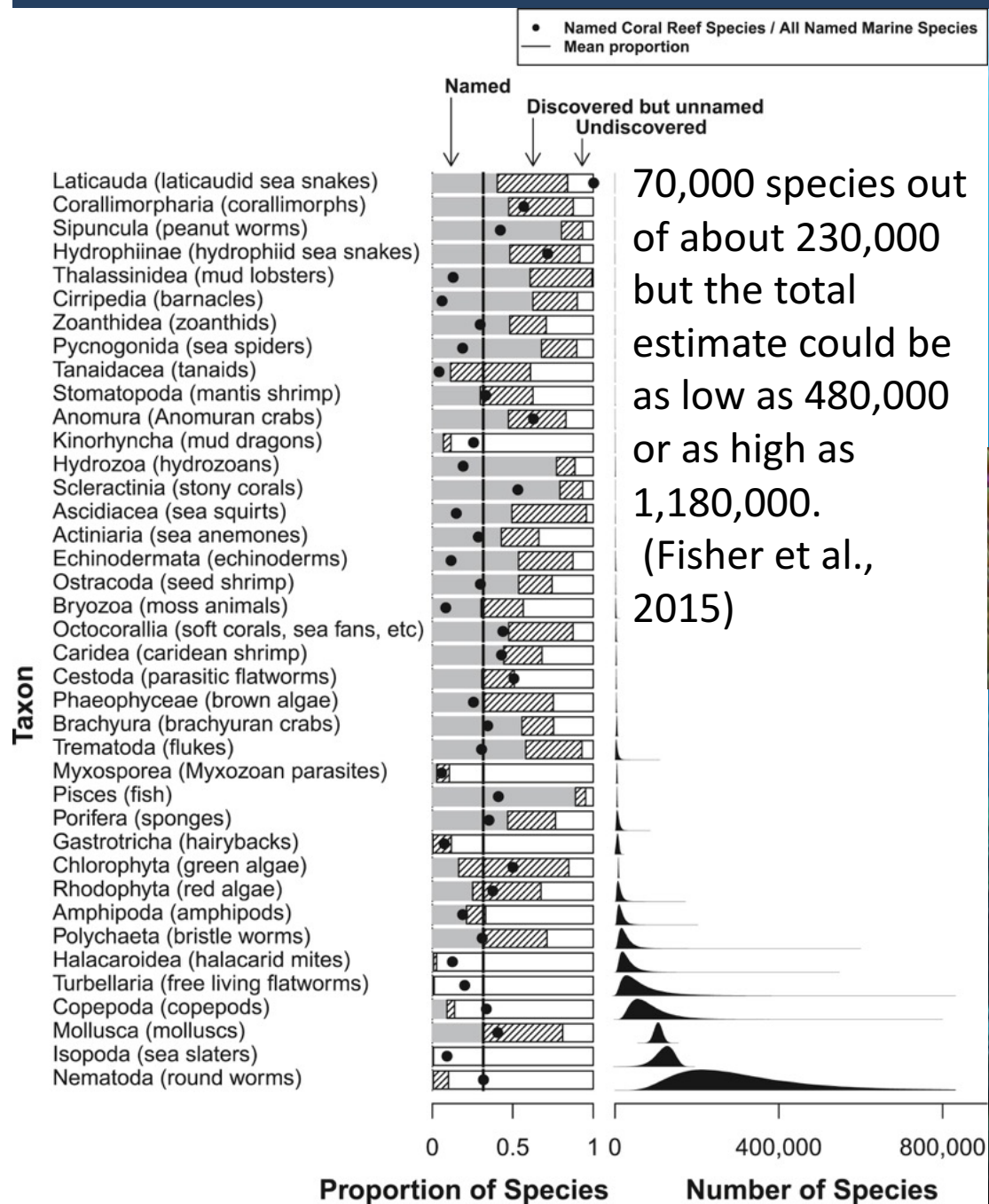
Coral reefs cover 0.17% of Earth surface but account for 25-30% of global marine biodiversity (Reaka-Kudla 1997; Knowlton et al., 2010)



Hotspots of endemisms considering corals, snails, fish, and lobsters (Roberts et al., 2002)



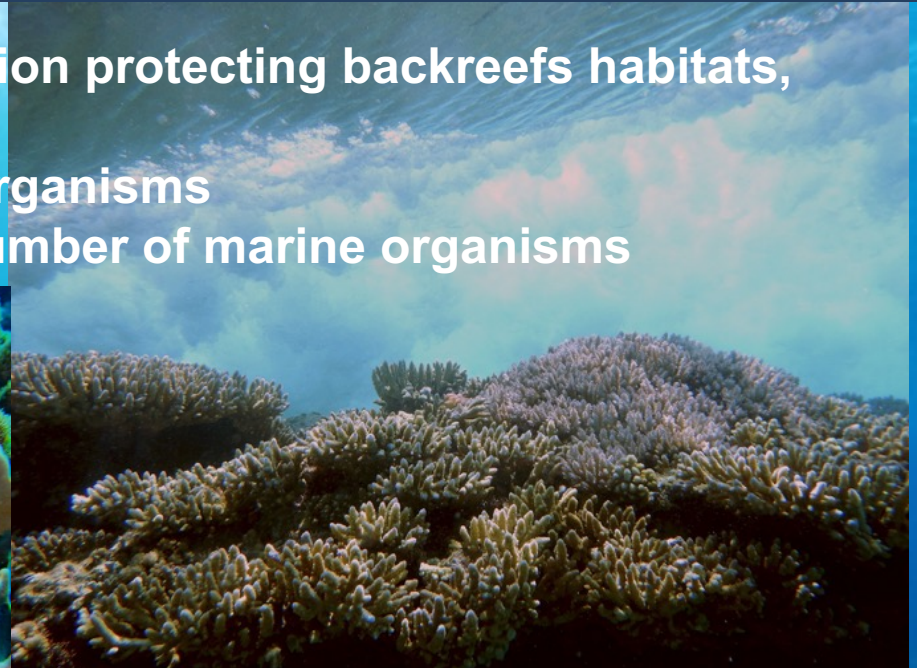
# Biodiversity





# Ecological role and functioning

Coral reefs act as a shield against wave action protecting backreefs habitats, such as seagrass  
Create substrate for settlement of marine organisms  
Provide food, refuge, nursery areas for a number of marine organisms





# Productivity

Coral reefs cover some 600000 km<sup>2</sup> of the Earth's surface (0.17% of the ocean surface). Gross CO<sub>2</sub> fixation is relatively high ( $700 \times 10^{12}$  g C year<sup>-1</sup>), but most of this material is recycled within the reefs.

Net production of organic material is much smaller, of the order  $20 \times 10^{12}$  g C year<sup>-1</sup> (15% is buried in reef structure, 10% is available for sustained human harvest, and the remaining 75% is available for export from coral reefs to adjacent areas). (Crossland et al., 1991)

Unlike rain forests, the contribution of coral reefs to organic CO<sub>2</sub> fixation is relatively minor. Moreover, the calcification process releases CO<sub>2</sub>:



Coral reefs are sink of inorganic carbon imprisoned in their calcium carbonate structure.





# Goods and services

**Food.** Coral reefs provide 9 to 12% of the world catch of edible fish, clams, lobsters, crabs, sea cucumbers (up to 20-25% for developing countries) (Moberg & Folke, 1999).

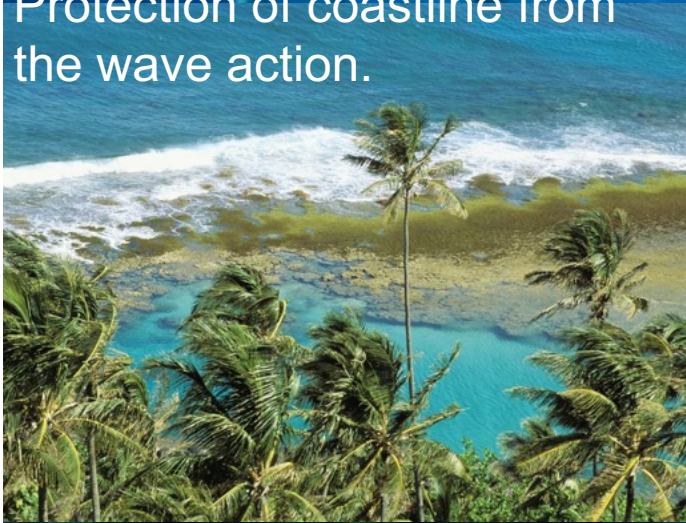
**Mineral resources.**  
Construction materials for local populations.



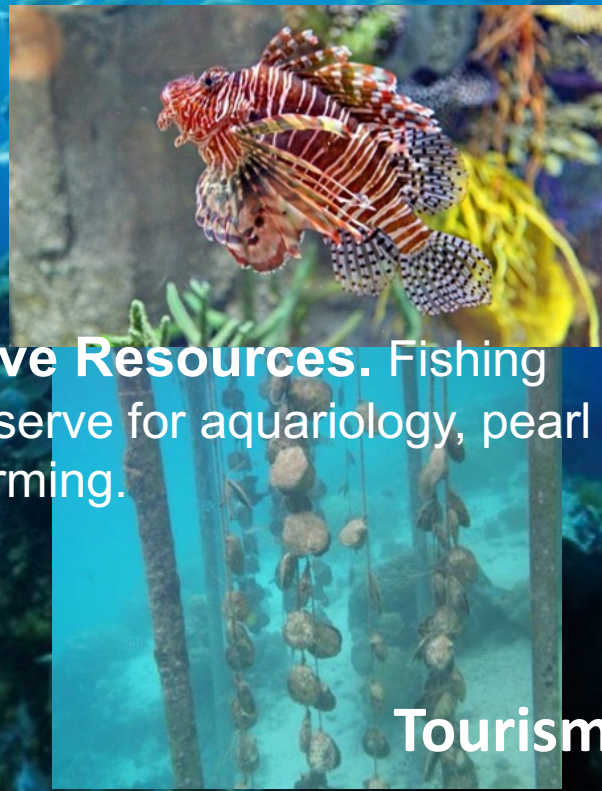
**Medical resources.** Marine invertebrates in coral reefs represent a potential supply of new drugs for human health.



**Coastal Protection.**  
Protection of coastline from the wave action.



**Live Resources.** Fishing reserve for aquariology, pearl farming.

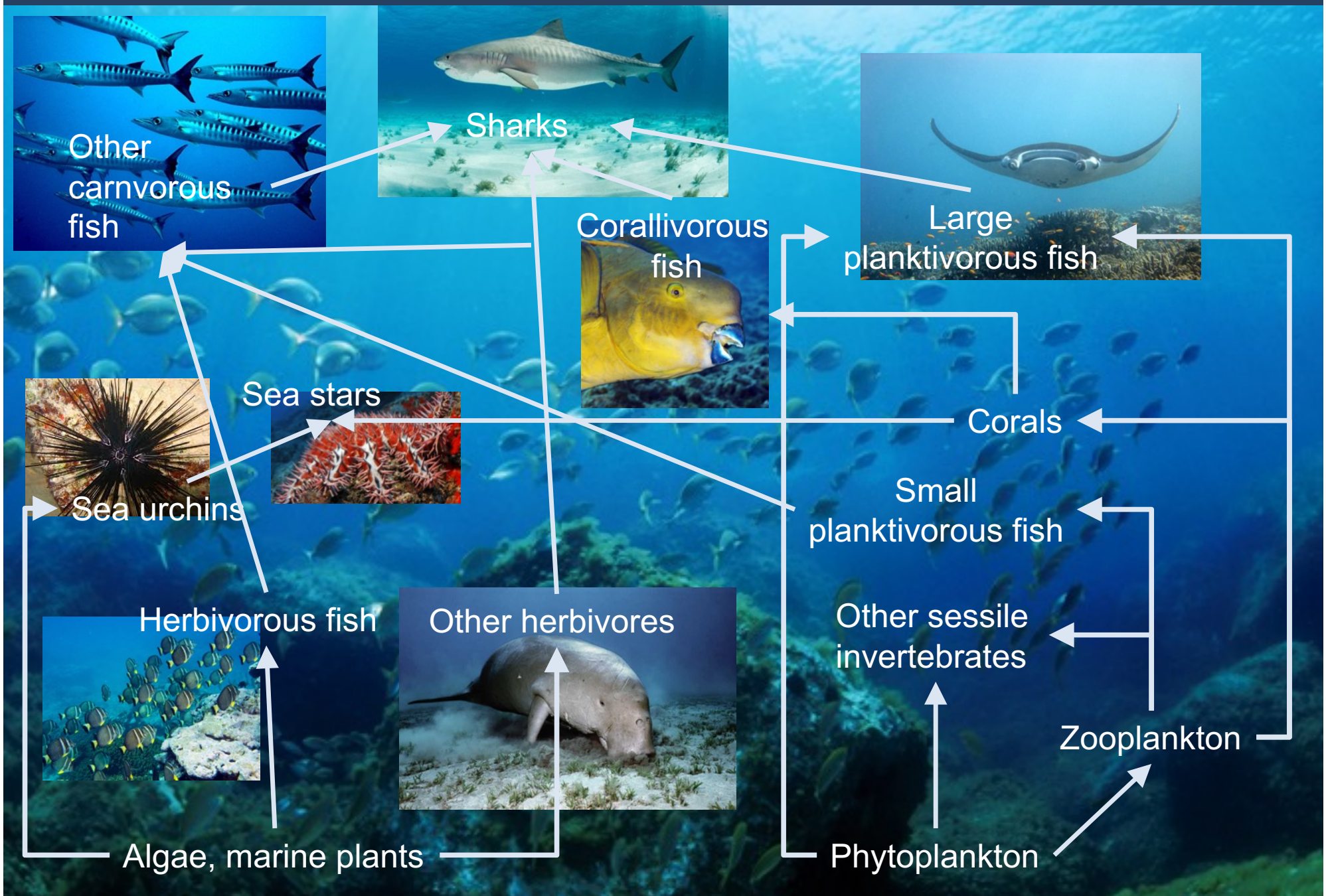


**Tourism and cultural heritage.**





# Trophic web





# Threats

Climate change (increasing extreme storm events, acidification, heat waves, sea level rise)

Eutrophication and increase in sedimentation rates

Oil spills – Pollution





# Bleaching

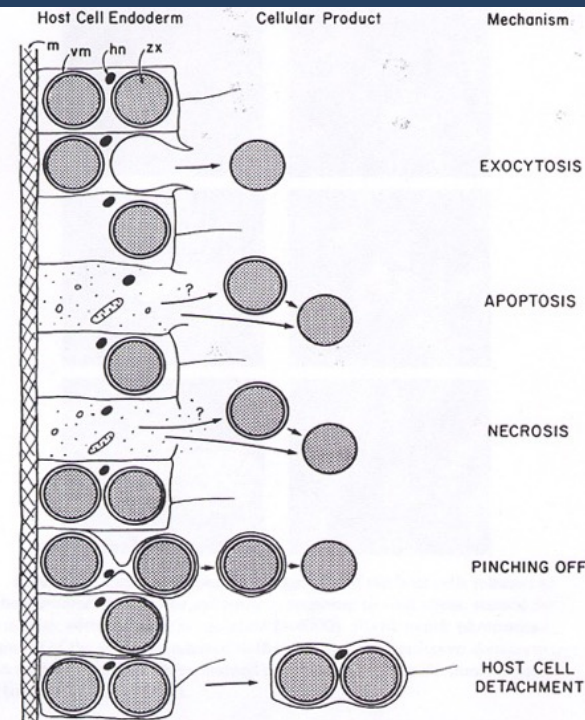
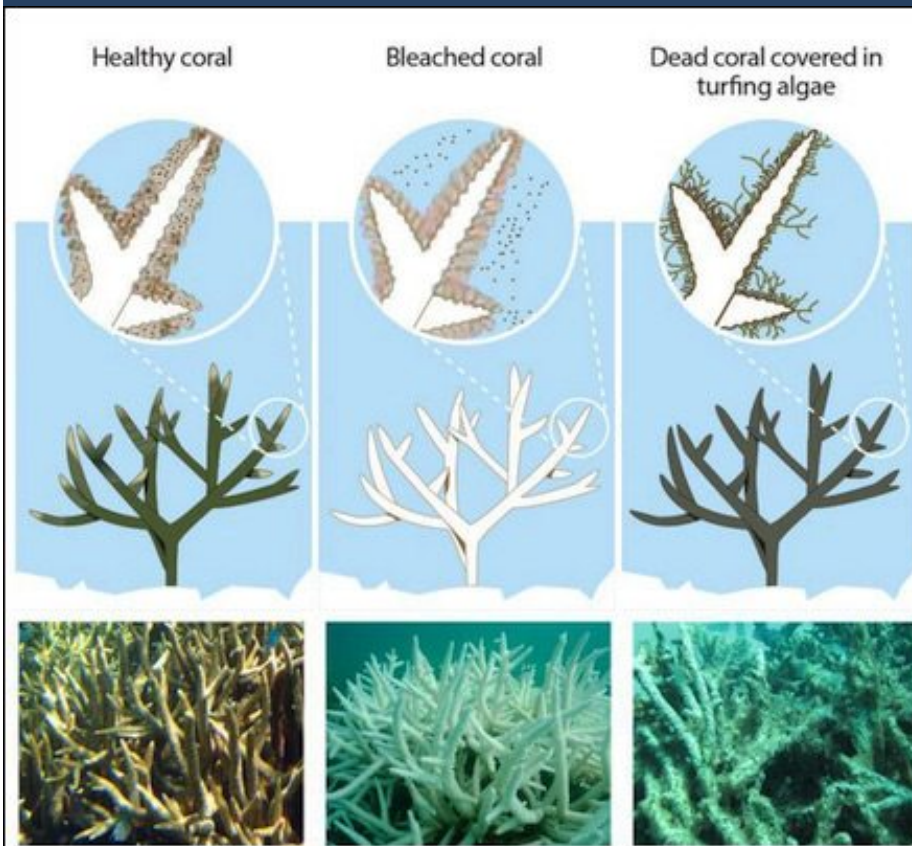


Figure 1. A schematic representation of five potential mechanisms by which zooxanthellae could be released from the endoderm of cnidarians; and the cellular entities associated with each mechanism. m, mesoglea; vm, host vacuolar membrane; hn, host cell nucleus; zx, zooxanthella (shaded for clarity of presentation).

Coral bleaching occurs when corals expel their symbiotic zooxanthellae. Zooxanthellae are responsible of colours of polyps (because they have photosynthetic pigments), so that when they are lost the colony appears “bleached”.

This phenomenon happens when corals experience stressful conditions, due to changes in the environment. Several factors could determine bleaching: changes in pH, nutrient and freshwater inputs, but especially sharp increases (or decreases) in seawater temperature.

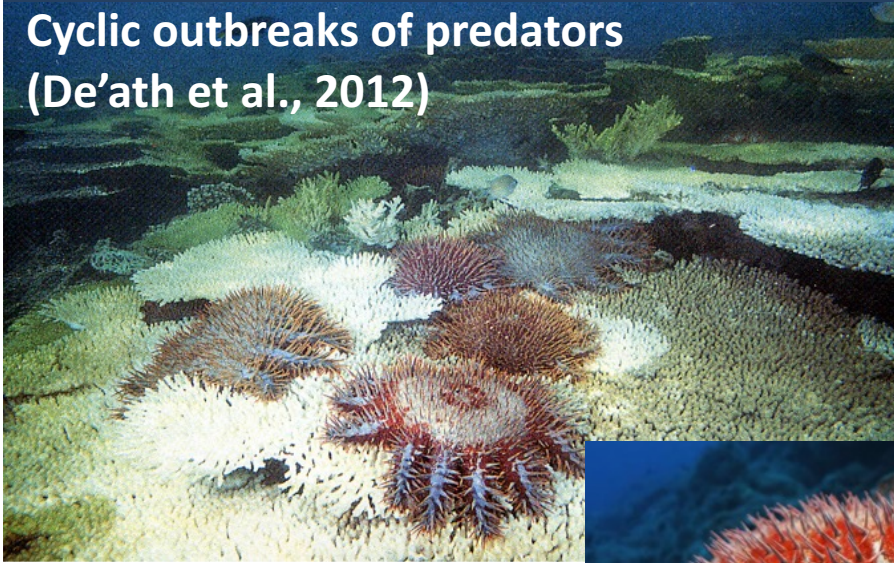
It could be reversible, if the cause of bleaching is not intense or prolonged.





# Diseases – Invasion – Predation

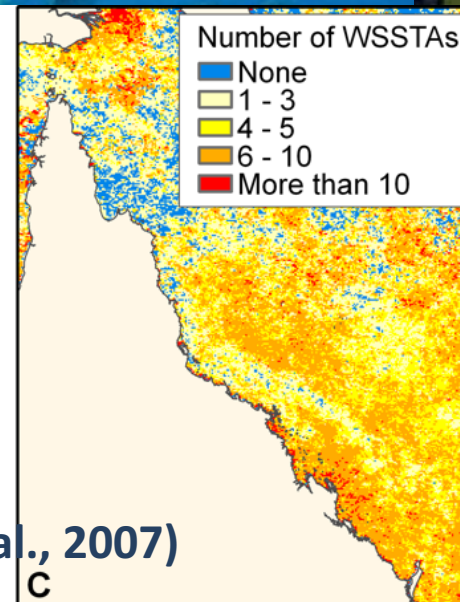
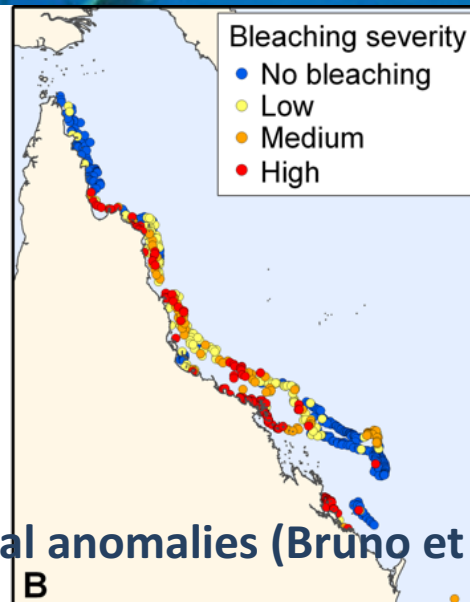
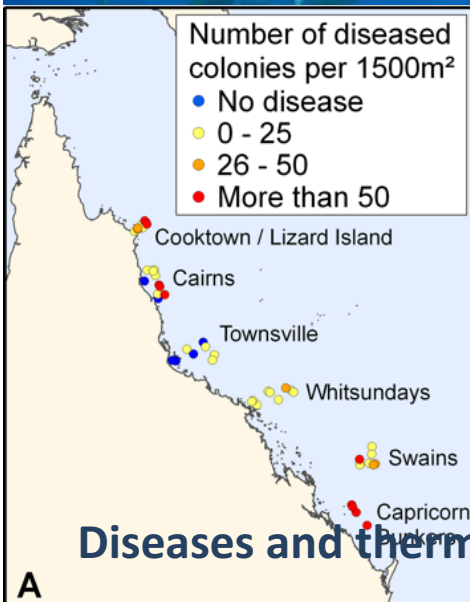
Cyclic outbreaks of predators  
(De'ath et al., 2012)



Rats, birds, and... coral reefs  
(Graham et al., 2018)



*Acanthaster planci*



Diseases and thermal anomalies (Bruno et al., 2007)



Black-band disease  
(Cyanobacteria)

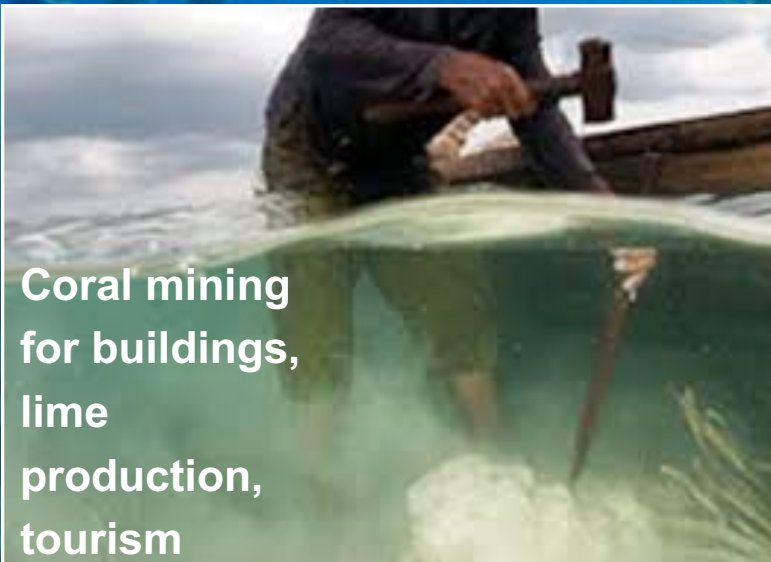
White-band disease  
(Bacteria)

Aspergillosis in sea fan  
associated to coral reefs



# Overexploitation

25% of local fishers exploit coral reef fish (The et al., 2013)



Coral mining  
for buildings,  
lime  
production,  
tourism

