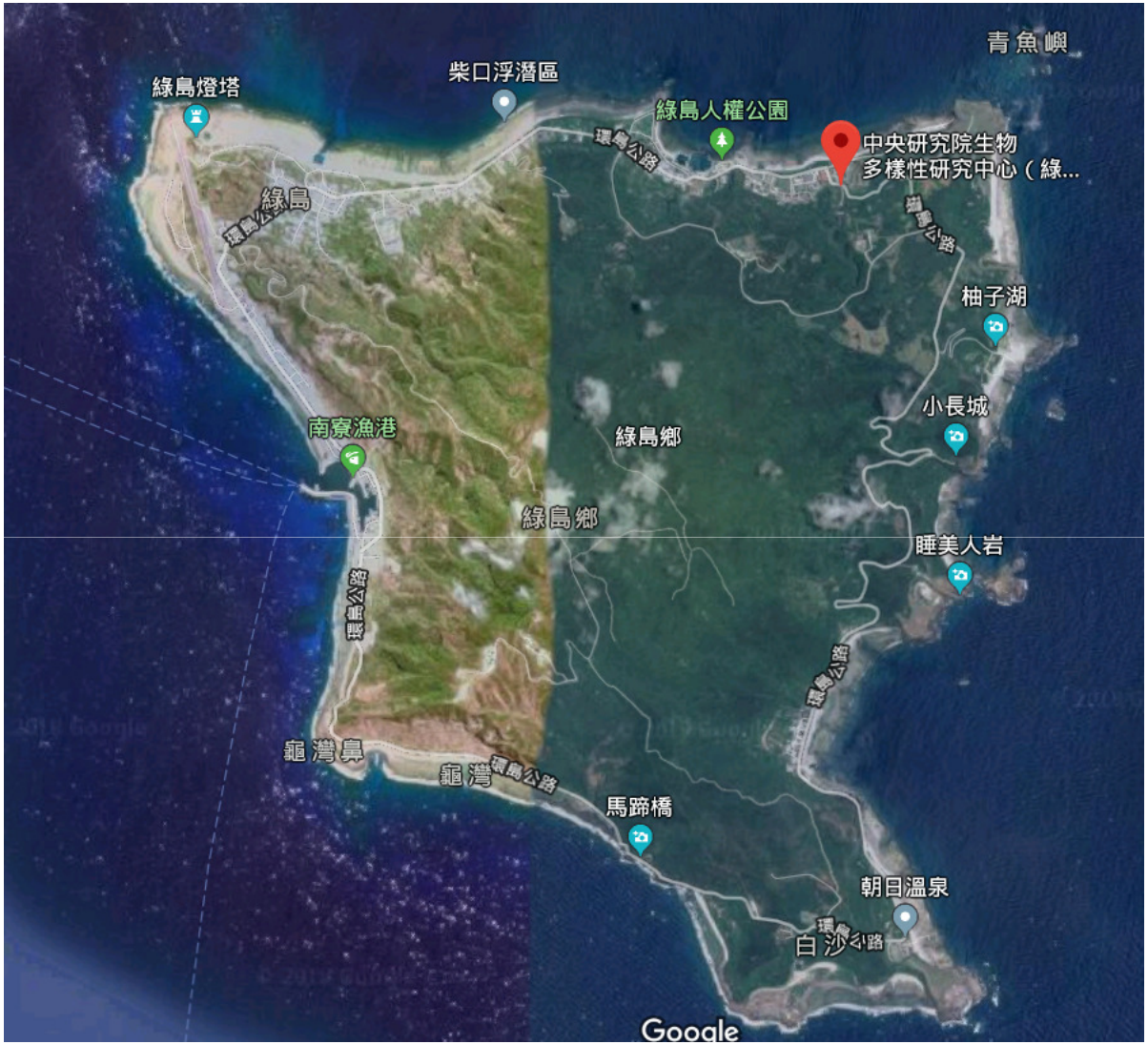
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南寮漁港
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睡美人岩
龜灣鼻
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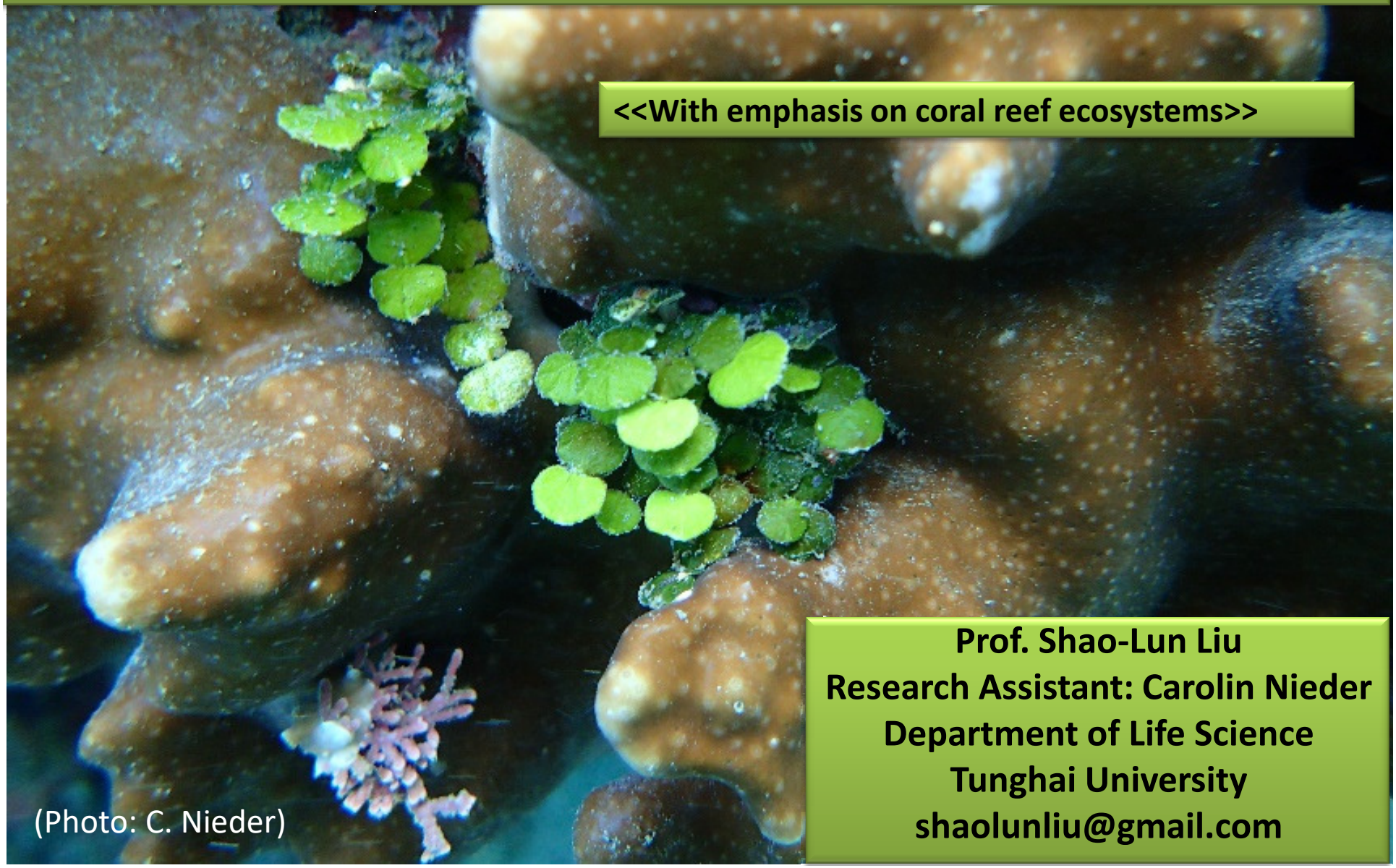
朝日溫泉
白沙
環島公路
Google

The Diversity and Ecology of Marine Macroalgae



<<With emphasis on coral reef ecosystems>>

(Photo: C. Nieder)

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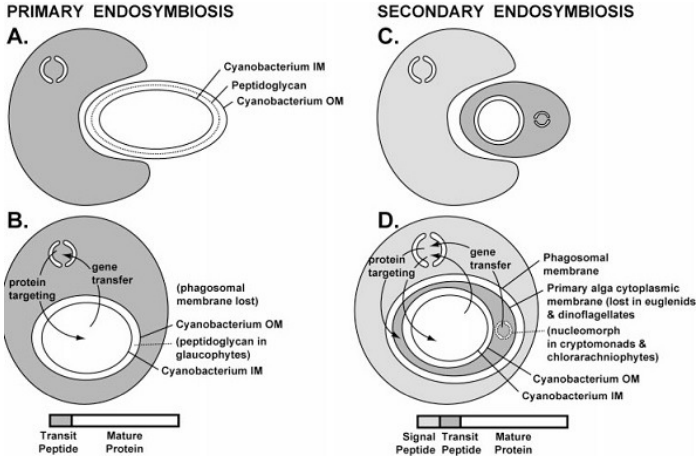
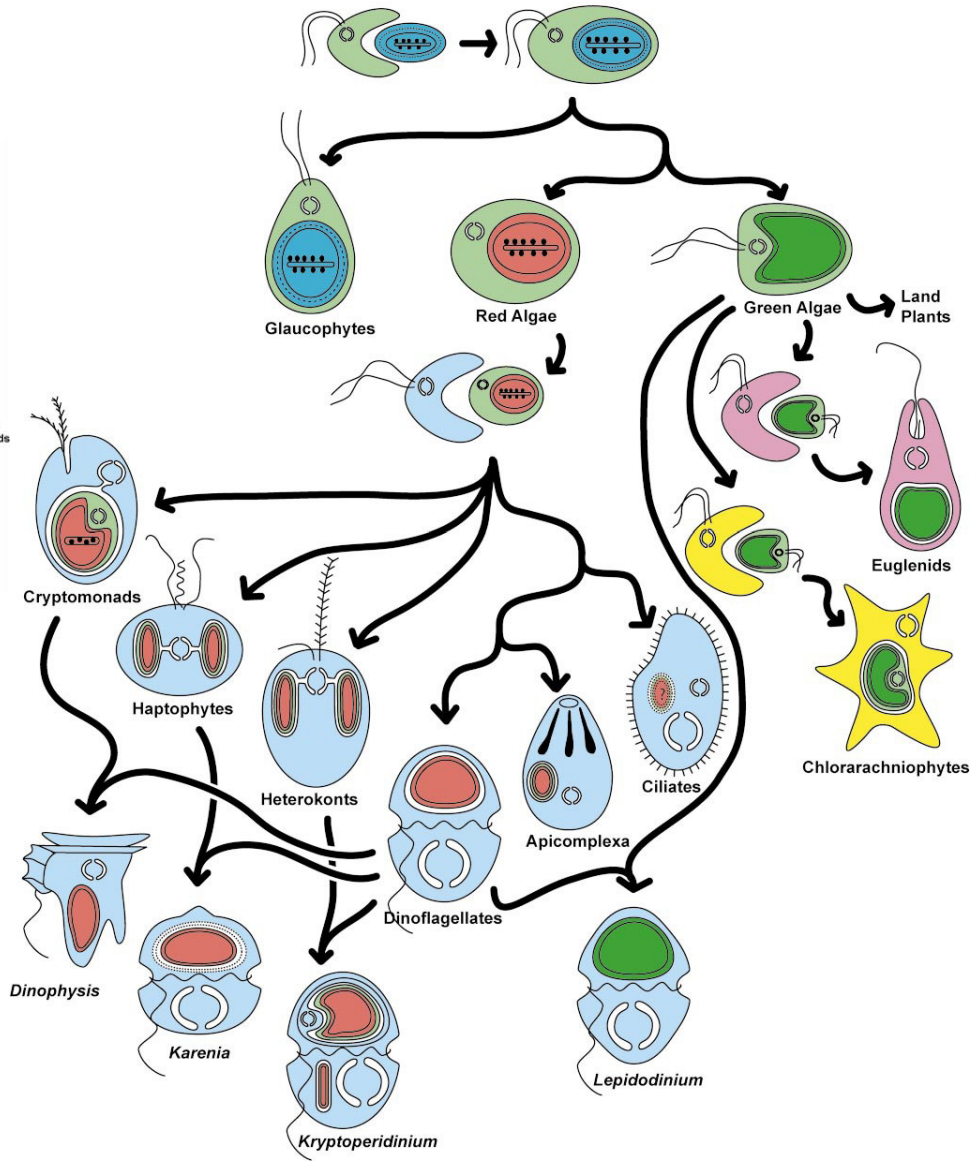
What are Macroalgae?

- **Macroalgae**: Collective term used for photosynthetic, multicellular, benthic algae, in aquatic ecosystems that are visible to the naked eye.
- **Benthos/benthic**: attached to the bottom
- **Microalgae:** photosynthetic, unicellular, algae, which require a microscope to be observed.
- **Seaweed:** refers to larger, marine macroalgae that have similar ecological roles to vascular plants.

Evolution of Algae

Endosymbiosis





PATRICK J. KEELING, American Journal of Botany 91: 1481–1493. 2004.

Taxonomic Diversity of Macroalgae

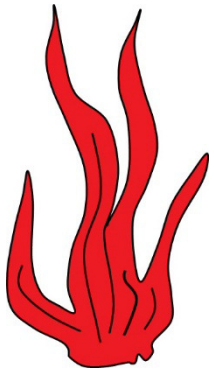
- Highly diversity, polyphyletic group
- Include members of 4 different phyla

	World-wide
Red algae	3900[(a)]-9500 [(b)]
Brown algae	1500 [(c)]-2151[(6)]
Green algae	>800 [(c)] – 1597 [(f)]
Total	6200-13248 [(d,f)]

[a] ref 149; [b] ref 145; [c] ref 110; [d] ref 130; [e] ref 20; [f] ref 64; Algae Base: <www.algaebase.org/>.

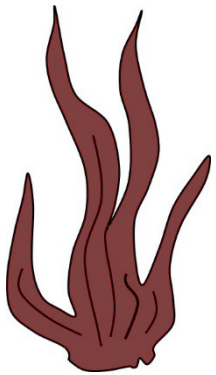
Different composition of photosynthetic pigments

Rhodophyta
Red Algae



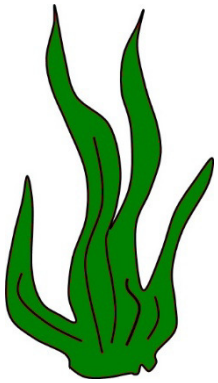
Greek “rhodo”=“red rose”
“phyton” = plant

Phaeophyta
Brown Algae



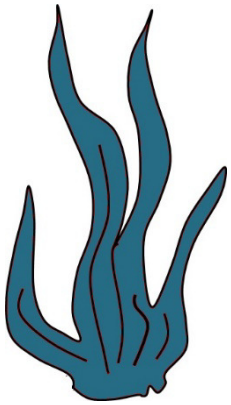
Greek “phaios” = “brown”

Chlorophyta
Green Algae



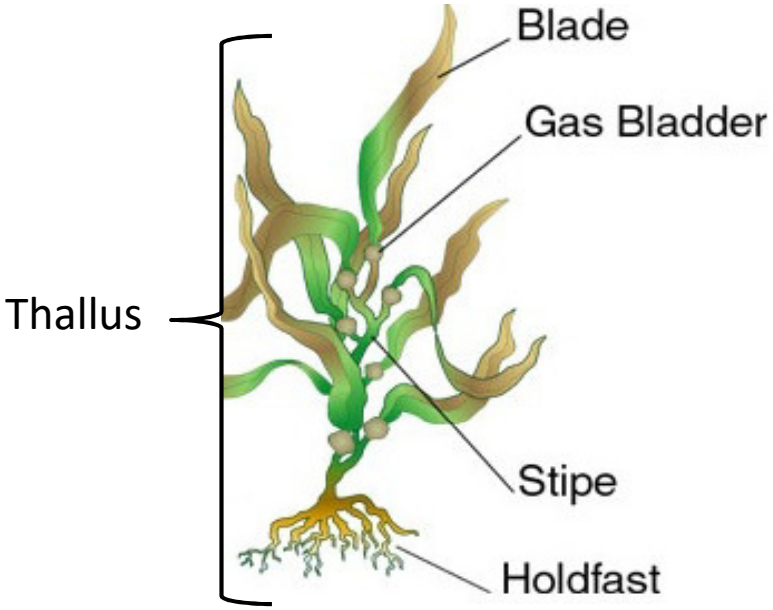
Greek “chloro” = “green”

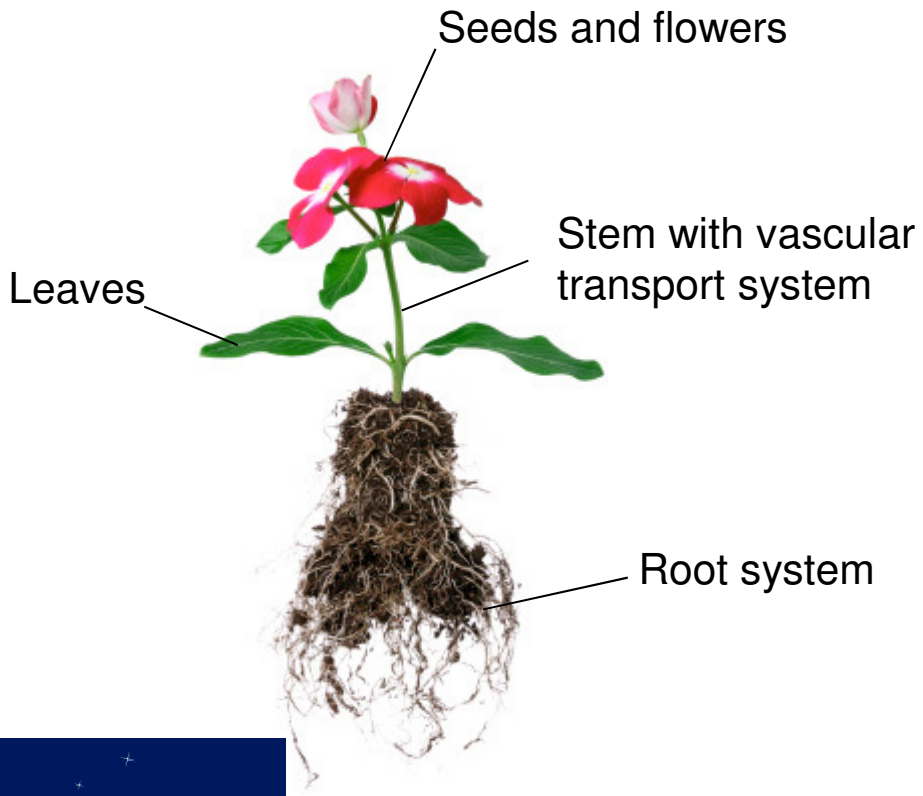
Cyanobacteria
Blue Algae

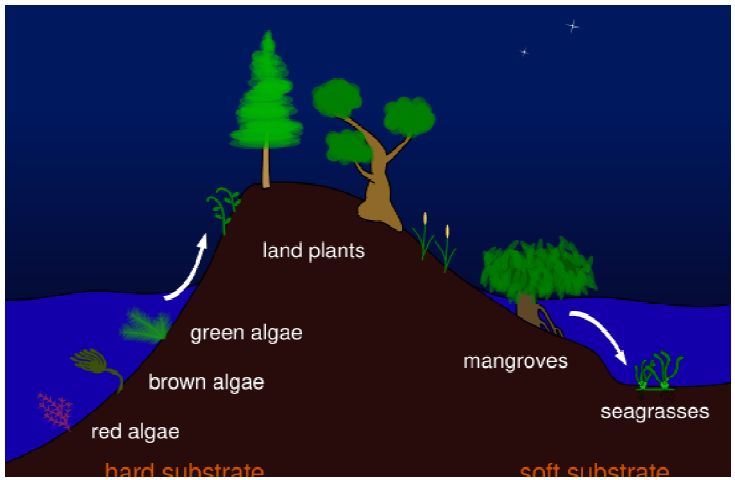


Greek “cyanos” = “blue”

Seaweeds are different from land plants







Functional Groups of seaweeds

Categorization according to:

- Size
- growth form → leafy, filamentous, crustose
- Degree of calcification → calcareous, fleshy
- Chemical compounds → allelopathic

Structural similarity can indicate similar ecological function

Turf algae

(< 1cm height)

Larger algae

Fleshy Calcareous

(> 1cm height)

Crustose algae

Fleshy Calcareous

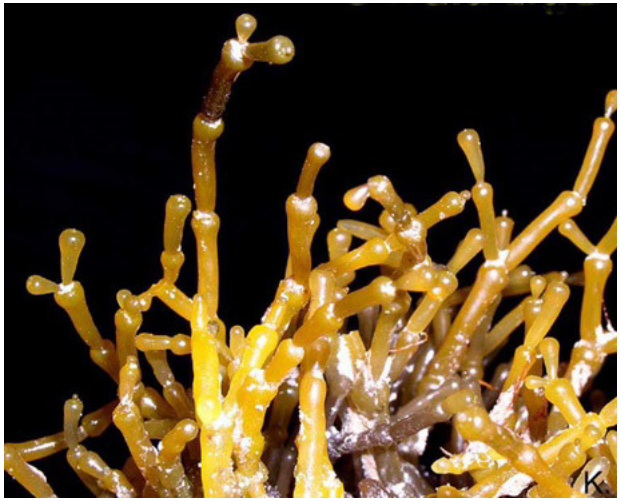
(Photo: C. Nieder)

Red Algae

- Oldest group of eukaryotic algae
- Largest group with more than 9,000 species
- use phycobiliproteins as accessory pigments (giving them their red color)

Hypnea pannosa

Gracilaria salicornia



Highly competitive: invasive algae on reef flats in Hawaii

Coralline Algae

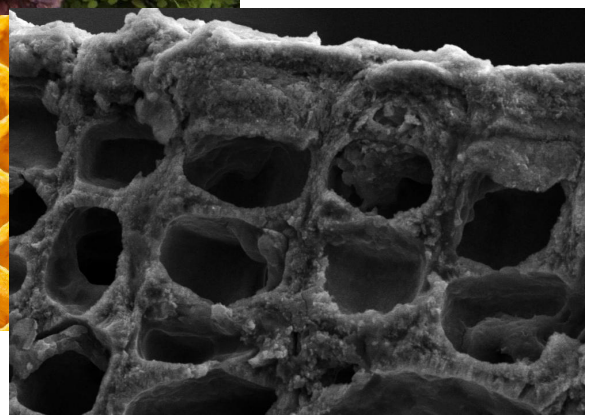
Red Algae

Encrusting "rock-like" coralline algae

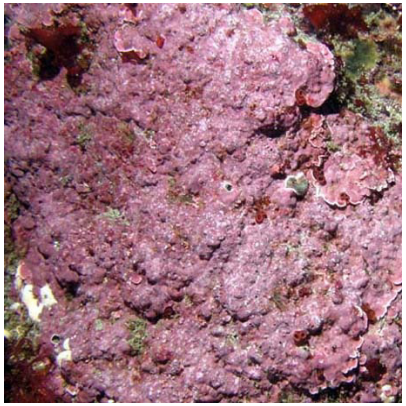
Lithothamnion sp.

- Important reef stabilizers: act as "cement" to join coral "bricks"
- Slow growth (1-3 cm/year)
- Depend on herbivores to remove overgrowing fleshy algae
- Promote settlement of coral larva

Honey comb structure of calcified cells



forming hard crusts



Coralline Algae

Red Algae

Articulated “erect” coralline algae

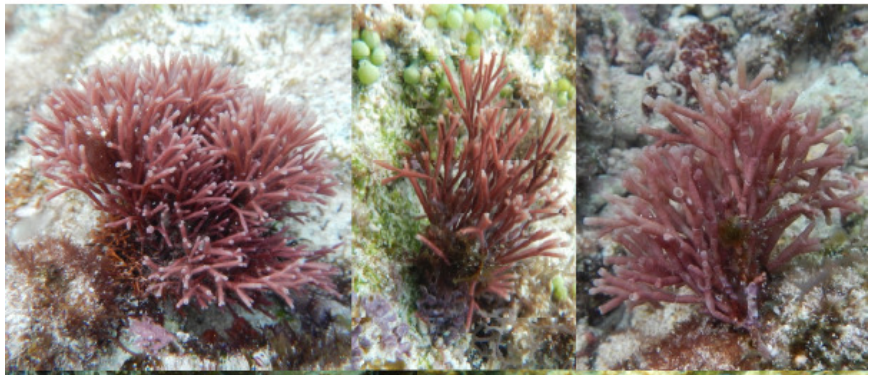
Jania rubens

Epiphytic, growing on brown algae

Galaxauraceae

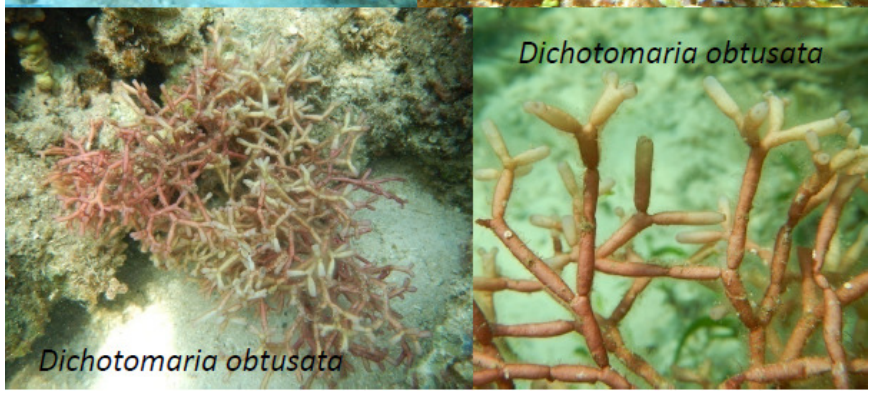
Red Algae

Tricleocarpa spp.



Dichotomaria elegans

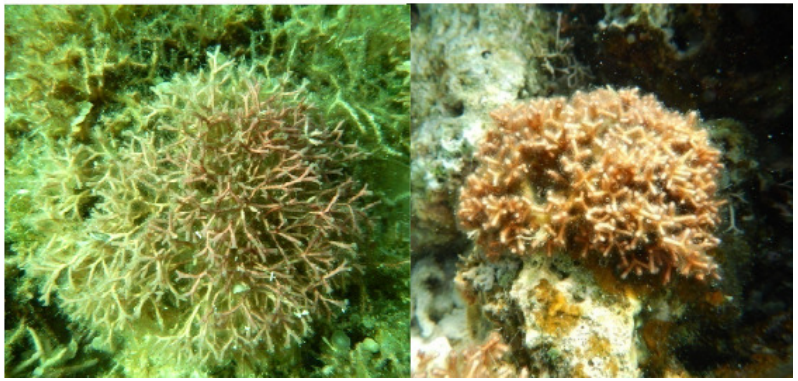
Dichotomaria marginata



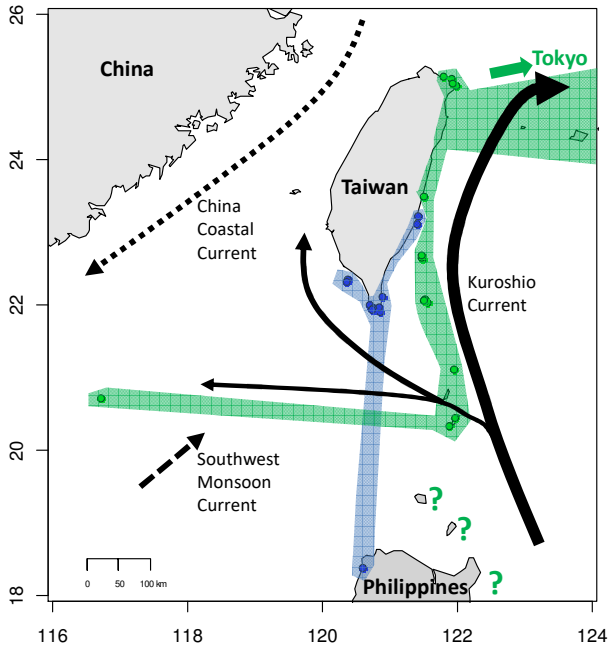
Dichotomaria obtusata

Dichotomaria obtusata

Galaxaura spp.



No. of Samples = **102** v.s. **39**



Green Algae

Ulva spp.

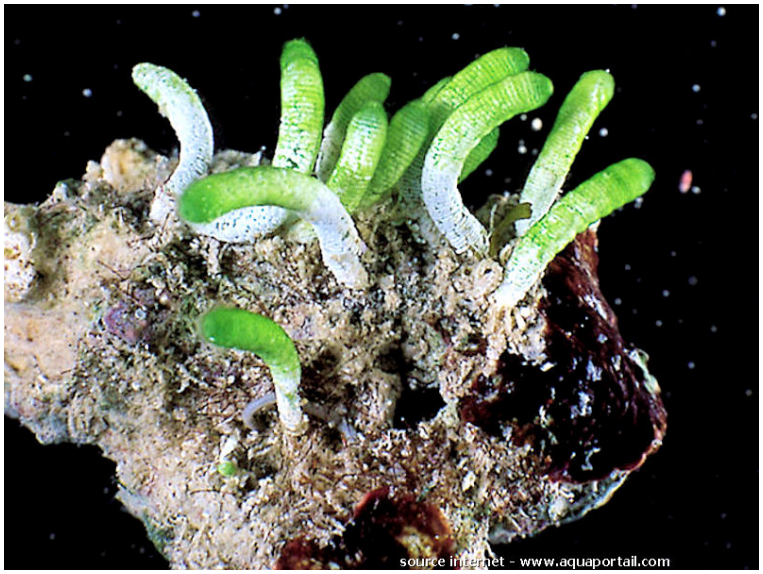
Green Algae

Caulerpa sp. – One giant, single cell

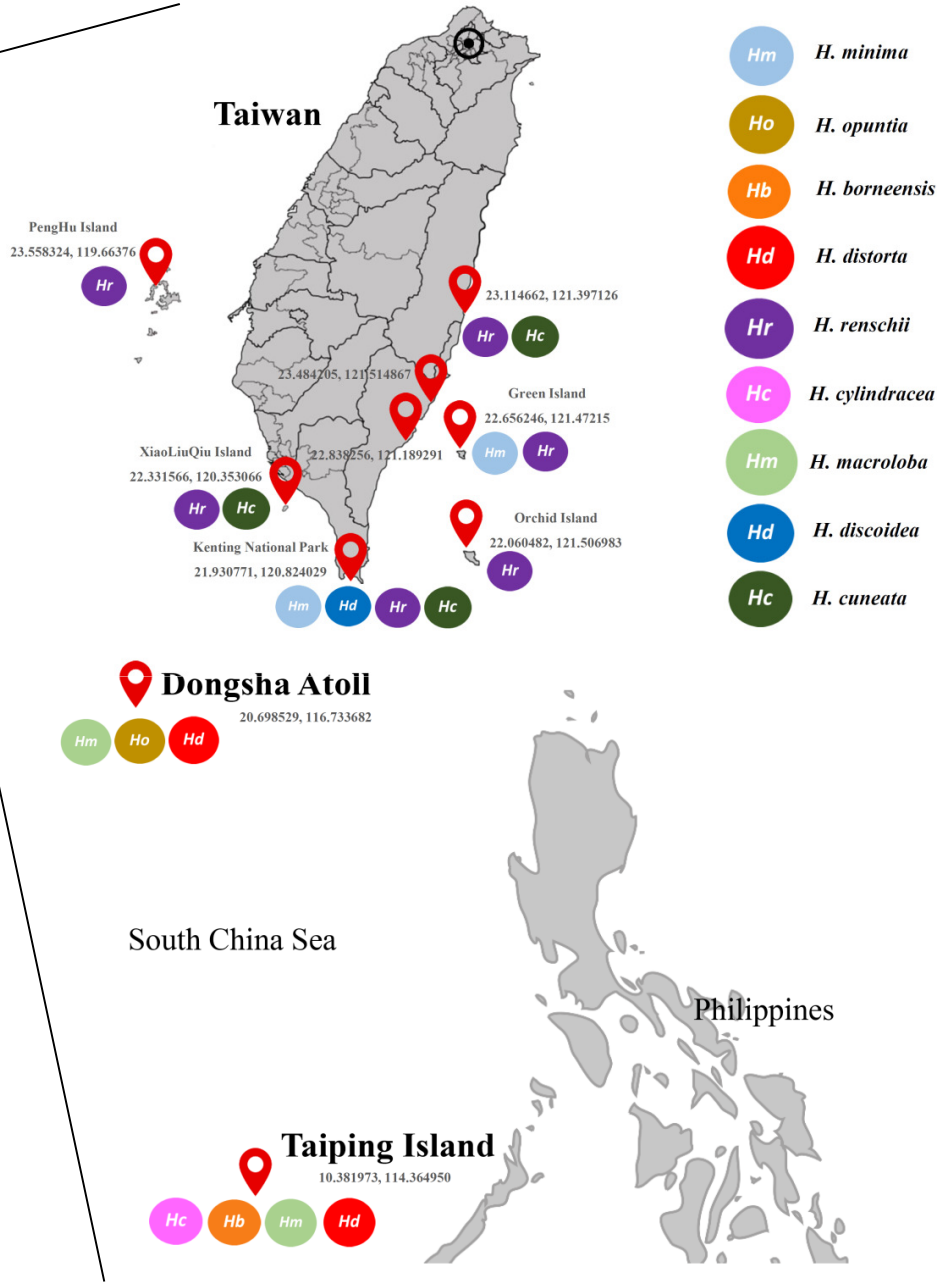
Caulerpa oligophylla

Caulerpa taxifolia

Halimeda spp.



Neomeris spp.

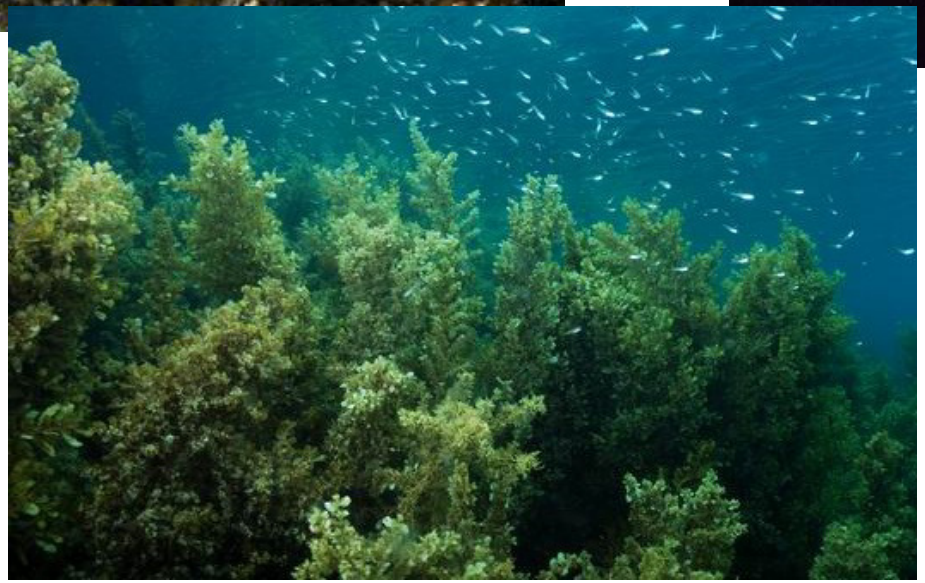


(Sinjai's work; Collaboration with Dr. Jaruwan at PSU)

Brown Algae

Padina sp.

Tubularia ornata



Sargassum spp.

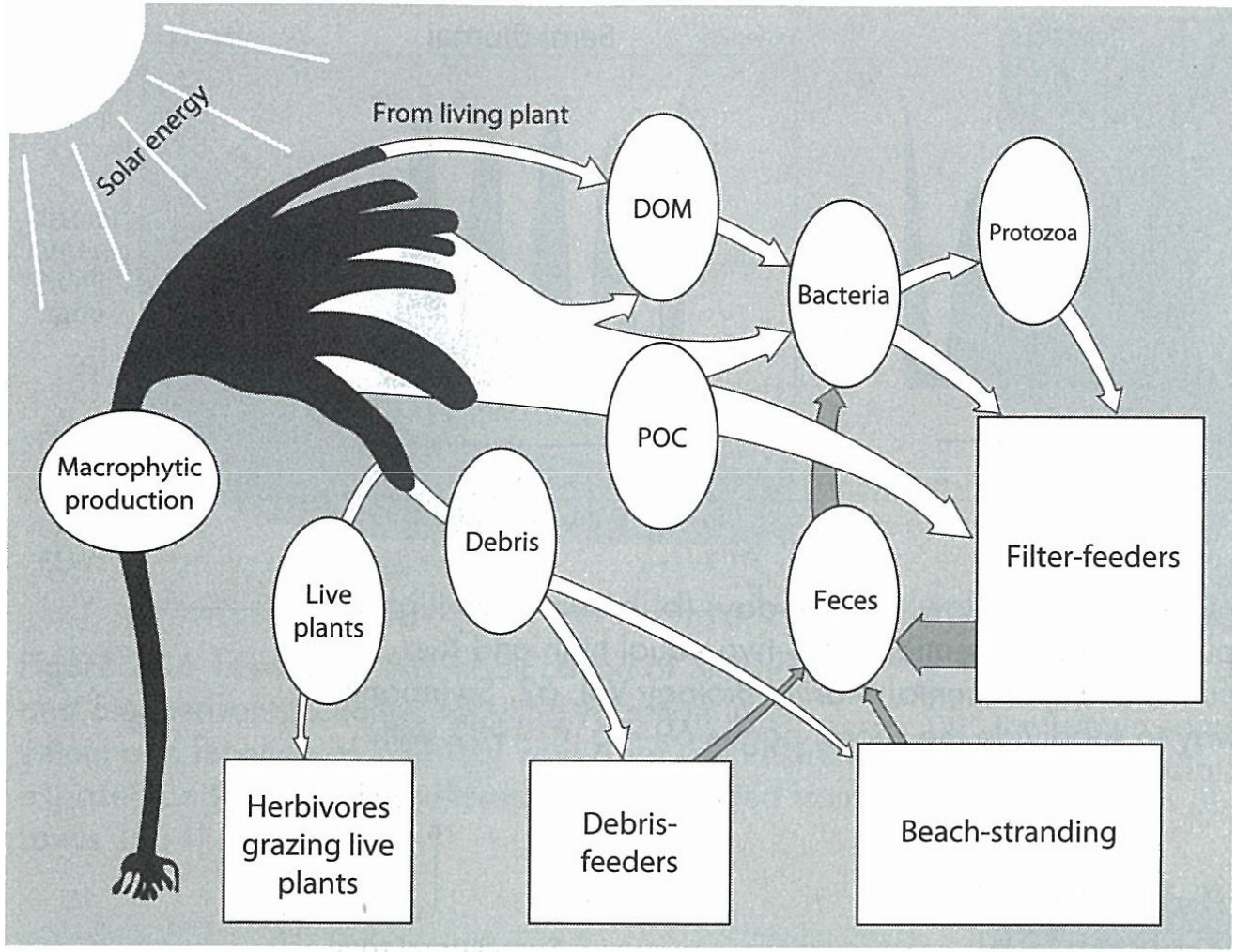
Macroalgae are the primary productivity

- The *Postelsia* community (the Pacific U.S. coast): 14.6 kg m^{-2} yr^{-1} (Leigh et al., 1987).
- The kelp community (eastern U.S. coast): 1.75 kg m^{-2} yr^{-1}.
- The rain forest community: 2 kg m^{-2} yr^{-1}.
- Important ecosystem for the past 500 Mya (Xiao et al., 1998).

Postelsia community

Kelp community

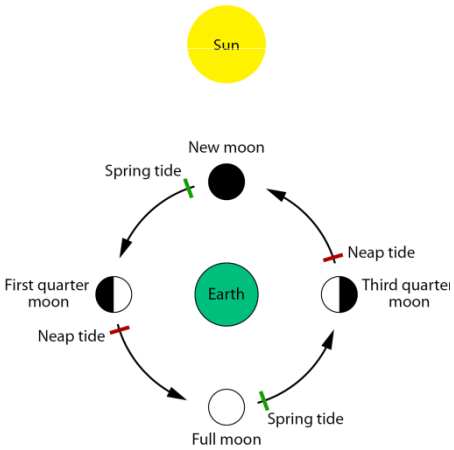
10% (Herbivores) & 90% (Food Webs)

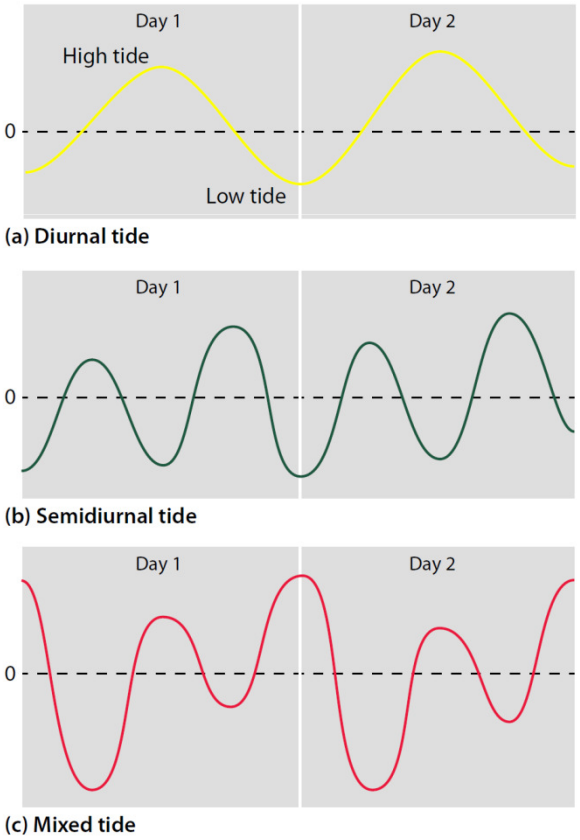


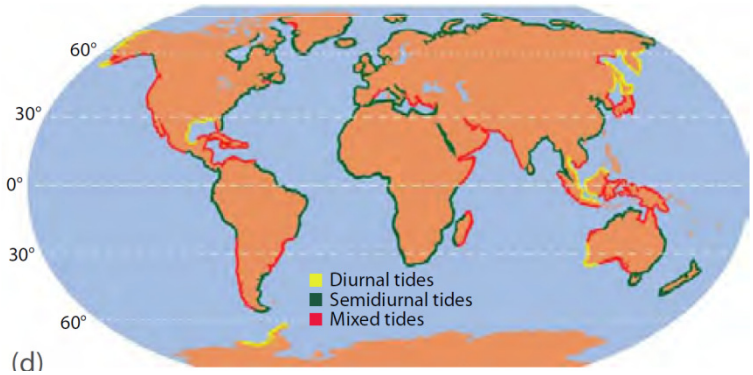
DOM, dissolve organic material; **POC**, particulate organic carbon.

Physical Factors: Tides

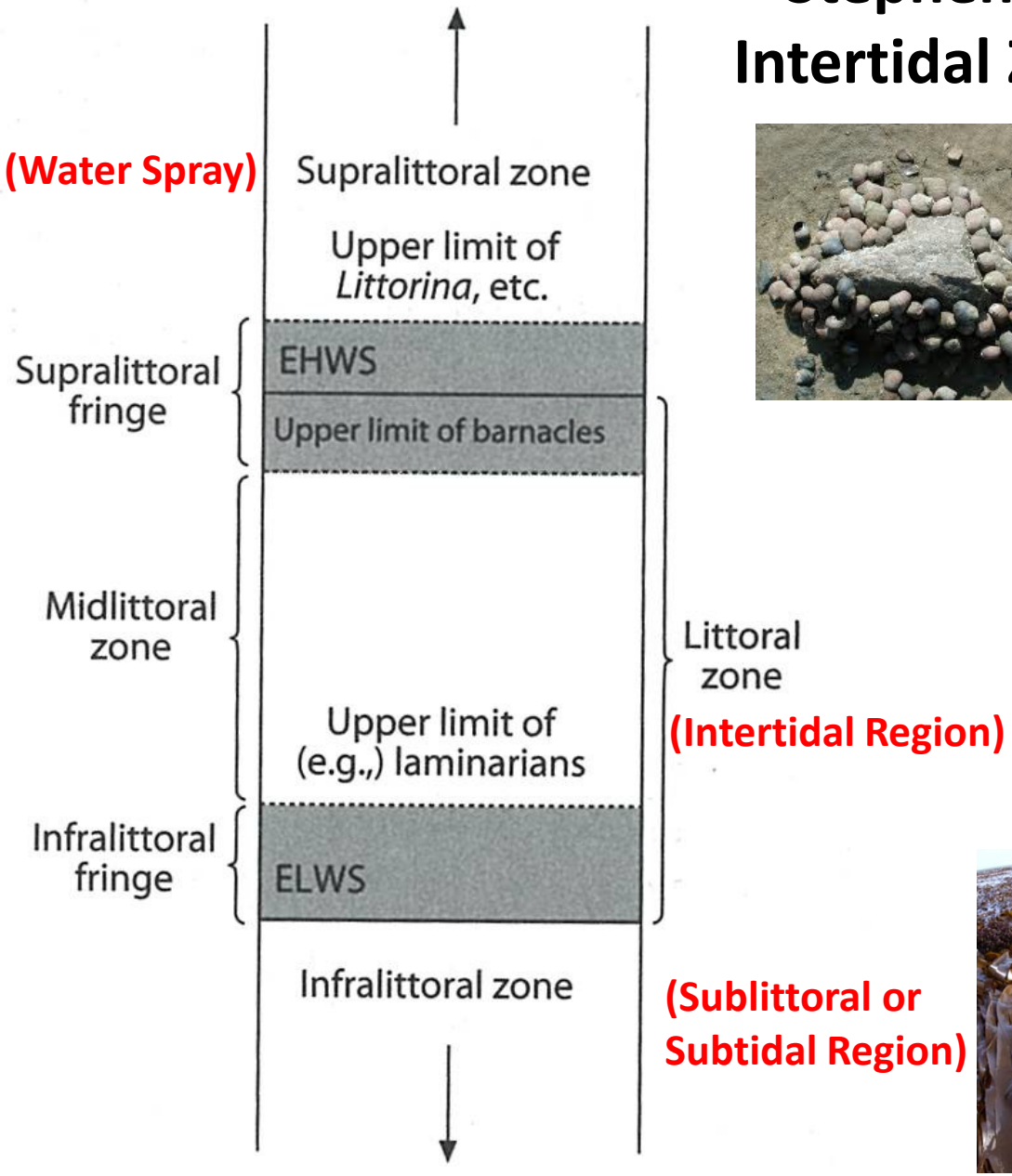
- The frequency and amplitude of tides affected by the morphology of the ocean basin.







Stephenson and Stephenson's Intertidal Zonation System (SSIZS)



Littorina spp.

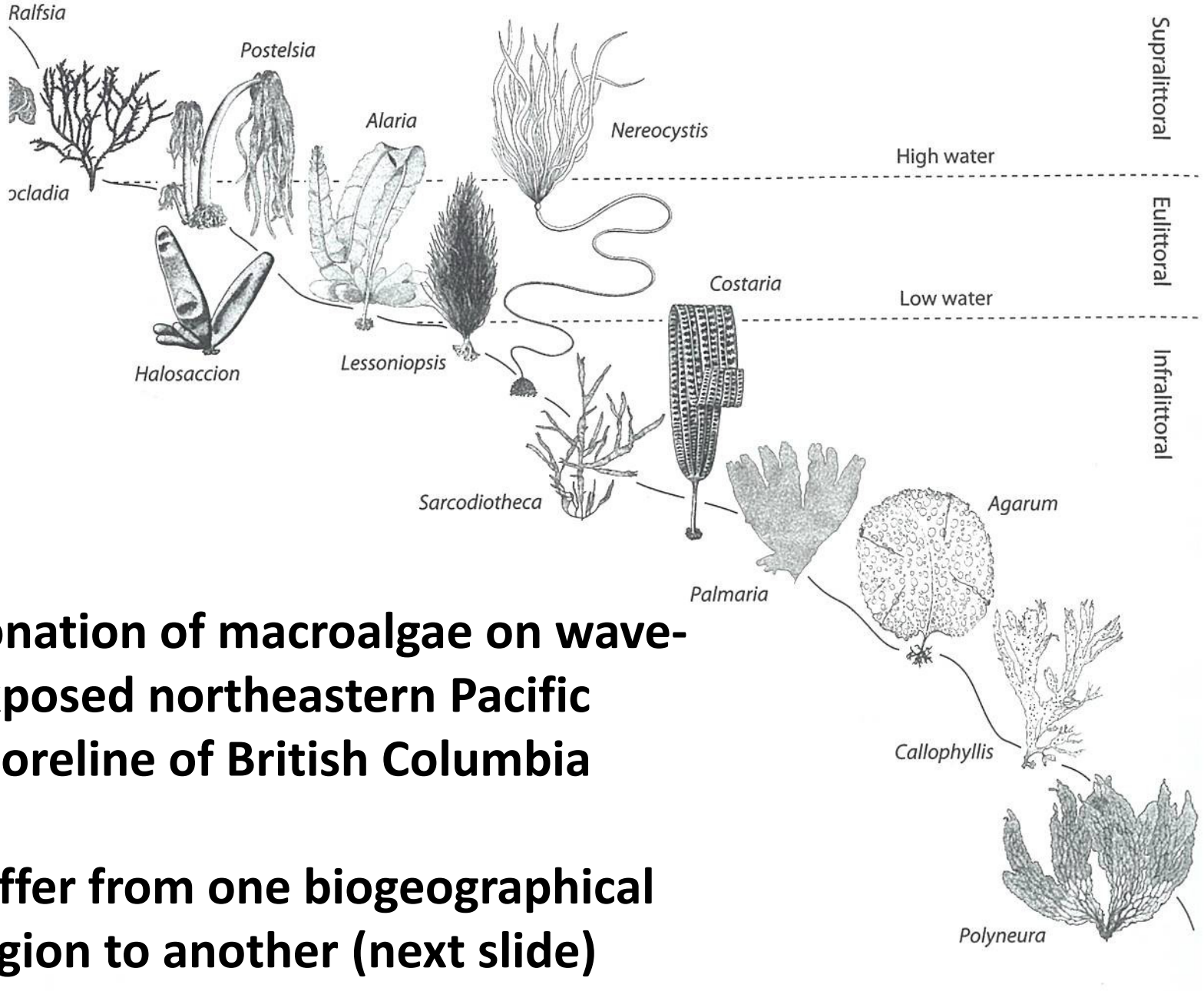
Barnacles

Seaweeds

Limpets

Laminaria sp.

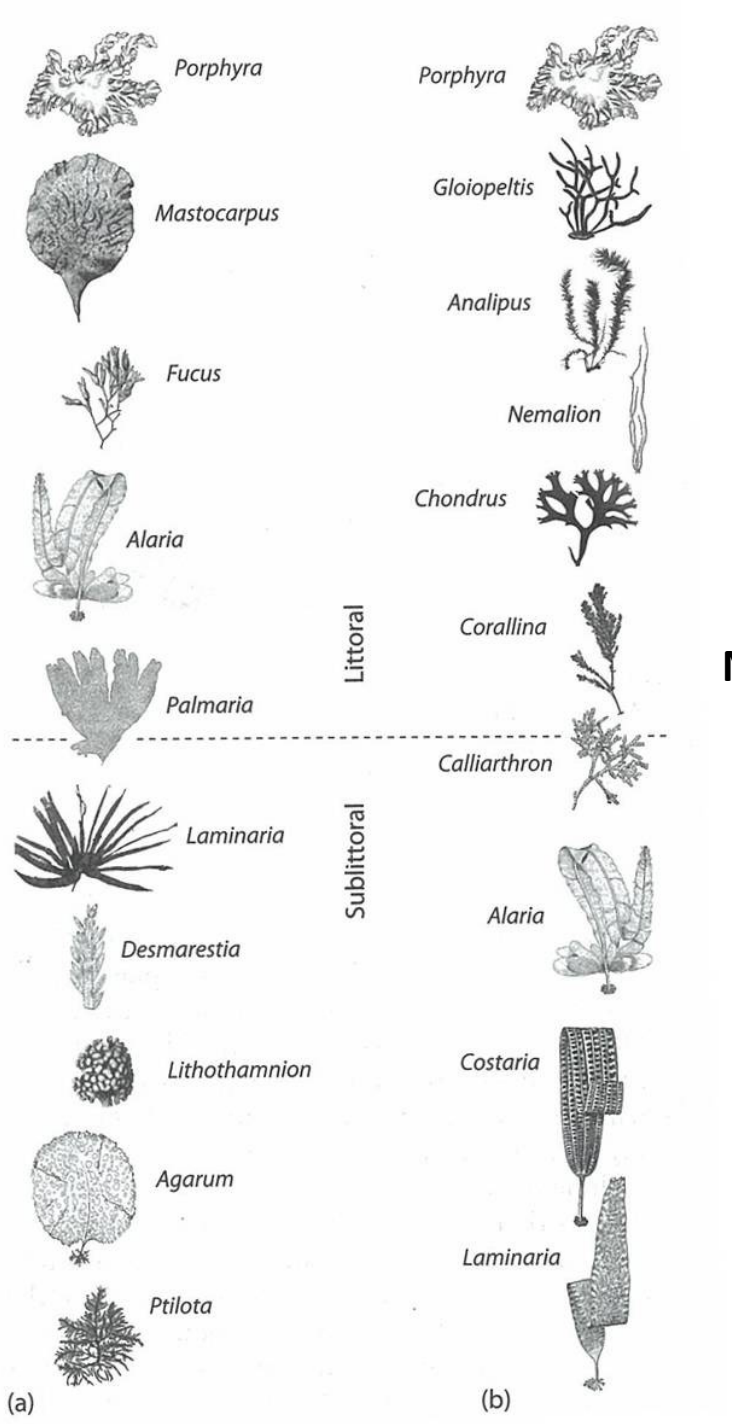
Corals



Zonation of macroalgae on wave-exposed northeastern Pacific shoreline of British Columbia

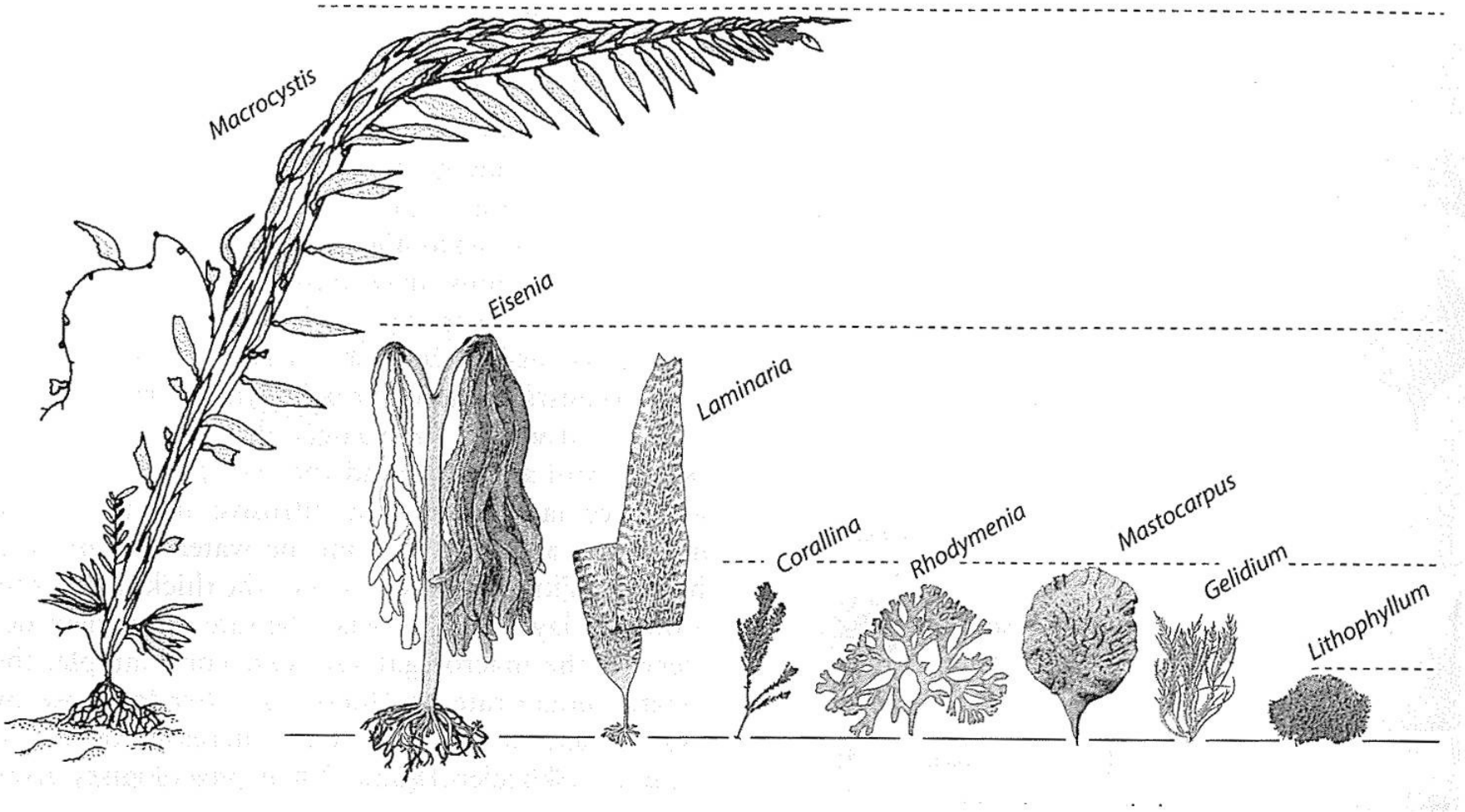
Differ from one biogeographical region to another (next slide)

Northwestern Atlantic (Newfoundland, Canada)

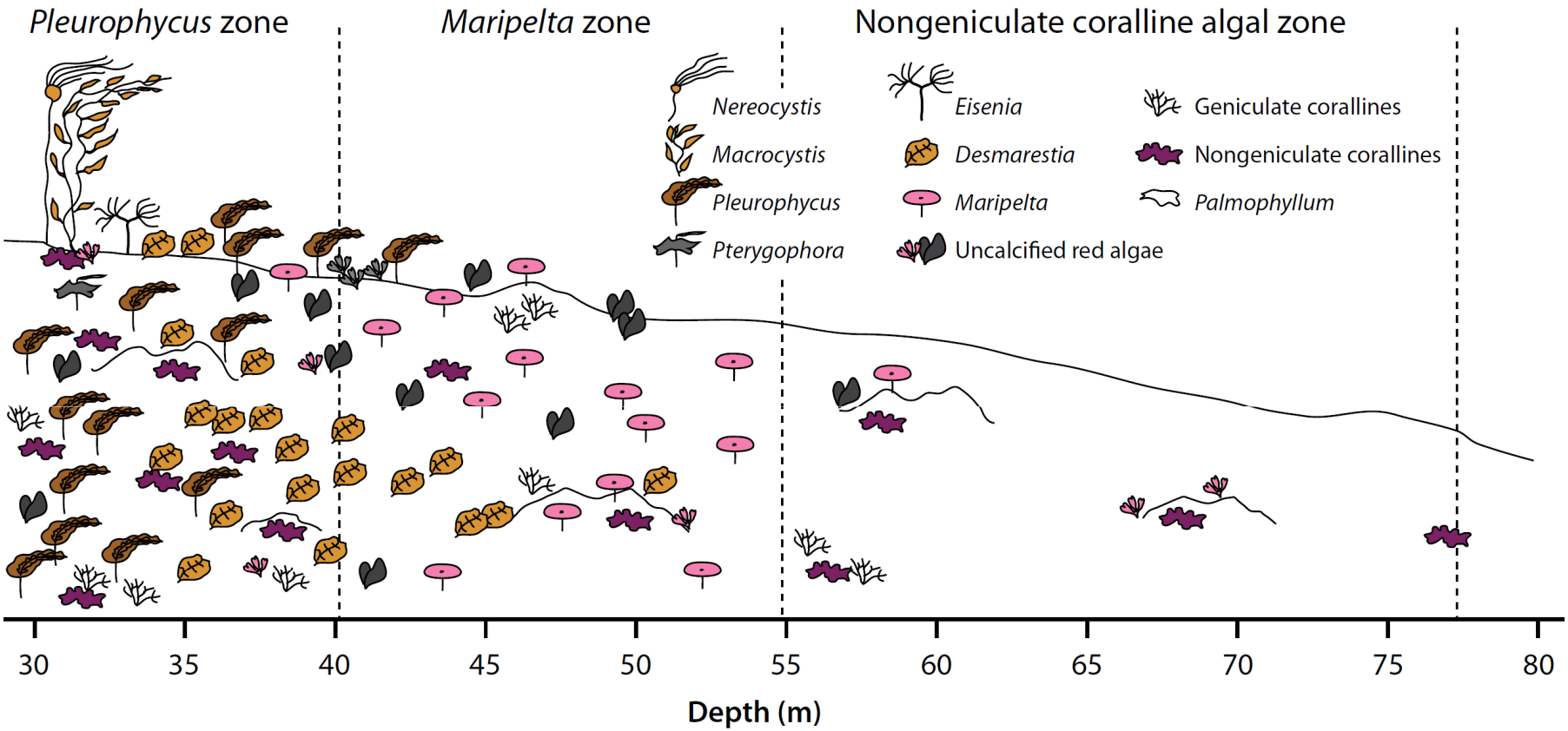


Northwestern Pacific (Japan)

Composition of mid-sublittoral community in California



Deep-water Community in California



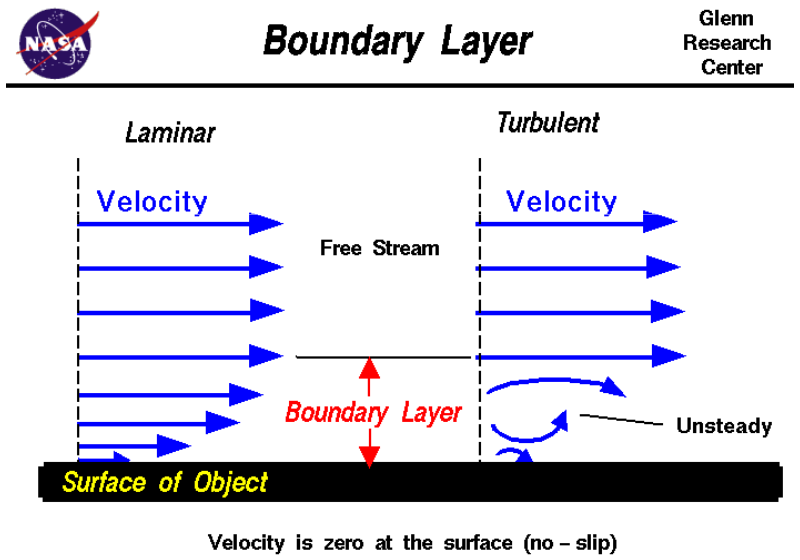
SCUBA + Remote Controlled Vehicle

(Spalding et al., 2003)

Physical Factors: Waves & Currents

- Reduce the thickness of boundary layer

  → Increase nutrient absorption efficacy



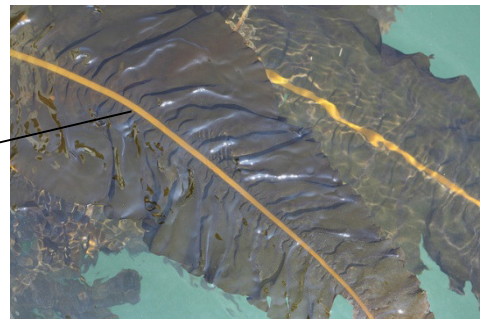
- Remove barnacles and limpets

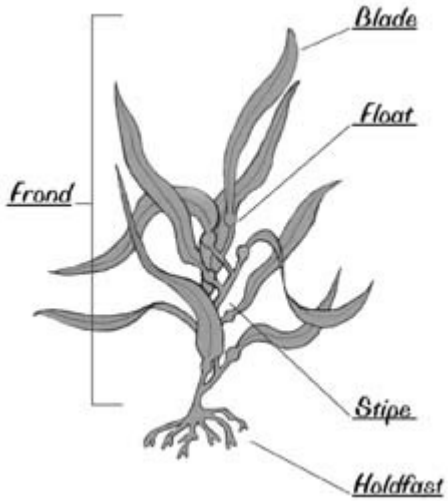
  → Open up the attachment space

Adaptations: Elasticity

Negative impact

- Damage, destruction, and removal.





Adaptations

- Elasticity

  →stretchiness, flexibility, twisting, & strength.

- Strong attachment adhesives (holdfast)

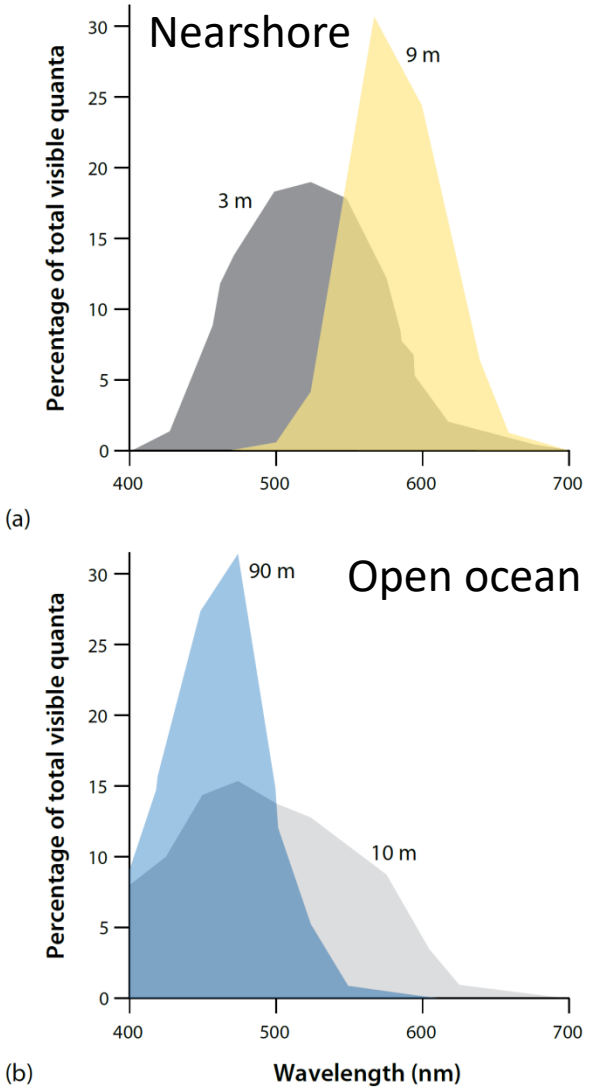
  → *Laminaria*: 40 kg cm^{-2} (Schwenke, 1971)

Other Physical Factors

- Light (too strong & not enough)
  → Changes of Pigments

- Salinity & Desiccation
  → Intertidal seaweeds (10-100 ‰; high tolerance to desiccation)
  →Subtidal seaweeds (18-52 ‰; low tolerance to desiccation)

- Nutrient (N, C, P)
  →Nitrate Reductase (N Usage)
  →Akaline Phosphatase (P limitation)



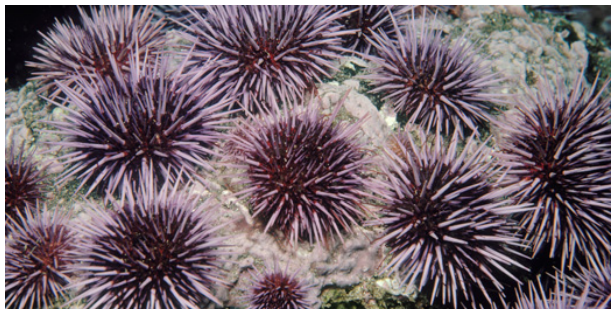
Biological Factors

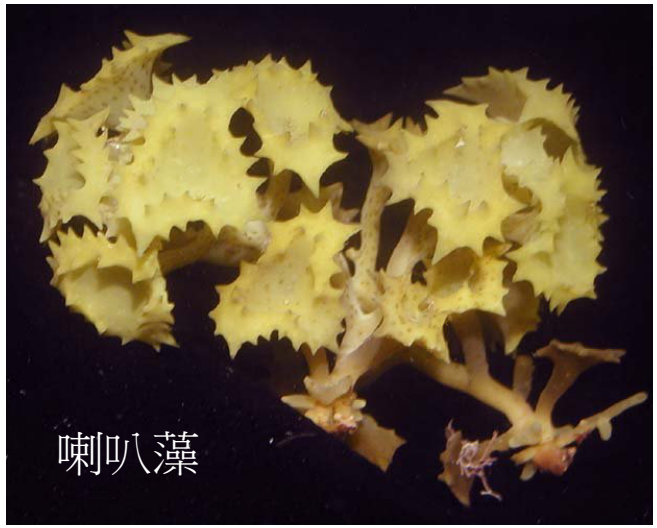
- Herbivory Interactions

  → Chemical Defense: secondary compounds (e.g., terpenes, acetogenins, alkoloids, and phenolics).

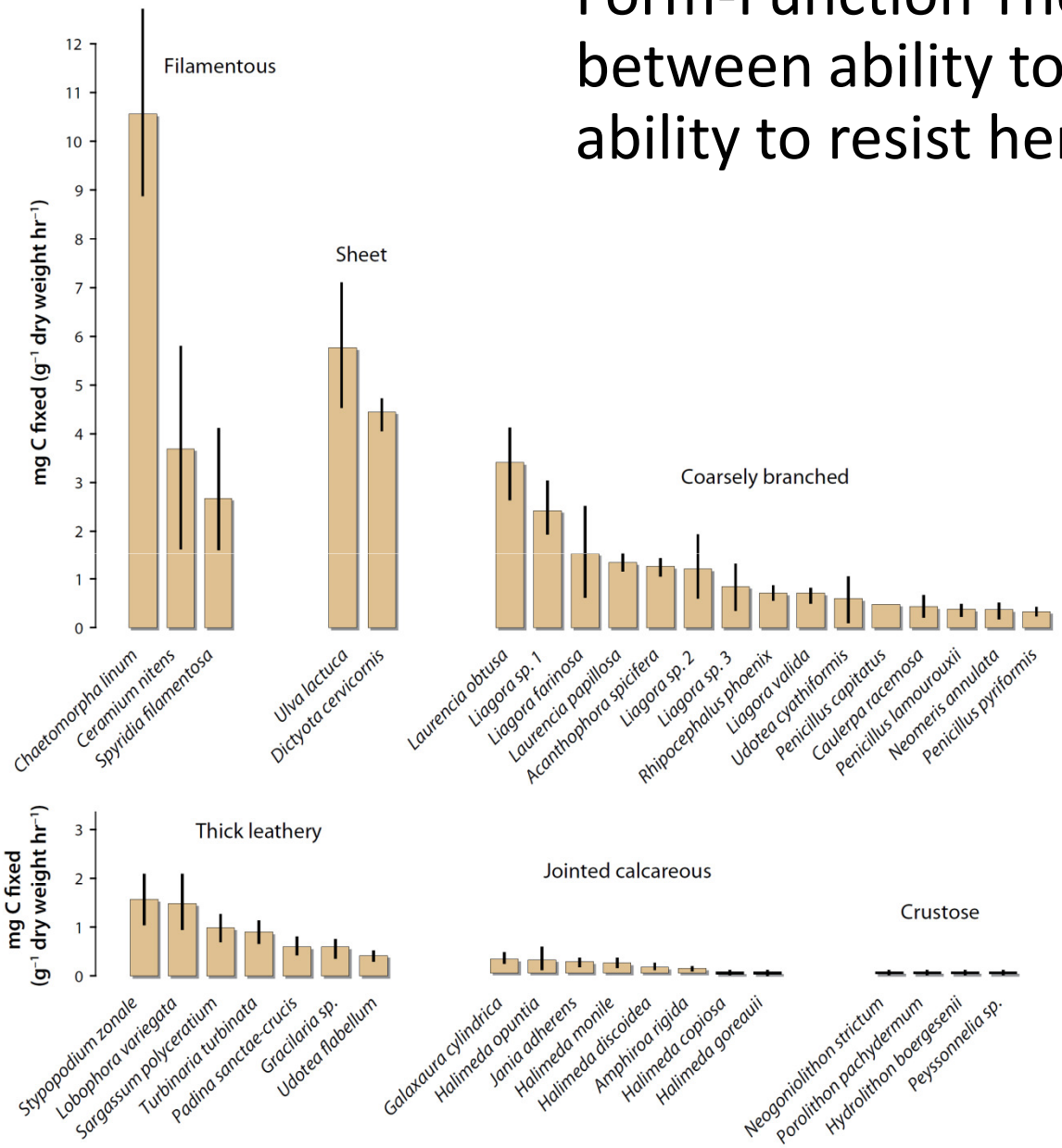
  → Physical Defense: spiny blades.

- Different herbivores prefer different life stages.

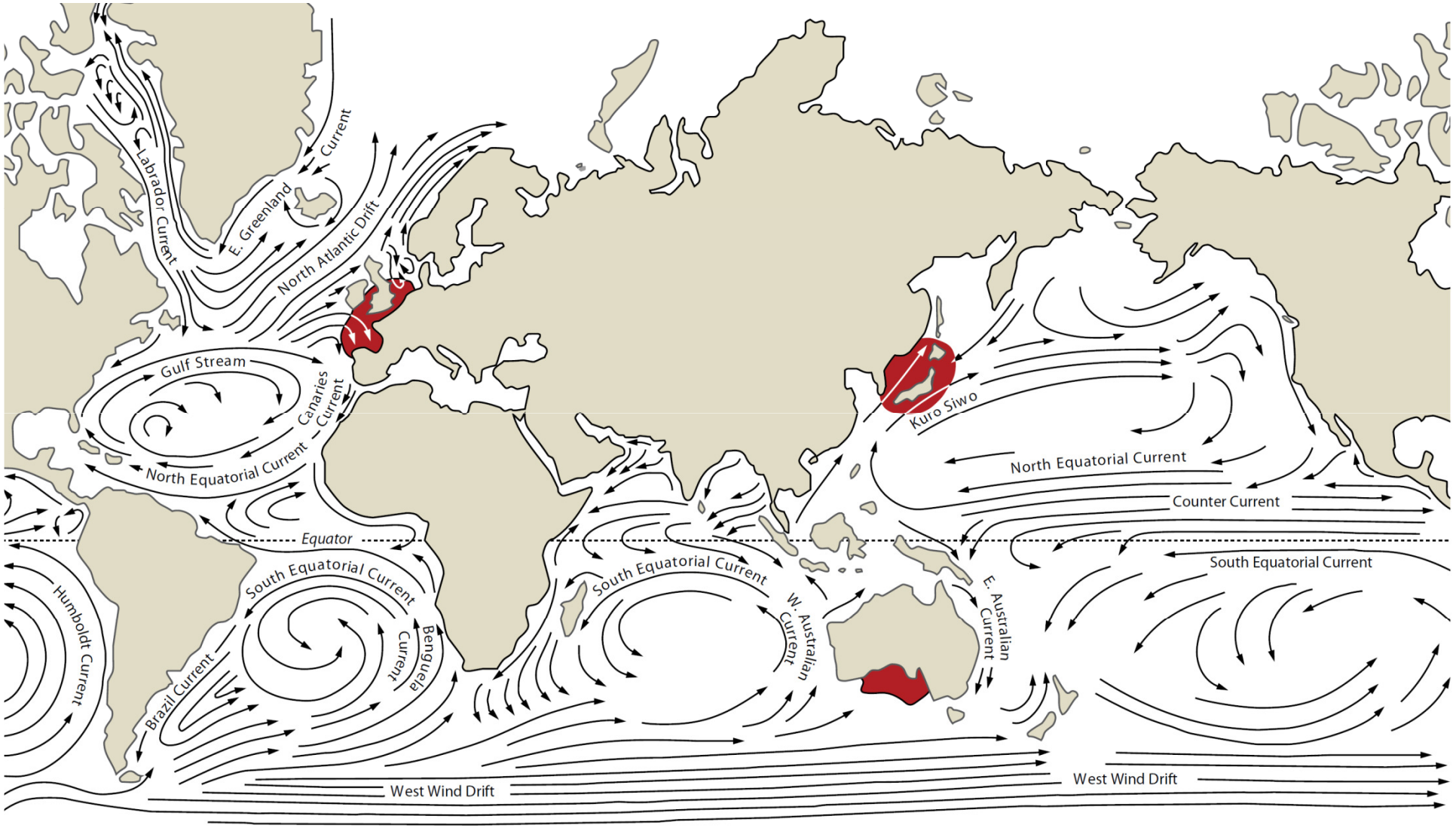




- Form-Function Theory: trade-off between ability to grow fast and ability to resist herbivores.

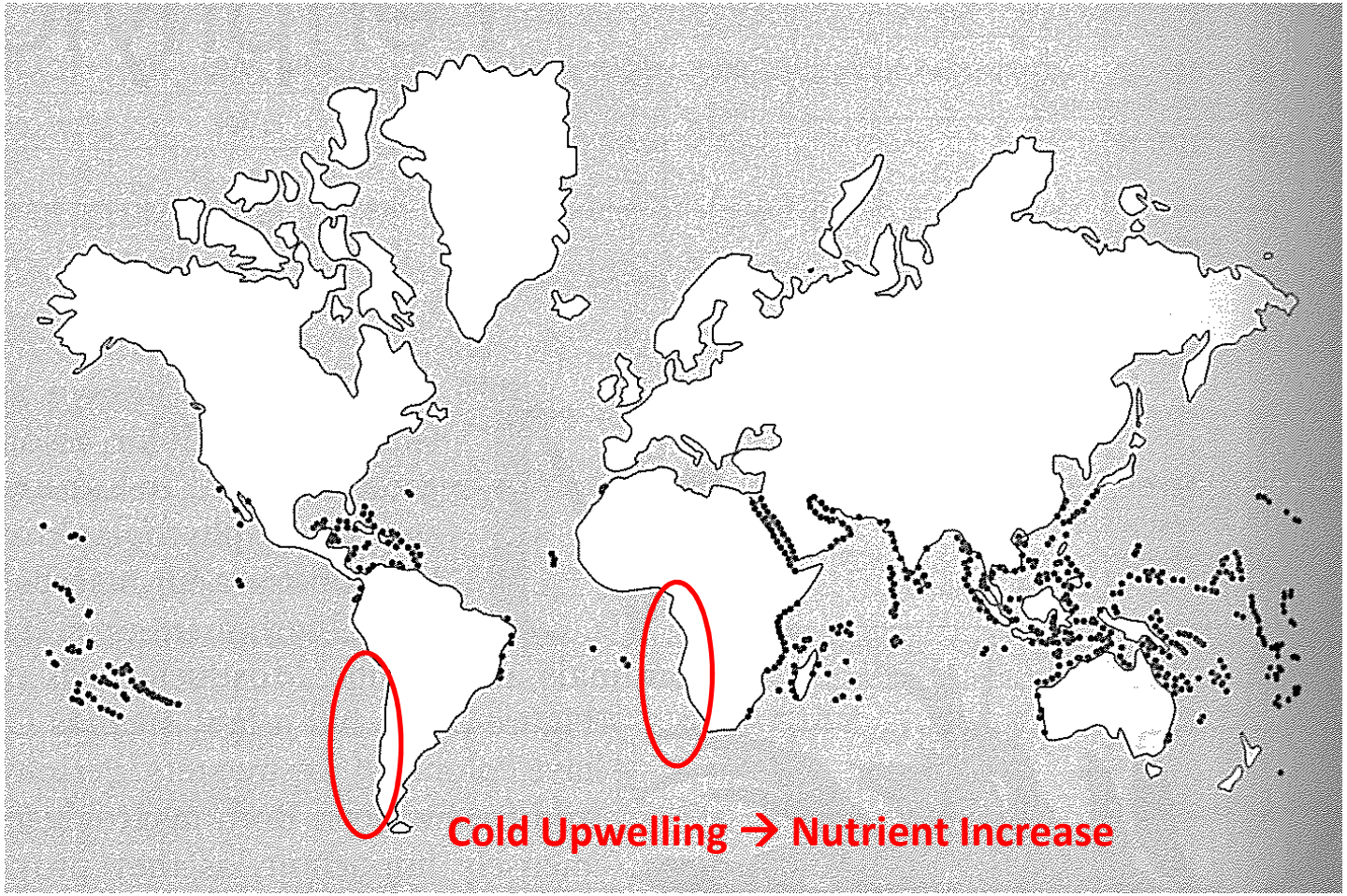


Seaweeds Biogeography



Three seaweed hotspots (warm temperate coast): Japan, southern Australia, and western Europe.

- **Hypothesis: Competitive Exclusion between Macroalgae & Corals**



Corals: latitude 30N~30S.

Nutrient increase or Herbivore decrease:

coral dominant → macroalgae dominant.

(Miller, 1998)

Global Patterns of Macroalgae Biodiversity

- High biodiversity in temperate regions
- Lower seaweed biodiversity in the tropics

- Temperature, salinity and other abiotic factors control biodiversity in temperate and polar regions.

- Biotic interactions are more important in the tropics (Wiens & Donoghue, 2004, Keith et al., 2013).

MACROALGAE COMPETE WITH CORAL FOR SPACE

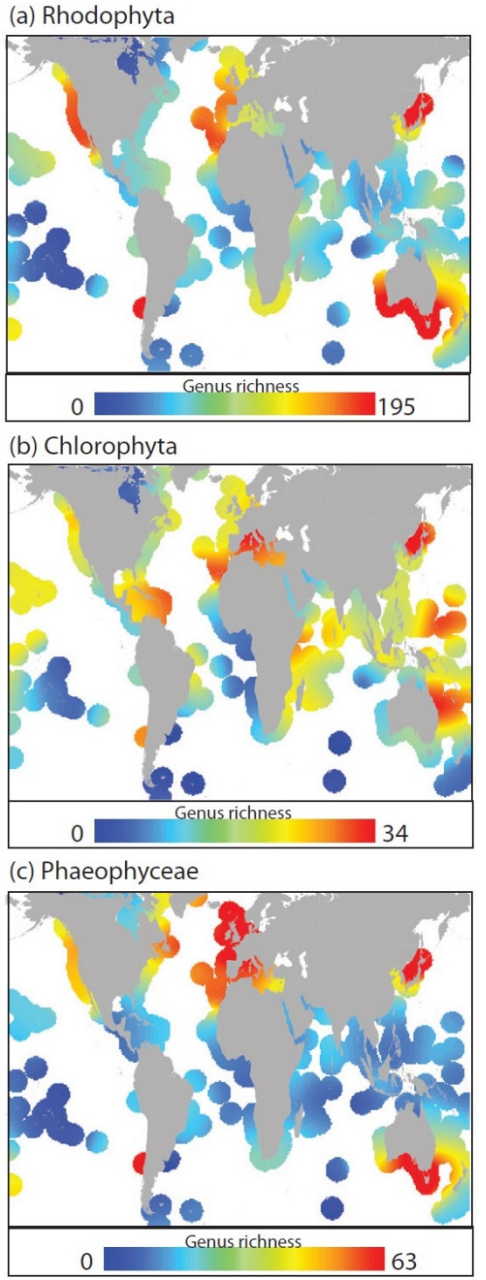
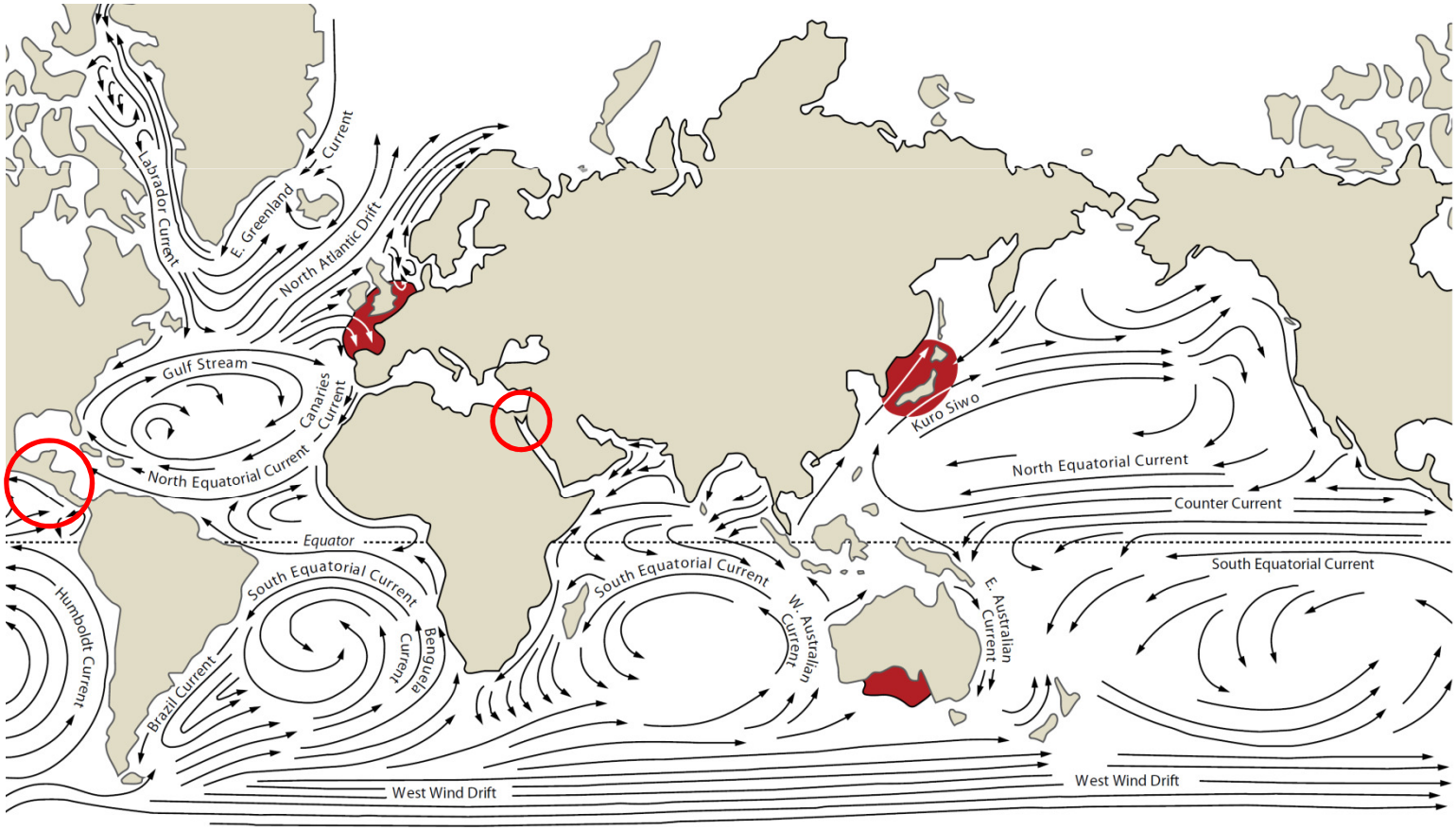


Figure 1 Global distribution of macroalgal genus richness for three clades: (a) Rhodophyta, (b) Chlorophyta, (c) Phaeophyce Note the maximum genus richness varies across groups. White indicates there were no data for that region. Map projection: World Equidistant Cylindrical. (Keith et al., 2013)

- Tropical Seaweeds have a circumglobal distribution.

  →Closure of Mediterranean (17 Mya)

  →Central American Land Bridge (3-4 Mya)

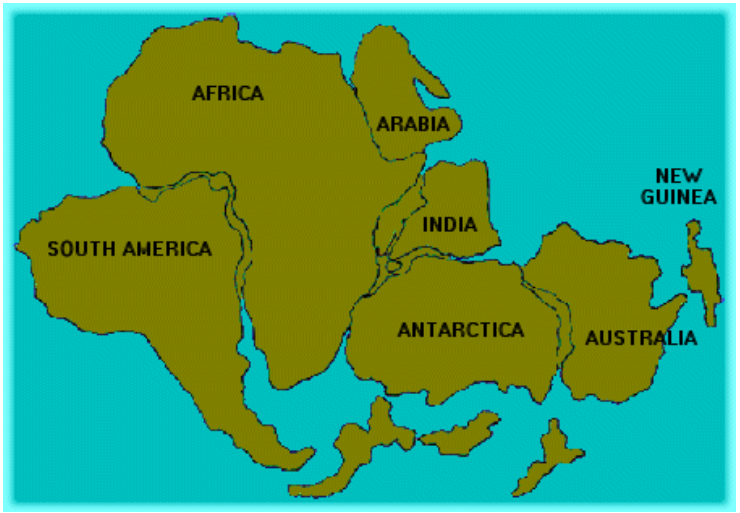


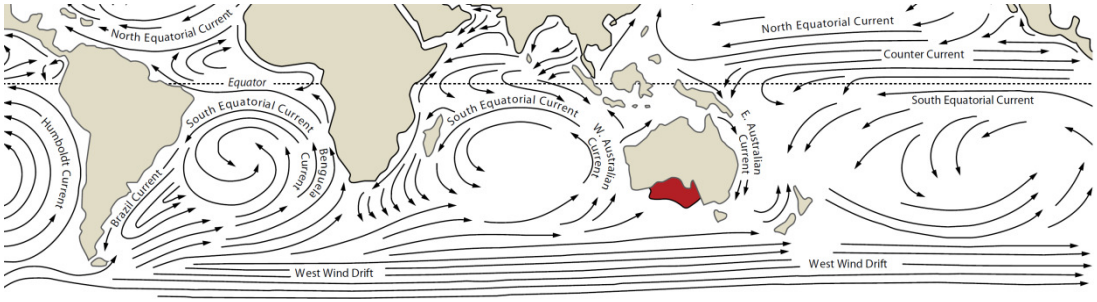
- The cold temperate seaweed flora in southern hemisphere is highly similar around the world.

  →Gondwana Coastline

  →West Wind Drift Current

Gondwana





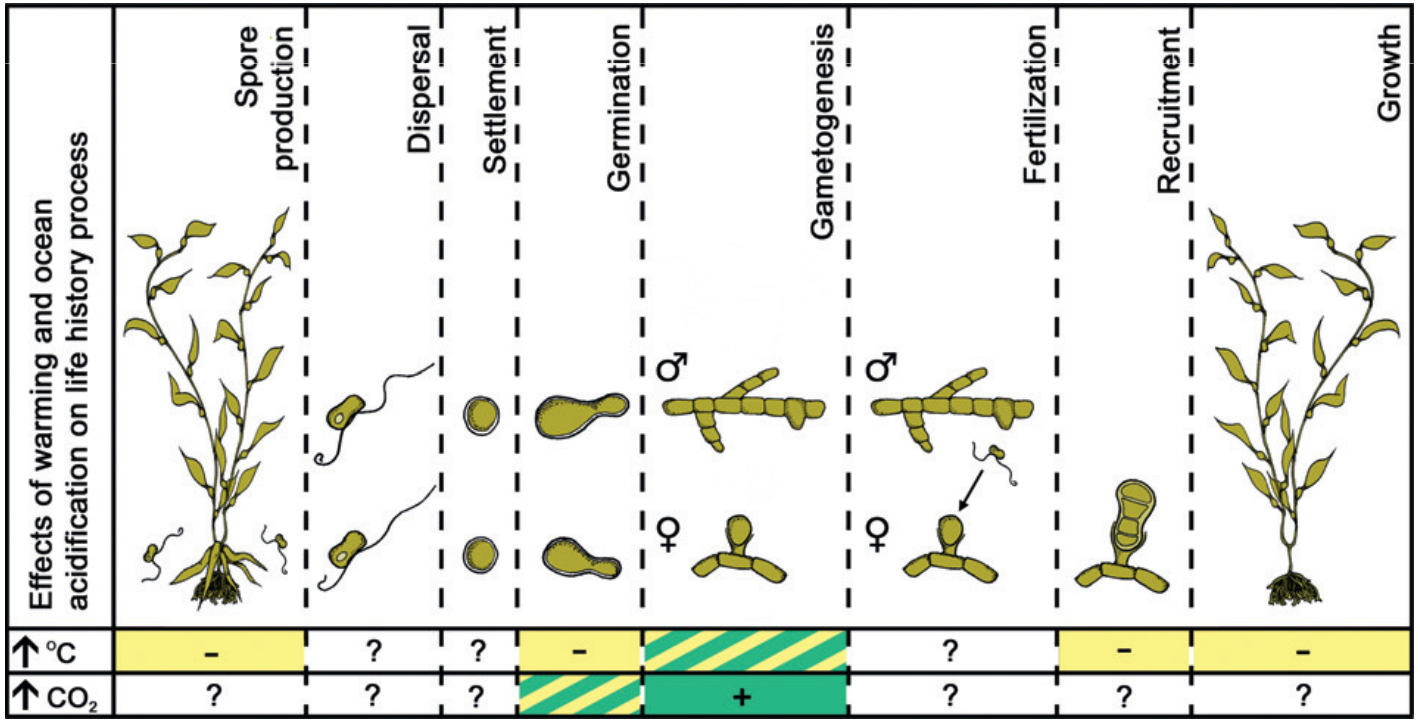
Effects of Climate Change

- Climatic Changes

  → Migrate North

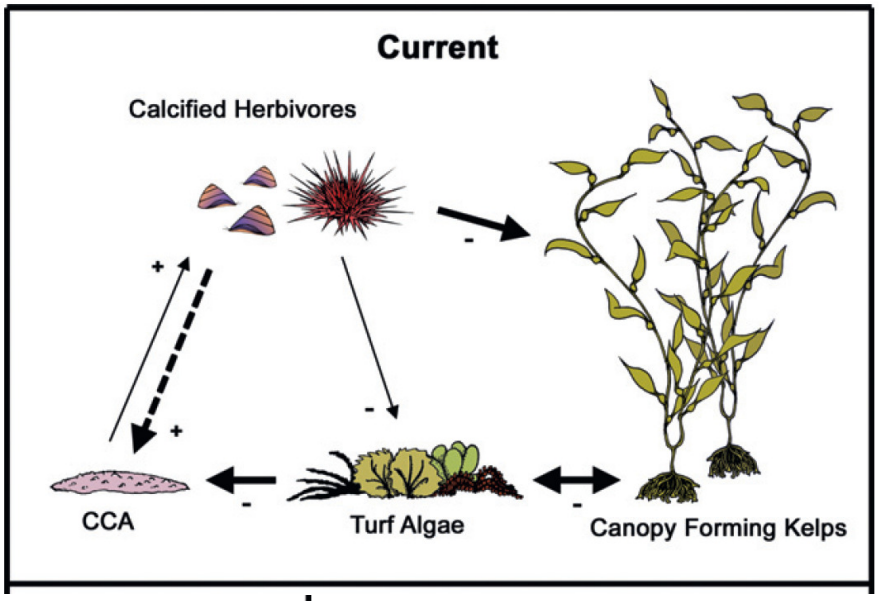
  → Global Warming & Ocean Acidification

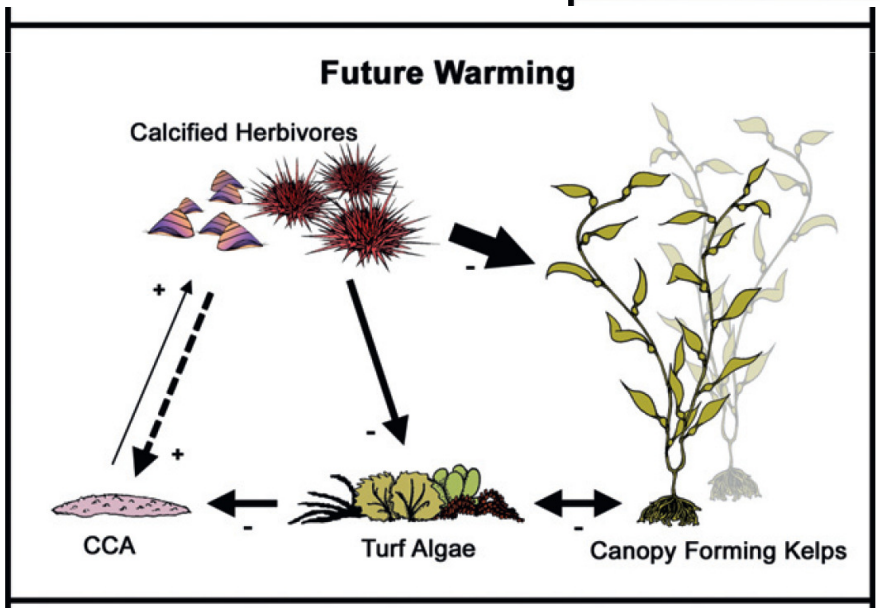
Global Warming

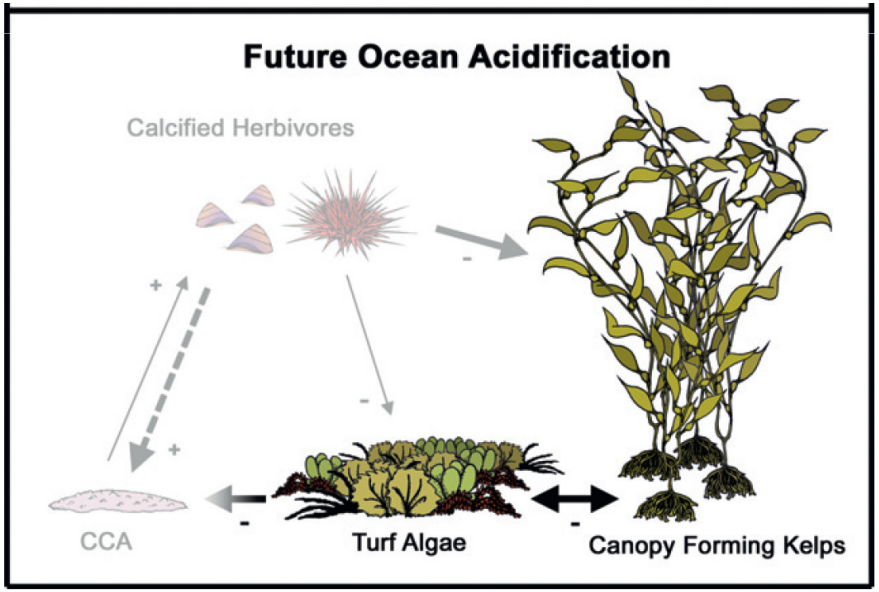


(Harley et al., 2012 JPhycol)

Ocean Acidification







(Harley et al., 2012 JPhycol)

Adverse Effect of Seaweed to Ecosystem

- Introduced Species

  → *Colpomenia* as “Oyester thief” (Japan → Europe)

  → *Sargassum muticum* as “kelp competitor” (Japan → USA)

  → *Kappaphycus* as “coral killer” (Philippines → Hawaii)

Colpomenia

Sargassum muticum

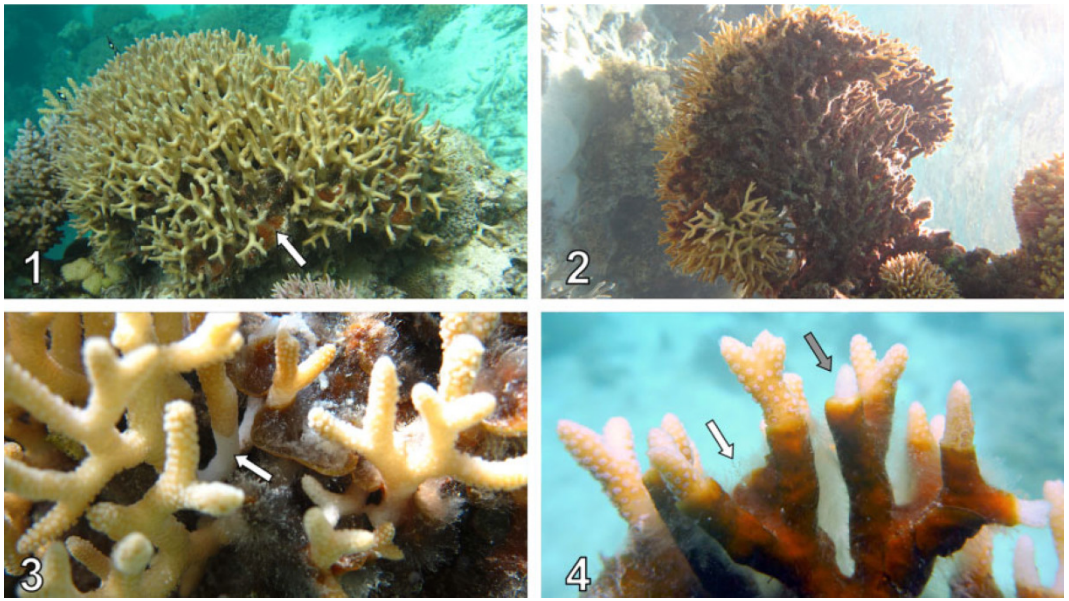
Kappaphycus sp.

- Pollution

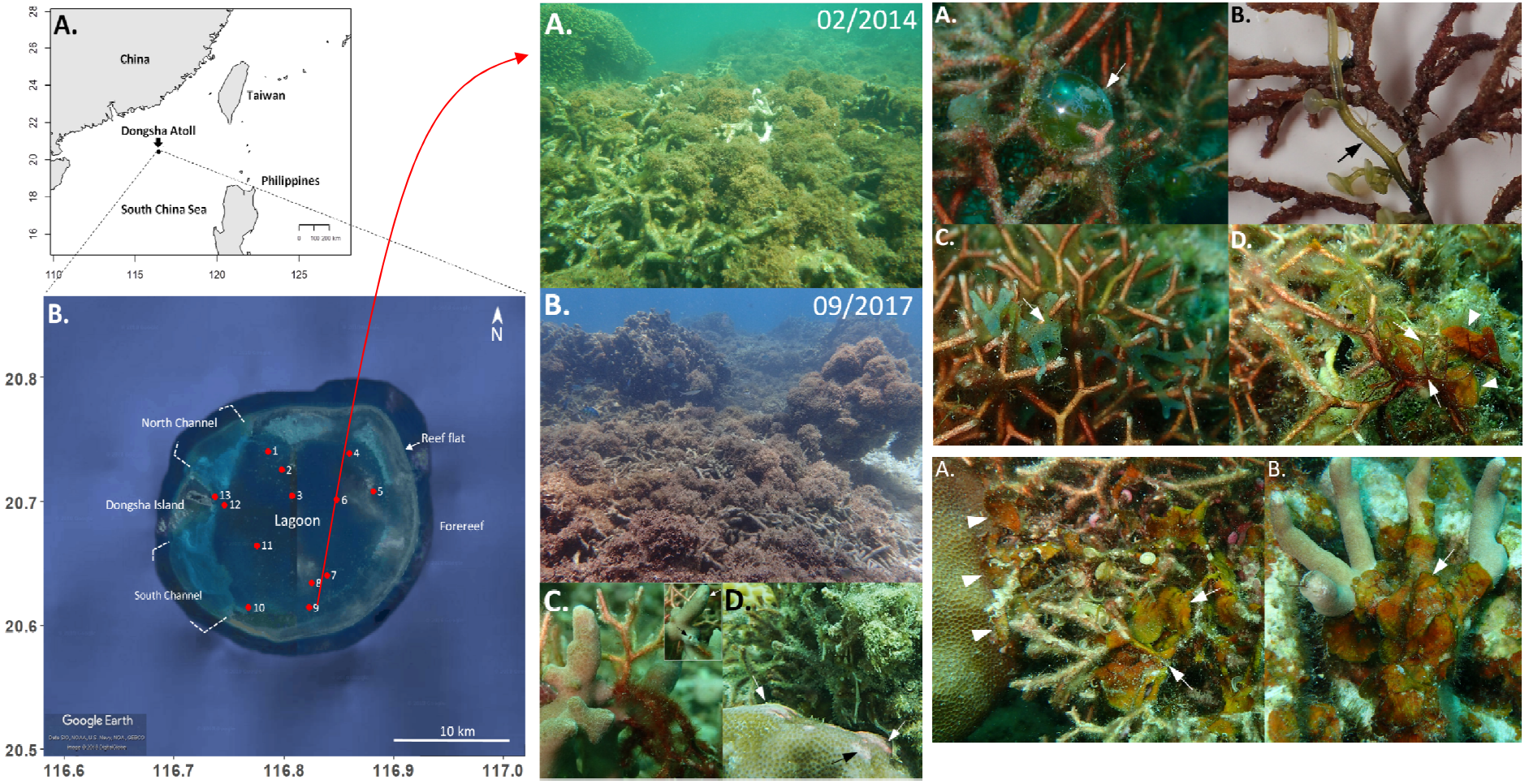
Overgrowth and killing of corals by the brown alga *Lobophora hederacea* (Dictyotales, Phaeophyceae) on healthy reefs in New Caledonia: A new case of the epizoism syndrome

Christophe Vieira,[1,2,3*] Claude Payri[1] and Olivier De Clerck[3]

Phycological Research (2015)



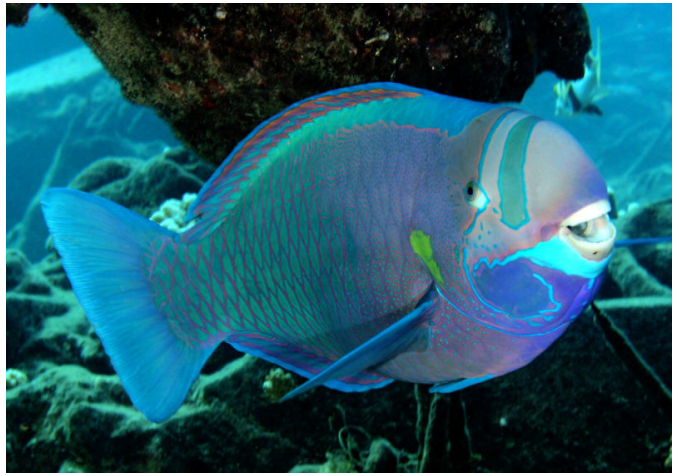
- Synergic effect competing with corals
  - ➢ Inner Lagoon of Dongsha Atoll



- Overfishing

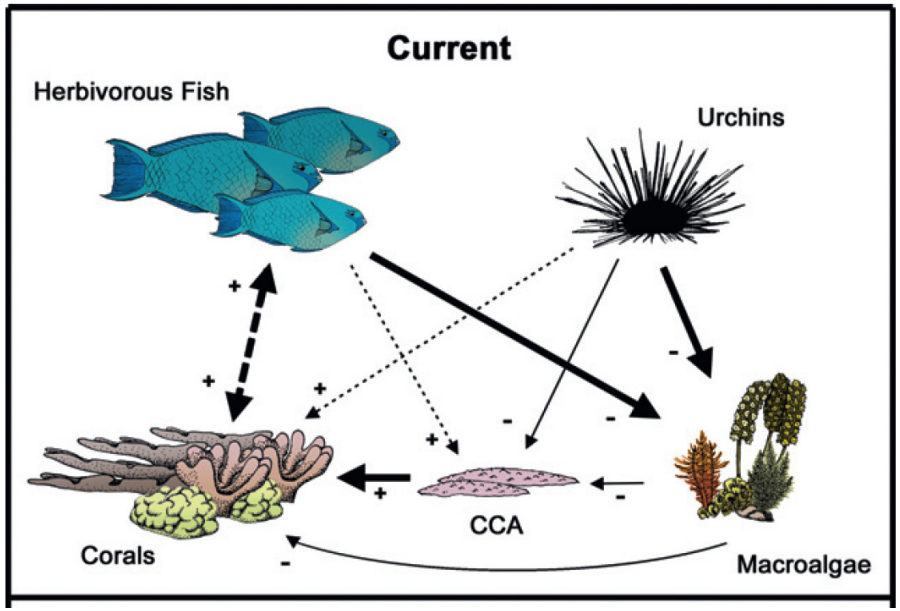
  Fiji: Overfishing Parrotfish

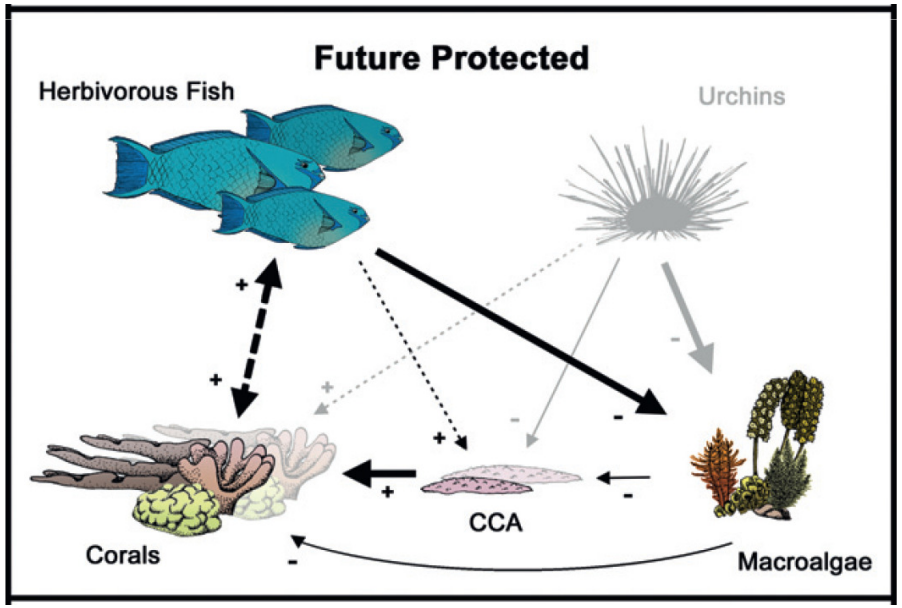
  → Phase shit from coral-dominant to algae-dominant system

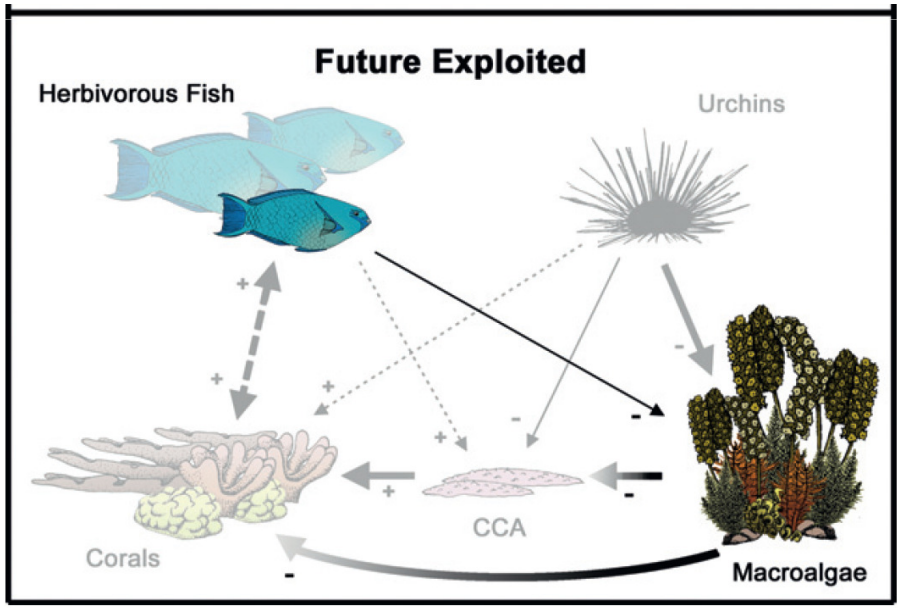


(Strain, 2011)

Overfishing



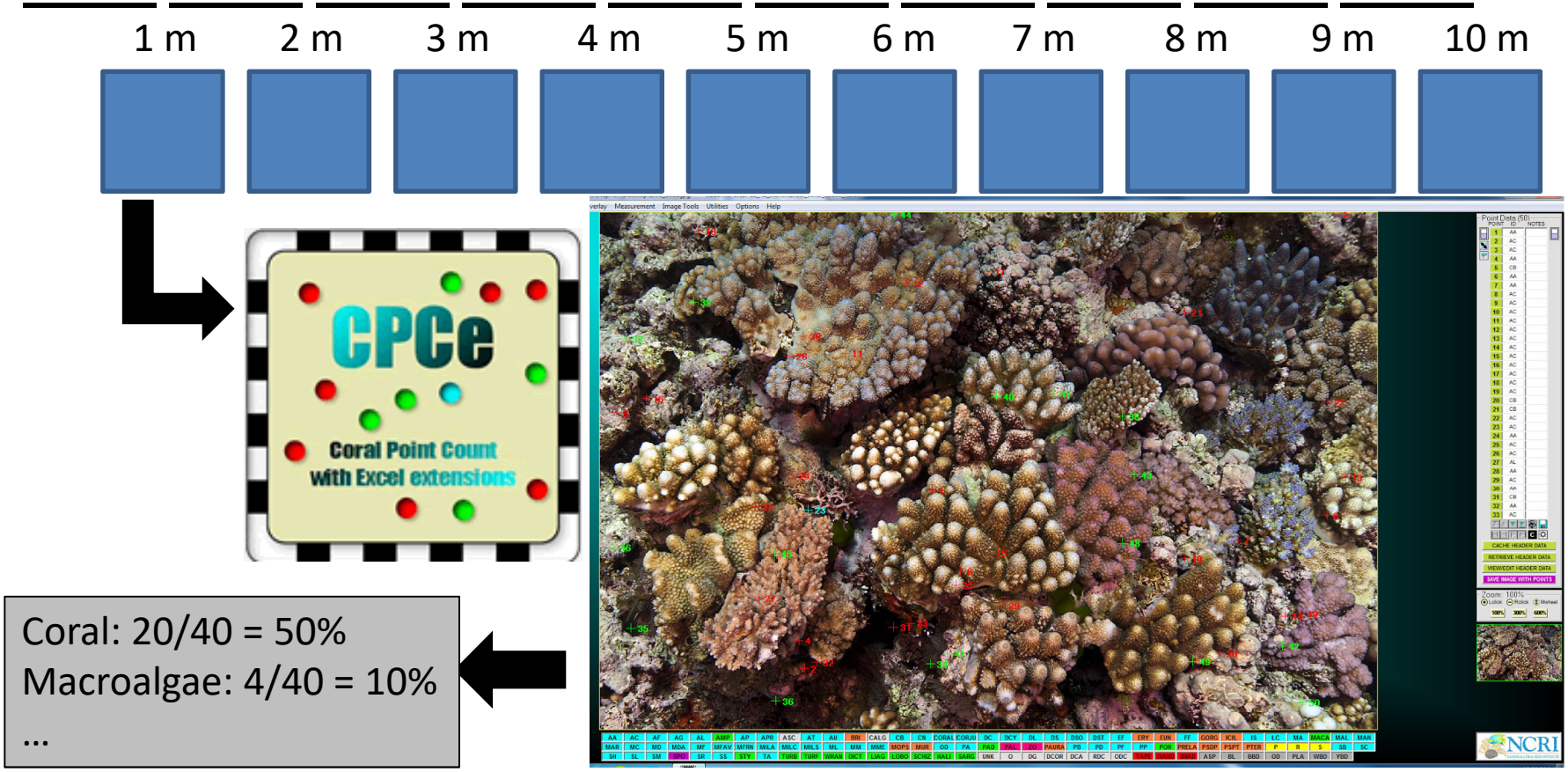




(Harley et al., 2012 JPhycol)

Assignment 1: How do we start an ecological question or hypothesis? → Observation

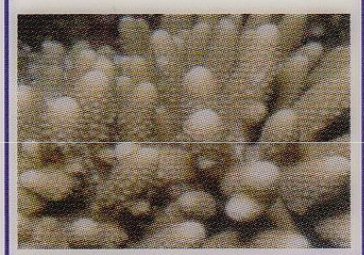
Transect line



REEF CHECK
Indo-Pacific Substrate Categories

Photos by K. Tun

Hard Coral (**HC**)
All living hard coral species. Includes fire coral (Millepora), blue coral (Heliopora) and organ pipe coral (Tubipora).

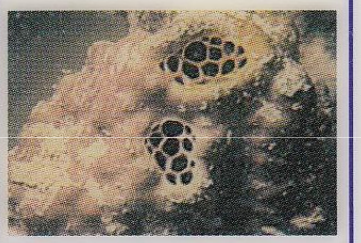


Soft Coral **(SC)**
Soft coral species and zoanthids. Does not include sea anemones.

Recently Killed Coral **(RKC)**
Bare skeleton with tissue gone and corallite structures are still recognizable.

Nutrient Indicator Algae **(NIA)**
All macro-algae except turf, crustose and coralline algae.

Sponge **(SP)**
All erect and encrusting sponge species.



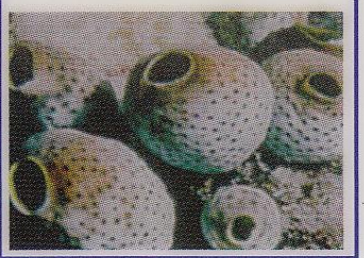
Rock **(RC)**
Any hard substrate. May be covered by turf or encrusting coralline algae, barnacles, oysters etc.

Rubble **(RB)**
Reef rocks between 0.5 and 15 cm in diameter.

Sand **(SD)**
Sediment less than 0.5 cm in diameter. In the water, sand falls quickly to the bottom when dropped.

Silt/Clay **(SI)**
Sediment that remains in suspension if disturbed. SI recorded if color of the underlying surface is obscured by silt.

Other **(OT)**
Any other attached organism (sea anemones, tunicates, gorgonians) and non-living objects (e.g. tires, log, etc).



Assignment 2: How do we start an ecological question or hypothesis? → Manipulative Experimental Design

Effect on X	Effect on Y	Type of interaction
-	-	Competition
-	0	Amensalism
-	+	Exploitation
0	0	Neutralism
0	+	Commensalism
+	+	Mutualism

Some types of relationships listed by the effect they have on each partner. '0' is no effect, '-' is detrimental, and '+' is beneficial.

Taking Photos

↓ **Q?**

Idea/Hypothesis

↓

Google Their Biology

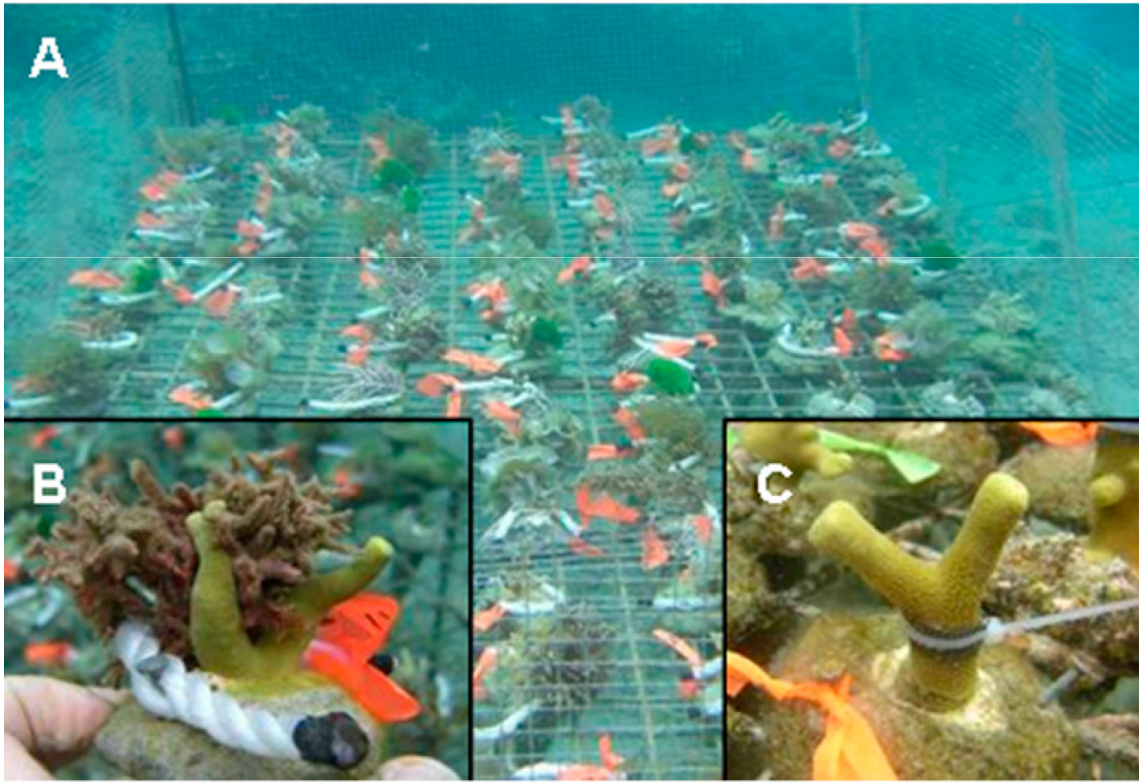
↓

Manipulative Experimental Design

Example
~Phase Shift and Competition~

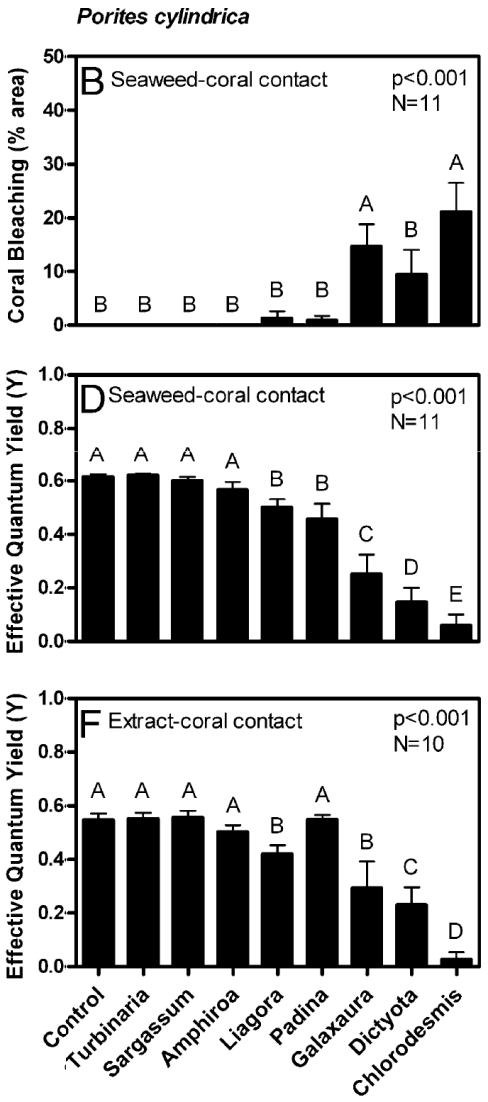
Manipulative Exp: Algal Allelopathy

***In-situ* manipulative experiment**



Contact treatment

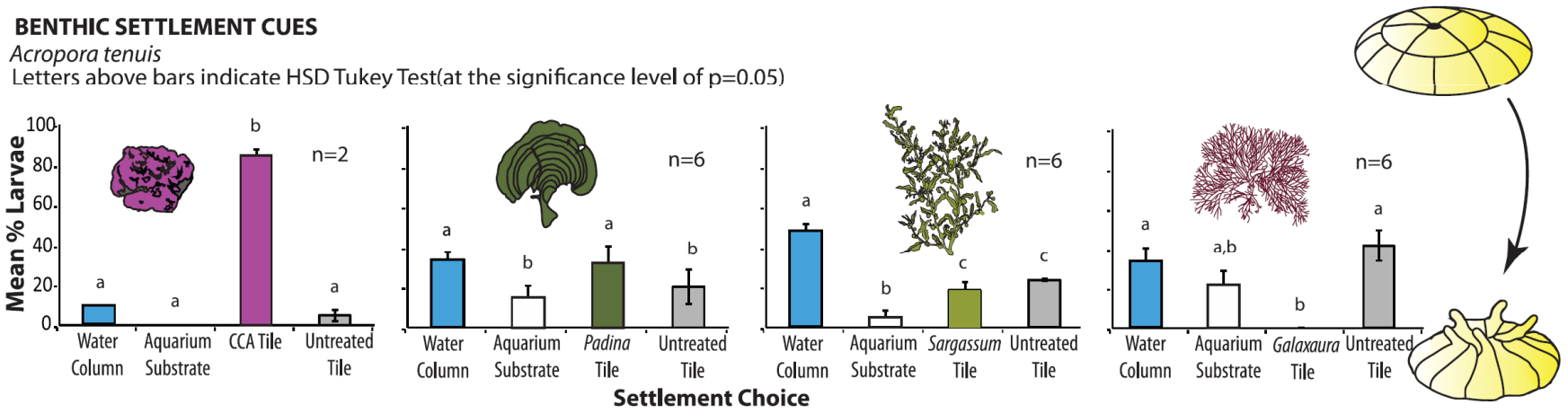
control



(Rasher et al., 2010 PNAS)

Manipulative Exp: Inhibition of Coral Recruitment

***Ex-situ* lab experiment**



(Dixson et al., 2014 Science)

How about the interaction between fish and algae?
Any experimental design?