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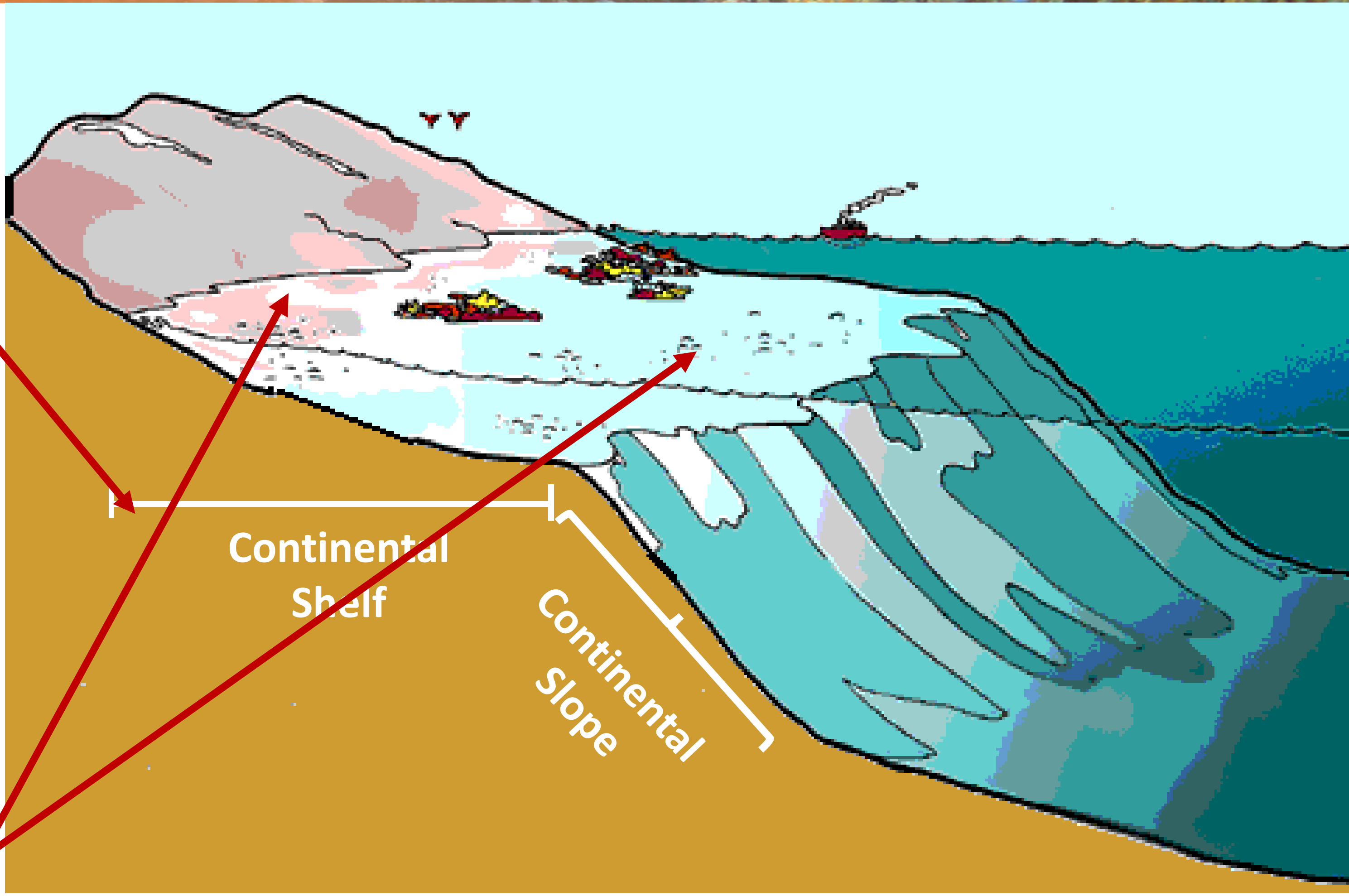
Overview:

Marine Ecosystems – The Subtidal, The Intertidal, and Estuaries

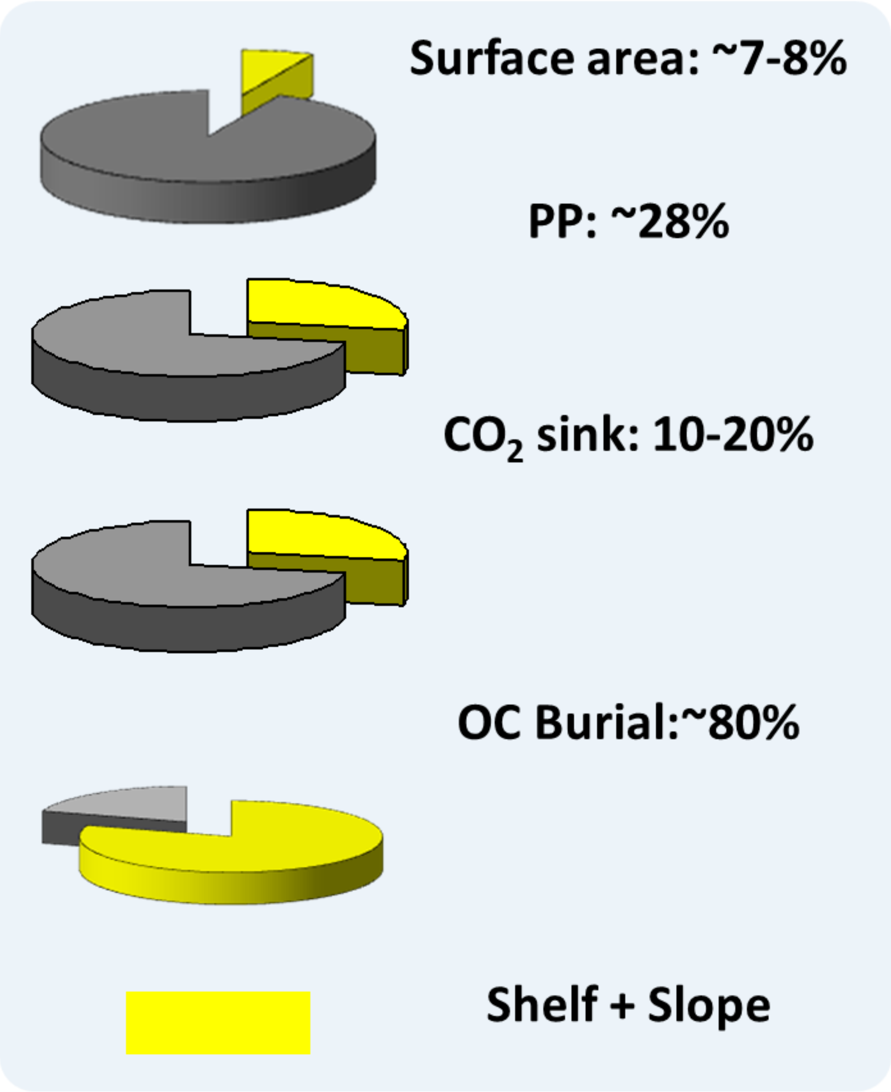
Continental Shelves and Coastal Seas

- **Continental Shelves**
  - Extend variable distances from continents
  - Land typically gradually descends to 140 m (460 ft) before dropping off as the continental slope

- **Coastal Seas**
  - The part of the world ocean that **covers the continental shelf**

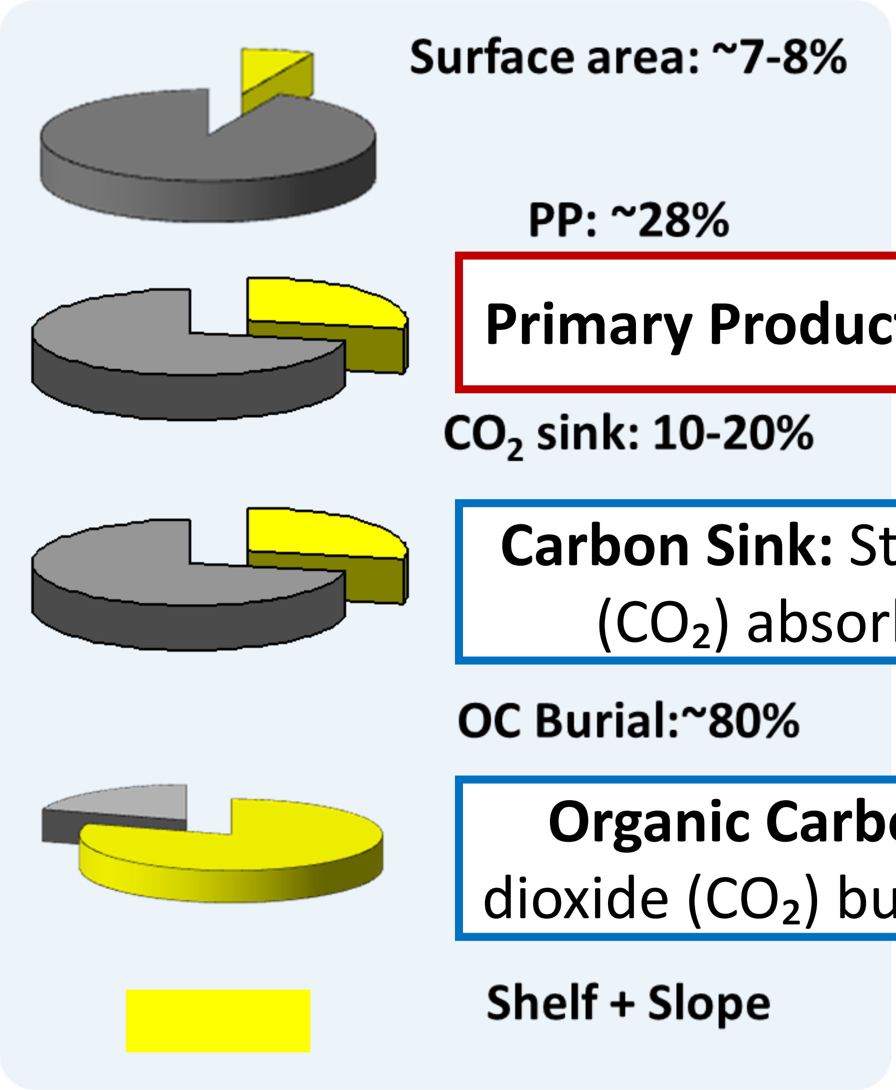


Coastal Seas



- Our coastal seas are **a rich community of plants and animals** working together, all of which are **vital to the health of our planet and humanity**
- Coastal seas count for **7% of our ocean**, yet they are responsible for **95% of the world's marine fishery production** - these are **our planet's fishing grounds**
- https://www.ourplanet.com/en/video/biome-tour-of-our-coastal-seas

Coastal Seas



Primary Production = Photosynthesis

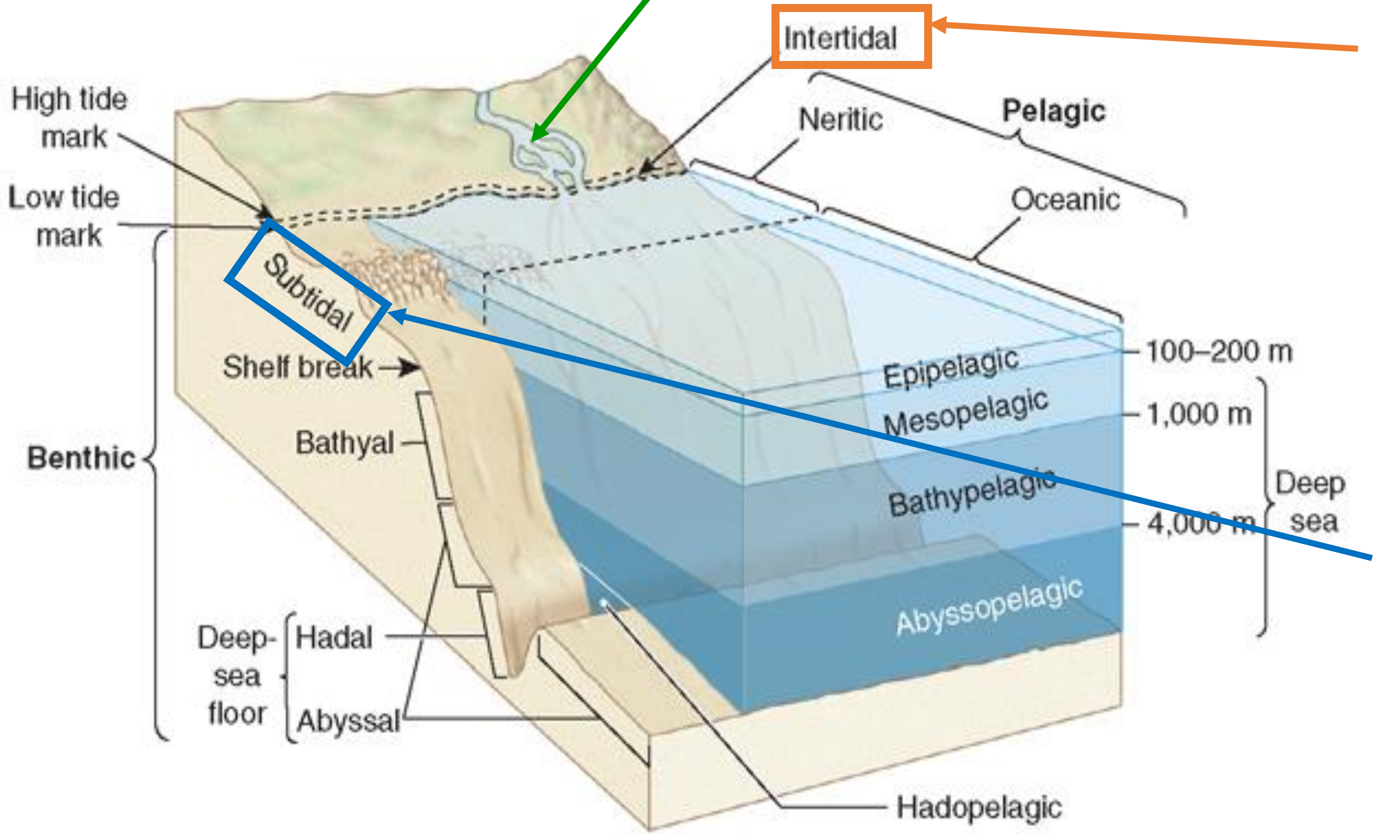
Carbon Sink: Stores carbon dioxide (CO_2) absorbed from the air

Organic Carbon Burial: Carbon dioxide (CO_2) buried in the sediment

- Our coastal seas are **a rich community of plants and animals** working together, all of which are **vital to the health of our planet and humanity**
- Coastal seas count for **7% of our ocean**, yet they are responsible for **95% of the world's marine** … **ion** - these are **our planet's**

…rplanet.com/en/video/biome- …stal-seas

Some Subdivisions of the Marine Environment



- **Estuaries**
  - Partially enclosed coastal regions where **fresh water from rivers meets and mixes with seawater**

- **Intertidal Zone (Littoral Zone)**
  - At the boundary between land and sea
  - Not always submerged
  - Affected by tides

- **Subtidal Zone (Sublittoral Zone)**
  - Below the low tide level to edge of continental shelf (shelf break)
  - **Always submerged** (even at the lowest of low tides)

Subtidal and Intertidal

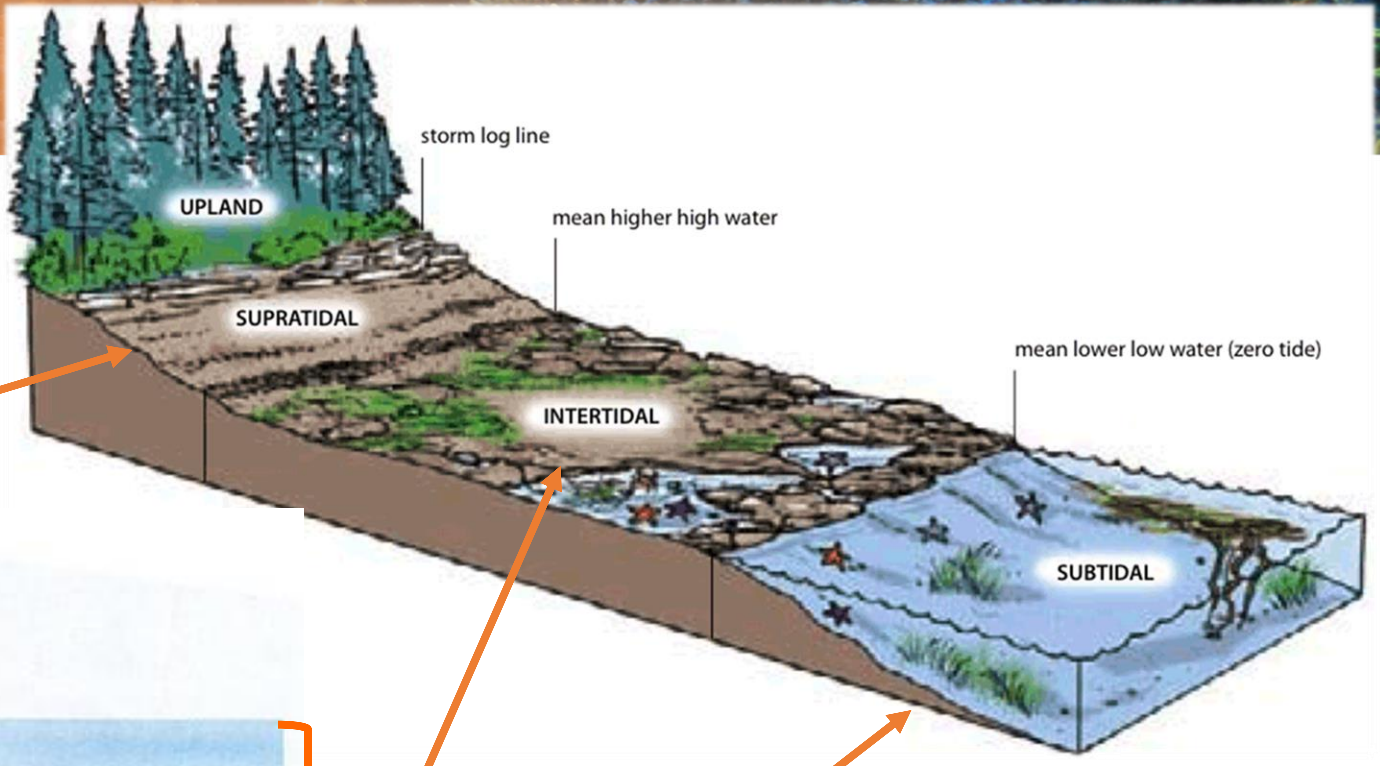


Image: Geocaching.com

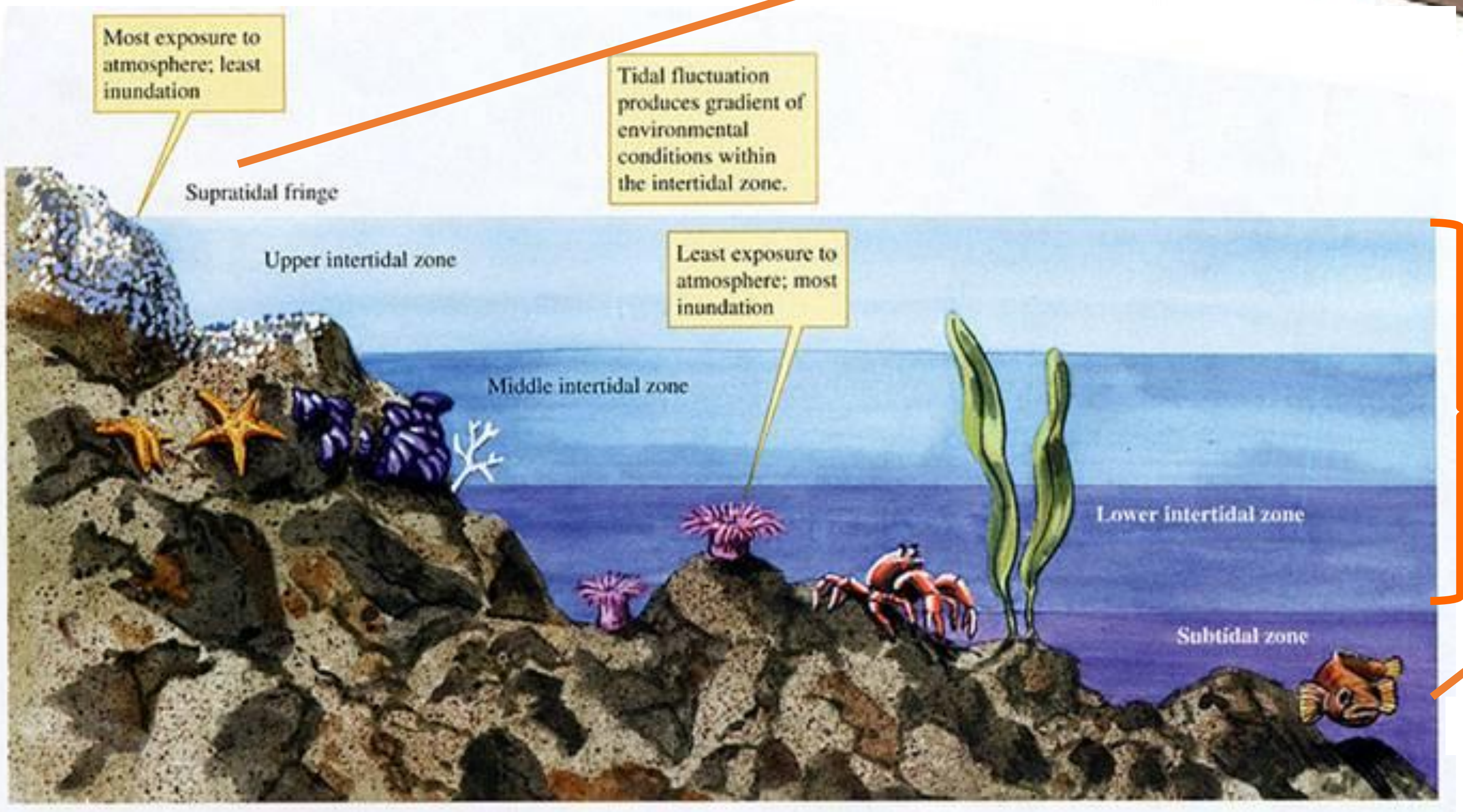


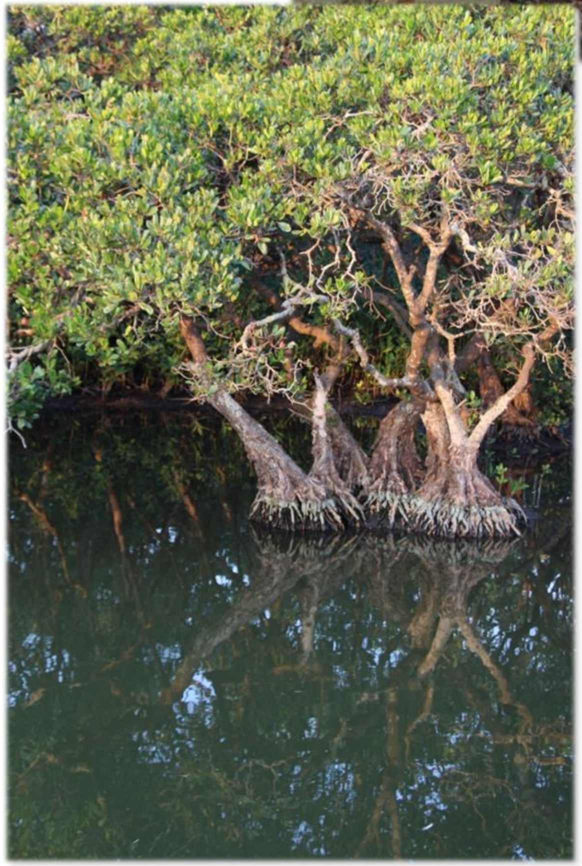
Image: South China Normal University

Marine Ecosystems

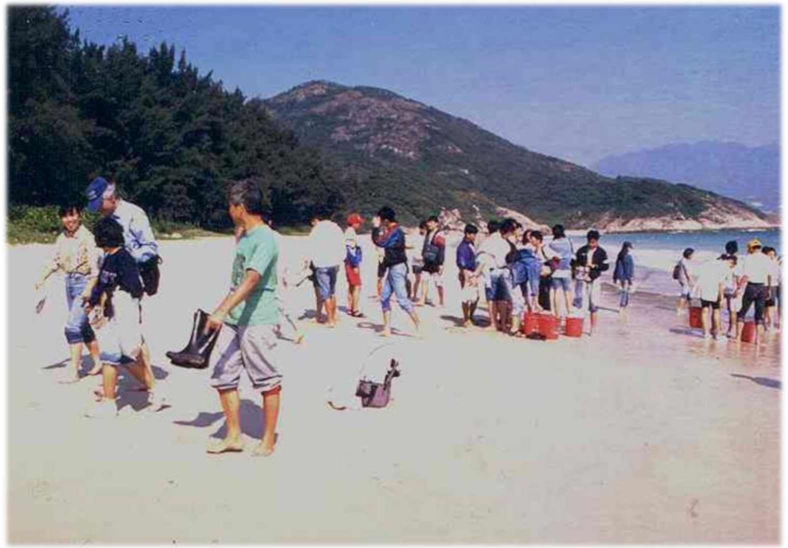
Source: Bill Ober

Subtidal

Rocky Shore

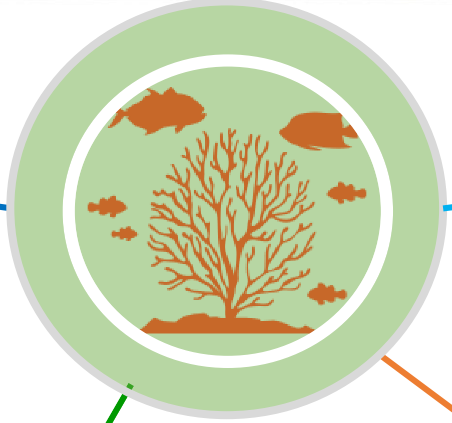


Mangrove



Sandy Beach

Marine Ecosystems – The Subtidal, Estuaries, and the Intertidal



Subtidal Zone

Always submerged

- ❑ Unvegetated Areas
- ❑ Kelp Forests
- ❑ Seagrass Beds
- ❑ Coral Reefs

Coastal Eutrophication

- ❑ Harmful Algal Blooms & Effects
- ❑ *Noctiluca Blooms*

Intertidal Zone

***Not always* submerged**

- ❑ Rocky Shores
- ❑ Sandy and Muddy Shores

Estuaries

Where rivers *meet* the sea

- ❑ Salt Marshes
- ❑ Mangroves

Hard Bottom vs Soft Bottom

Hard Bottom	Soft Bottom



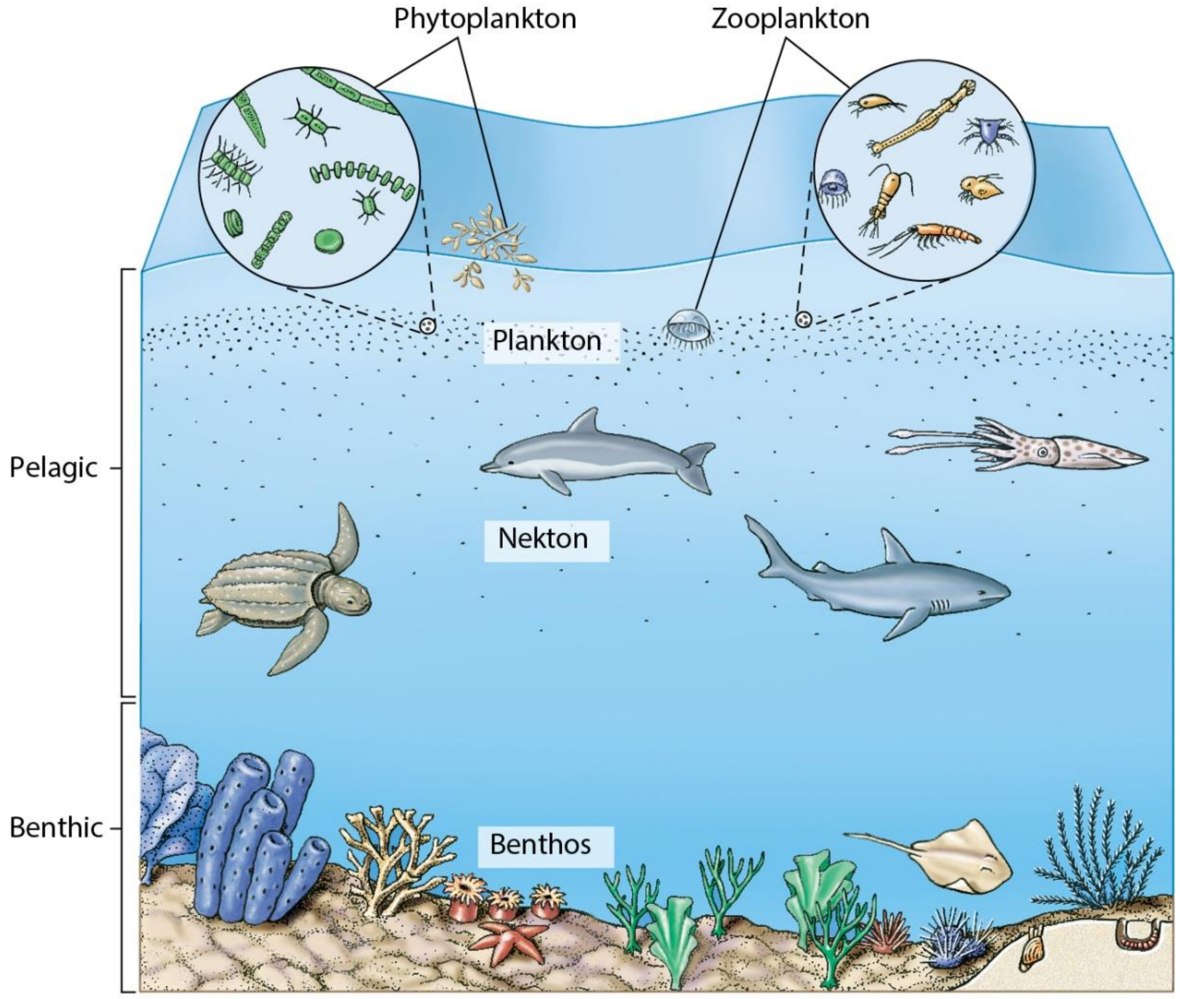

Hard Bottom

- **Rocky** Shores and Hard Substrates Subtidal Communities
- Organisms **attach onto** rocky surface

Soft Bottom

- **Sandy and Muddy** Shores, and Unvegetated soft-bottom sea floor
- Organisms **bury into** soft sediment

Re-cap from Previous Module – Basic Lifestyle Groups of Marine Organisms



Source: Bill Ober

- **Benthic** organisms (**Benthos**) – live *on* or *buried in* the bottom
  - Sessile – attached to one place (*e.g. sponges*)
  - Move around *(e.g. crabs)*

- **Pelagic** organisms – live in the *water column*
  - **Plankton** – **drift** with currents *(phytoplankton and zooplankton)*
  - **Nekton** – **swim** to oppose currents *(mostly vertebrates, e.g. fishes, marine mammals; a few invertebrates e.g. squids)*

Benthic Fauna – Habitat Classification

- **Epifauna**: Animals that live **on the surface** of the sediment
- **Infauna**: Animals that **burrow in** the sediment

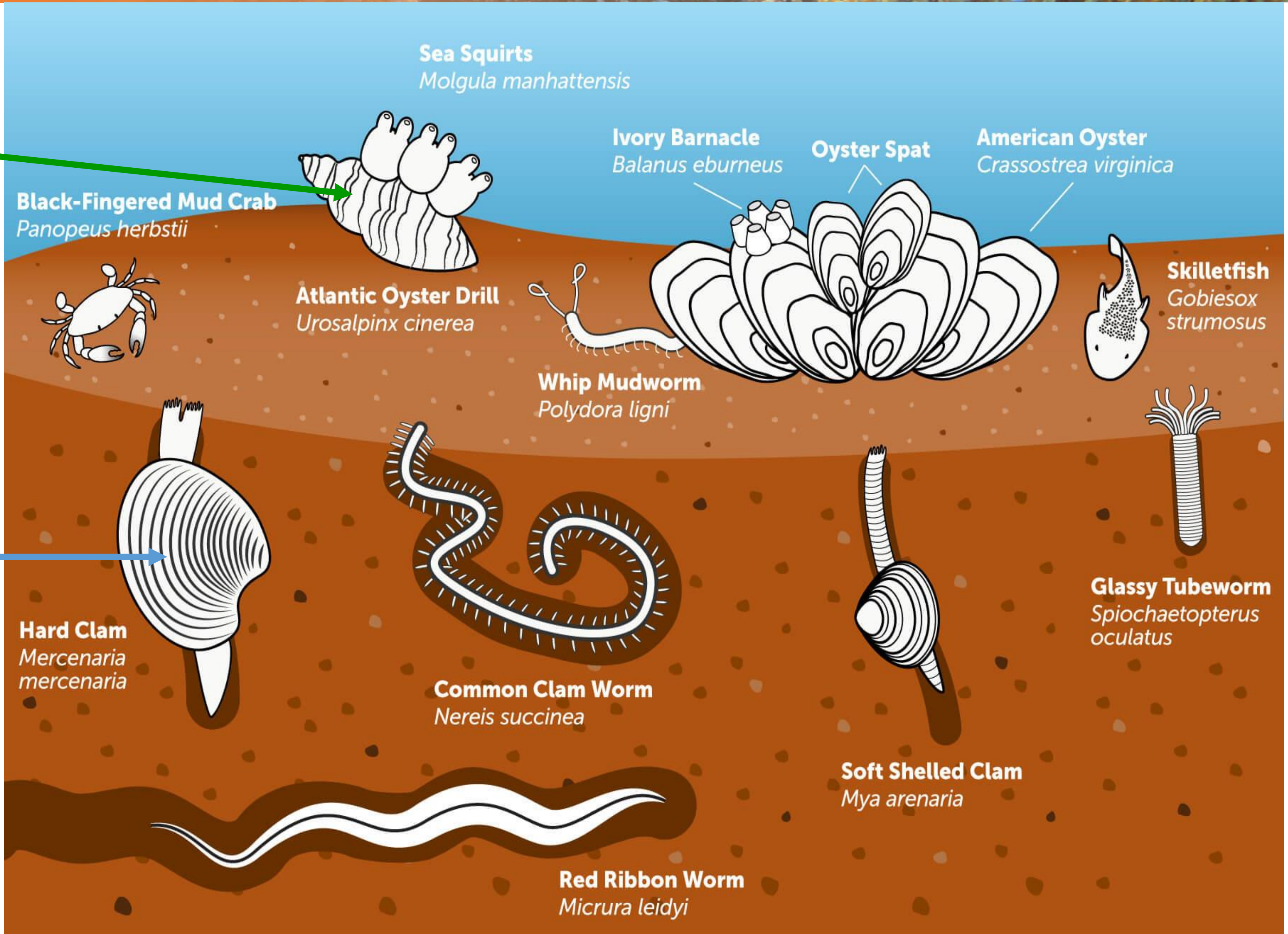
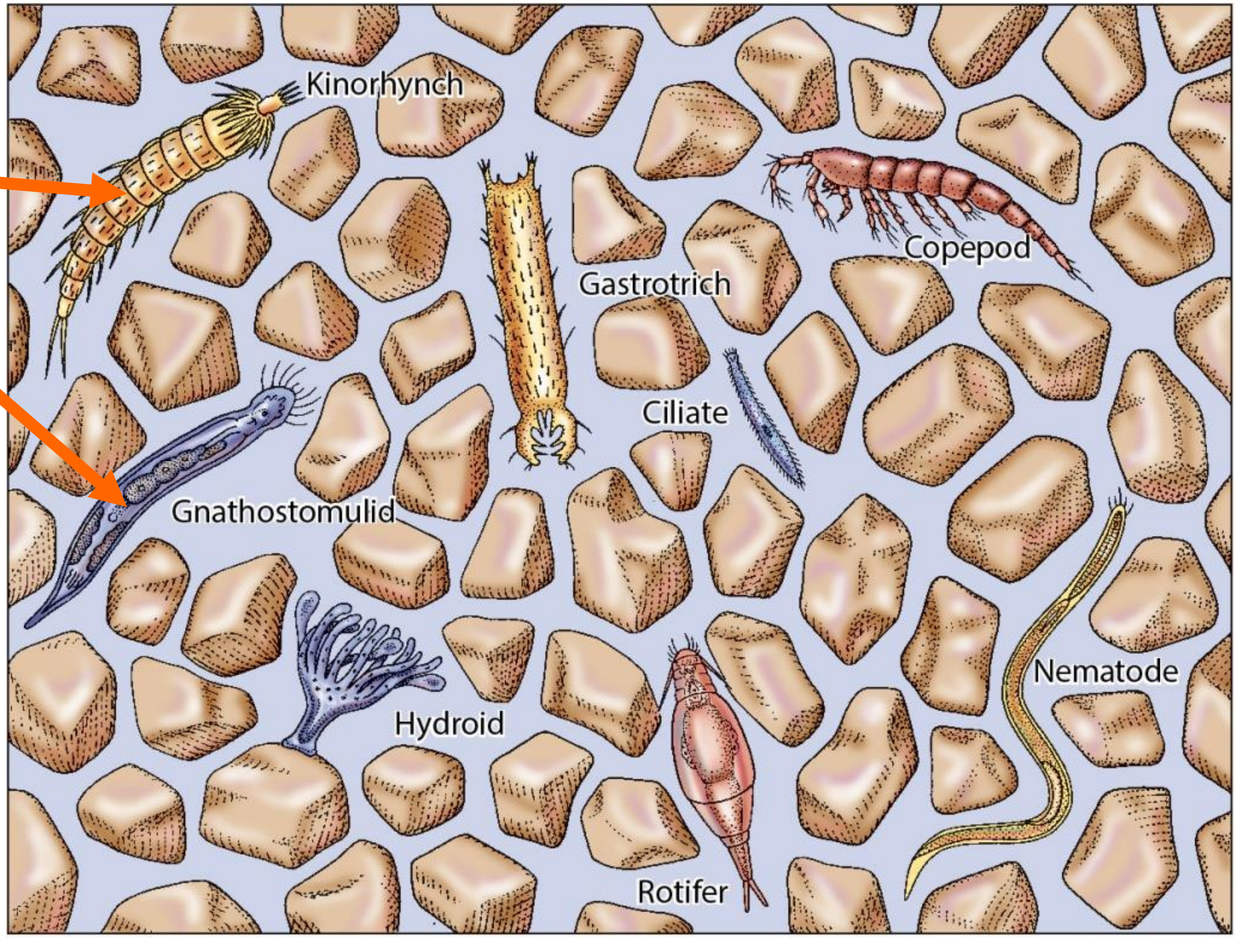


Image: Chesapeakebay.net

Benthic Fauna – Size Classification

- **Meiofauna:** Animals that live in **spaces between sediment particles**



Source: Bill Ober

- Macrofauna: > 0.5 mm
- Meiofauna: 0.5 – 0.062 mm
- Microfauna: < 0.062 mm

Learning Outcomes

After this part of Module III, students are expected to be able to

- Understand the **characteristics and biodiversity** of the **Subtidal Zone**, **Estuaries**, and **Intertidal Zone**;

- Learn more about the **ecology** of these ecosystems and the **environmental challenges** of the coastal seas.

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The Subtidal Ecosystems – The Unvegetated Areas

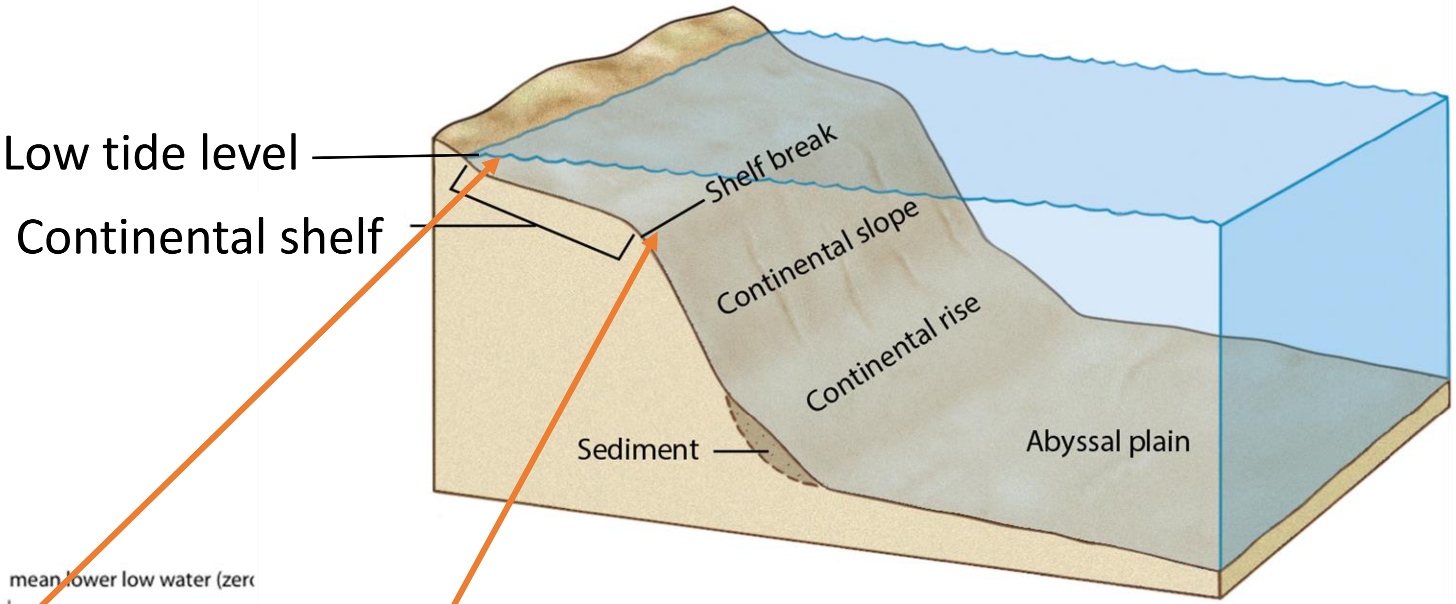
Learning Outcomes – The Subtidal

After this segment, students should be able to

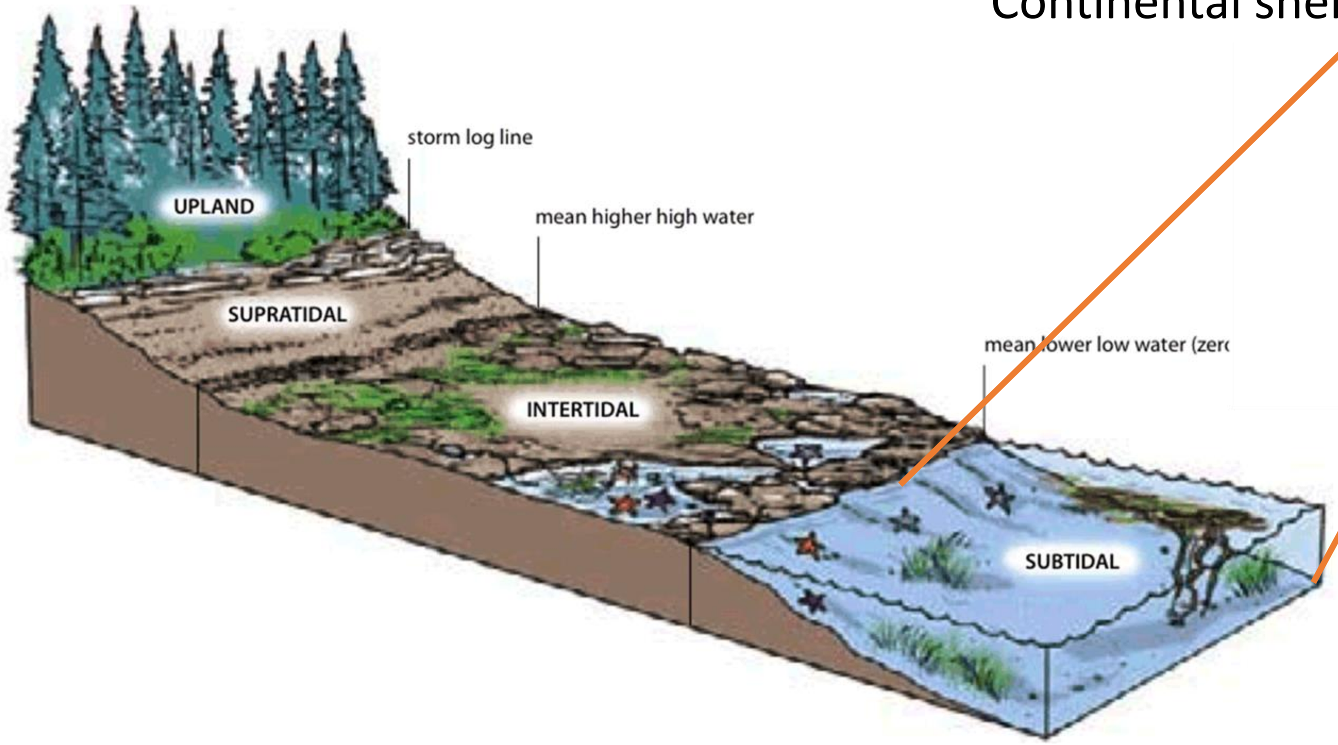
- Describe the soft bottom **Subtidal ecosystems**;
- Demonstrate an understanding of the **physical characteristics** influencing Subtidal communities;
- Explain the distribution and dynamics of **deposit and suspension feeders** in the Subtidal;
- Describe the **biodiversity** and their **feeding relationships** of different types of Subtidal ecosystems.

The Subtidal

- Also called the **Sublittoral Zone**
- On the continental shelf, extending from low tide level to shelf break
- **Always submerged**

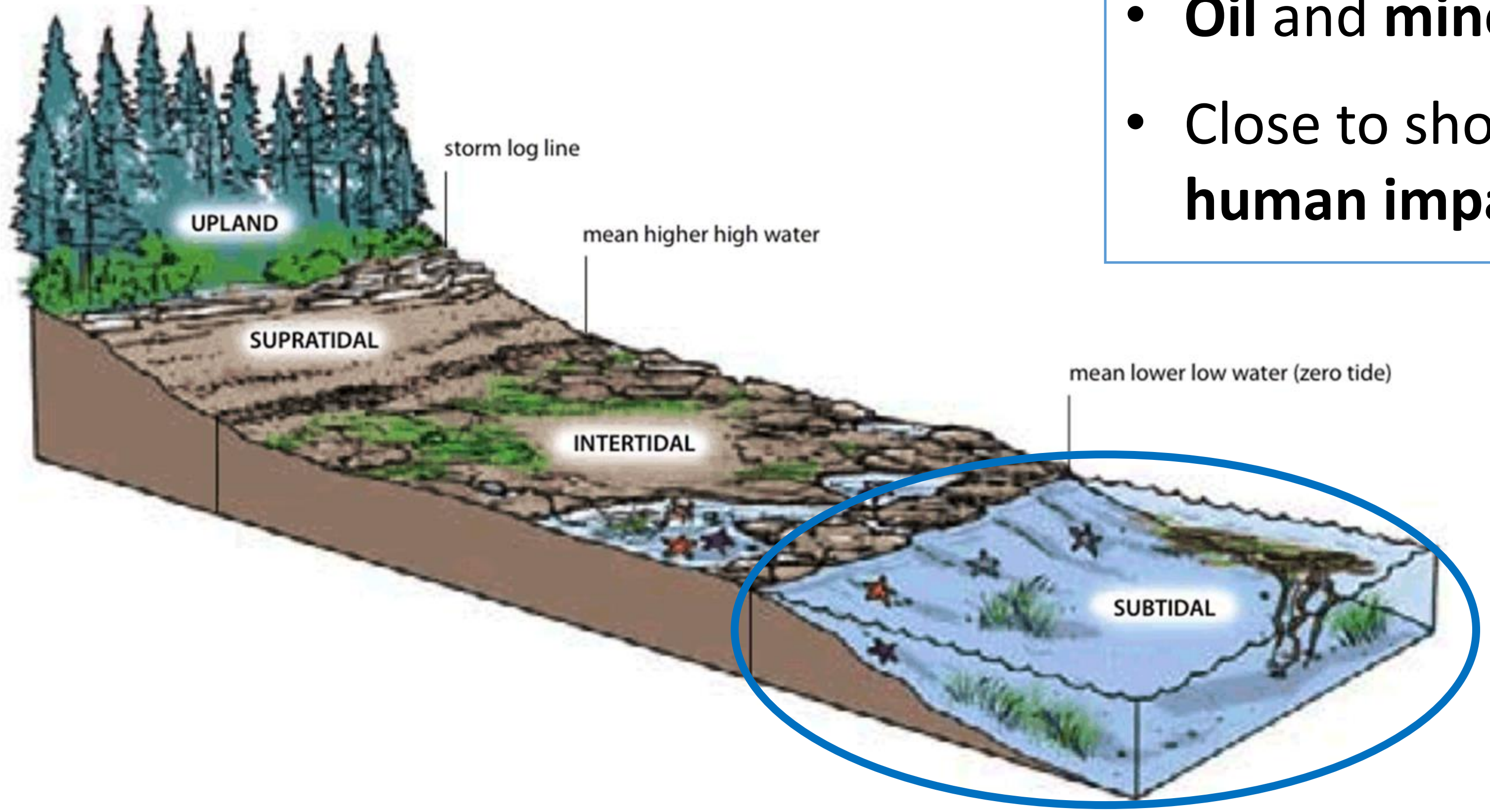


Source: Bill Ober



The Subtidal

- Coral Reefs, Seagrass Beds, and Kelp Forests – among the **most productive marine ecosystems** – are found on the shelf
- Includes the world's **most important fishing grounds** (~90% of marine global catch)
- **Oil** and **minerals** are found on the shelf
- Close to shore, particularly vulnerable to **human impacts**



The Subtidal – Characteristics

The *physical factors* that affect Subtidal organisms are linked to two characteristics of the continental shelf

– its relatively **shallow water** and its **close proximity to land.**

- **Temperature varies more** from place to place in the Subtidal Zone than on the deeper bottom beyond the shelf.
- Its bottom is **much more affected by waves and currents than in deep water**
- **More stable environment than intertidal** because always submerged in water
- Rivers bring in **large amounts of fresh water, nutrients and sediment**

The Subtidal Ecosystems – The Unvegetated Areas

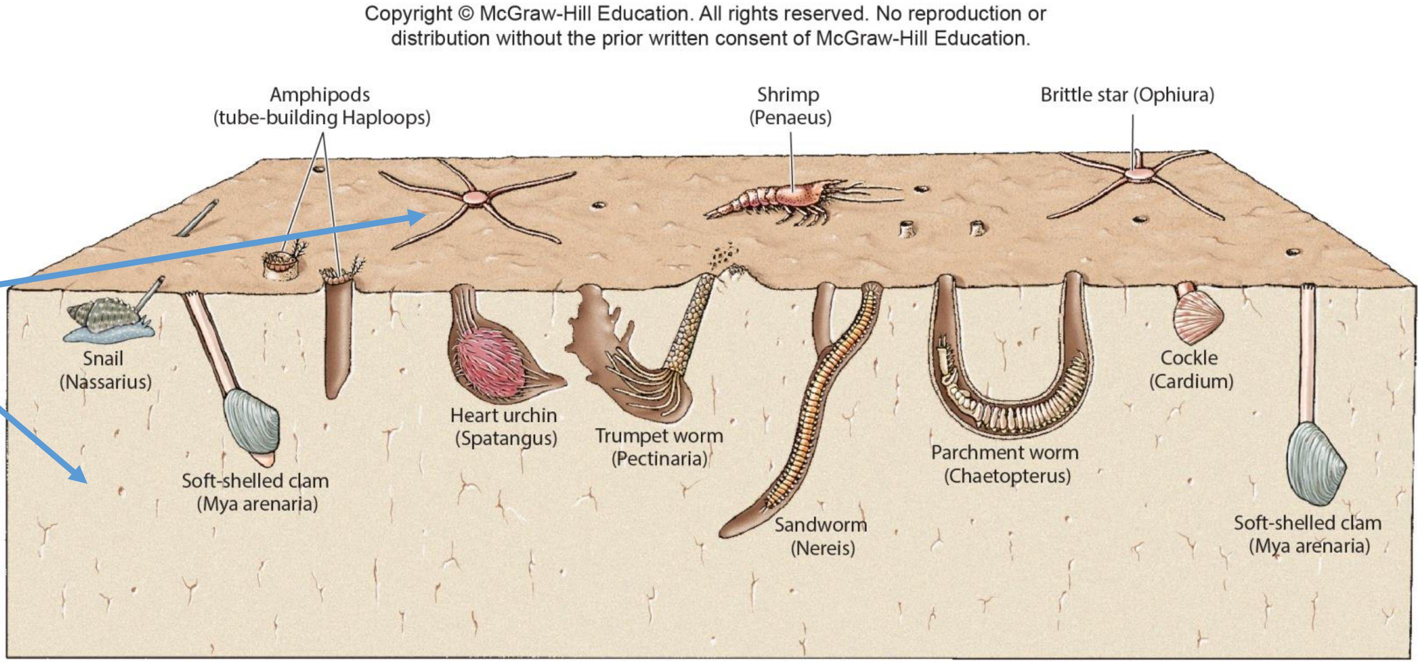
The great majority of the continental shelf's seafloor is covered by sediment (i.e. soft bottom)

- **the Unvegetated communities**
- **lacking large amounts of seaweed or seagrass**

A flatfish on shallow, sandy bottom.

The Soft-Bottom Subtidal Communities

- **Dominated by infauna**
- **Some epifauna** exist
  - Sea stars, brittle stars



Source: Bill Ober

- Due to **lack of hard substrates**
  - **Sessile** species (can't move) – ***rare***
  - **Producers** – ***grow on sand or mud particles***
    - Diatoms
    - Microscopic algae
    - Photosynthetic bacteria

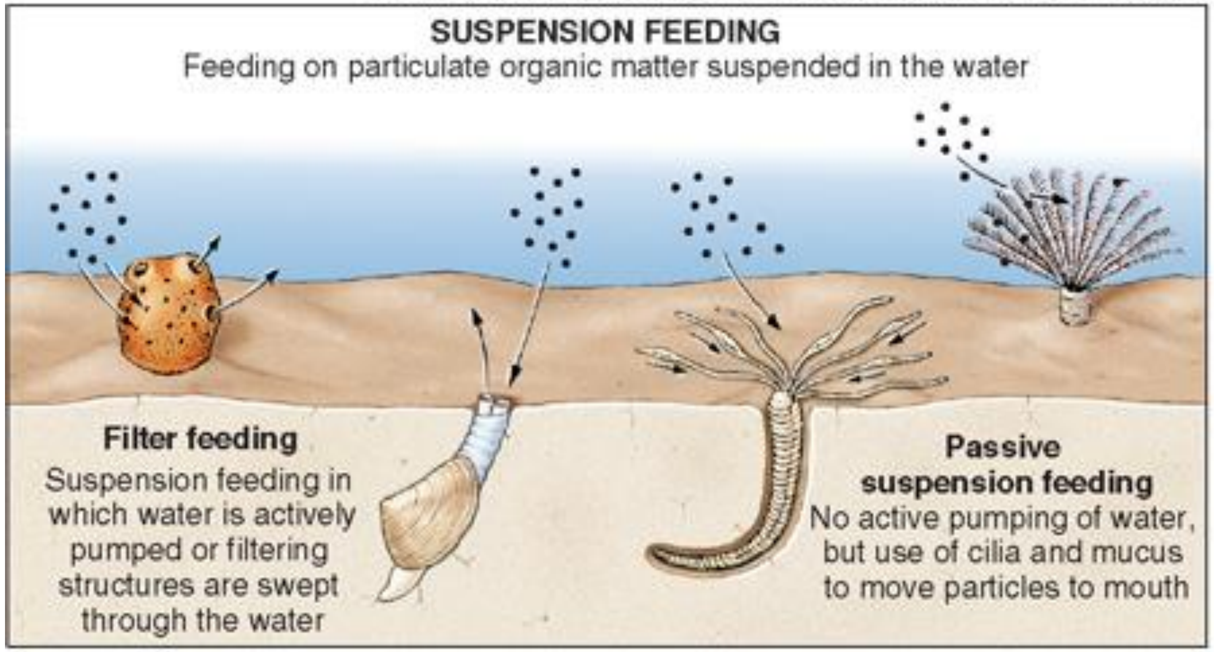
The Soft-Bottom Subtidal – Rely on Detritus Feeding

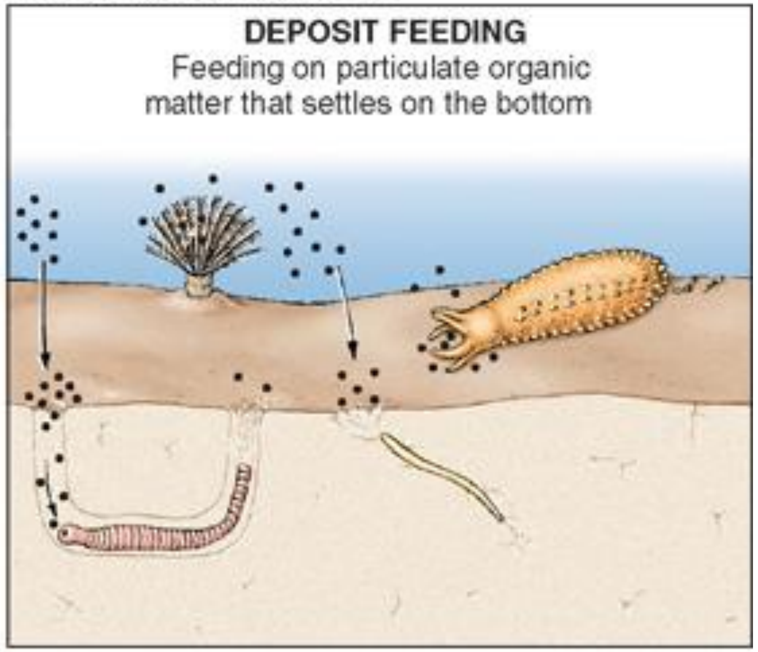
- Because there is little primary production, **detritus** is an **important food source** for many inhabitants

- Sources of detritus at the Subtidal
  - **Brought in by currents** from estuaries, rocky shores, and other more productive coastal communities
  - **Feces, dead individuals, other debris** from plankton and nekton in the water column
  - **Generated by the benthos**

- Detritus is used by bacteria and infauna (**deposit, suspension and filter feeders**)

Unvegetated Soft-Bottom Subtidal – Suspension and Deposit Feeders





Suspension Feeders

- Catch food floating nearby
- More common on ***sandy*** bottoms

Deposit Feeders

- Pick-up food deposited on the bottom
- More common on ***muddy*** sediments
- **More detritus** settles in areas of *low turbulence* and retained in the smaller interstitial space between mud particles

Unvegetated Soft-Bottom Subtidal – Suspension and Deposit Feeders

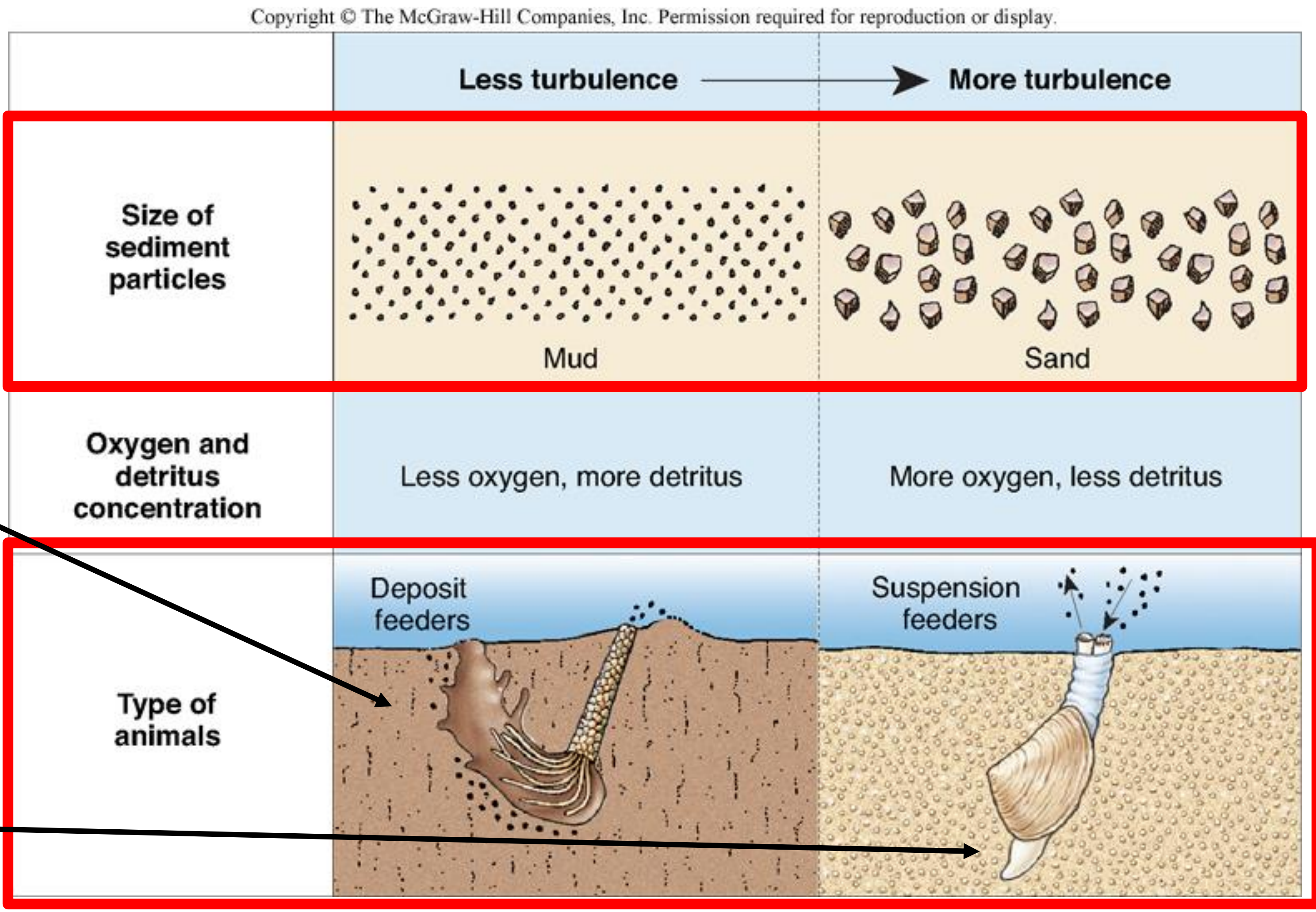
The **distribution** of suspension and deposit feeders on soft bottoms is largely influenced by the **size of the sediment particles**.

Many species are Deposit Feeders

- In ***less* turbulent** areas, **smaller sediment particles**

Others are Suspension Feeders

- In ***more* turbulent** areas, **larger sediment particles**



Unvegetated Soft-Bottom Subtidal – Suspension Feeders

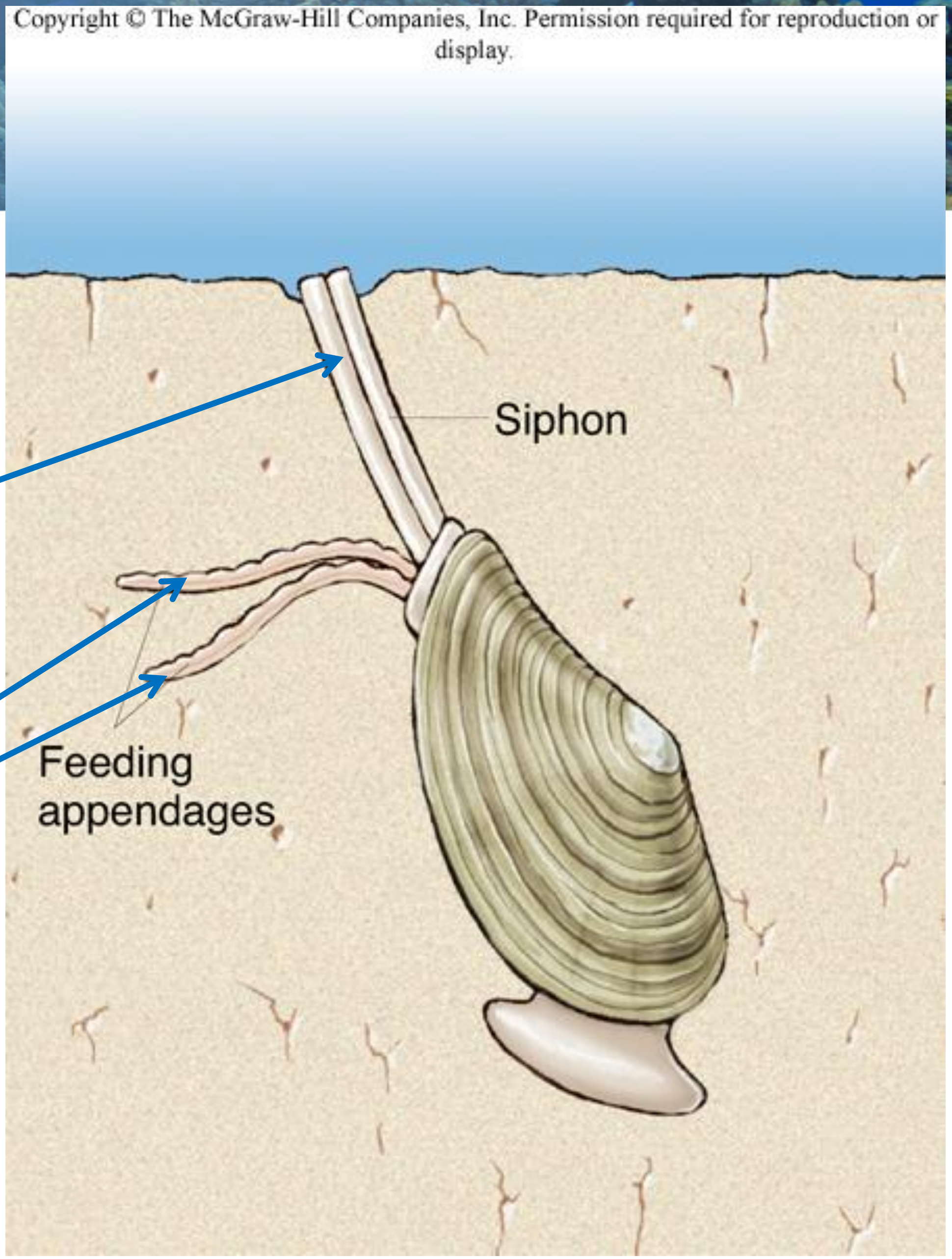
Sea Pens – catch food floating nearby

Unvegetated Soft-Bottom Subtidal – Deposit Feeders

Most clams are filter feeders,
***some* are deposit feeders.**

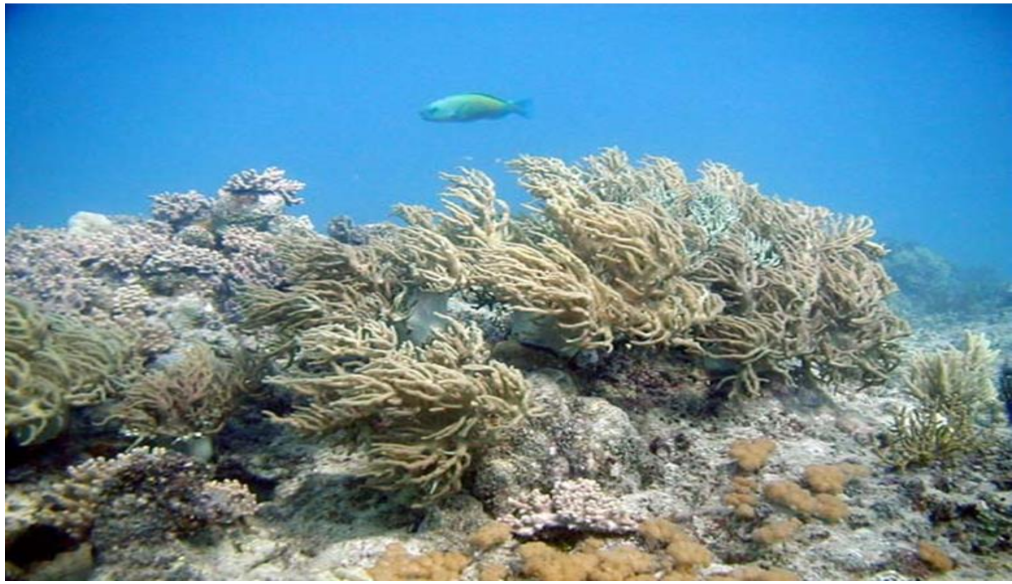
The siphon brings water in,
but is not used for feeding as in
most other clams.

Instead, it **uses two tentacle-like appendages to feed**.



Hard-Bottom Subtidal Communities

- Make up a relatively small portion of the continental shelf
- Usually are the submerged extensions of rocky shores
- May include organisms that produce **calcium carbonate** (e.g. coral reef, oyster reef)
- Rich in **epifauna** but less as infauna
- Most important organisms are **seaweeds** (able to settle on rocks/hard substrates)



Summary – The Subtidal Unvegetated Areas

Characteristics of the Subtidal	• Always submerged • More stable environment than the intertidal • More affected by waves and currents than in deep water
Unvegetated Areas (Soft Bottom)	• Covered by sediment (i.e. soft bottom), lacking large amounts seaweeds or seagrasses • Dominated by infauna • Detritus feeding is important (suspension and deposit feeding)

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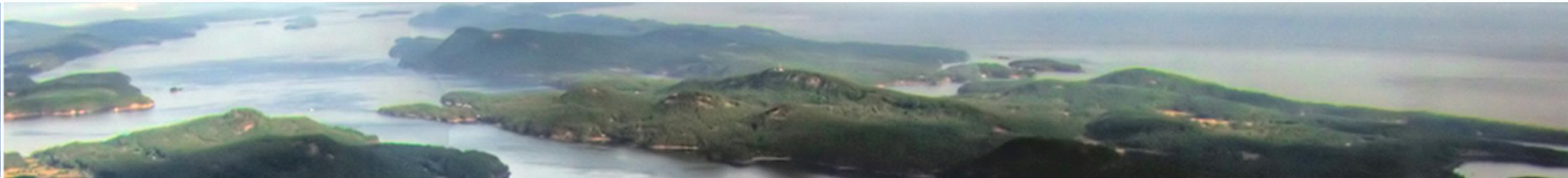

Kelp Forest

Seagrass Beds

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The Subtidal Ecosystems – Kelp Forests & Seagrass Beds

Seaweed – Kelp

Hard Bottom

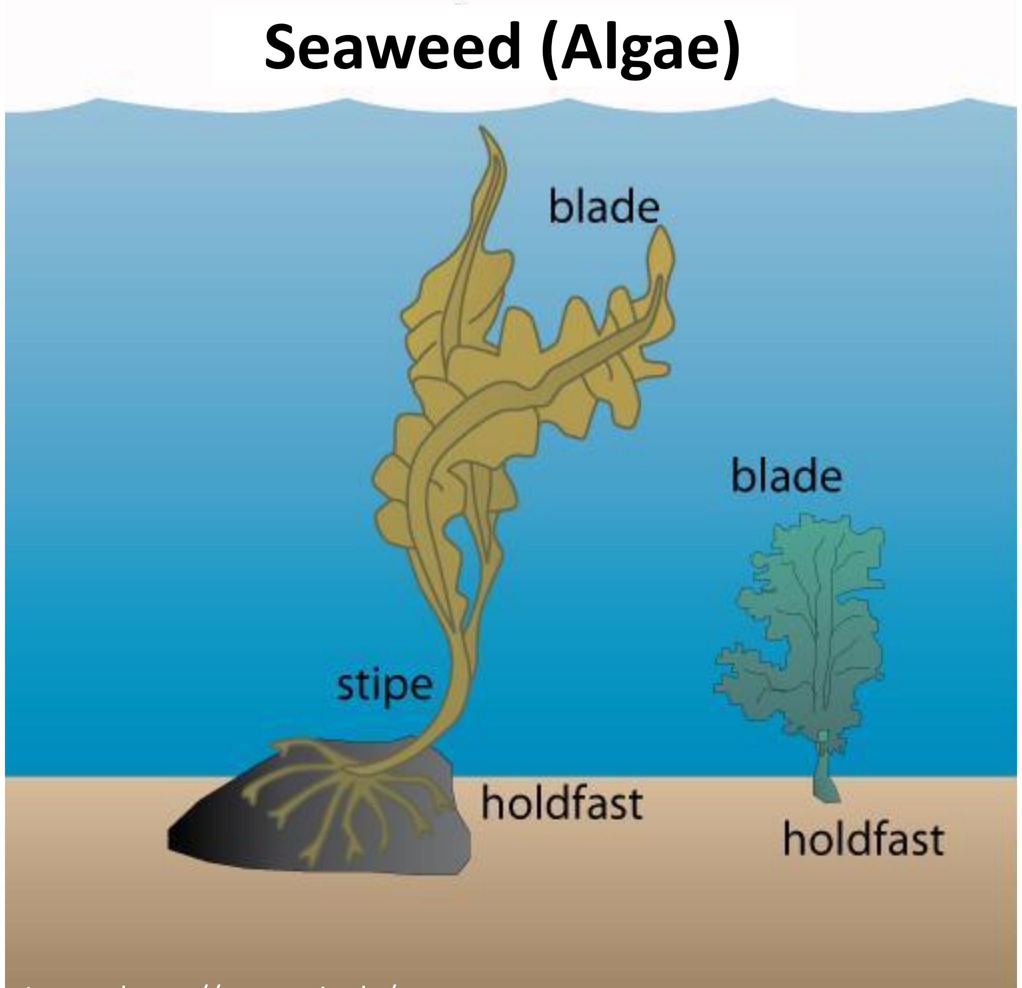
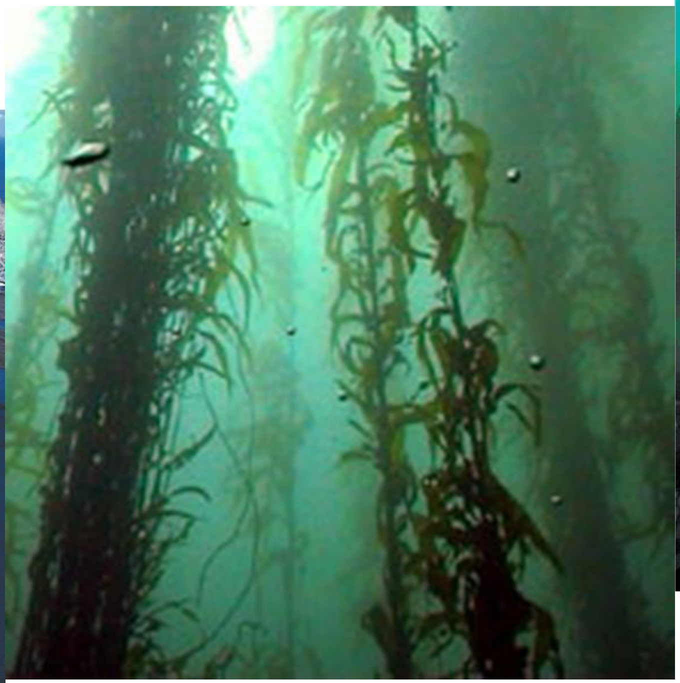


Image: https://ocean.si.edu/

The Subtidal Ecosystems – Kelp Forests

- **Kelp – a type of seaweed** that develops only on **hard (rocky) bottoms**, in water as deep as light allows
- **High primary production**
  - **One of the most productive marine communities**

©Dale Glantz



Giant kelp (*Macrocystis pyrifera*) forest at Cedros Island, Mexico

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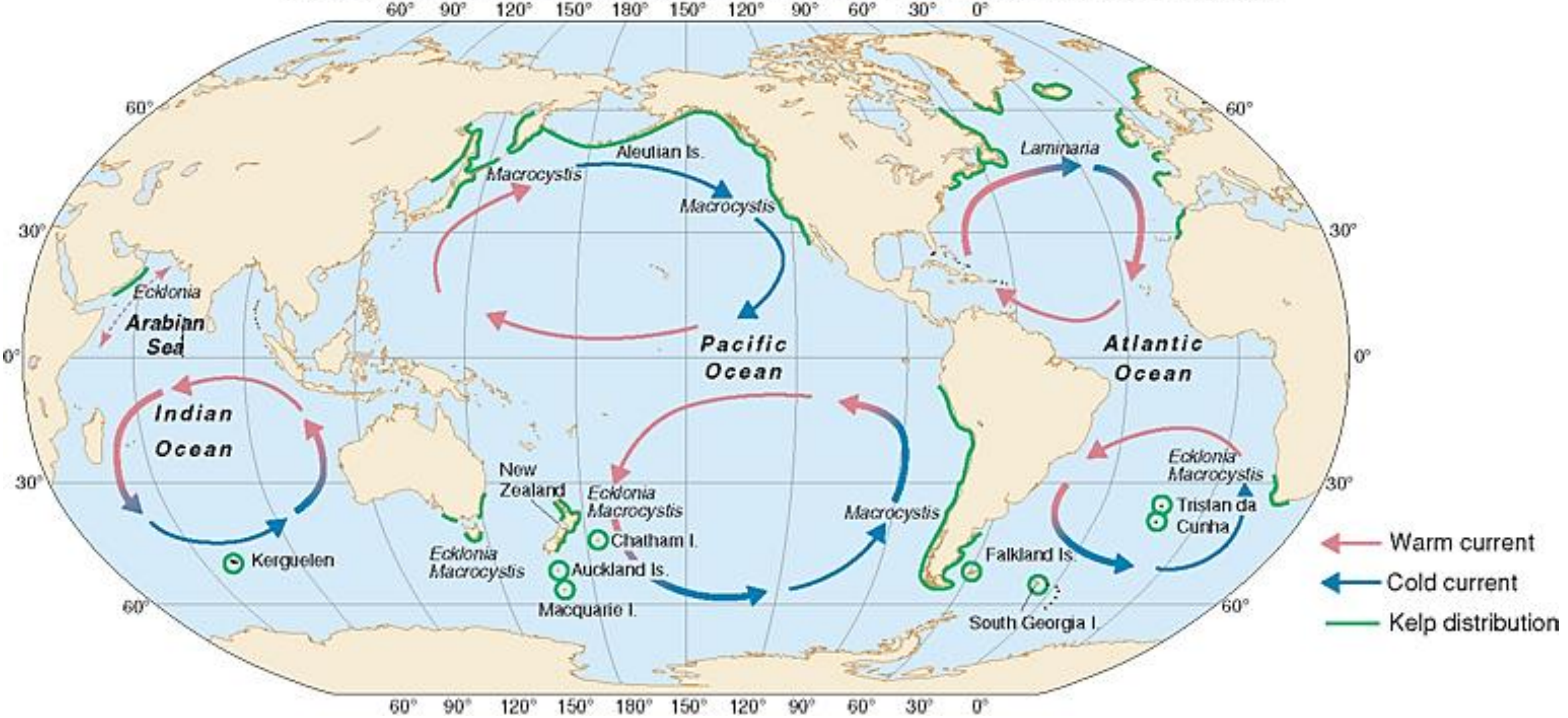
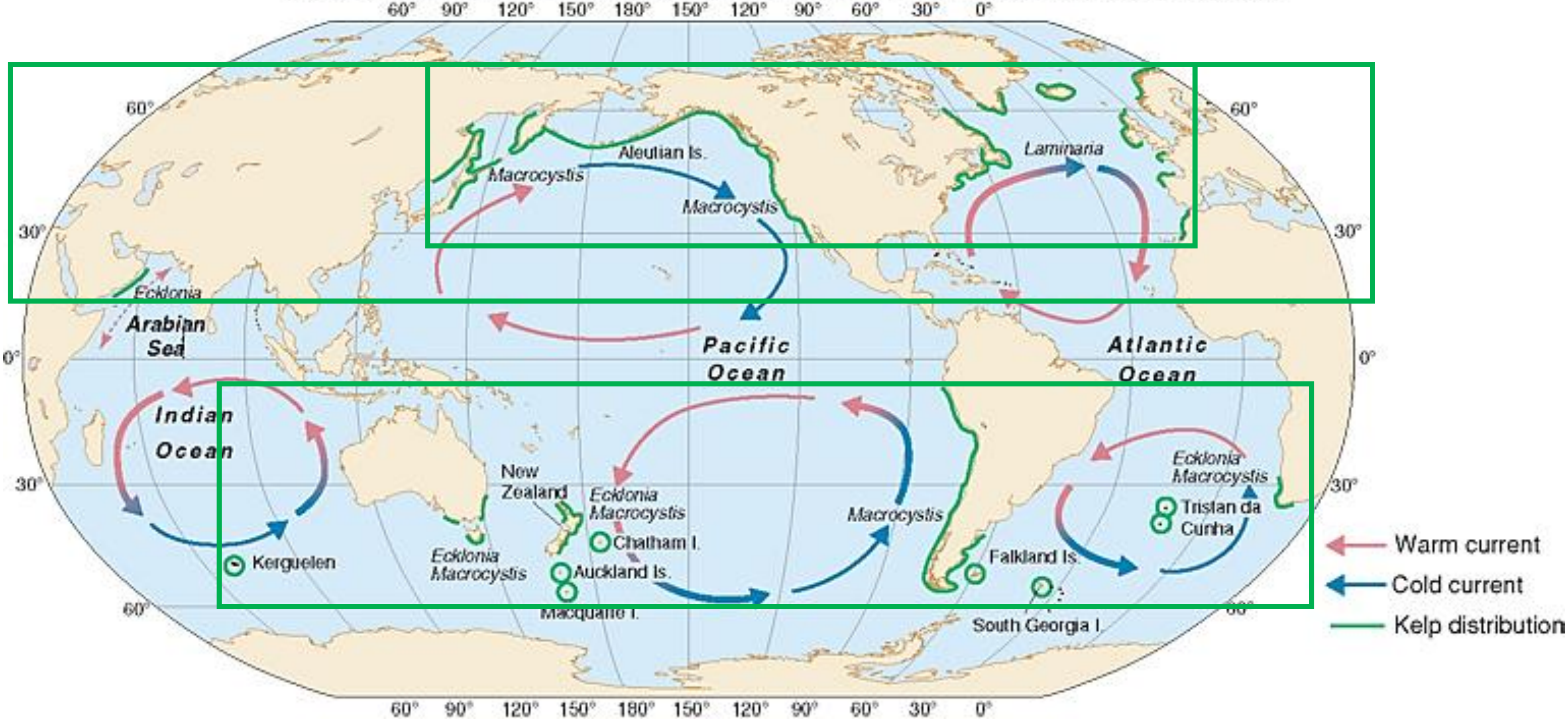
The elk kelp (*Pelagophycus porra*)

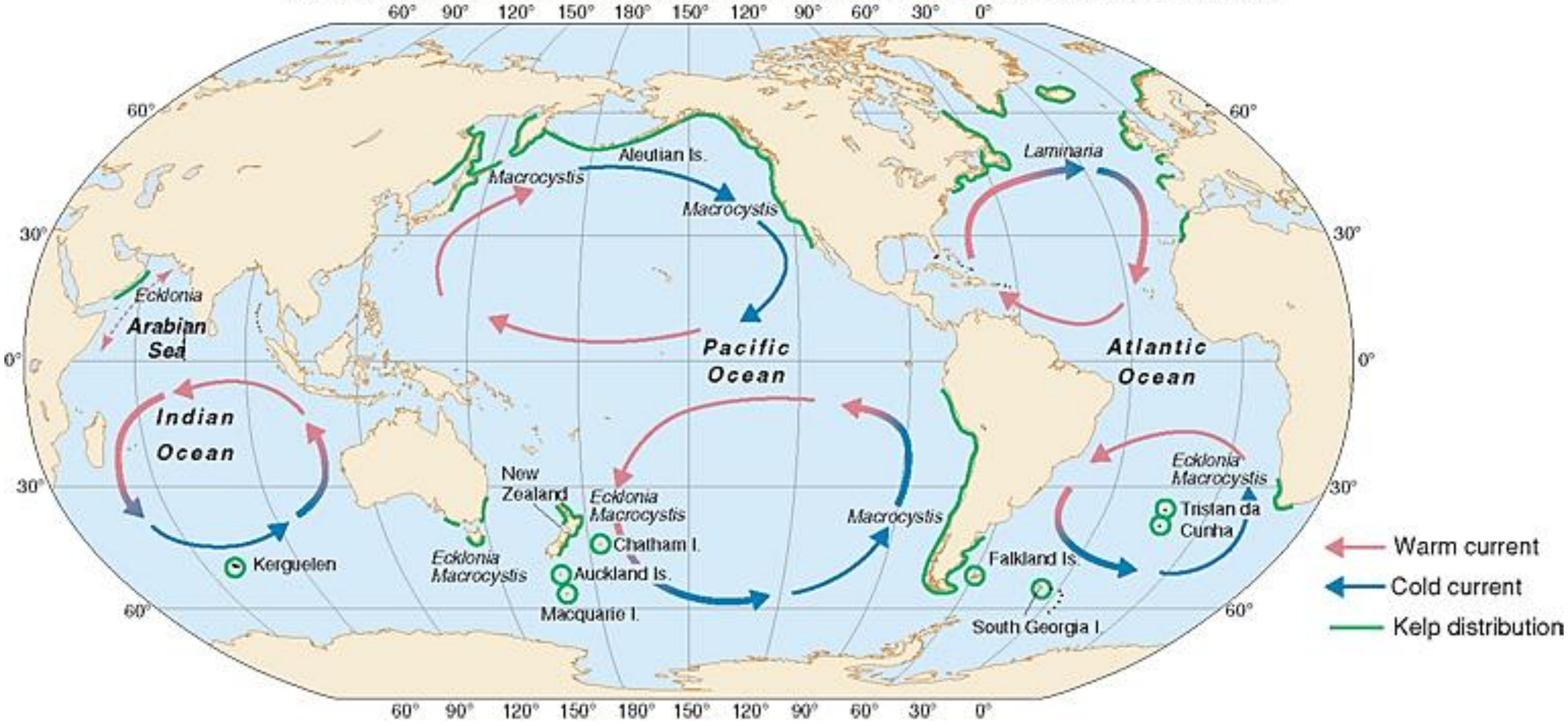
Kelp Forests – Distribution (Cold Temperate Regions)



Kelp Forests – Distribution (Cold Temperate Regions)



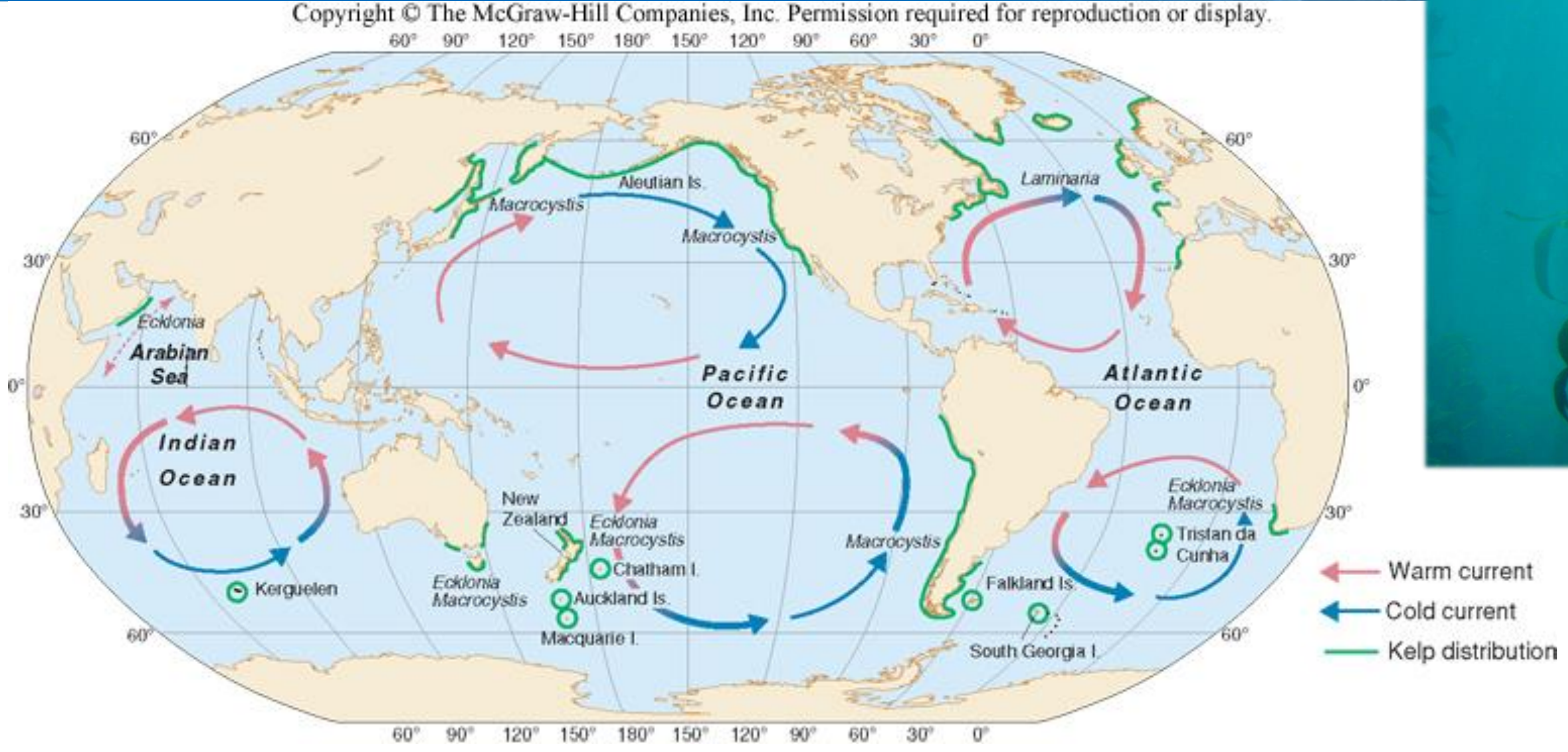
Kelp Beds and Kelp Forests



Dominated by genera –
Laminaria, *Pterygophora*, & *Ecklonia*

Kelp Beds – large, dense patches of kelp *near* North Atlantic & Asiatic coast

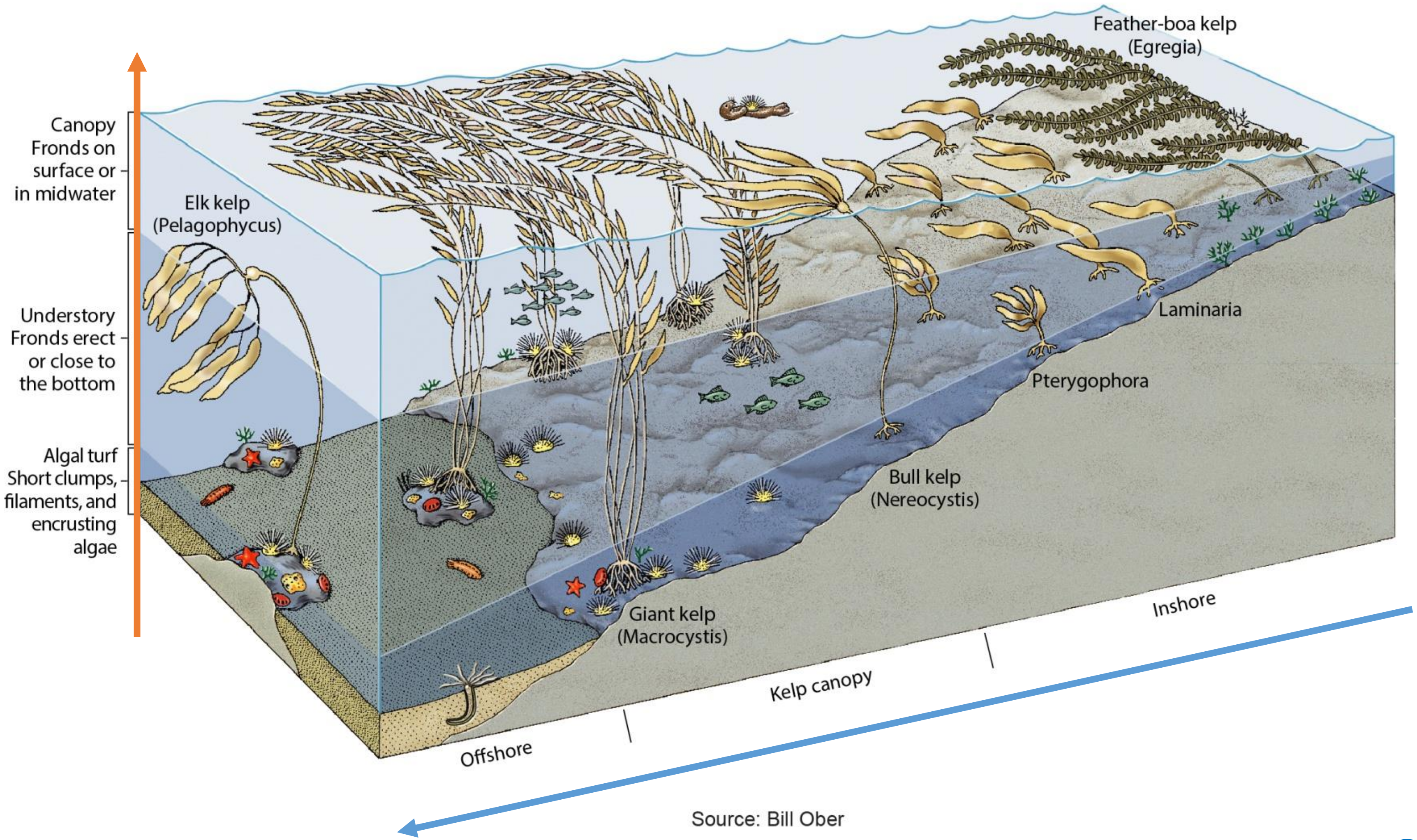
Kelp Beds and Kelp Forests



Dominated by genera –
Macrocystis (giant kelp) & *Nereocystis*

- **Kelp Beds** – large, dense patches of kelp *near* North Atlantic & Asiatic coast
- **Kelp Forests** – long, giant dense patches of kelp with a floating surface canopy
- **Kelp Beds AND Kelp Forests** – used interchangeably

Kelp Forests – Vertical and Horizontal Zonation



Source: Bill Ober

Distribution of the major types of kelps and other seaweeds in a generalized giant kelp (*Macrocystis*) forest, Pacific coast of North America.

Vertical:

- Canopy
- Understory
- Algal turf

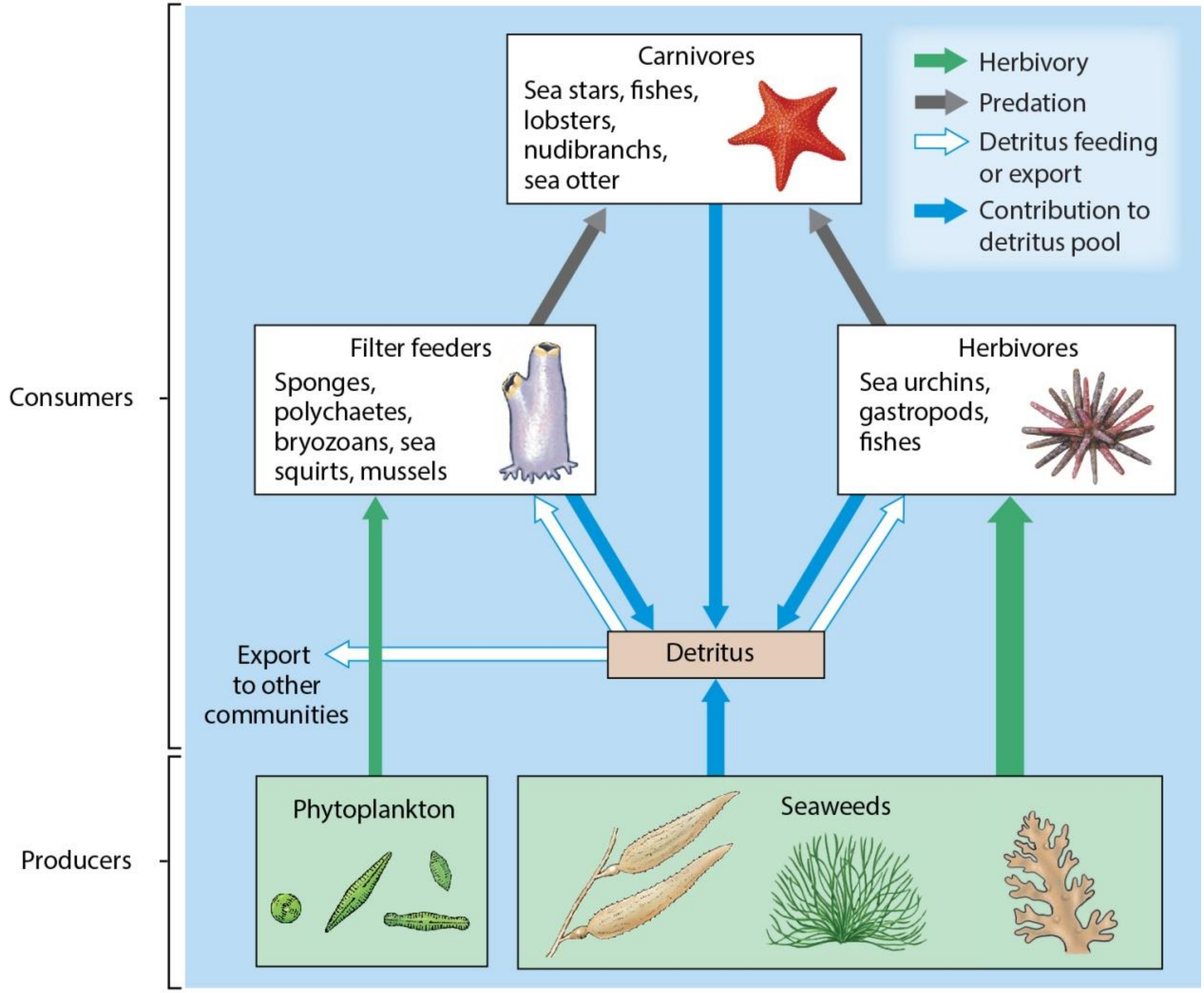
Horizontal:

- Inshore
- Kelp canopy
- Offshore

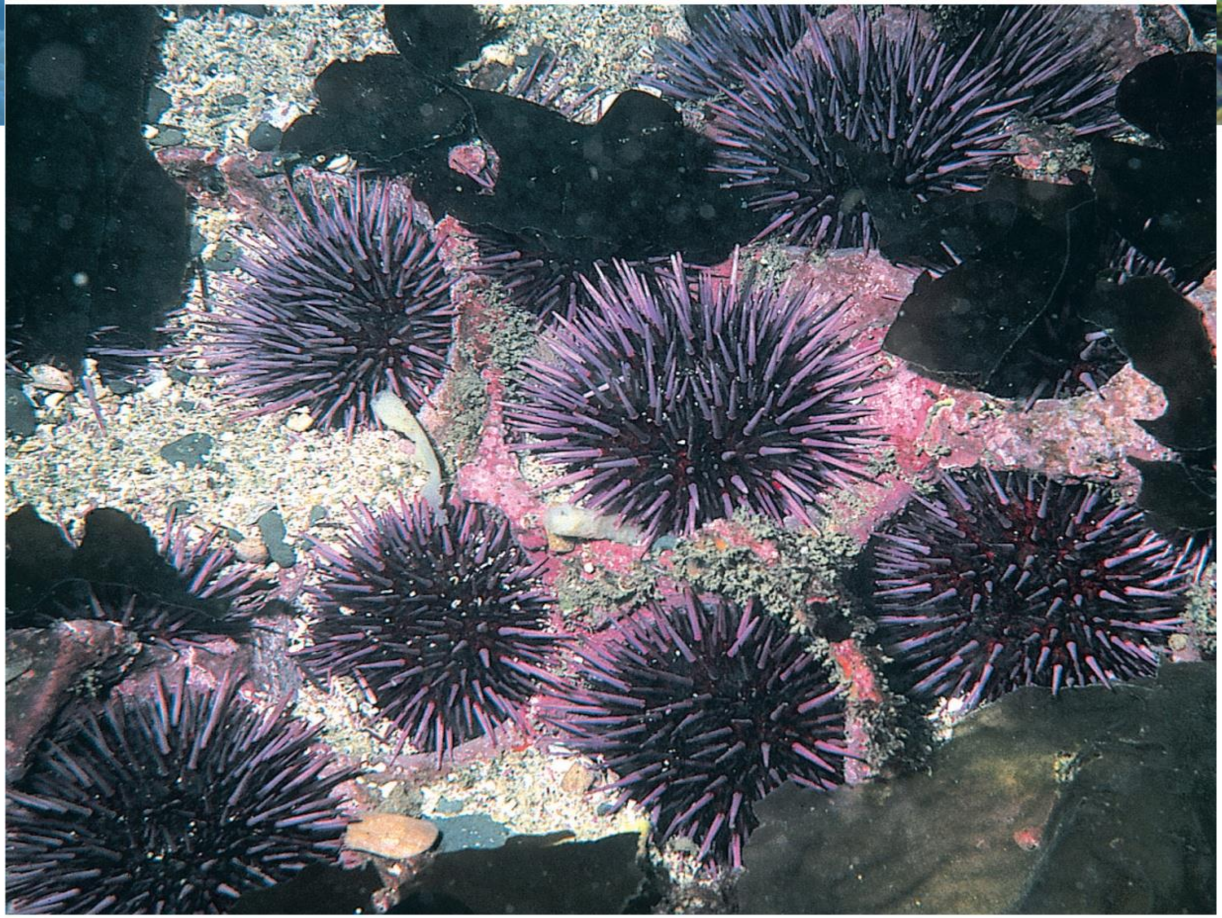
Kelp Forests – Competition for Space

Jostling for room, sea anemones, corals, and sponges vividly paint the floor of a kelp forest.

Kelp Forests – Food Web



Source: Bill Ober



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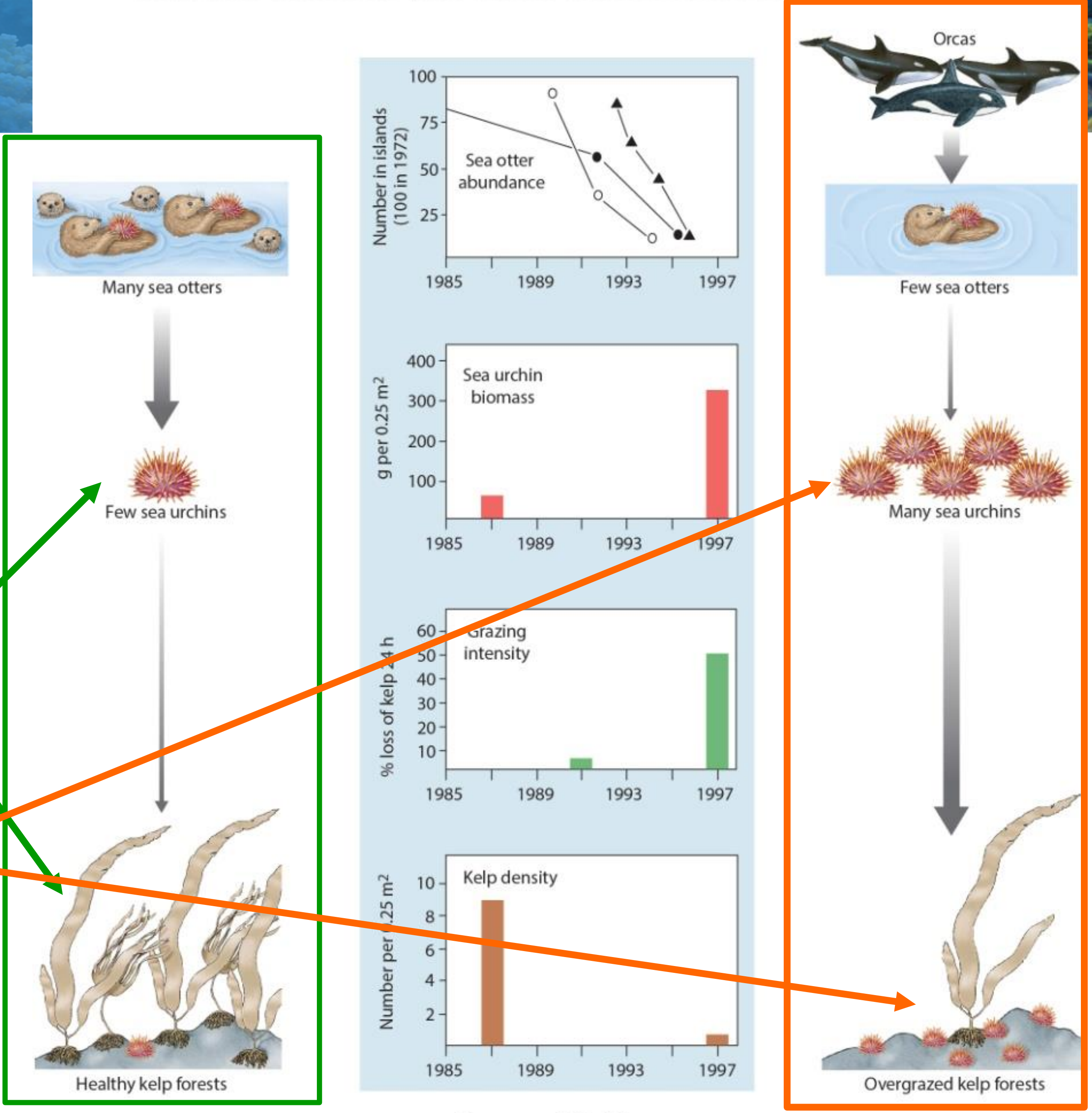
Sea Urchins (herbivores)

Kelp Forests
– The Effect of Predation

- **The effect of predation of sea otters by killer whales (orcas) on the population of sea urchins and kelps** in the kelp forests of the Aleutian Island, Alaska.

- **A healthy ecosystem requires a balance of all species**
  - If there are **few sea urchins**, there will be a **healthy kelp forest**
  - If there are **too many sea urchins**, the **kelp forest will be overgrazed**.

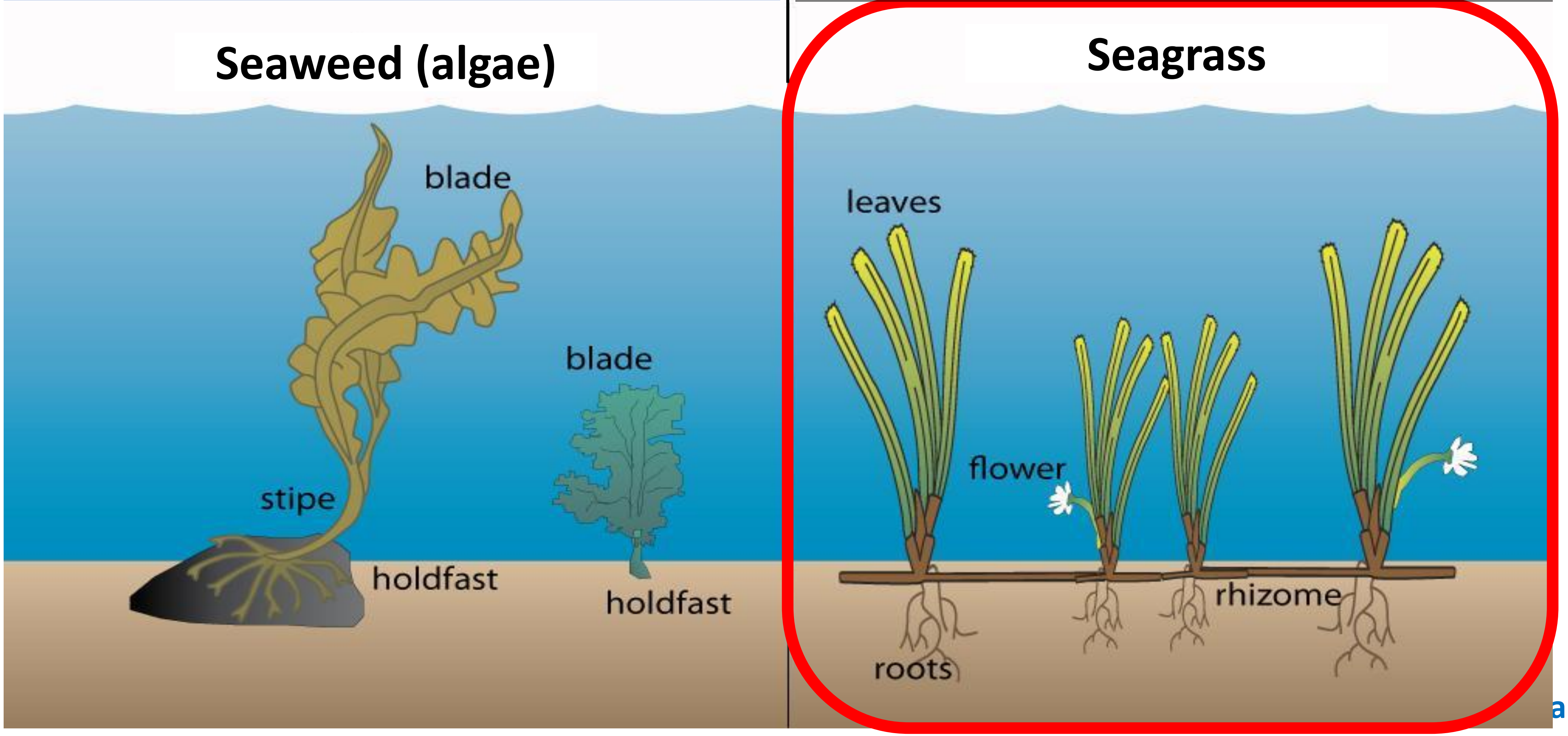
(*Note:* The years without bars in the graphs indicate years without data and not zero values.)



Source: Bill Ober

Seagrass

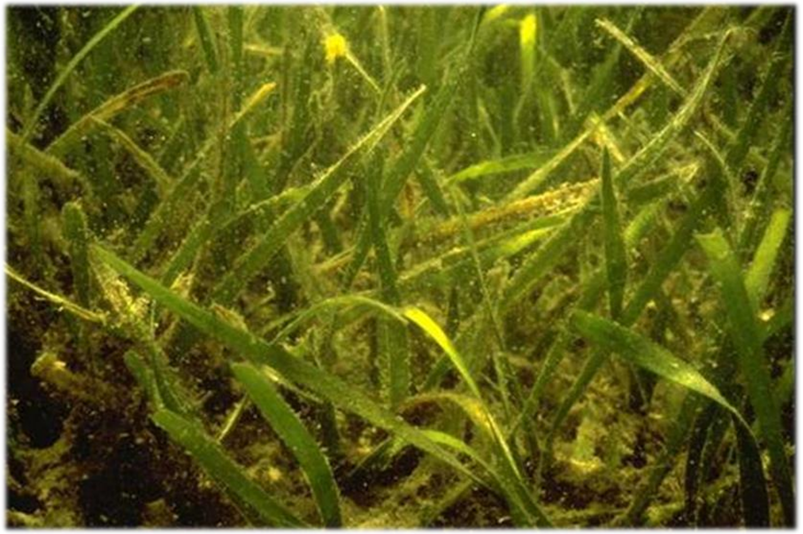
Hard Bottom	Soft Bottom



The Subtidal Ecosystems – Seagrass Beds

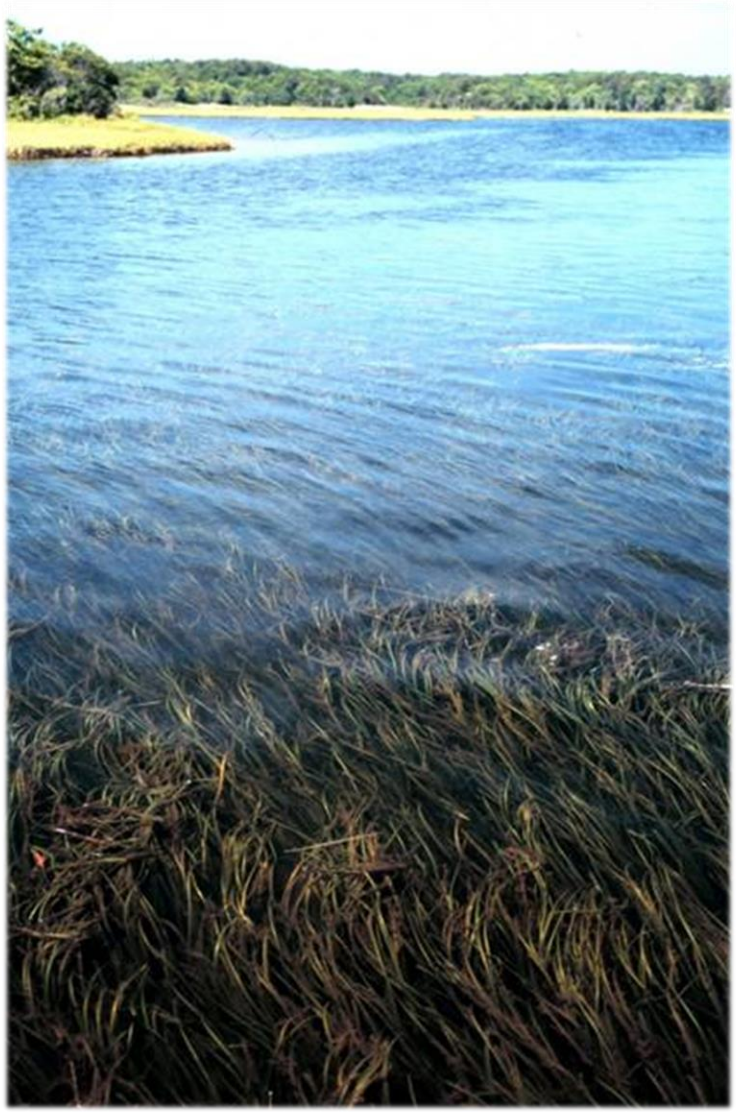
Seagrasses

- Flowering plants, >50 species
- Unlike seaweeds, have **true roots** (can absorb nutrients from sediment)
- Develop **mainly** on **soft bottoms** and in **sheltered, shallow waters**
- Also found in **estuaries** and in association with **mangroves**



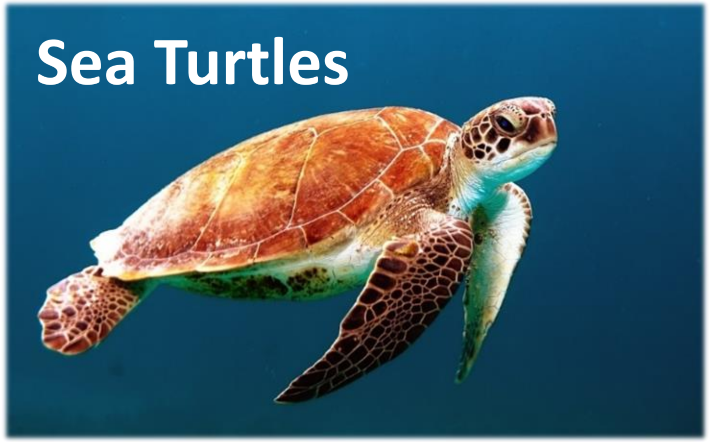
Turtle grass
(*Thalassia testudinum)*
Warmer, tropical &
subtropical zones

Eelgrass
(*Zostera marina*)
Colder, temperate
zones



The Subtidal Ecosystems – Seagrass Beds

- Seagrass may occur at **high density**
- **High biomass, high primary production**
- Help **stabilize sediments**
- Some herbivores feed on the **leaves**, but most biomass is available to consumers as **detritus**



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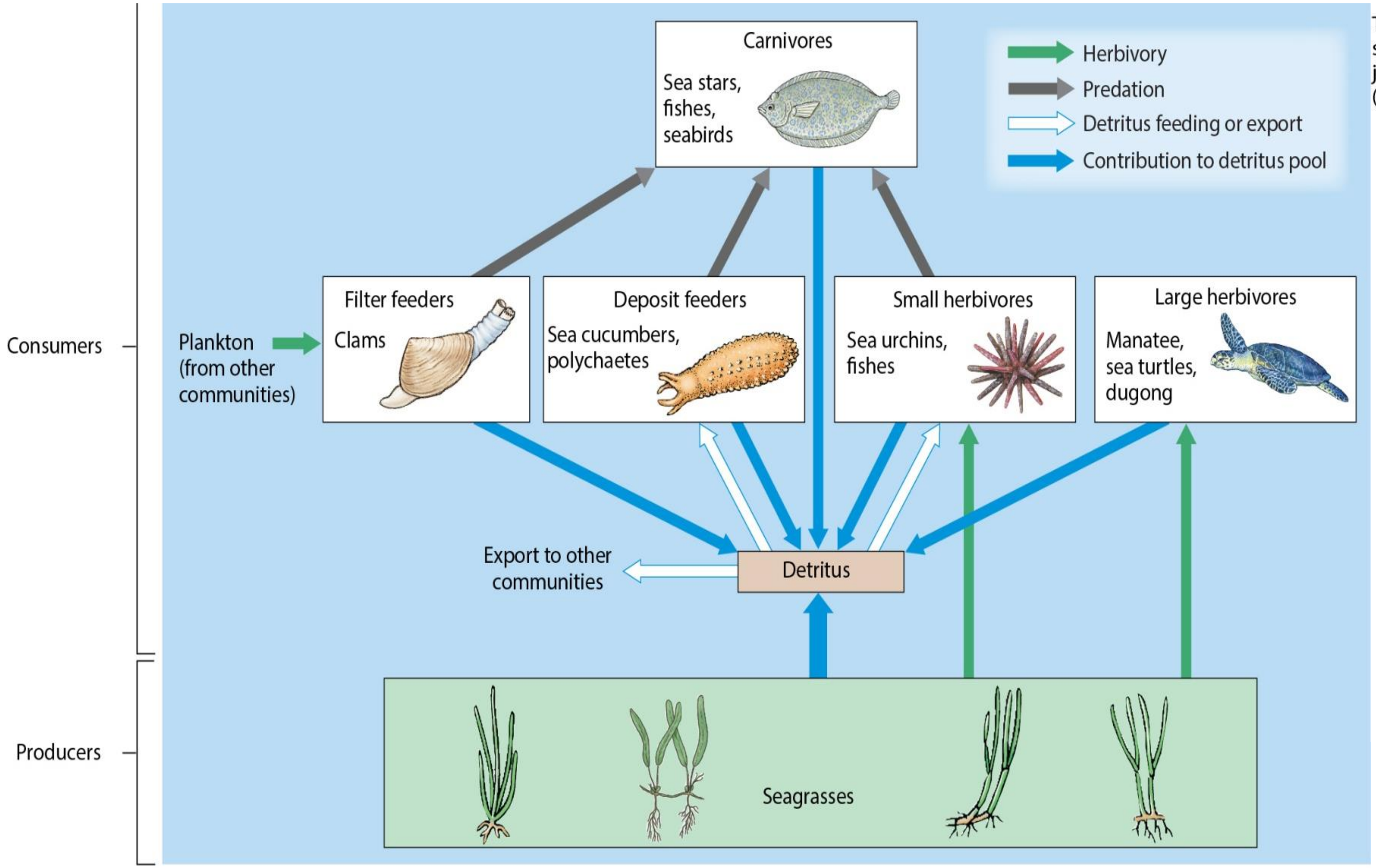
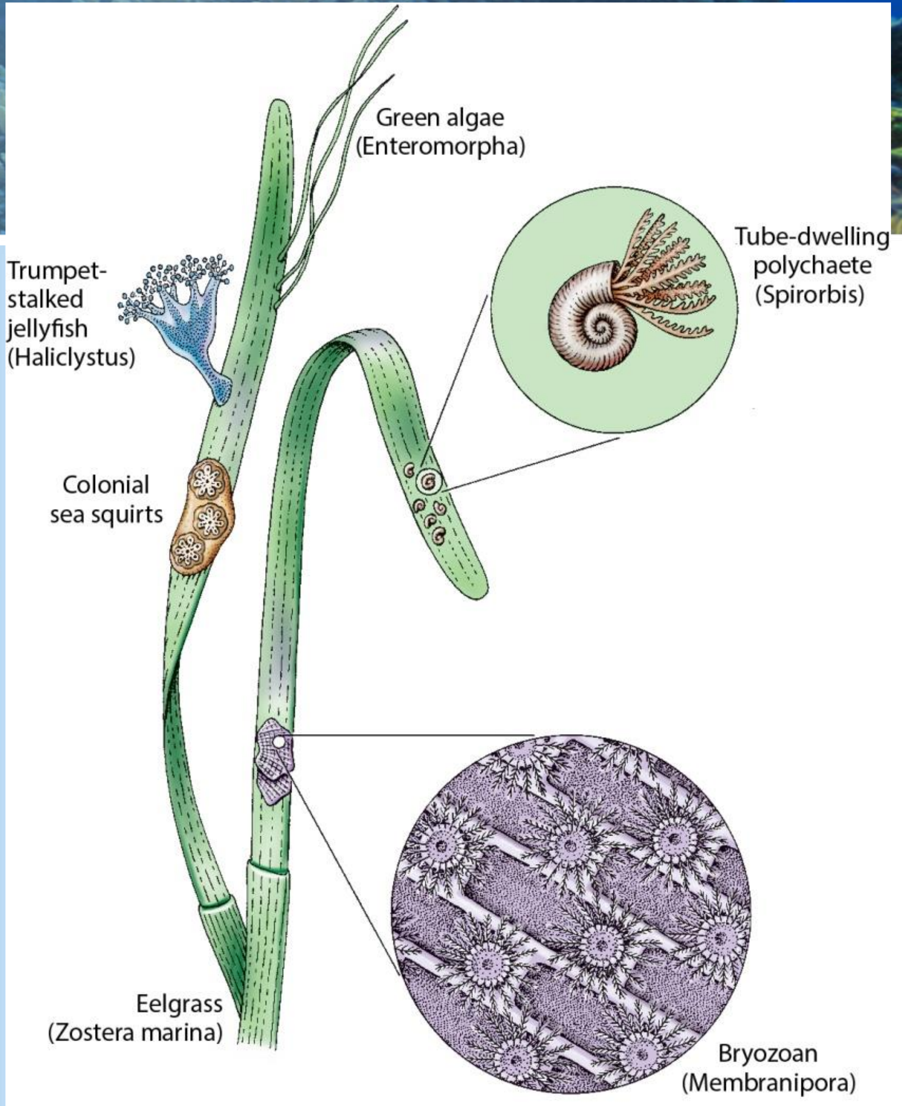
The queen conch (*Stombus gigas*) is a large snail commonly associated with seagrass beds in Florida and the Caribbean. It is highly prized as food.

Seagrass Beds – High Biodiversity



Source: Bill Ober



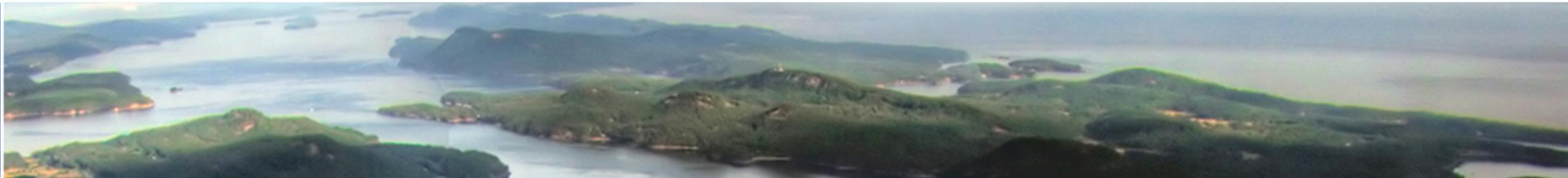
Source: Bill Ober

Many other organisms *(e.g. small algae)* grow on the surface of seagrass leaves.

Summary – Kelp Forest and Seagrass Beds

Valuable biodiverse ecosystems with high primary production

	Kelp Forests (Seaweed)	Seagrass Beds
Substrates	• Hard bottoms	• Mostly on soft bottoms
Distribution	• Cold temperate regions	• Temperate and tropical regions
Organisms	• Organisms feed on kelp and grow on the floor of kelp forest	• Organisms feed on leaves and grow on the leaves of seagrass beds • Detritus feeding important



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The Subtidal Ecosystems – Coral Reefs

Overview – Coral Reefs

- What are Coral Reefs?
- Growth Forms (Shapes) and Distribution
- Types and Formation of Coral Reefs
- Coral Reef Food Web
- Environmental Stress can Cause Coral Bleaching

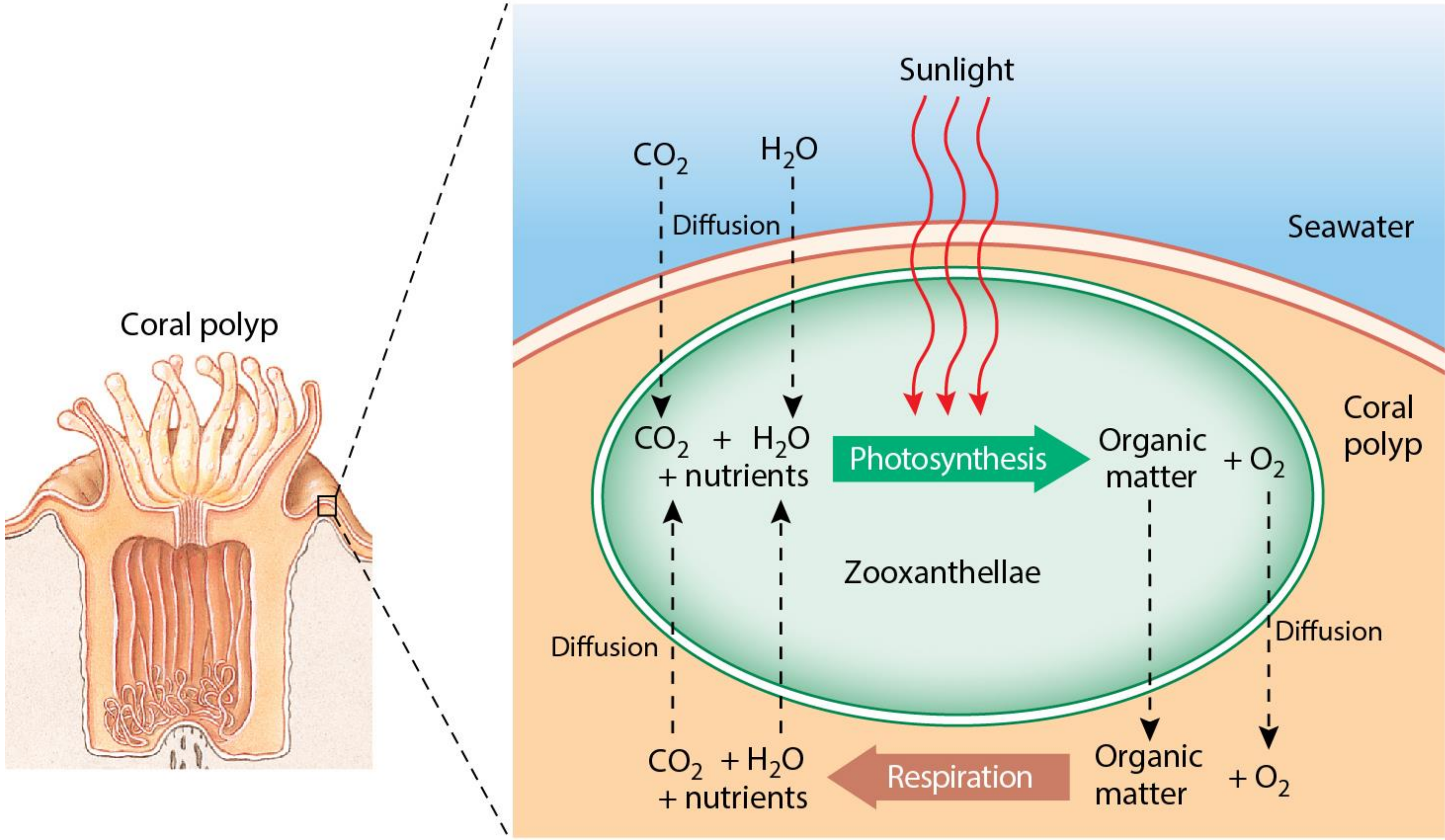
What are Coral Reefs?

- An underwater ecosystem found in shallow water
- A massive (rock-like) framework made of huge amounts of **calcium carbonate ($CaCO_3$) deposited by organisms**
- **Include Biological Communities and Geological Structures**
  - The *largest* geological features built by organisms

Image: McGraw-Hill Education

Re-cap from Previous Module – Symbiosis between Corals and Zooxanthellae

- Most **reef-building coral contain photosynthetic algae, Zooxanthellae** (i.e. mutualism).
- The **coral provides algae with protective environment** and compounds they need for photosynthesis.
- In return, **the algae produce oxygen, provide nutrients and help the coral remove waste.**



Source: Bill Ober

Reef-Building Organisms

- **Hard / Stony Corals**
  (the most important reef builders)

Reef-Building Organisms

- **Hard / Stony Corals**
  (the most important reef builders)
- Oysters
- Polychaete worms
- Red algae
- Giant clams

Image: McGraw-Hill Education

The Subtidal Ecosystems – Coral Reefs

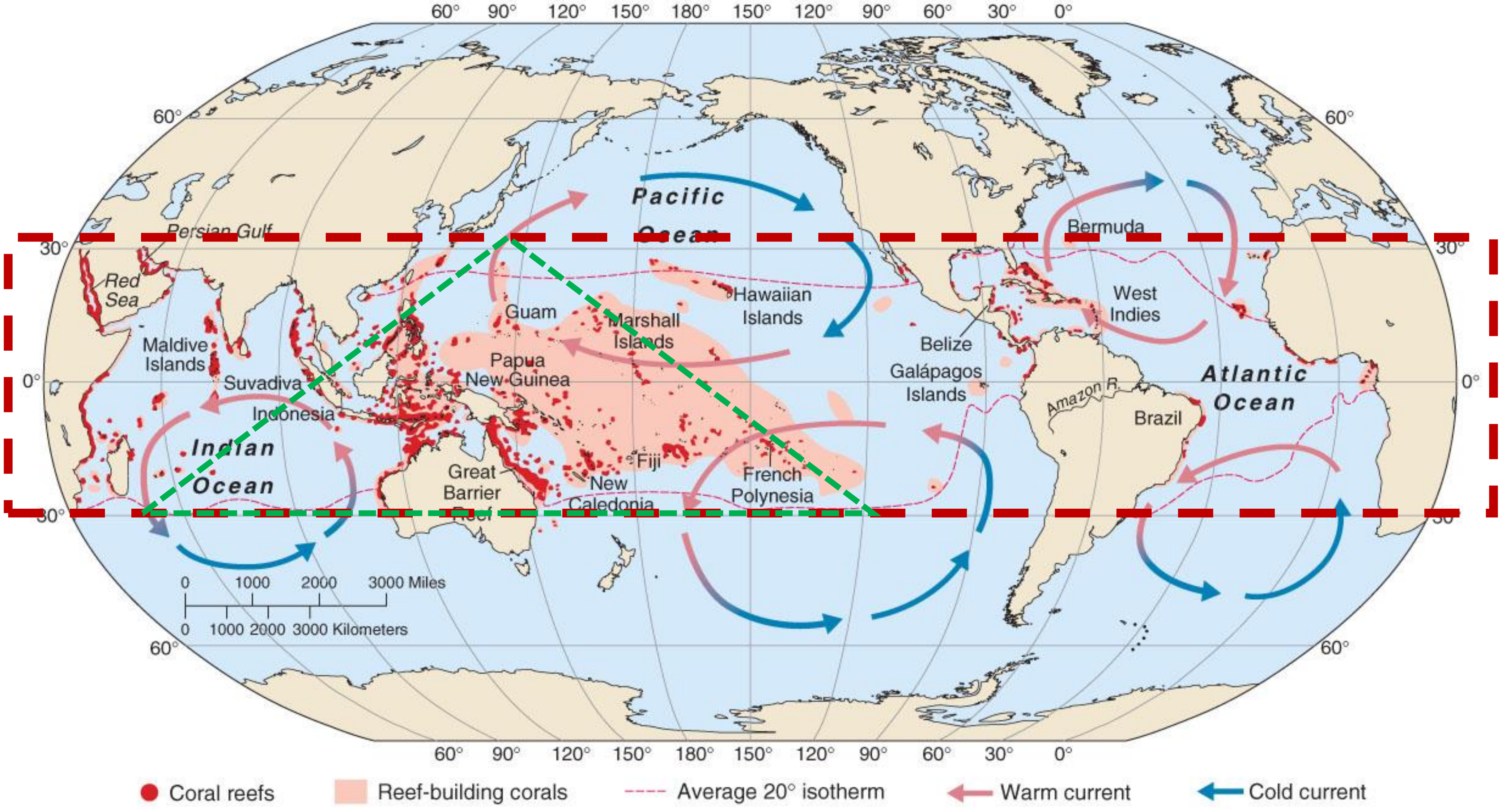
One of the most biodiverse and productive ecosystems.

- **Habitats to many organisms** – *e.g. fishes, sponges, shrimps, crabs, mollusks, sea urchins, sea turtles, sea snakes, polychaete worms*

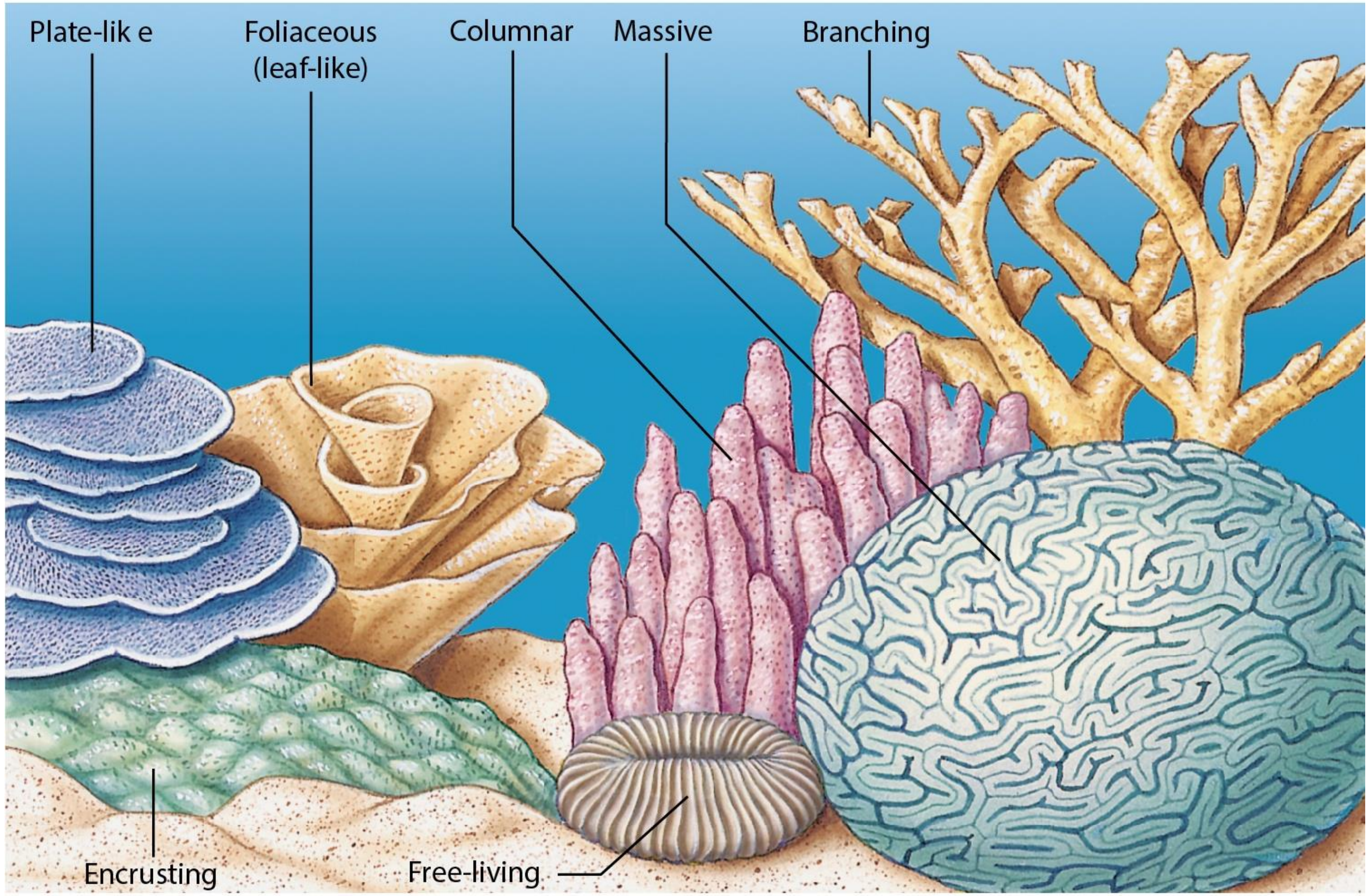
- The coral reef ecosystem is **very complex** and **limited by**
  - **Physical factors** – temperature, light, depth, nutrients, wave action
  - **Biological factors** – competition, predation, grazing

©richcarey/Getty Images

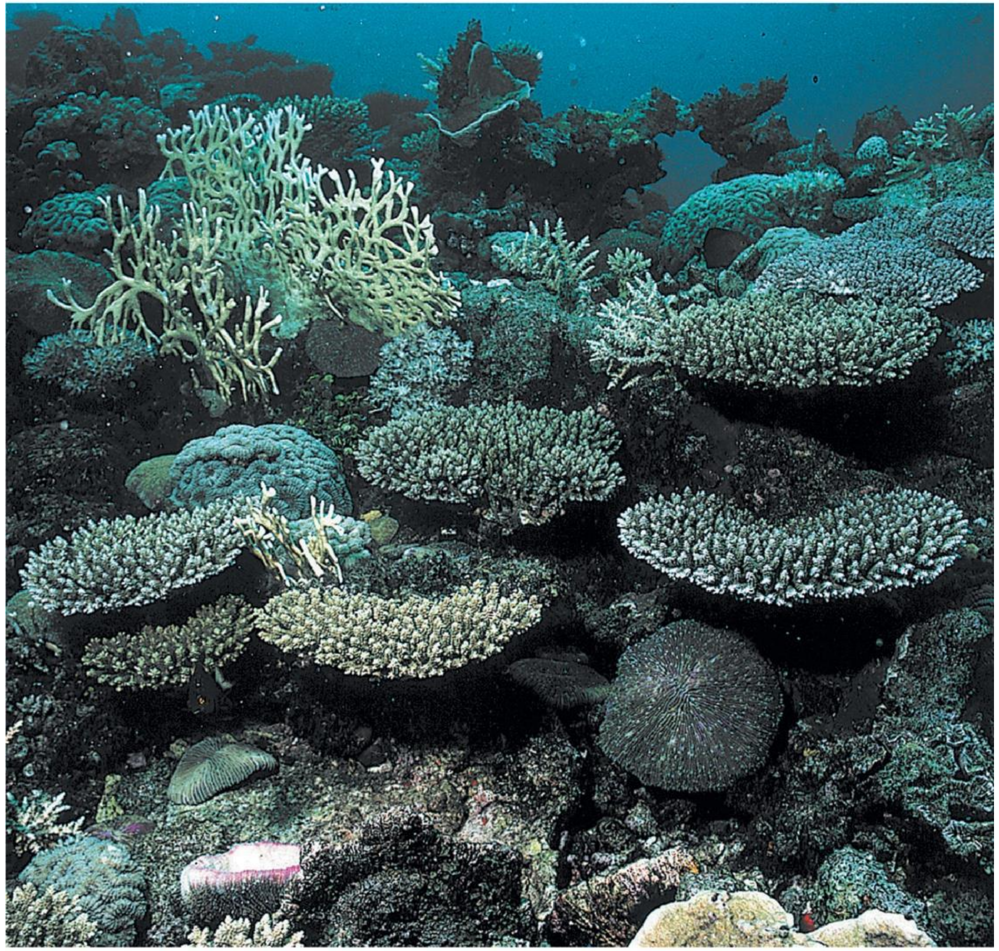
Coral Reefs – Distribution (Warm Waters)



Corals – Different Growth Forms (Shapes)



Source: Bill Ober



©Michael Huber

Soft Corals

© Michael Huber

Soft Corals can form dense patches on coral reefs, as on this reef in Papua New Guinea.

Soft Corals lack a $CaCO_3$ skeleton and are able to grow faster than **hard corals**.

Coral Reefs – Three Main Types of Formation

The formation of these three types of reefs takes a long time – tens or hundreds of thousands of years, or even longer.

Fringing Reef

Bismarck Archipelago, Southwest Pacific

(Image: McGraw-Hill Education)

Barrier Reef

The Great Barrier Reef, Australia

(Image: www.thetourspecialists.com.au)

Atoll

Palau, Western Pacific

(Image: McGraw-Hill Education)

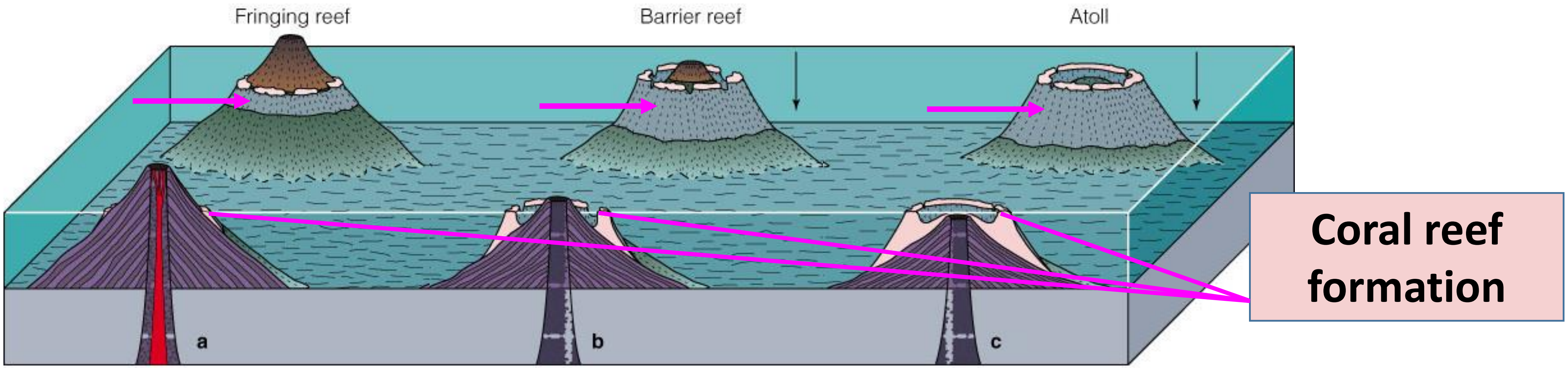
The Great Barrier Reef (Australia)

Image: Holobionics

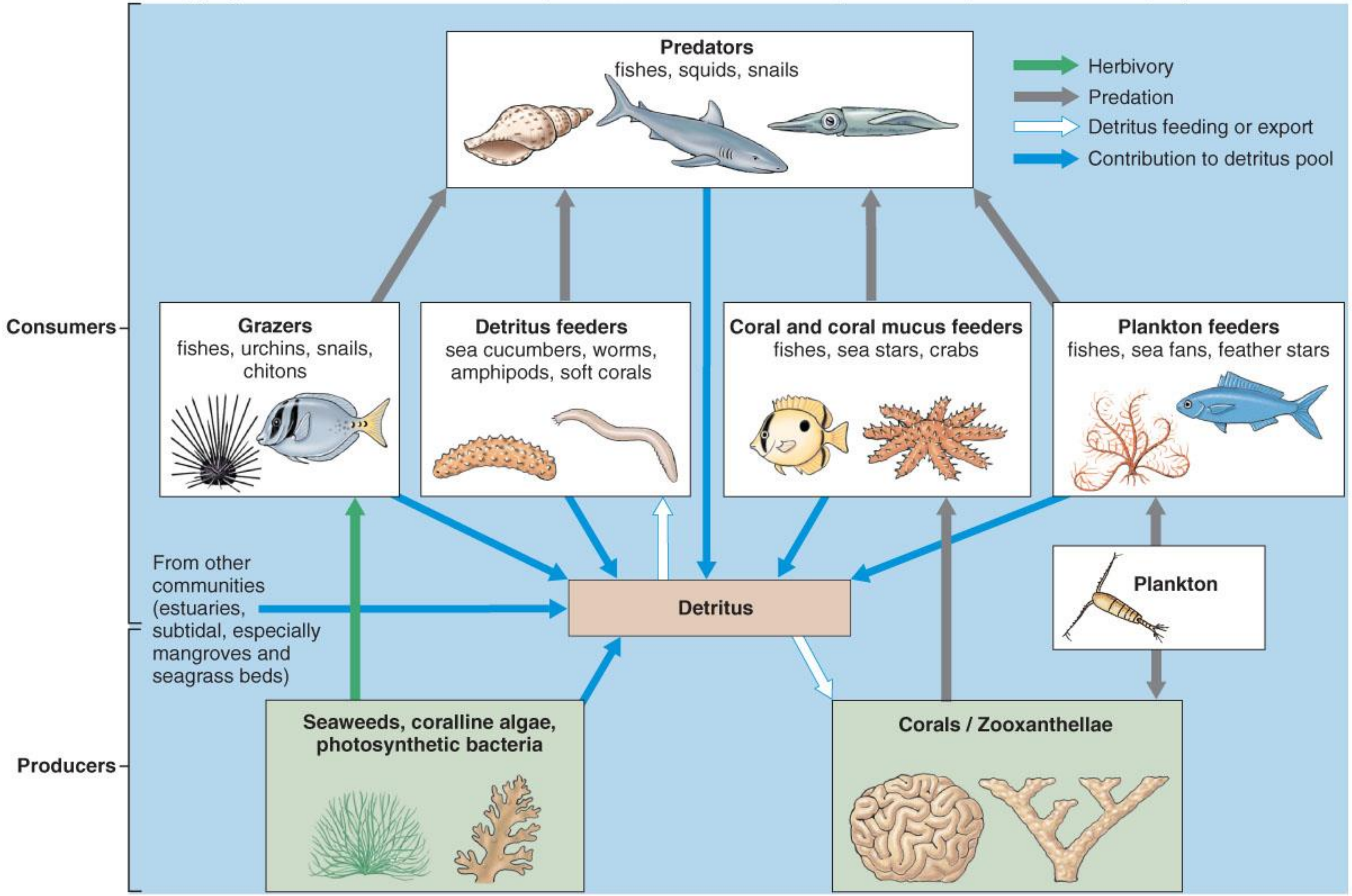
The world's *largest* coral reef system

Coral Reefs – Formation

- When a deep-sea volcano erupts to build an island, corals soon colonize the shores of the new island, and a **Fringing Reef** develops.
- After thousands of years, the island sinks while the coral organisms can build upward forming a **Barrier Reef**.
- After thousands of more years, the island eventually disappears beneath the surface, but the coral remains at the surface as an **Atoll**.



Coral Reef Food Web

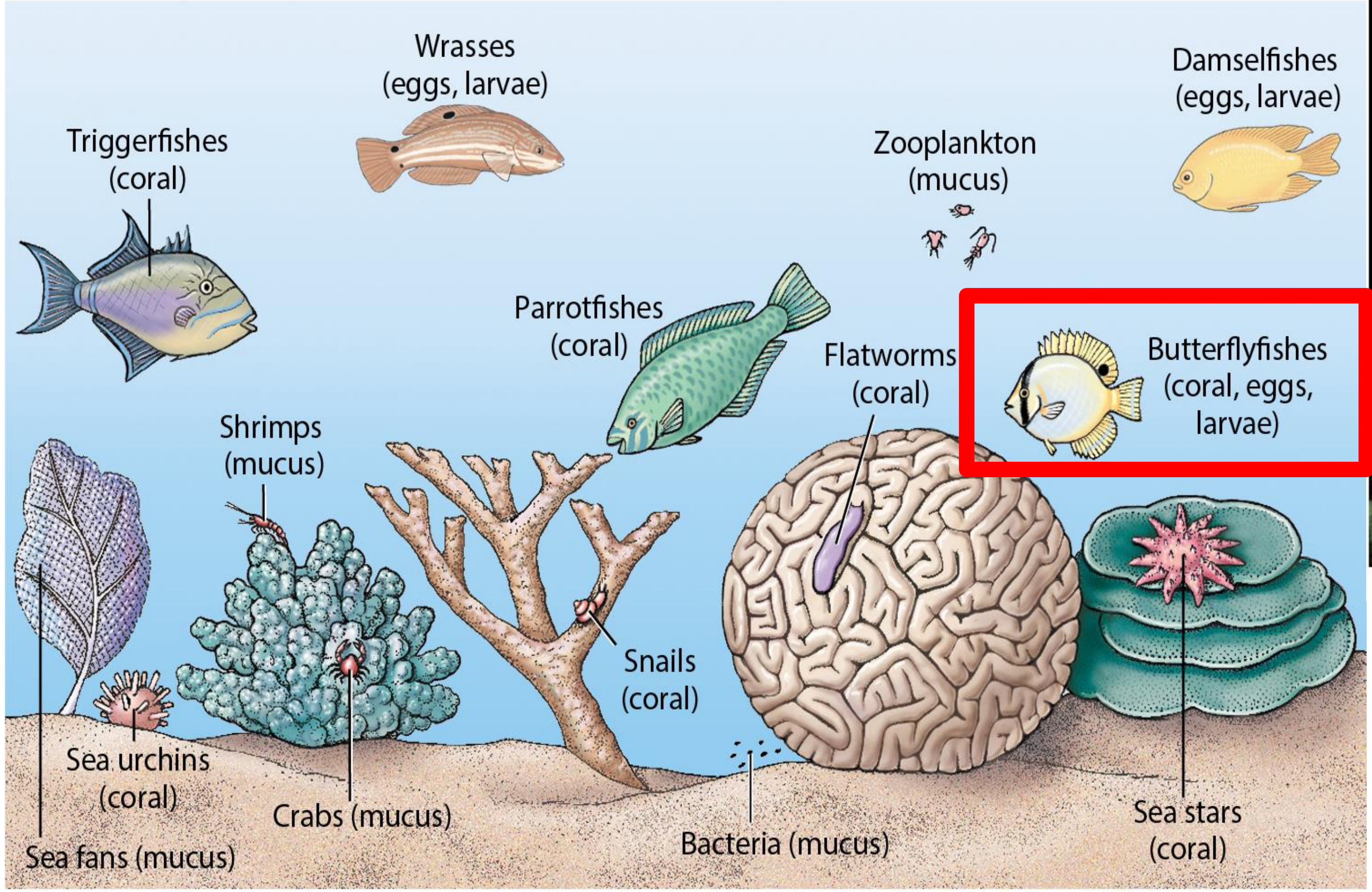


Coral reefs are extremely diverse.

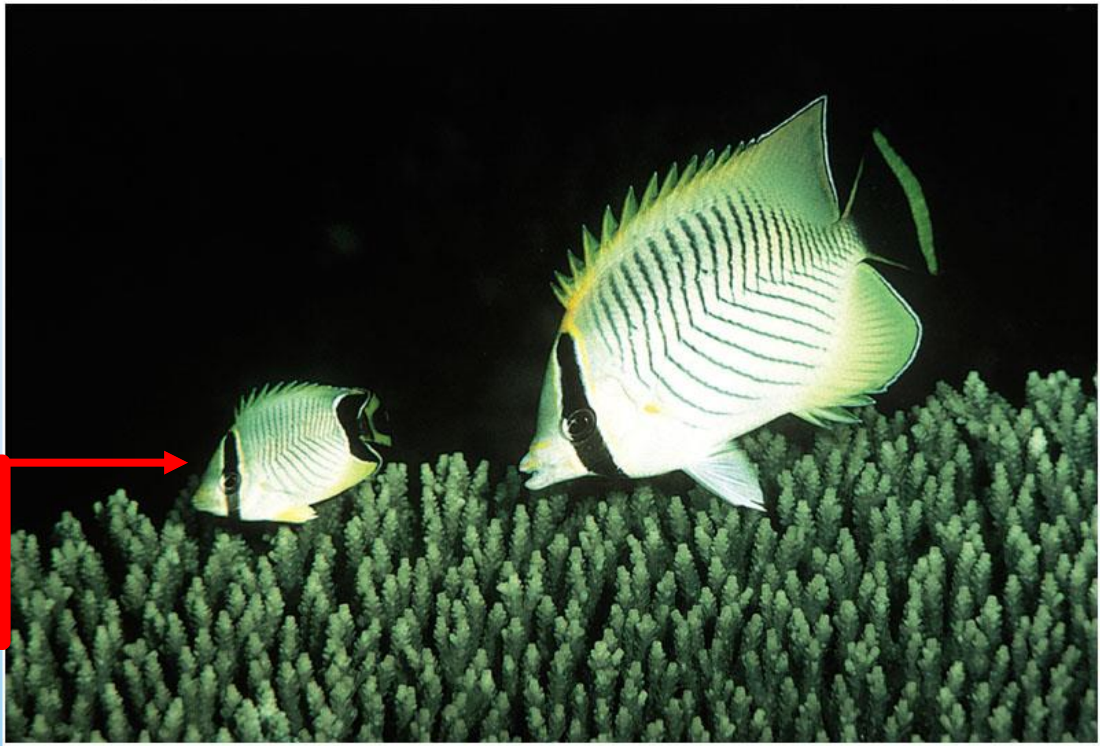
Most components include many organisms in addition to those listed here.

Environmental changes, pollution, and environmental stress could disrupt the food web.

Organisms Feeding Directly on Corals



Source: Bill Ober



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The Chevron Butterflyfish (*Chaetodon trifascialis*) is one of many reef animals that feed on corals without killing the entire coral colony.

Coral Reef Fishes
– Competitive Relationships Poorly Understood

© Vol. DV13 Digital Vision/Getty Images

Coral reef fishes are another group in which **competition** may be important.

Many of them share **similar diets**: **coral-eating, grazing on algae, and carnivorous**. However, their competitive relationships are **poorly understood**.

(Carnivore = An animal that eats other animals)

Corals – Very Sensitive to Environmental Changes

Coral Bleaching

- When water is **too warm**, **corals will expel the algae (zooxanthellae)** living in their tissues (major food source) causing the corals to turn **completely white** **(i.e. bleaching)**.

This image shows the same reef in American Samoa *before*, *during*, and *after* a coral bleaching event.

Image: https://www.downtoearth.org.in

Coral Bleaching

Summary – Coral Reefs

- **Coral Reefs are massive deposit of $CaCO_3$ built by hard/stony corals and other organisms (i.e. Coral Reefs = Biological Communities + Geological Structures)**

- **Why are Coral Reefs important?**
  - They are one of the most biodiverse and productive ecosystems on Earth but also vulnerable to warming, pollution and other environmental stress
  - Disruption to marine life food web could result from such environmental stress

- **What are the major types of Coral Reefs?**
  - Fringing Reefs, Barrier Reefs, and Atolls

- **Complex food web**; **competitive relationships among coral reef fishes poorly understood**

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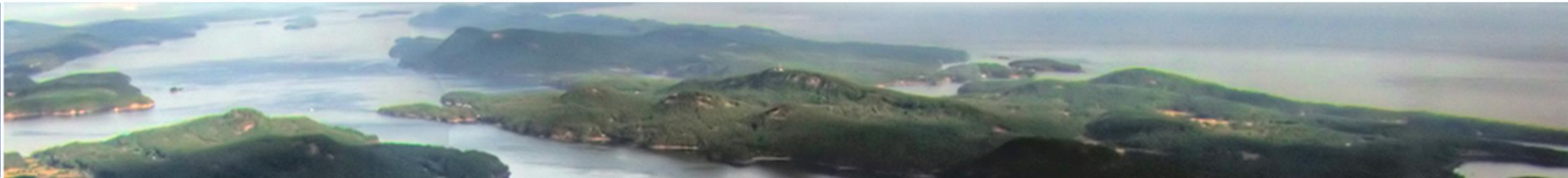

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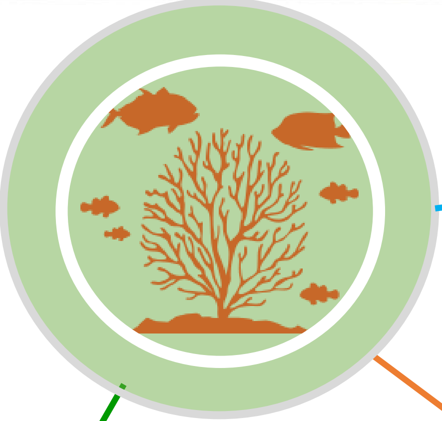
The Intertidal – Hard Bottoms (Rocky Shores)

Marine Ecosystems – The Subtidal, Estuaries, and the Intertidal



Subtidal Zone

Always submerged

- ❑ Unvegetated Areas
- ❑ Kelp Forests
- ❑ Seagrass Beds
- ❑ Coral Reefs

Coastal Eutrophication

- ❑ Harmful Algal Blooms & Effects
- ❑ *Noctiluca Blooms*

Intertidal Zone

***Not always* submerged**

- ❑ Rocky Shores
- ❑ Sandy and Muddy Shores

Estuaries

Where rivers *meet* the sea

- ❑ Salt Marshes
- ❑ Mangroves

The Intertidal Zone

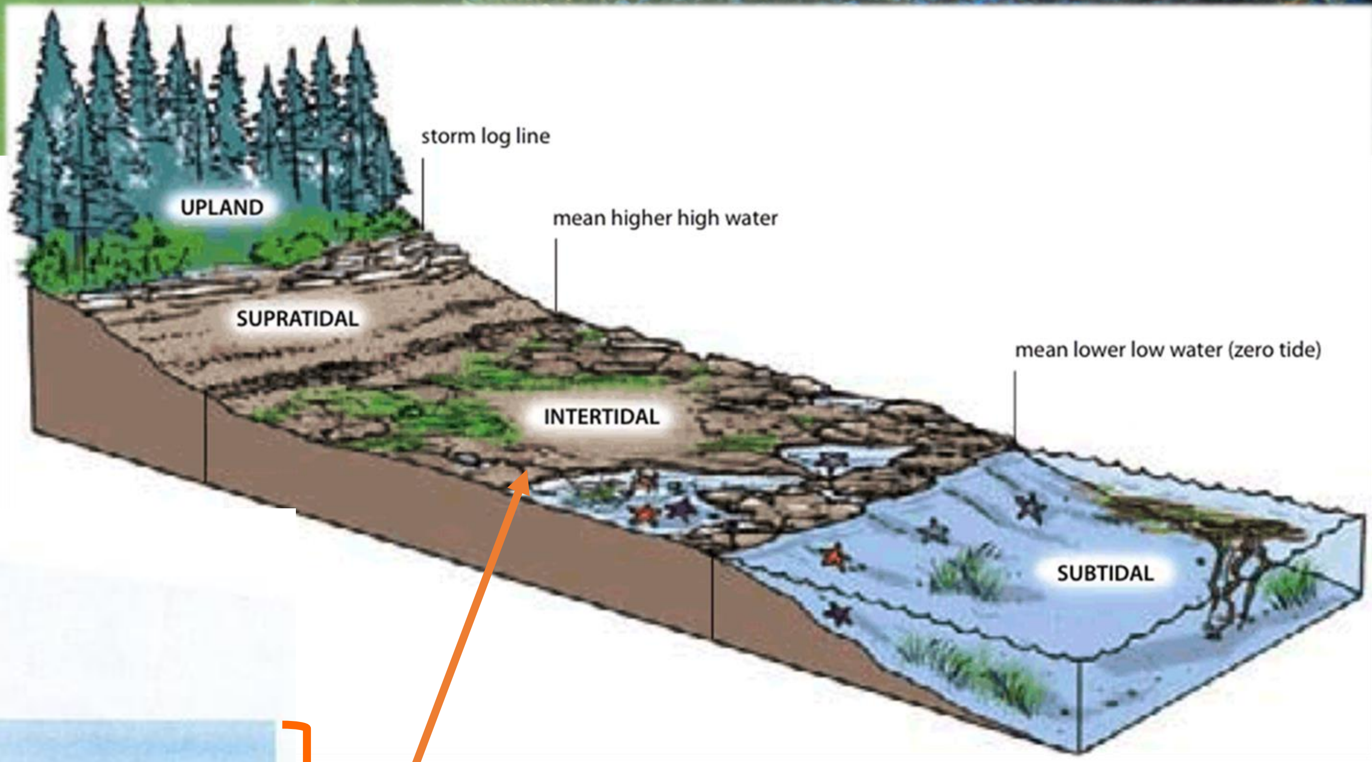


Image: Geocaching.com

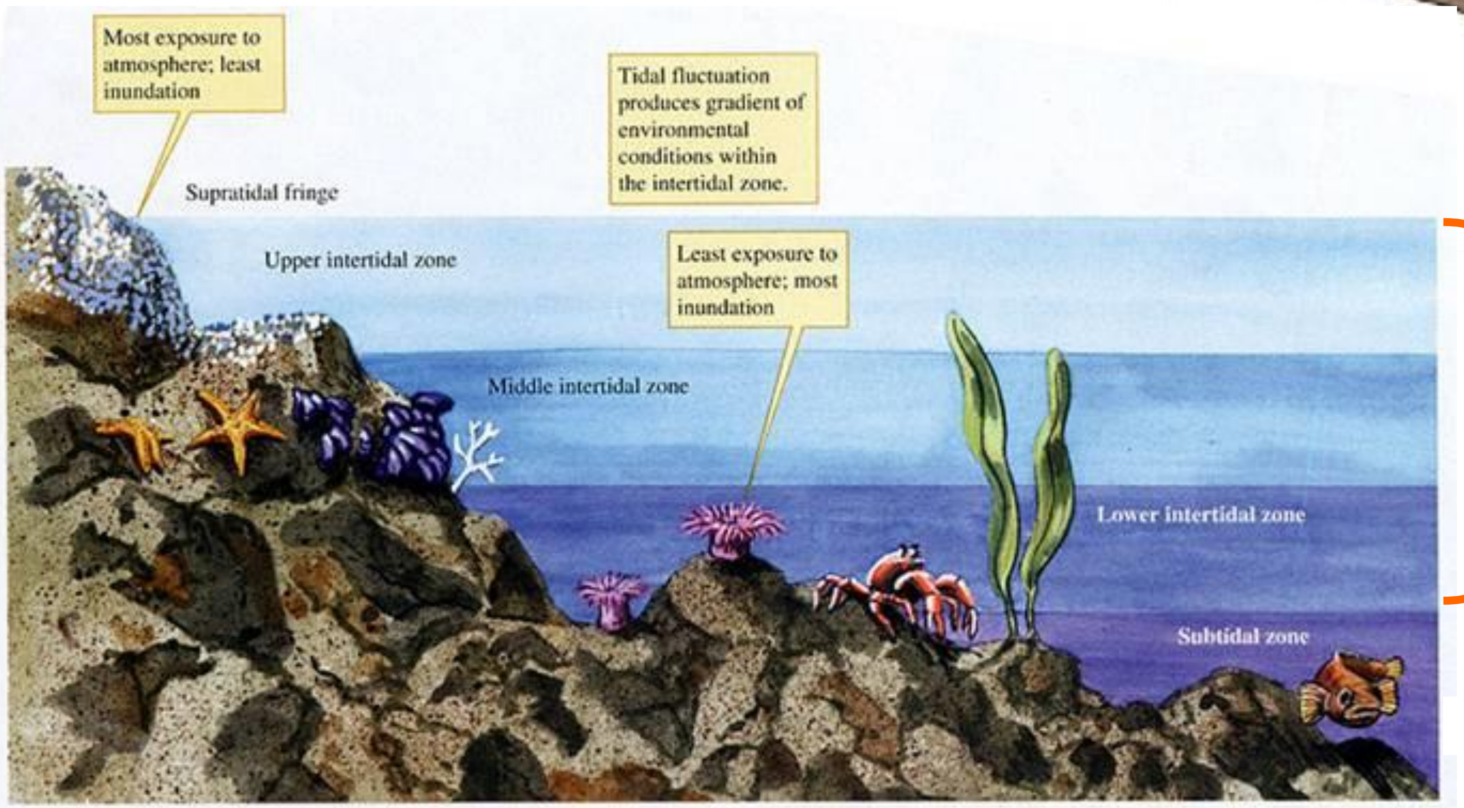


Image: South China Normal University

The Intertidal Zone

Among all marine ecosystems, the Intertidal Zone is the **best known to marine biologists and the public**.

We can explore the Intertidal Zone ***without* any specialized and expensive equipment.**

It is the zone affected by **low tides and high tides**

Although the Intertidal Zone comprises only a tiny part of the marine environment, the study of it allows us to gain **a better understanding of ecology** (the interaction between organisms and their environment).

The cliffed beach of Newport, Rhode Island

(Image: Geoking66)

Intertidal Communities

The nature of the intertidal communities depends on the **type of the bottom** (**substrate** – the material on or in which an organism lives).

Hard Bottoms (Rocky Shores)

Image: w3.marietta.edu

Soft Bottoms (Sandy & Muddy Shores)

Image: www.soest.hawaii.edu

Learning Outcomes – The Intertidal Hard Bottoms

After this segment, students should be able to

- Demonstrate an understanding of how **physical factors (in particular, exposure to air and space availability)** affect the Intertidal communities;
- Explain the factors determining **vertical zonation** on Rocky Shores;
- Describe some of the **typical organisms** inhabiting the characteristic zones of Rocky Shores, and their **feeding relationships**.

The Intertidal – Rocky Shores

Rocky Shores occur on coasts *without* large amounts of sediment.

- Recently uplifted or geologically young coasts
- Coasts where erosion is removing sediments and soft rock

Dominated by epifauna, where most organisms live *on* the rock surface

- Some *move around* on the rocks
- Many are *sessile* (attached to rock surface)

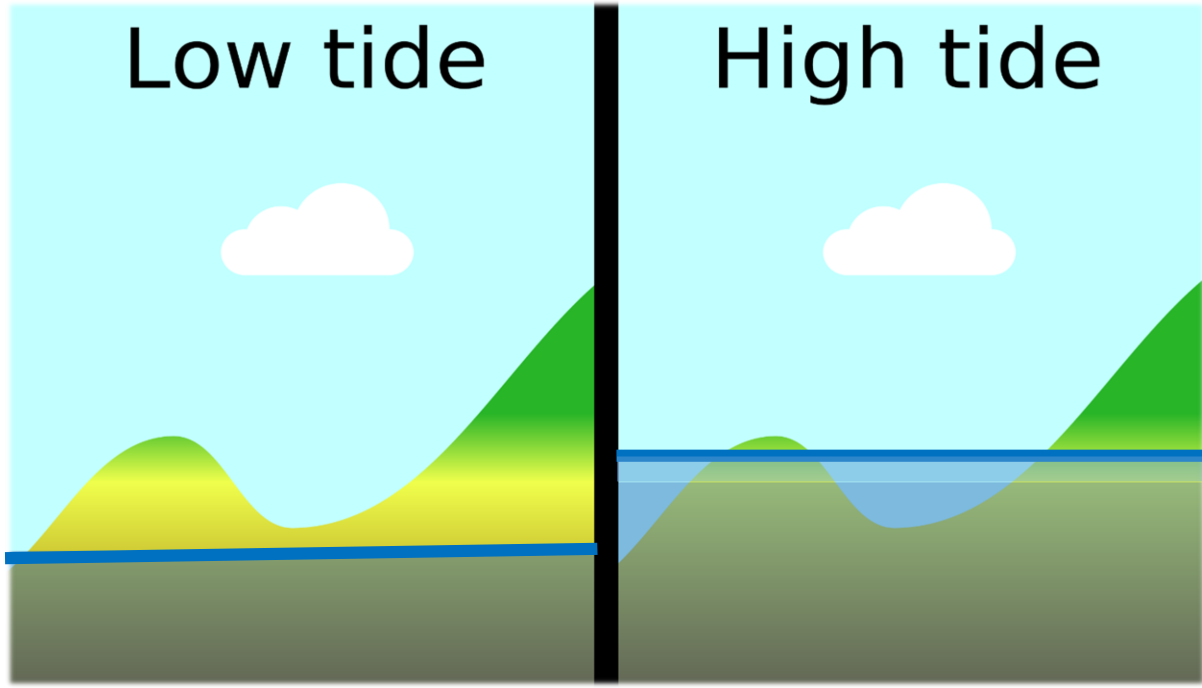
©Michael Huber

Rocky Shores – Physical and Biological Challenges

Due to regular exposure to air, intertidal organisms face different challenges.

Major Physical Challenges

- **Desiccation (water loss)** – low tide



High Tide

Low Tide

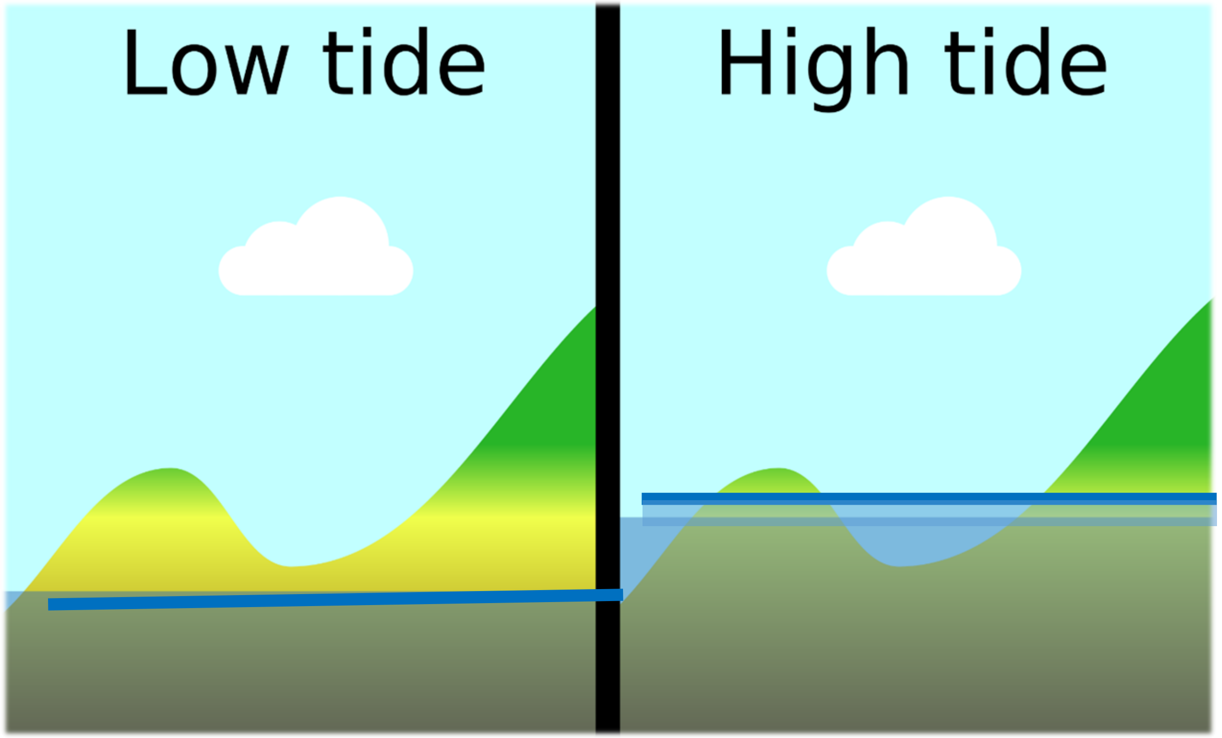
Image: https://www.amusingplanet.com

Rocky Shores – Physical and Biological Challenges

Due to regular exposure to air, intertidal organisms face different challenges.

Major Physical Challenges

- Desiccation (water loss) – low tide
- Temperature fluctuations
- Salinity changes
- Wave action and tides
- Oxygen availability and build-up of CO_2 at low tide



Rocky Shores – Physical and Biological Challenges

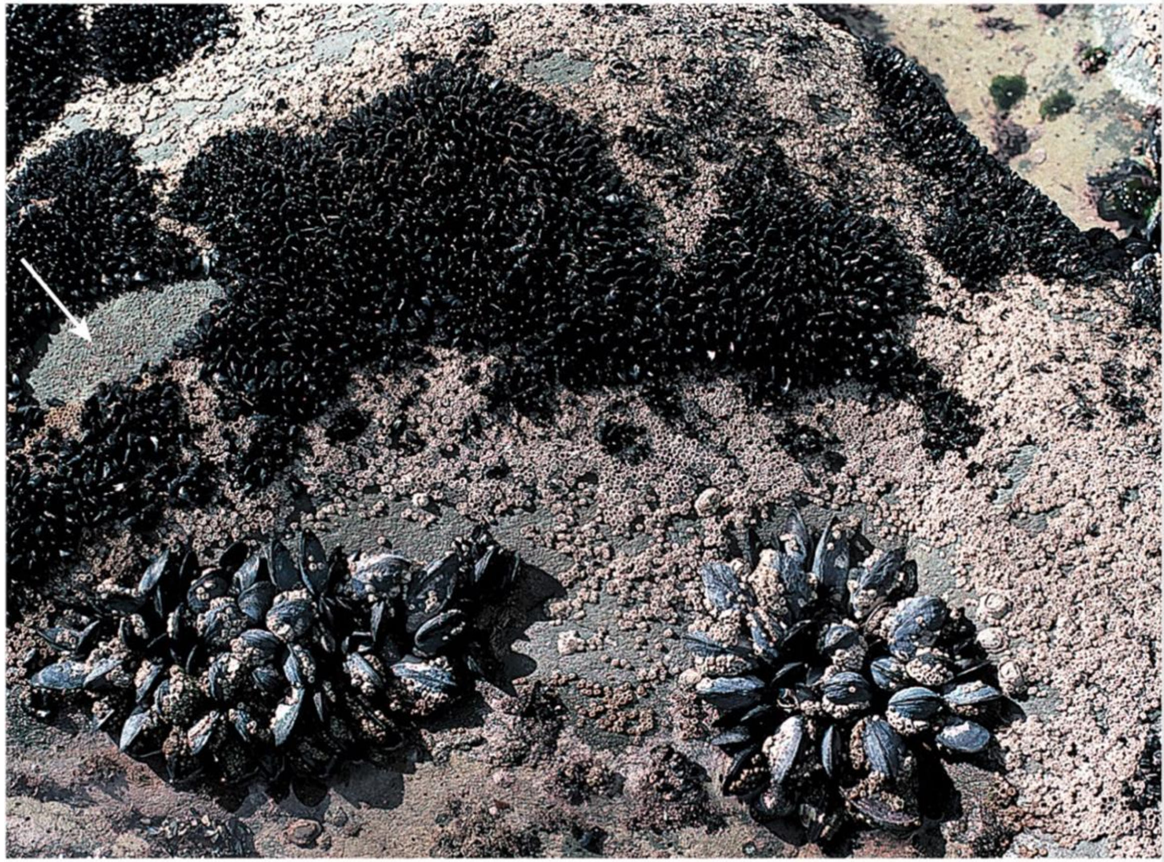
Due to regular exposure to air, intertidal organisms face different challenges.

Major Physical Challenges

- Desiccation (water loss) – low tide
- Temperature fluctuations
- Salinity changes
- Wave action and tides
- Oxygen availability and build-up of CO_2 at low tide
- Limited space

Major Biological Challenges

- Predation
- Grazing
- Competition
- Larval settlement



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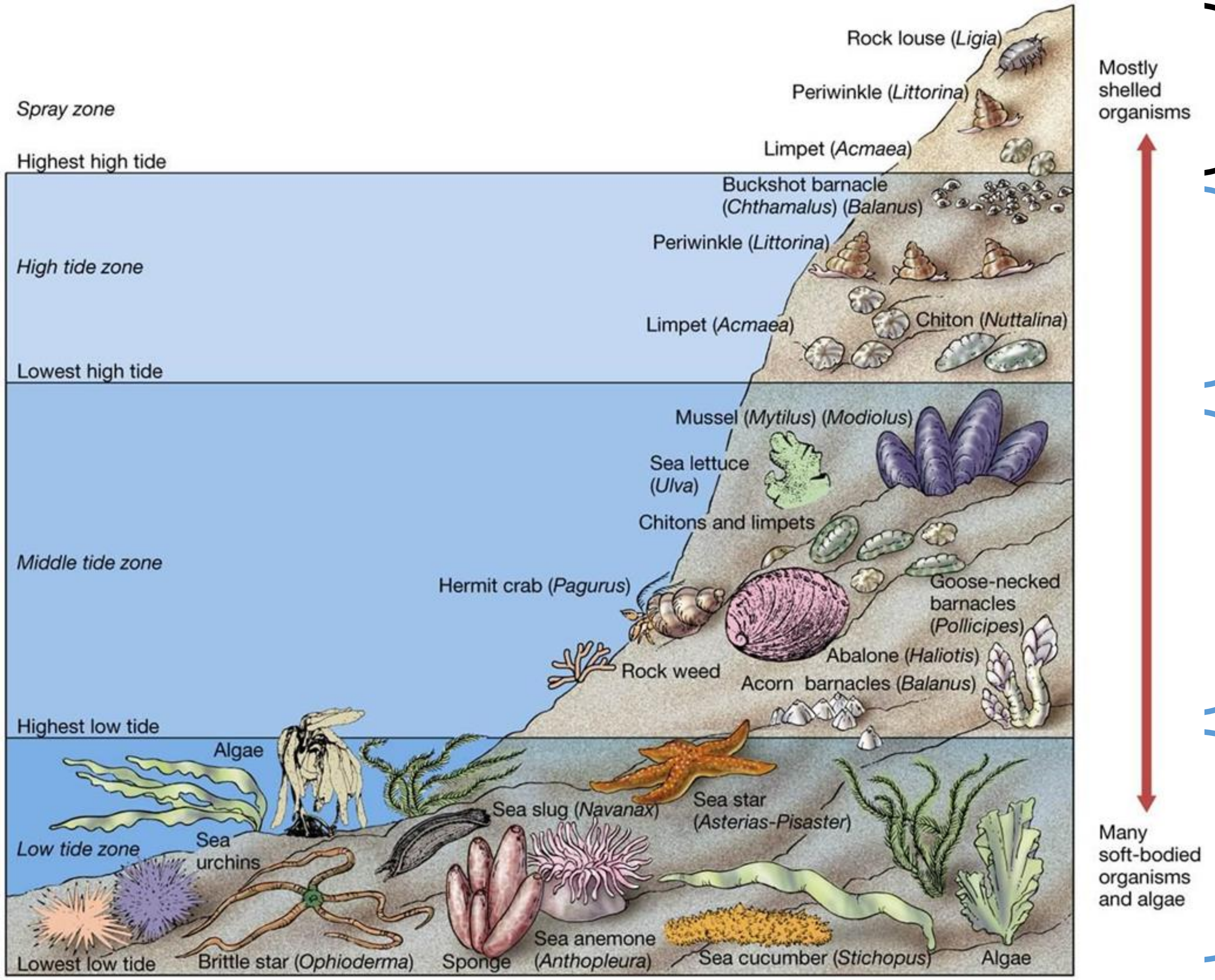
Rocky Shores – Vertical Zonation by Water Levels



Spray Zone

High Intertidal Zone

Middle Intertidal Zone

Low Intertidal Zone

Rocky Shores
– Vertical Zonation by Water Levels

- When the shore consists of an evenly sloping rock face, the zones often appear as **distinct bands** (**different colors of the organisms**).

- Zonation results from the complex interaction of **physical and biological factors**.

Spray Zone

High Tide

Mid-Tide

Low Tide

Rocky Shores
– A Gradient of Physical Conditions

Distribution of a species on a rocky shore:

- **Upper limit** – governed by **physical factors**
  (e.g. water loss, extreme temperature, space)

- **Lower limit** – governed by **biological factors**
  (e.g. predation, competition, grazing)

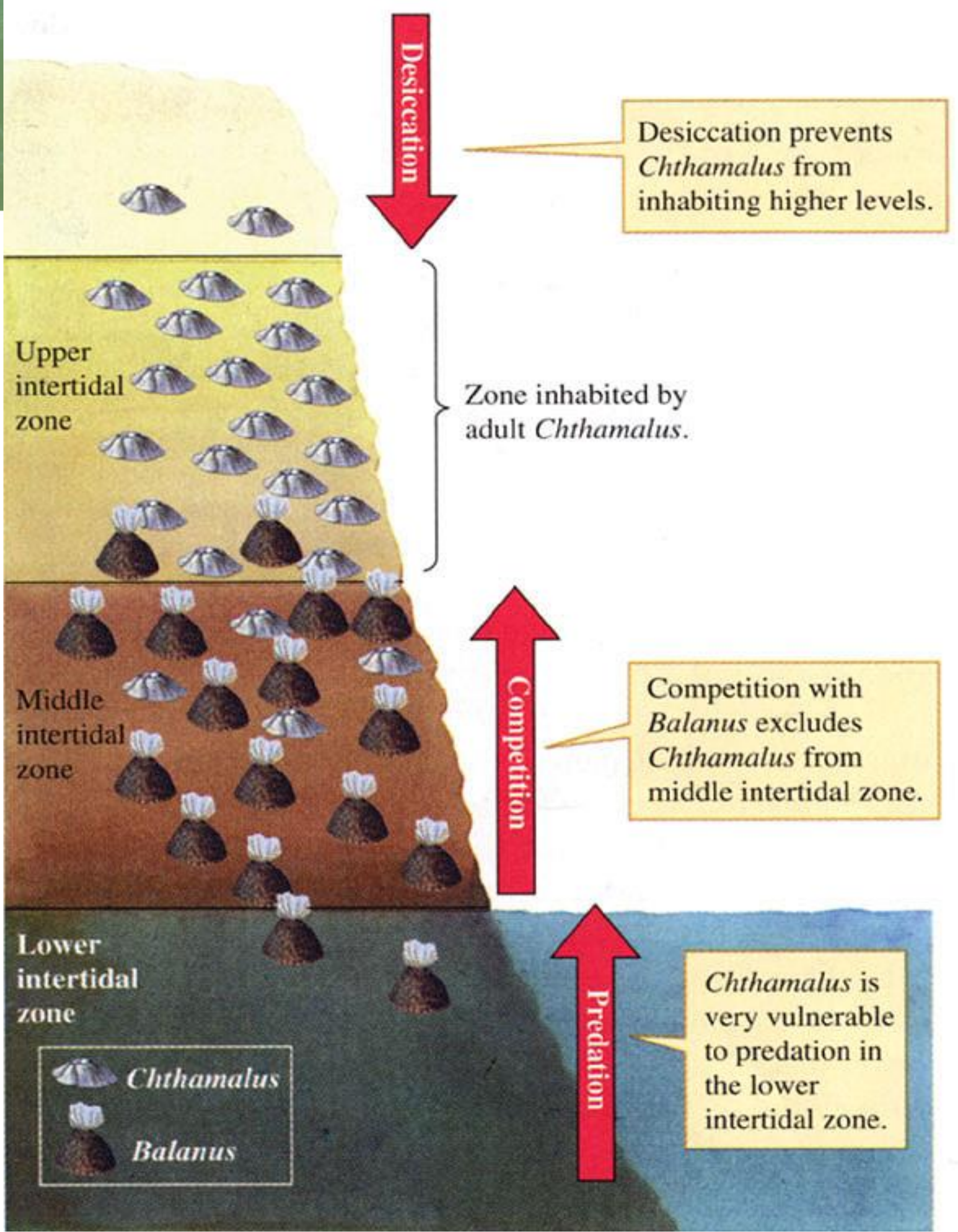
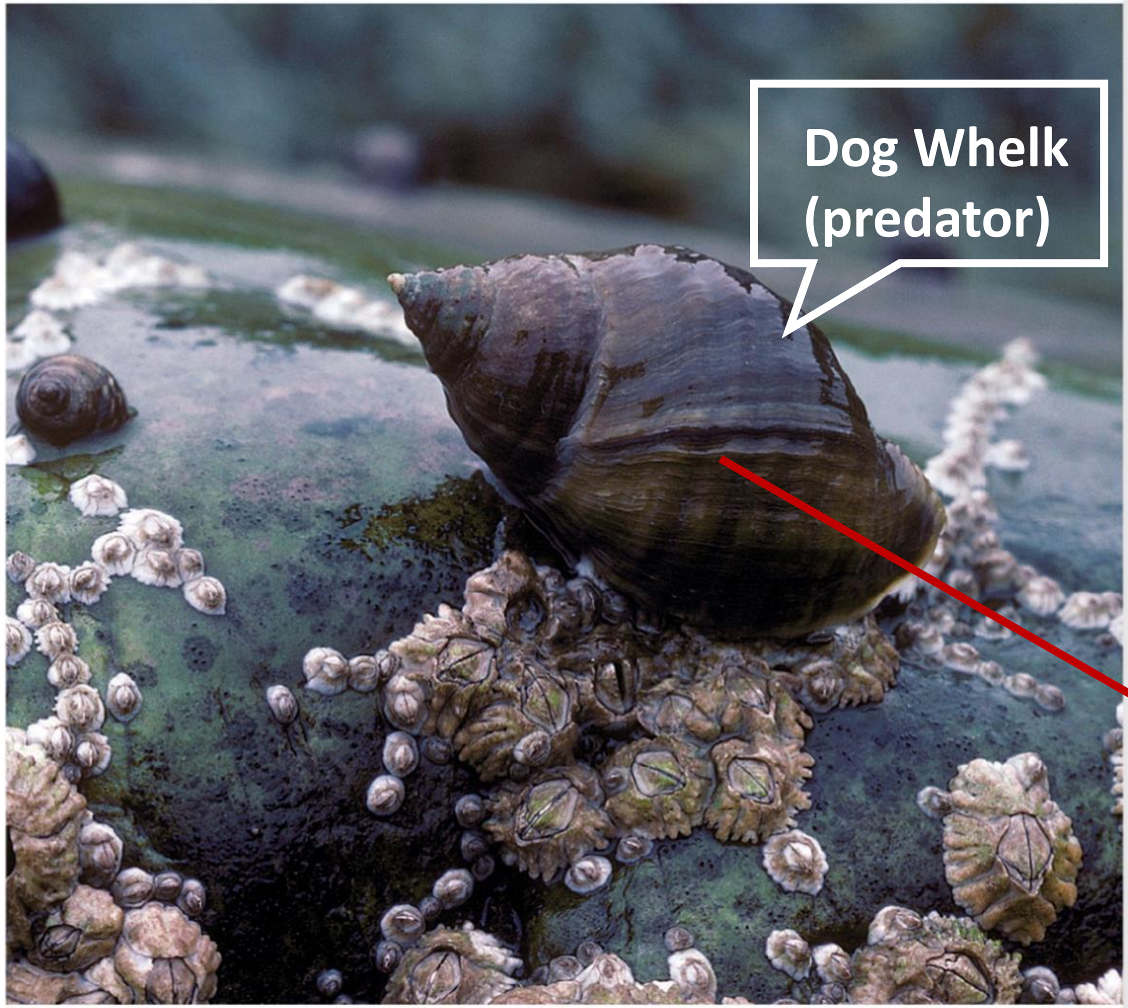
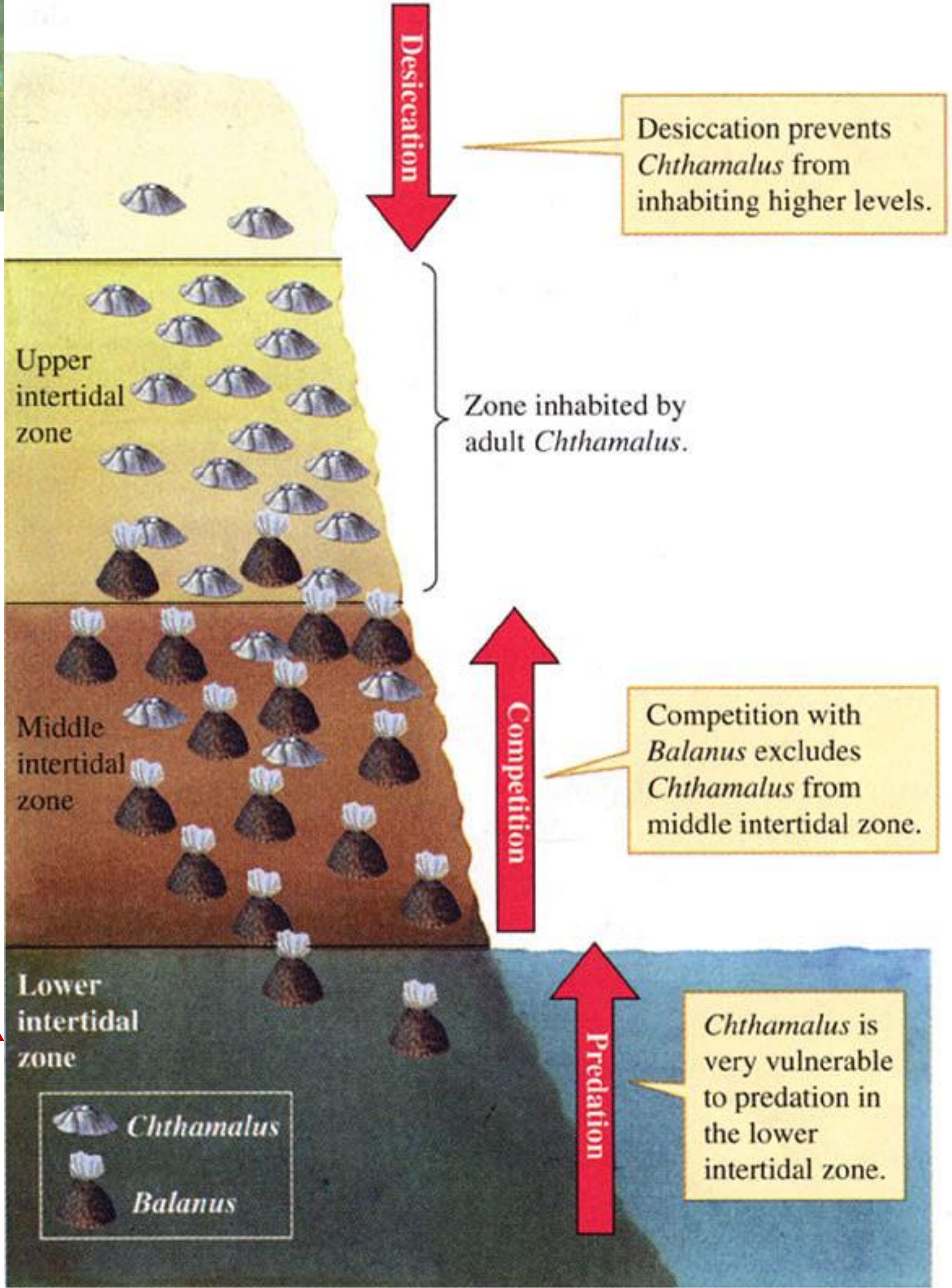


Image: McGraw-Hill Education

Rocky Shores
– A Gradient of Physical Conditions



©Stephen P. Parker/Science Source



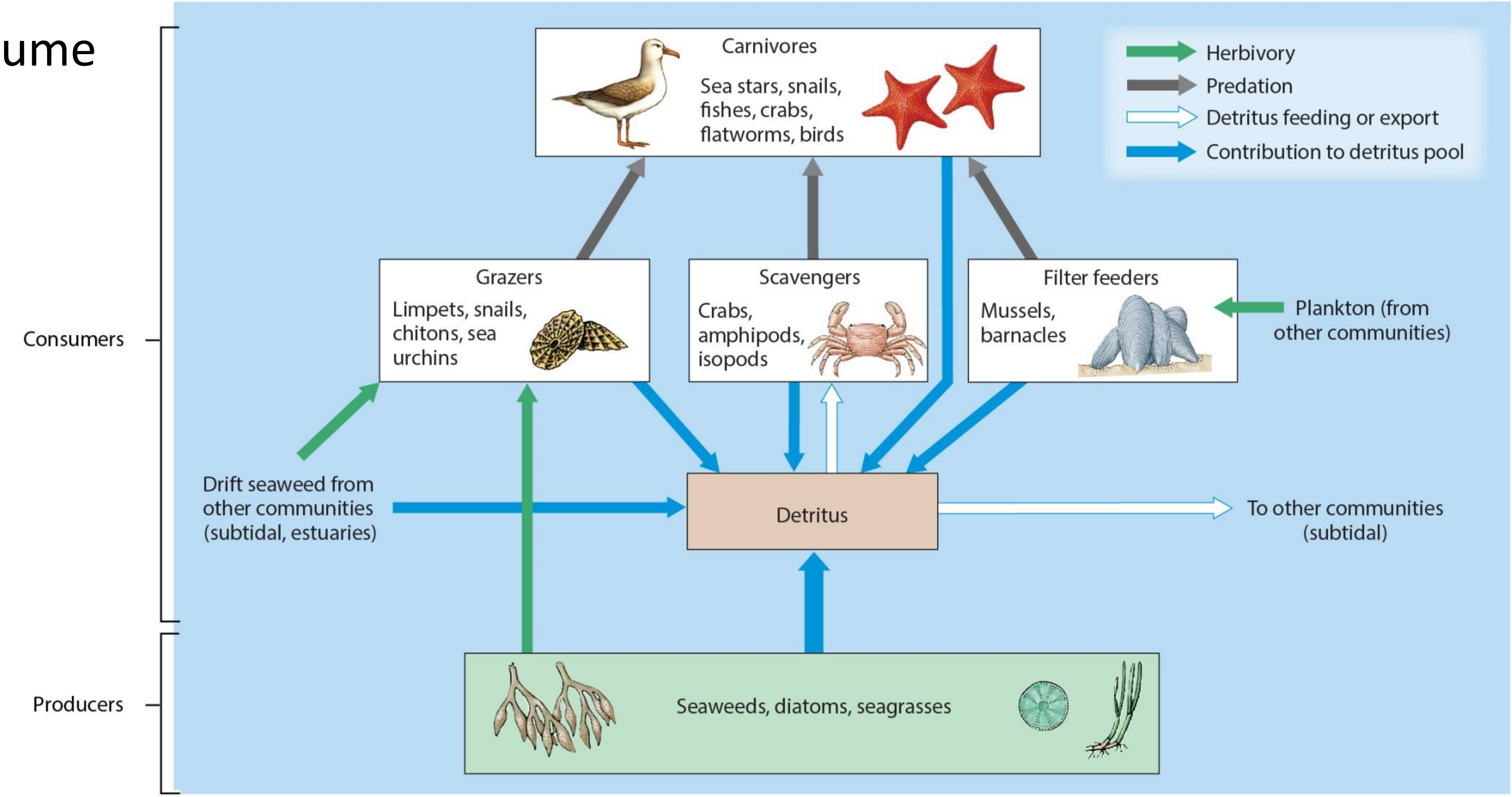
Question

*What is the **key limiting factor** on Rocky Shores?*

Answer: **Space**.

Rocky Shore Food Web

- **Grazers** directly consume *primary producers*
- **Scavengers** feed on *detritus*
- **Filter feeders** ingest *plankton*



Source: Bill Ober

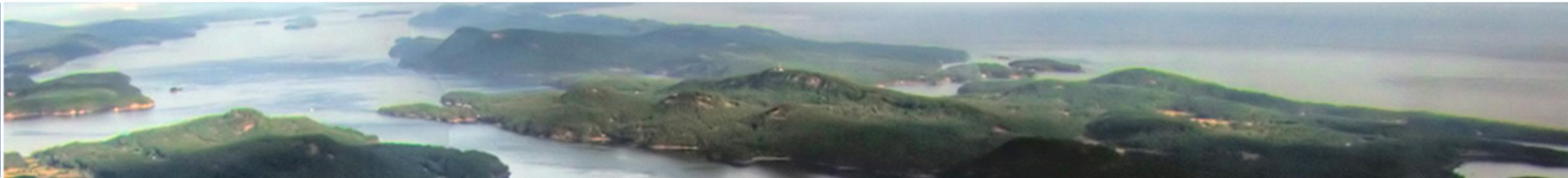
Summary – Rocky Shores

- **What is the Intertidal zone?**
  - The zones affected by low tides (exposed) and high tides (submerged)

- **What are the main challenges faced by Rocky Shore organisms?**
  - Limited space, exposure to air, extremely variable physical and chemical conditions

- **What are some of the physical and biological factors that govern the vertical zonation?**
  - Upper limit: Physical factors (e.g. desiccation, temperature and salinity changes, wave)
  - Lower limit: Biological factors (e.g. predation, grazing, competition, larval settlement)

Characteristics	Provides hard substrates for organisms to attach
Animal Groups	Dominated by epifauna (organisms living on the surface of the substrate)



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The Intertidal – Soft Bottoms (Sandy & Muddy Shores)

Intertidal Communities

The nature of the intertidal communities depends on the **type of the bottom** (**substrate** – the material on or in which an organism lives).

Hard Bottoms (Rocky Shores)

Image: w3.marietta.edu

Soft Bottoms (Sandy and Muddy Shores)

Image: www.soest.hawaii.edu

Learning Outcomes – The Intertidal Soft Bottoms

After this segment, students should be able to

- Describe the characteristics of the sediment types of Soft-bottom Intertidal habitats **(Sandy and Muddy Shores)**;

- Demonstrate an understanding of the **challenges** faced by the Soft-bottom Intertidal communities;

- Describe some of the **typical organisms** inhabiting different types of Soft-bottom Intertidal habitats, and their **feeding relationships**.

Soft Bottom – Any Bottom that is Composed of Sediment

Sandy and Muddy Shores occur on coasts where sediments *accumulate*.

- Whether and what kind of sediment (sand, mud) accumulates in an area depends on **how much water motion** there is and on the **source of the sediment**
- The type of sediment strongly influences the community

Sandy Shore

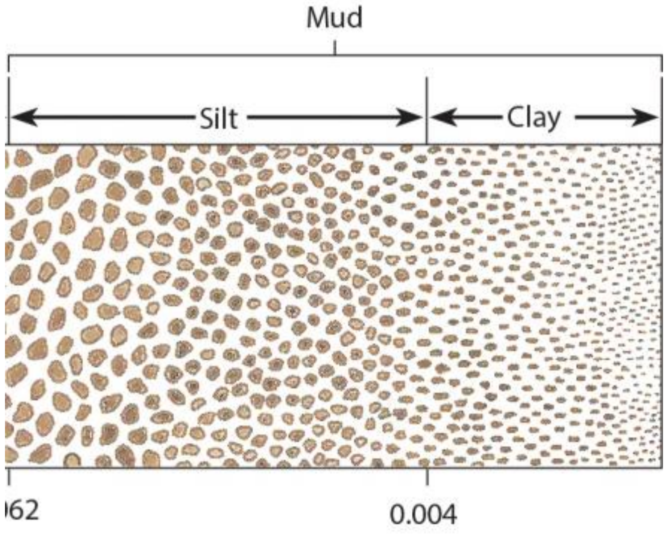
© Andrea Pickart

Muddy Shore

Soft-Bottom Sediment Types

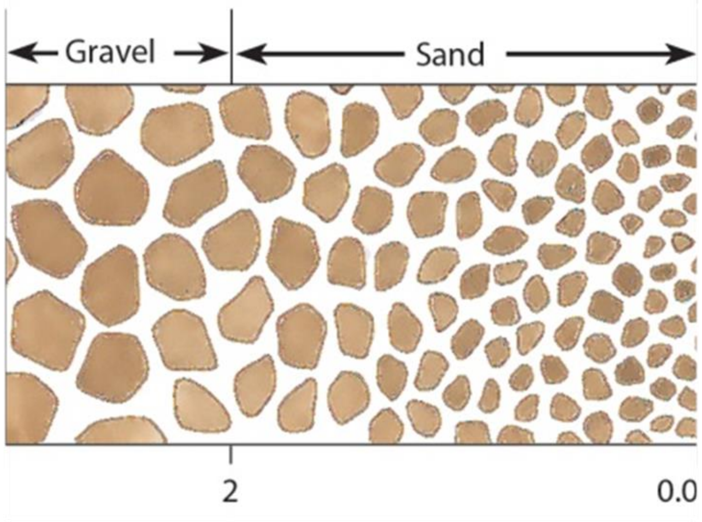
Fine sediments

- Calm areas
  (e.g. bays)



Coarse sediments

- Areas affected by **waves and currents** *(e.g. exposed beaches)*



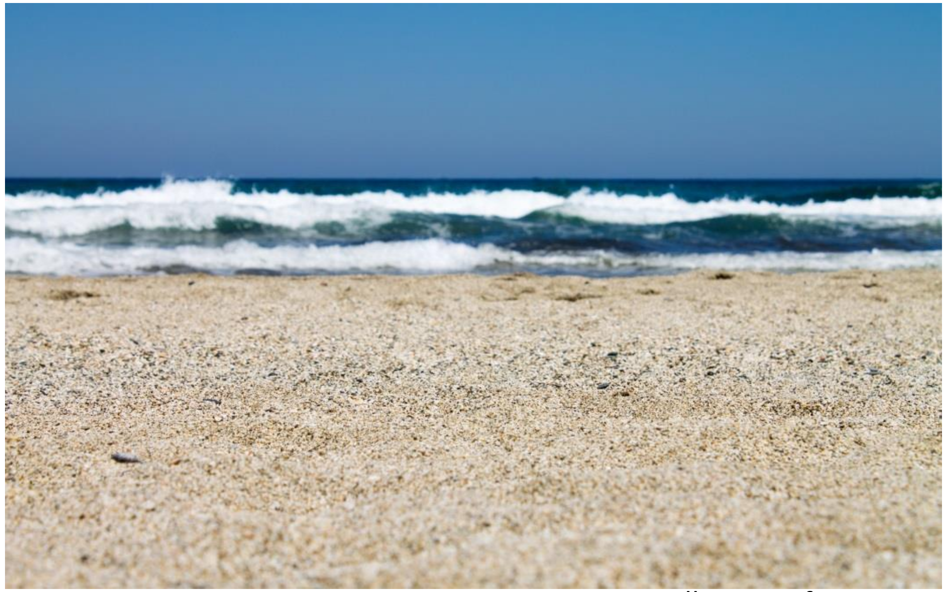
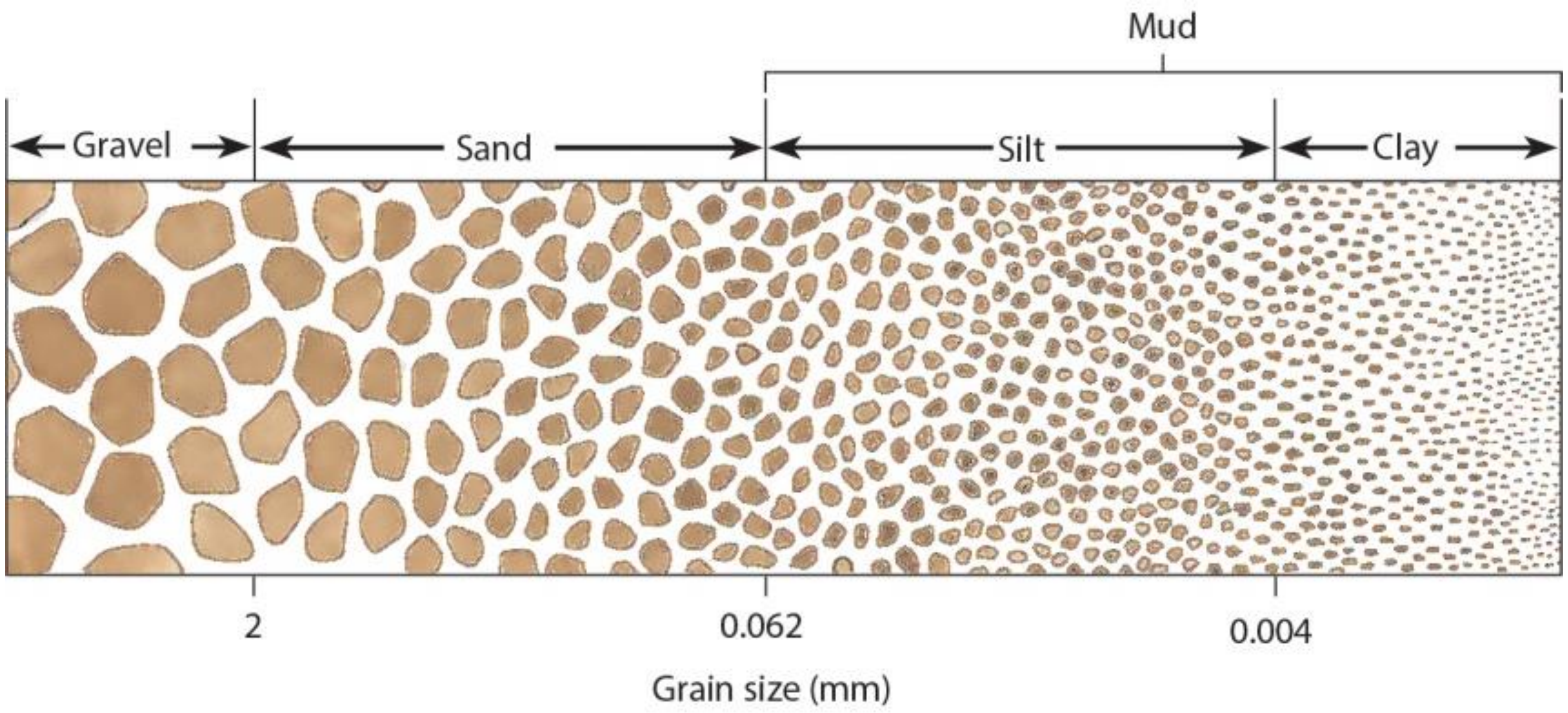


Image: wallpapersafari.com

Sediment Types – Classified by Particle Size

The smaller the sediment size, the less oxygen in the water filling spaces.

More oxygen → Less oxygen



Sediments

- **Sand**: Relatively coarse
- **Clay**: Very fine
- **Mud**: Clay + Silt

Source: Bill Ober

Soft-Bottom Intertidal Sediments

The sediment size can be small so that *all except the top few centimeters* is **anoxic:**

- **Without oxygen**
- Contains **hydrogen sulfide (H_2S)**, which is produced by **anaerobic bacteria**
- **H_2S: Toxic to most animals**; anoxic zone has relatively little animal life

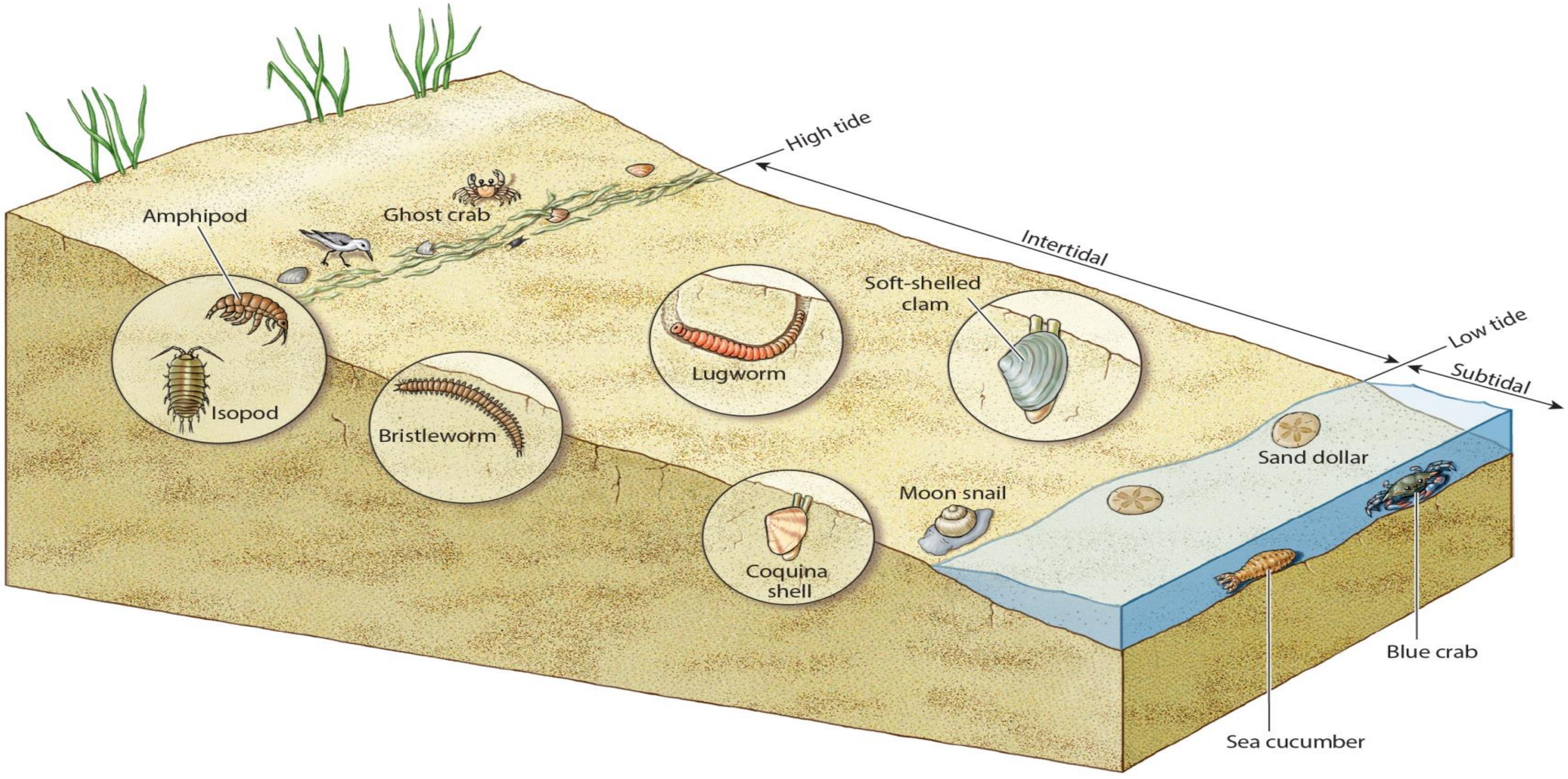
Anoxic Zone
(the black layer)

©Michael Huber

Soft-Bottom Intertidal Zonation

Generalized zonation pattern on **sandy beaches** of the Atlantic coast of North America.

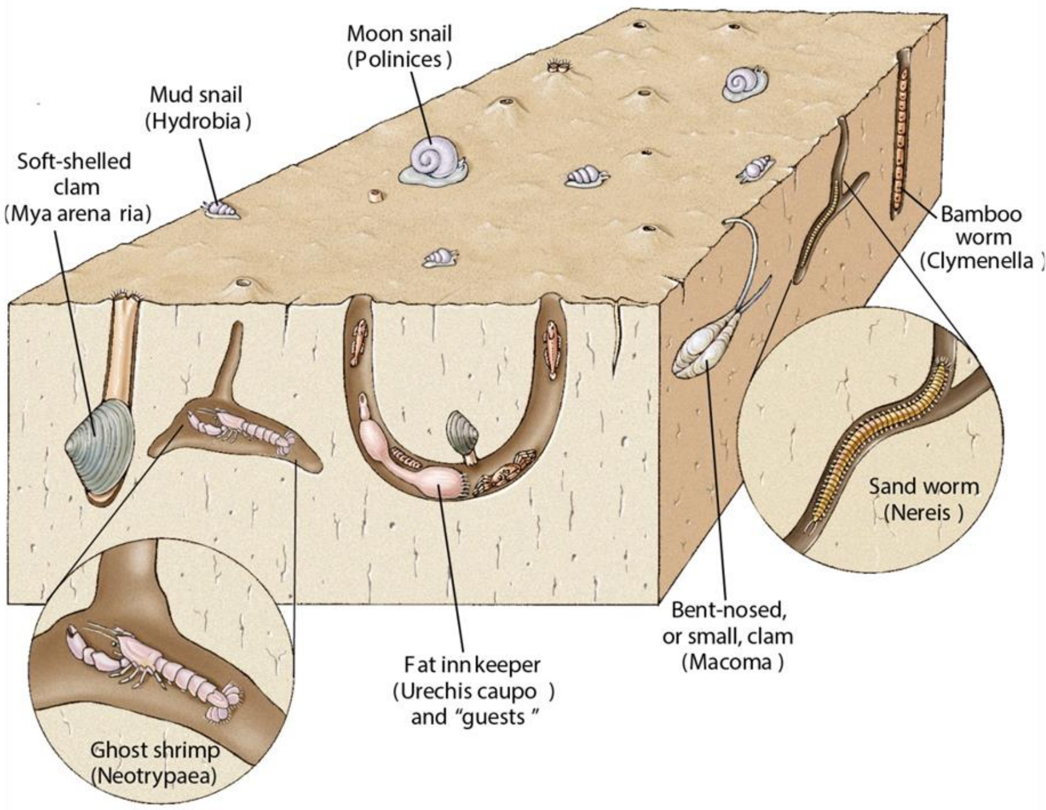
Sheltered and exposed beaches have different communities.



Source: Bill Ober

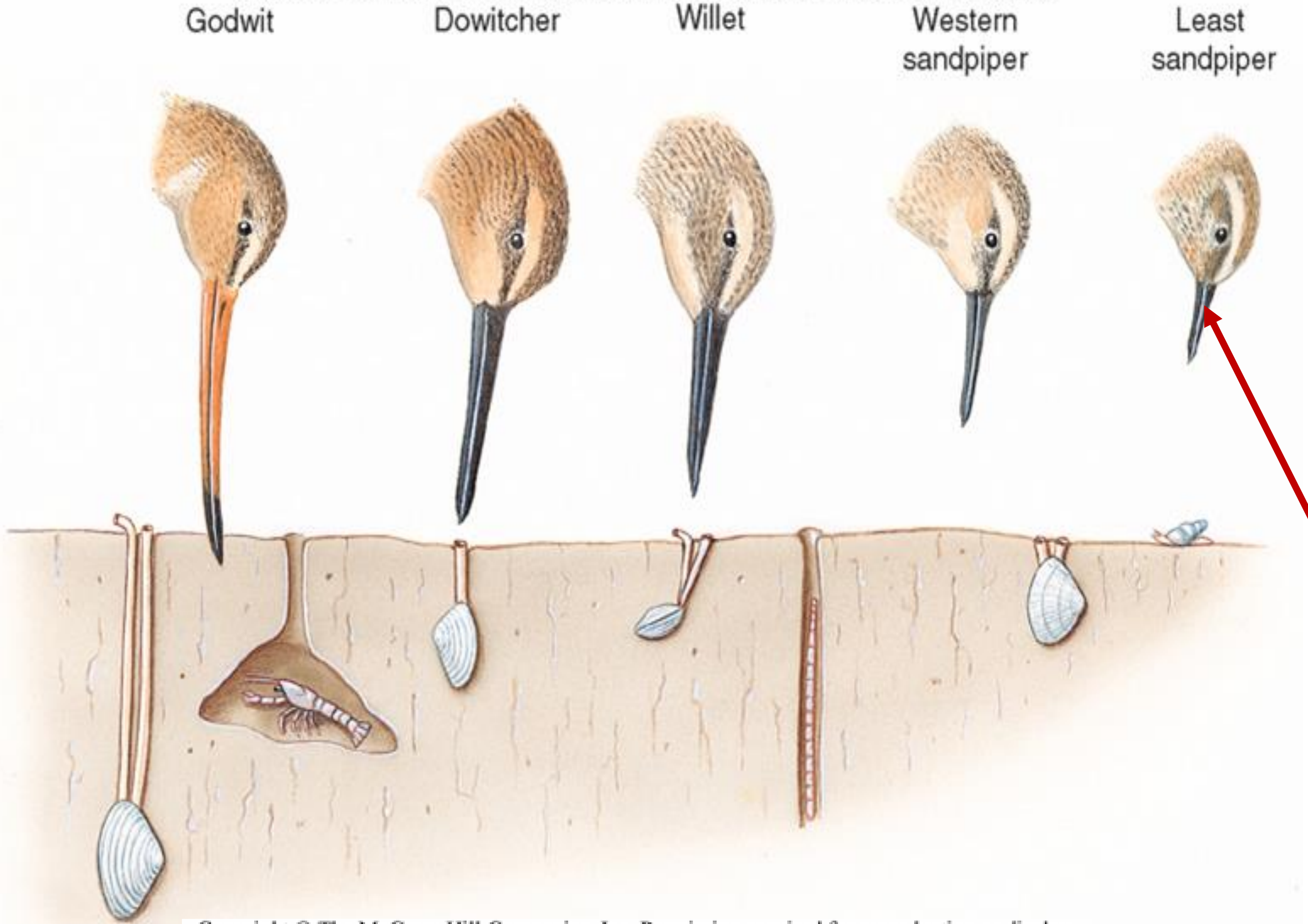
Soft-Bottom Communities

- **Soft bottoms are unstable** and shift in response to waves, tides, and currents
- **Soft-bottom organisms lack a solid place to attach**
  - Plants
    - Very few seaweeds have adapted to this environment
    - Seagrasses are the most common large primary producers
  - Animals
    - Infauna and deposit feeders dominate
    - Epifauna are less common
    - Fishes and birds are key predators



Source: Bill Ober

Mudflat Communities – Predators



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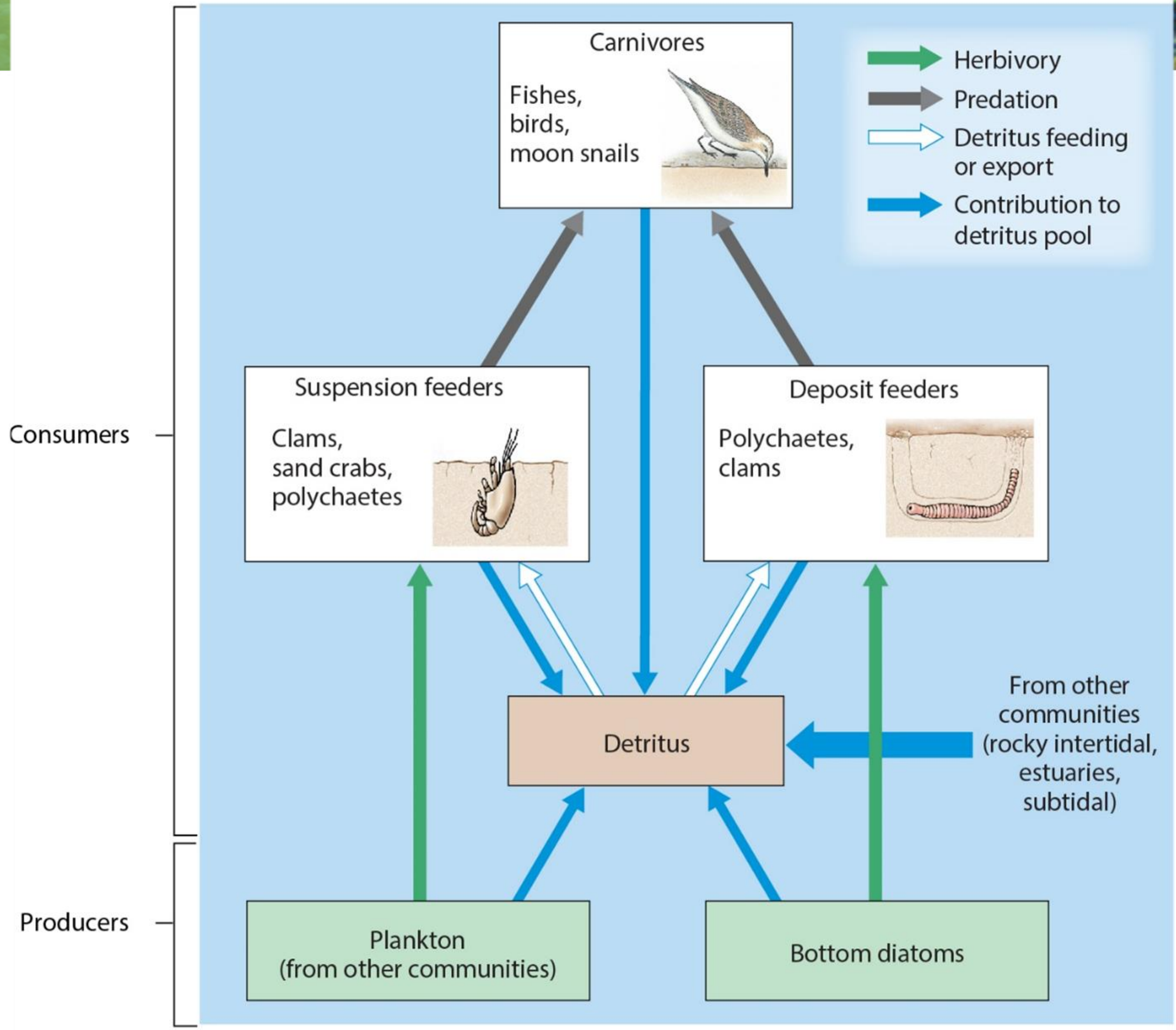
- Different types of prey live at *different depths* in the mud.
- ***Difference* in the bill length** of wading shorebirds allow them to feed on ***particular* mudflat animals**.

(bill = the mouthpart of a bird)

Soft-Bottom Food Web

Like the Rocky Shore communities, the Soft-bottom food web is also centered on **detritus**, with **infauna the dominant consumers**.

Suspension feeders are more common in sandy shores, while **deposit feeders** are more abundant in muddy shores.



Source: Bill Ober

Summary – Rocky Intertidal vs Soft-Bottom Intertidal

Desiccation, drastic changes in temperature and salinity create physical challenges and biological challenges for the organisms.

	Hard-Bottom Intertidal (Rocky Shores)	Soft-Bottom Intertidal (Sandy & Muddy Shores)
Characteristics	• Provide hard substrates for organisms to attach • Limited space for organisms	• Unstable sediments, lack solid place to attach • Subsurface sediment is anoxic • The smaller the particles, the less oxygen the sediment contains
Animal Groups	• Dominated by epifauna	• Dominated by infauna
Plants	• Seaweeds	• Seagrasses and benthic diatoms

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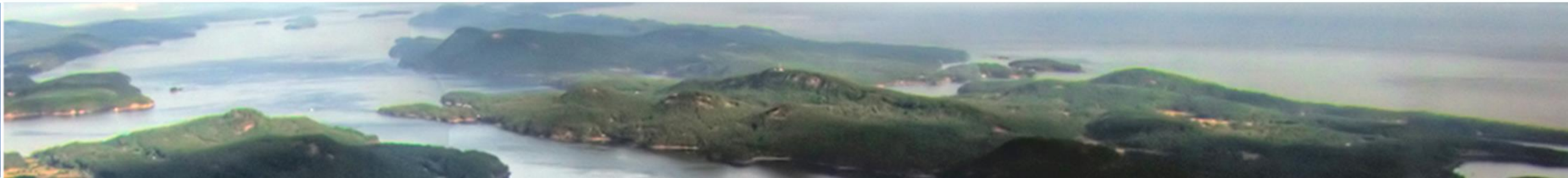

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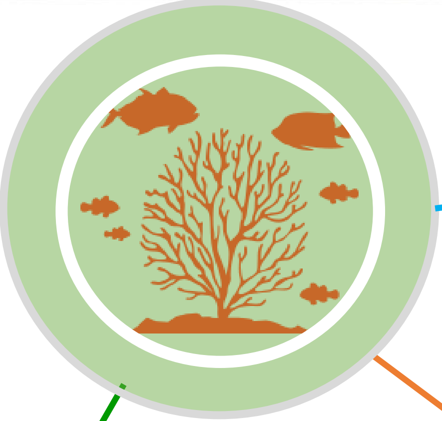
Estuaries

Marine Ecosystems – The Subtidal, Estuaries, and the Intertidal



Subtidal Zone
Always submerged
- ❑ Unvegetated Areas
- ❑ Kelp Forests
- ❑ Seagrass Beds
- ❑ Coral Reefs

Coastal Eutrophication
- ❑ Harmful Algal Blooms & Effects
- ❑ *Noctiluca* Blooms

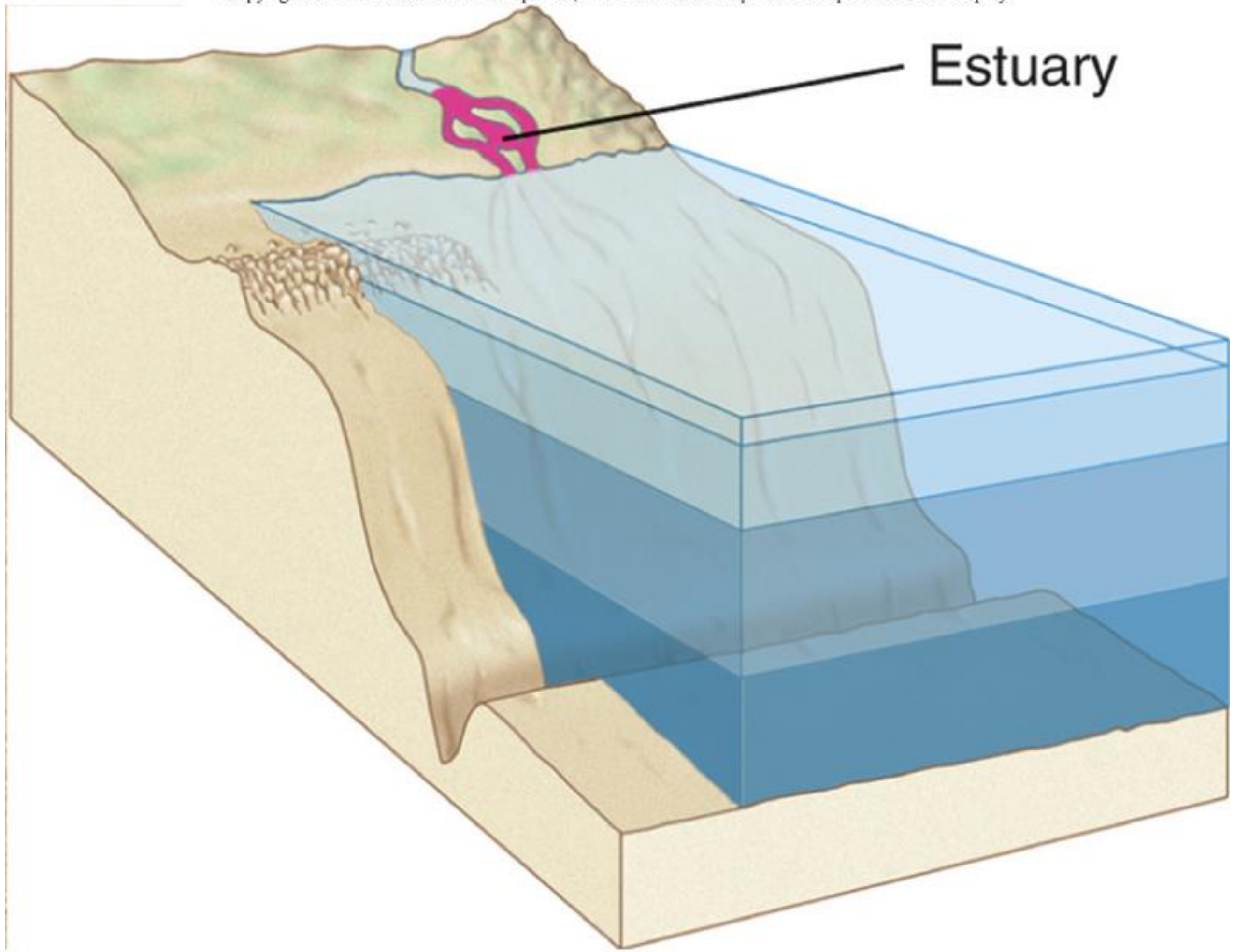
Intertidal Zone
***Not always* submerged**
- ❑ Rocky Shores
- ❑ Sandy and Muddy Shores

Estuaries
Where rivers *meet* the sea
- ❑ Salt Marshes
- ❑ Mangroves

Estuaries – Where Rivers Meet the Sea

Estuaries are partially enclosed coastal regions where *fresh water from rivers* meets and mixes with *seawater*.

- Scattered along the shores of all the oceans and vary widely in origin, type, and size
- A **close interaction between land and sea**
- Among the ecosystems with **most human impacts**



Learning Outcomes – Estuaries

Though they are intertidal, coastal communities along Estuaries are important enough to use a few segments to discuss. After these segments, students should be able to

- Compare and contrast between the **major types** of Estuarine communities;
- Demonstrate an understanding of the **physical and chemical characteristics** of Estuaries;
- Compare and contrast between **primary production** and **biodiversity** in different types of Estuarine habitats;
- Describe the **biodiversity** and their **feeding relationships** of the Estuarine habitats.

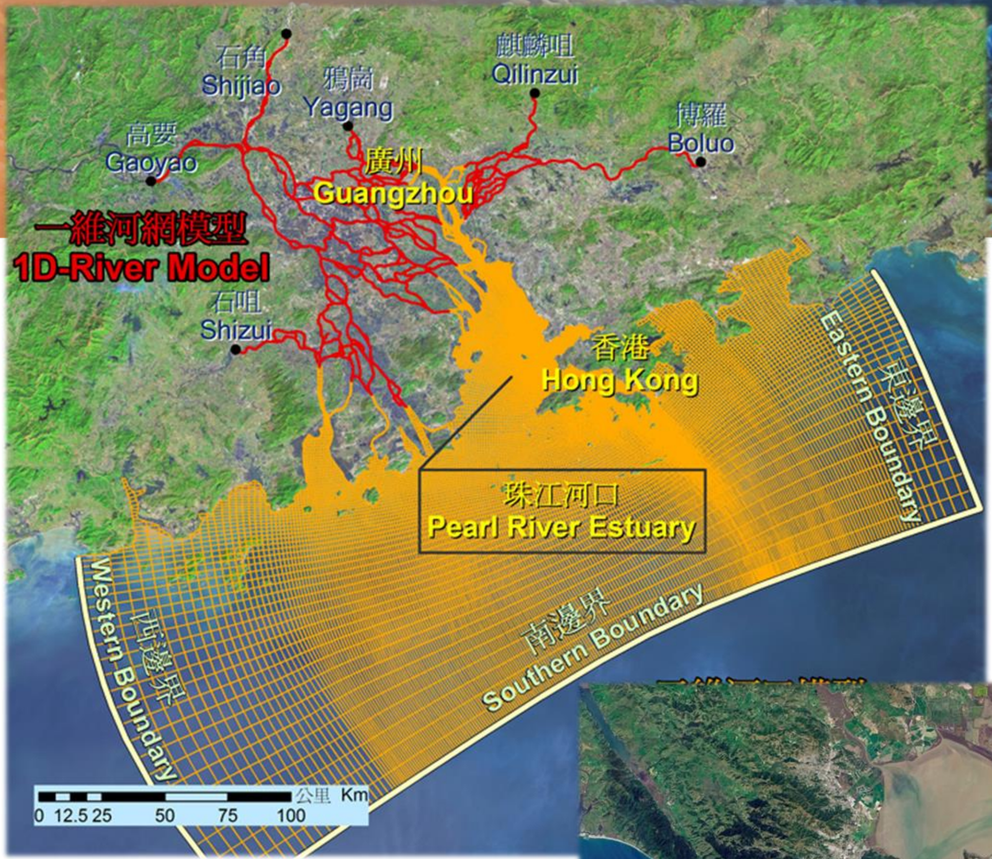
Estuaries
– Important to Humans

- **Ecological services**
  - Filtering out sediments and pollutants from rivers and streams

- **Food sources** *(e.g. fish, shellfish)*

- **Economic and commercial centers**

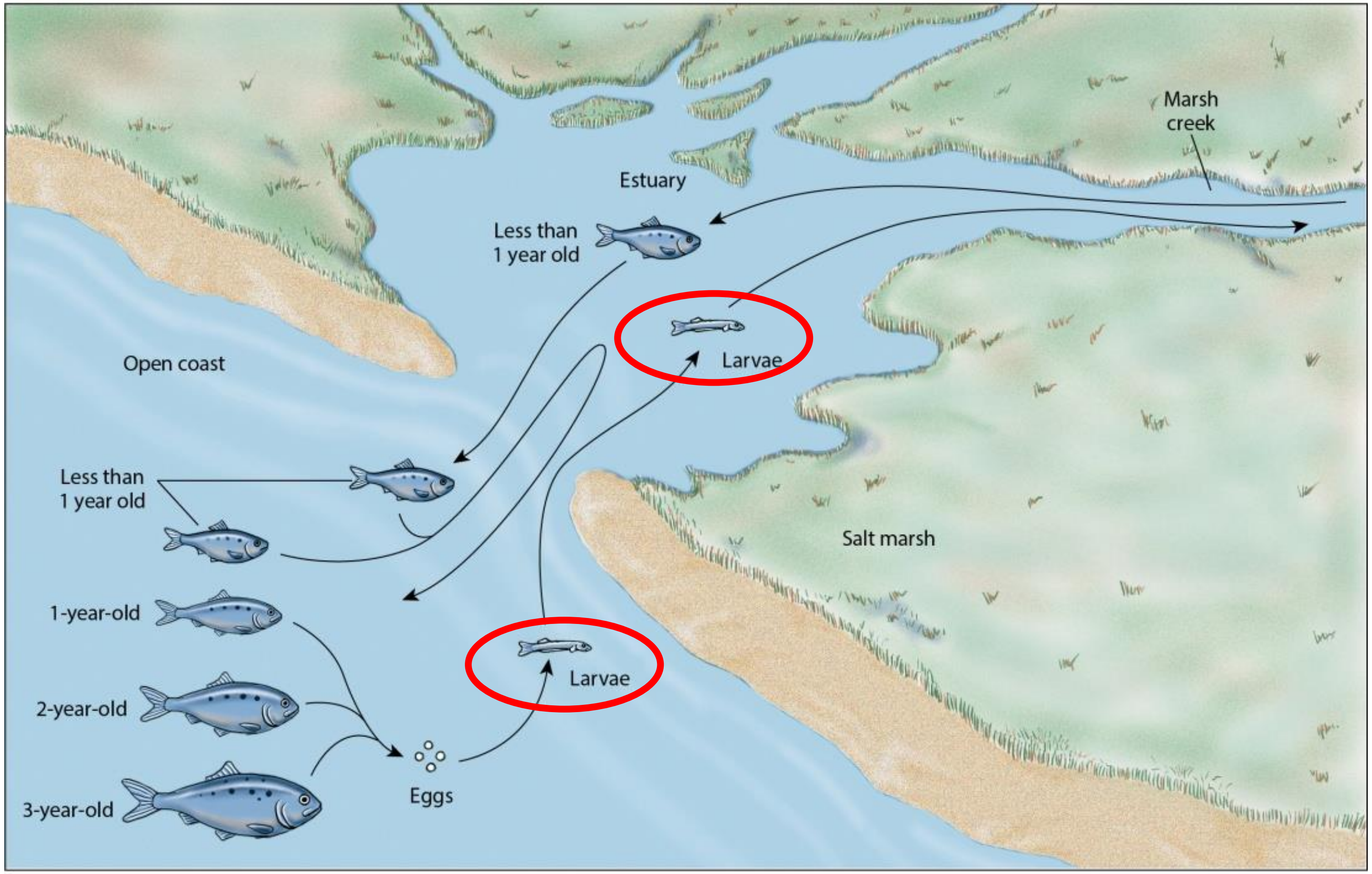
  Examples:
  - *Pearl River Delta*
  - *San Francisco Bay*
  - *New York Harbour*
  - *Sidney Harbour*
  - *Amazon River*



Pearl River Estuary
(Image: Hong Kong Environmental Protection Agency)

San Francisco Bay
(Image: NASA)

Estuaries – Important to Many Marine Species



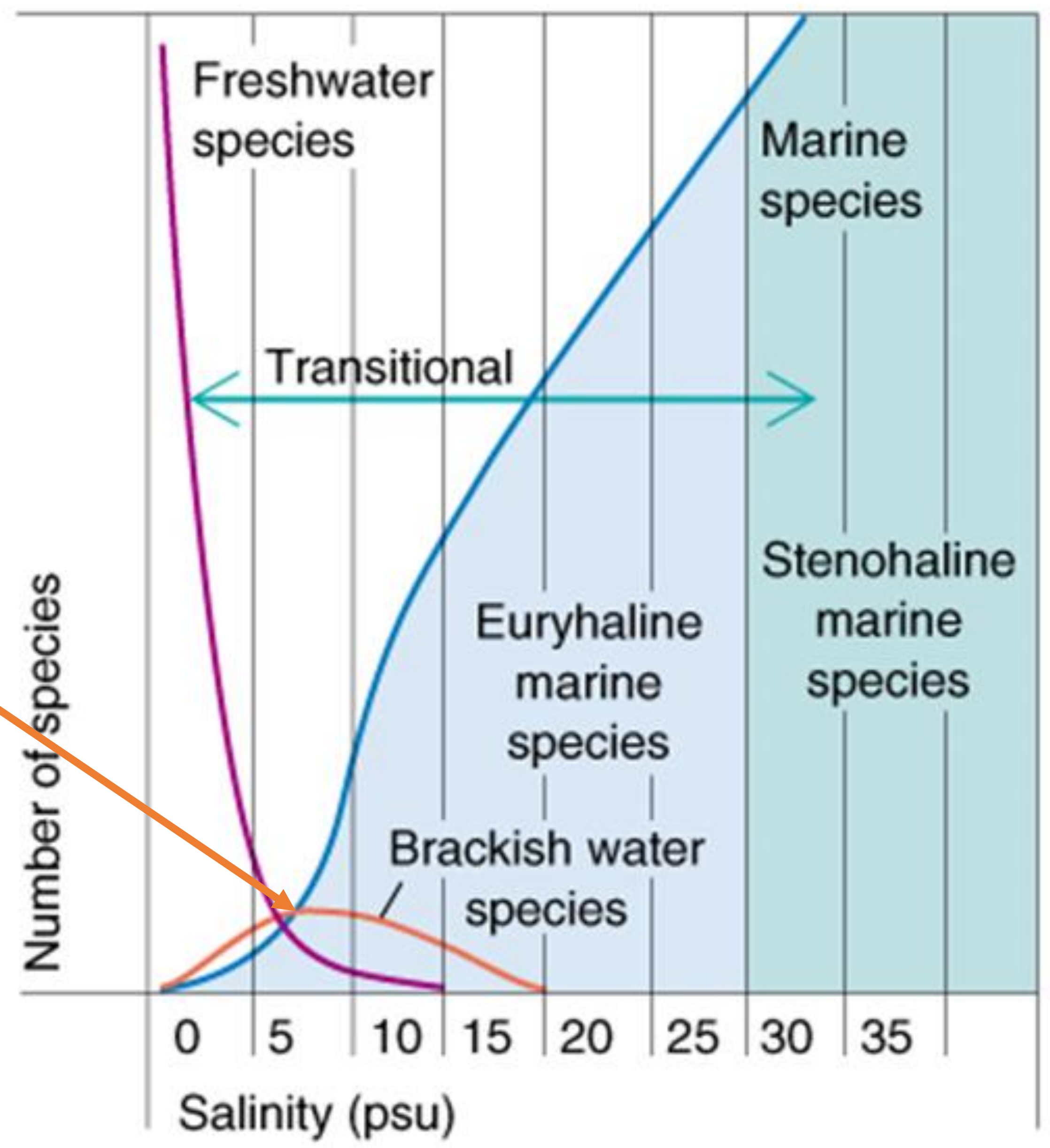
Source: Bill Ober

Estuaries are important **feeding and nursery habitats.**

Many marine species spend at least a portion of their lives in an estuary, mostly as **larvae**.

Estuarine Communities – *Low* in Diversity

The **number of species** inhabiting estuaries is **significantly lower** than those inhabiting nearby marine or freshwater habitats.



Question

Why are there so few Estuarine species?

Answer:

- The **fluctuating environmental conditions, mainly salinity,** are so extreme that few species have evolved the necessary **physiological specializations** to survive over there.
- Estuaries **have not had a long enough geological history** to permit a complete estuarine fauna to develop.

The Estuarine Ecosystems – Three Types

Mudflats

©James Lynch, USGS

Salt Marshes

Mangroves

The Estuarine Ecosystems – Mudflats

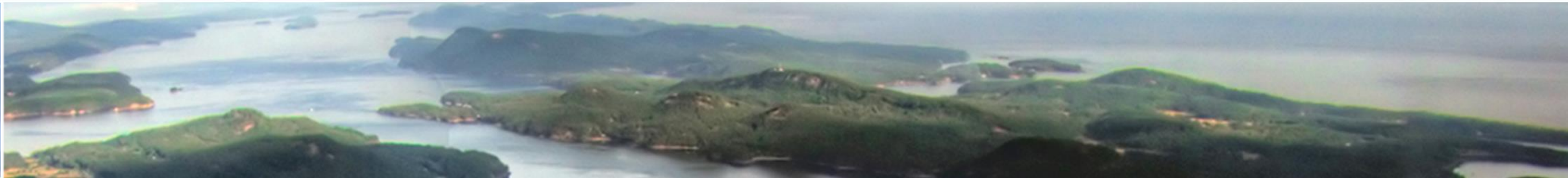
Mudflat communities in estuaries are **similar to those on muddy shores** (one of the soft-bottom intertidal habitats).

On mudflats, **low tides** expose the organisms to **desiccation**, **wide variations in temperature**, and **predation**, similar to that occur in any other intertidal community.

In estuaries, however, mudflat organisms must also withstand regular, often drastic, **variations in salinity** that define estuaries.

Summary – Estuaries

- **What are Estuaries and why are they important?**
  - Estuaries are coastal areas where rivers meet the sea
  - They are important feeding and nursery habitats for many organisms; provide different types of food for humans; and are important hubs of economic activities
- **Why are there so few Estuarine species?**
  - The environmental conditions (especially salinity) fluctuate significantly, relatively few species can adapt to those changes
- **What are the major types of Estuarine habitats?**
  - Mudflats (similar to muddy shores), salt marshes and mangroves



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The Estuarine Ecosystems – Salt Marshes & Mangroves

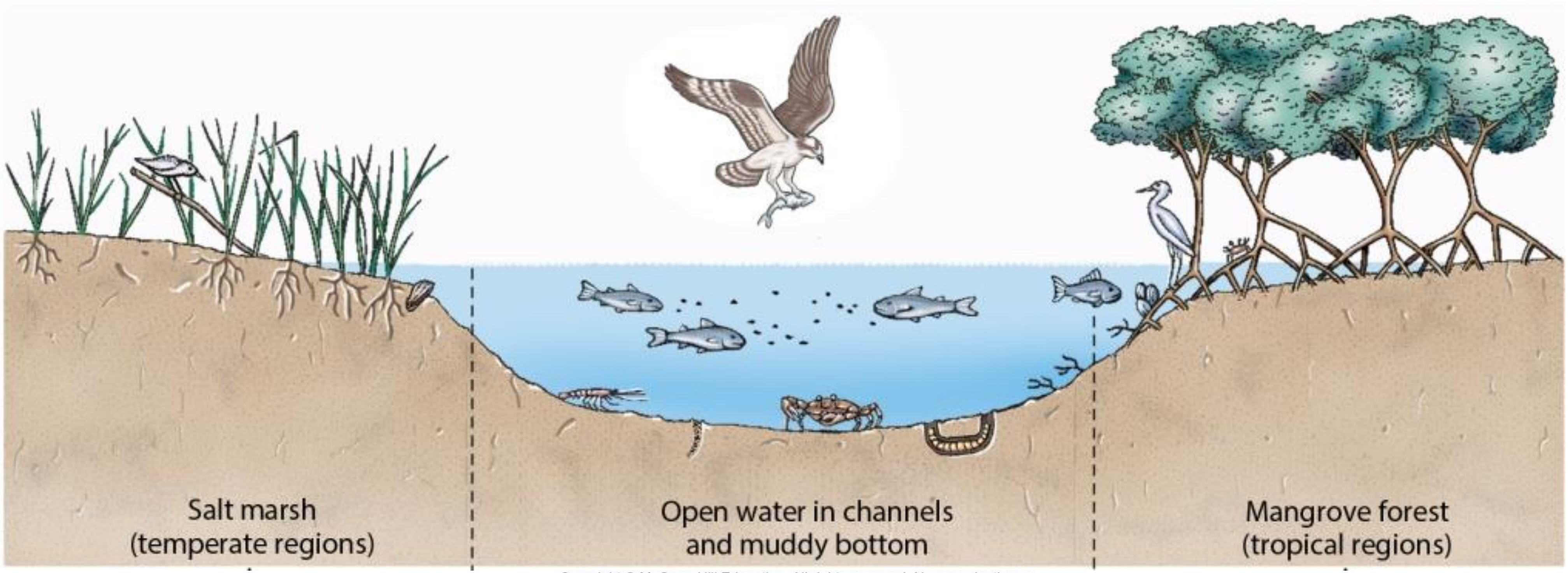
Salt Marshes vs. Mangroves

Salt Marshes

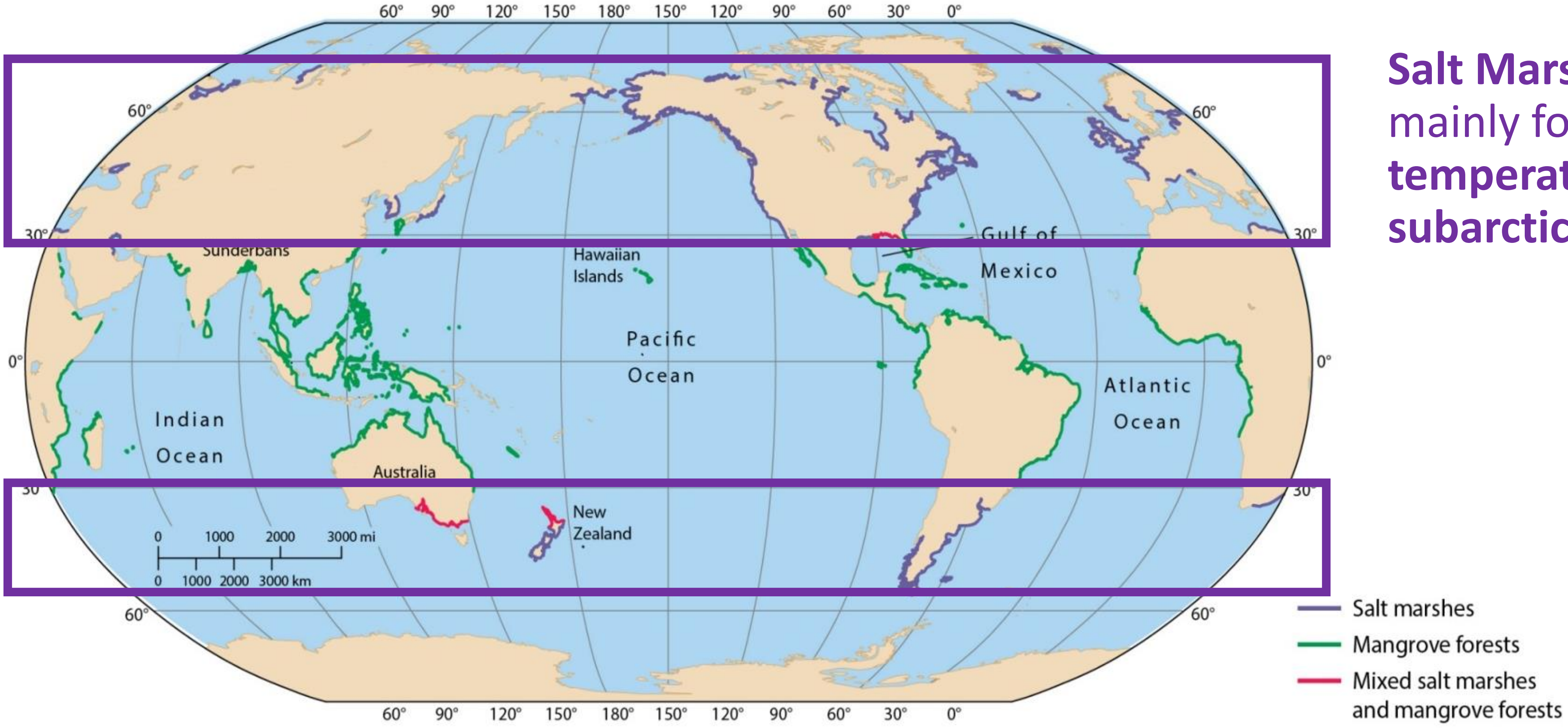
Grassy vegetation that lives along the shores of estuaries and sheltered coasts in **temperate and subarctic regions.**

Mangroves

Trees and shrubs that live along the intertidal shores in **tropical and subtropical regions.**



Salt Marshes – Distribution (Colder Regions)



Salt Marshes – mainly found in **temperate and subarctic regions.**

Source: Bill Ober

Salt Marshes / Tidal Marshes

- Estuaries in **temperate** and **subarctic** regions worldwide are usually bordered by **extensive grassy areas** that extend inland from the mudflats

- These intertidal areas are **partially flooded at high tide** and are known as **Salt Marshes (or Tidal Marshes)**

- Sometimes they are grouped with freshwater marshes and collectively called **Wetlands**

Cordgrass (*Spartina* species)

©James Lynch, USGS

Salt-Marsh Communities

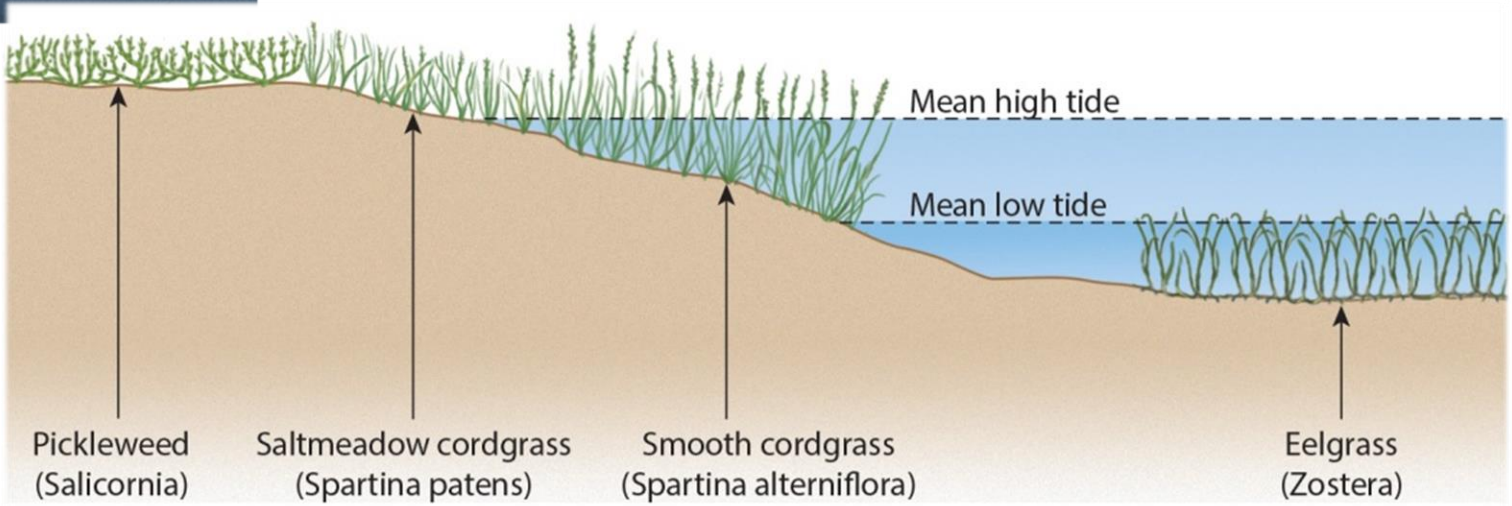
- Subject to the **same extremes in *salinity*, *temperature*, and *tides* that affect mudflats**
- The mud is held together by the roots of marsh plants – **substrate is more stable**
- **Plants** – dominated by **a few hardy grasses** and **other salt-tolerant land plants**
  - Provide **shelter** and **food** to many marine and land animals
- **Animals** – some burrowing animals of mudflats, nematodes, crabs, larvae of land insects, fishes, birds, mammals *(e.g. ospreys, raccoons)*

Salt-Marsh Communities – Marsh Plants

©Scott Taylor, Duke Marine Laboratory

Cordgrass (*Spartina* species) dominates along water edge in most salt marshes

- **High primary production**
- **Nursery** for young of many species
- Contribute **detritus** to the estuary



Source: Bill Ober

Salt-Marsh Communities – Marsh Plants

Cattails (*Typha* spp.)

Smooth Cordgrass
(*Spartina alterniflora*)

Black Needle Rush
(*Juncus gerardi*)

Some common plants in Salt Marshes around the world.

Glasswort (*Salicornia* spp.)

Sea Lavender
(*Limonium nashii*)

Saltmarsh Hay
(*Spartina patens*)

Salt-Marsh Communities – Marsh Animals

- **Filter feeders** *(e.g. mussel)* – Cordgrass provides attachment sites and enhance food supply for mussels. Mussels filter feeding deposit nutrient rich feces on roots.
- **Deposit feeders** *(e.g. fiddler crab)* – Both the burrowing and the animal's deposit-feeding aerate the soil and increase the rate of below-ground decomposition, thereby enhancing the productivity of the cordgrass.
- **Grazers** *(e.g. nutria)* – Could damage salt marshes.

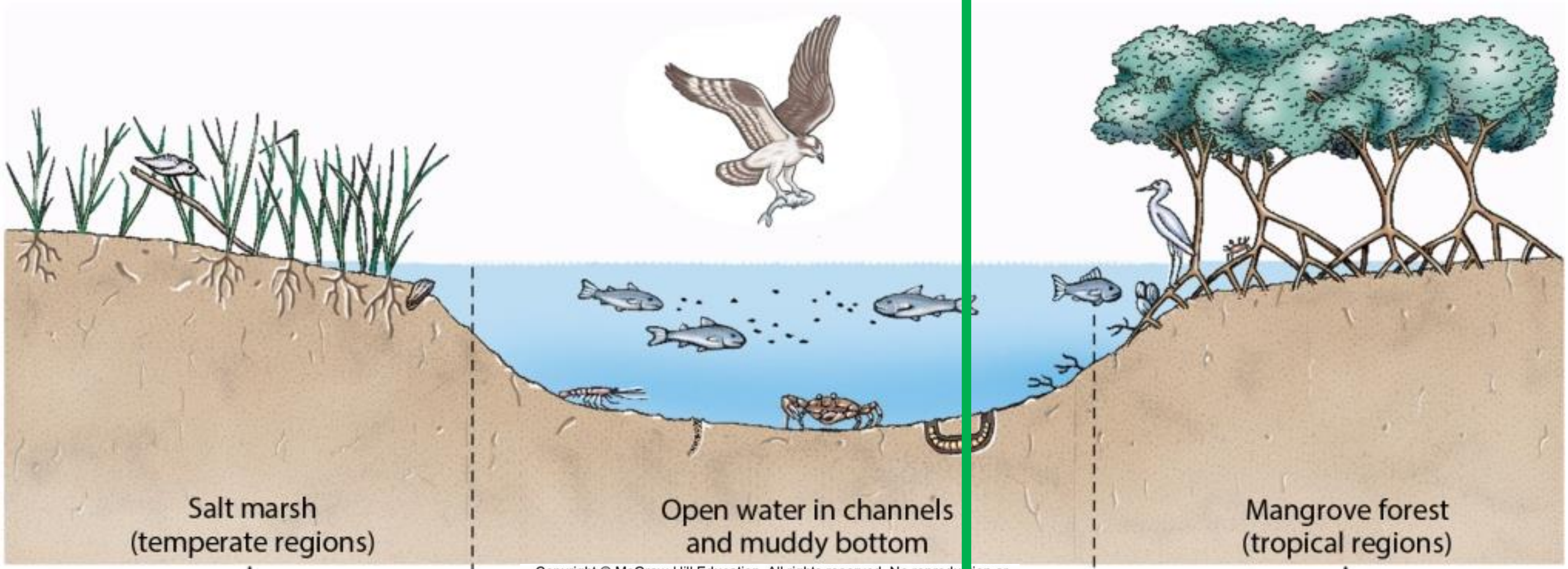
Salt Marshes vs. Mangroves

Salt Marshes

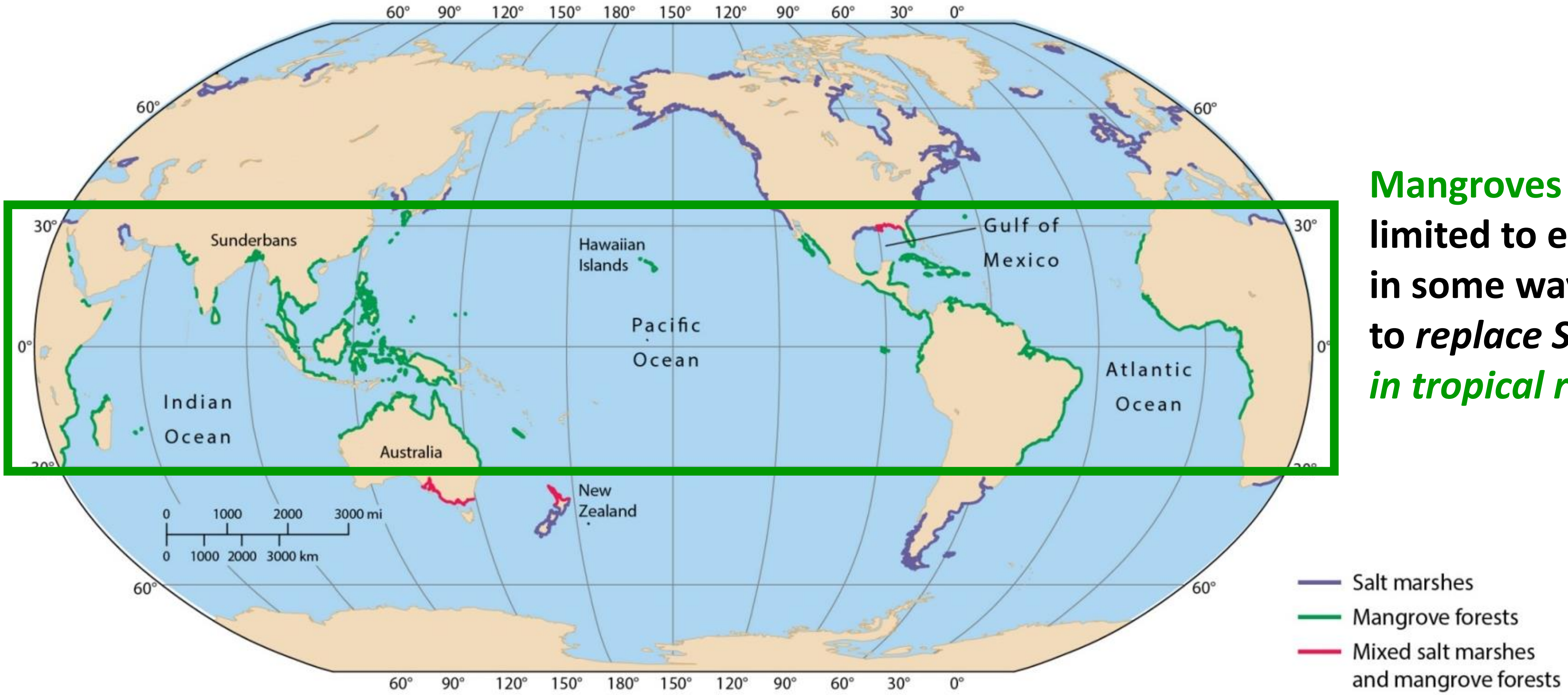
Grassy vegetation that lives along the shores of estuaries and sheltered coasts in **temperate and subarctic regions.**

Mangroves

Trees and shrubs that live along the intertidal shores in **tropical and subtropical regions.**



Mangroves – Distribution (Warmer Regions)



Mangroves are not limited to estuaries, but in some ways they tend to *replace Salt Marshes in tropical regions*.

Source: Bill Ober

Mangroves

Mangroves

- **Trees and shrubs** (land plants) *adapted* to live in the *intertidal*

©Peter Castro

Mangals

- **Dense forests** formed by the mangroves

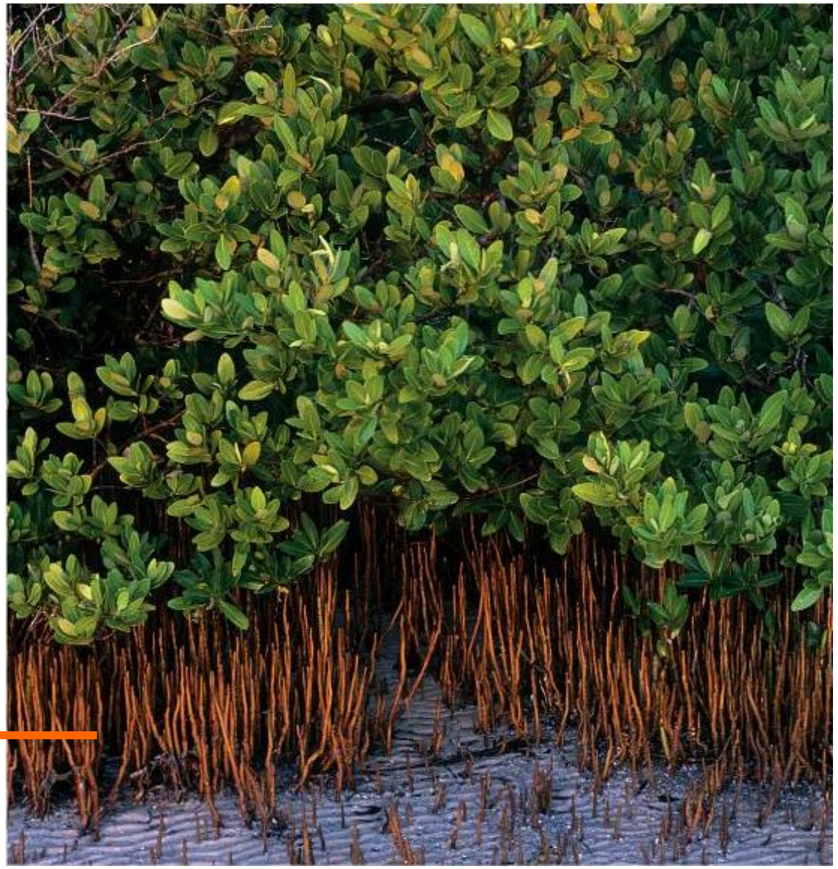
©Charlie Arneson

Mangroves – Adaptations

© Kazuo Ogawa/Getty Images

Prop roots help trees remain stable in **shifting substrates**, Okinawa, Japan.

Aerial roots improve **oxygen transport to roots** in black mangroves, *Avicennia germinans*, Florida USA



© Gary Meszaros/Visuals Unlimited/Corbis

Mangrove Communities

Many marine and land animals live in mangrove forests.

- The **muddy bottom** is inhabited by a range of deposit and suspension feeders, as on mudflats
  - **Polychaetes, shrimps, crabs, clams**

- **Crabs** are particularly common
  - Many species feed on the abundant **leaf litter** that accumulates below the mangrove tree
  - Some species also feed on **mangrove leaves, flowers, and seedlings**

- Many organisms **attach to**, or **take shelter among**, the **submerged mangrove roots**
  - **Cyanobacteria, seaweeds, sponges, polychaetes, gastropods, oysters, barnacles**

Mangrove Forests – Habitats to Many Species

Small fishes, many of which are *juveniles* of commercially important species, seek **shelter** from predators and find **food** among the **mangrove roots**.

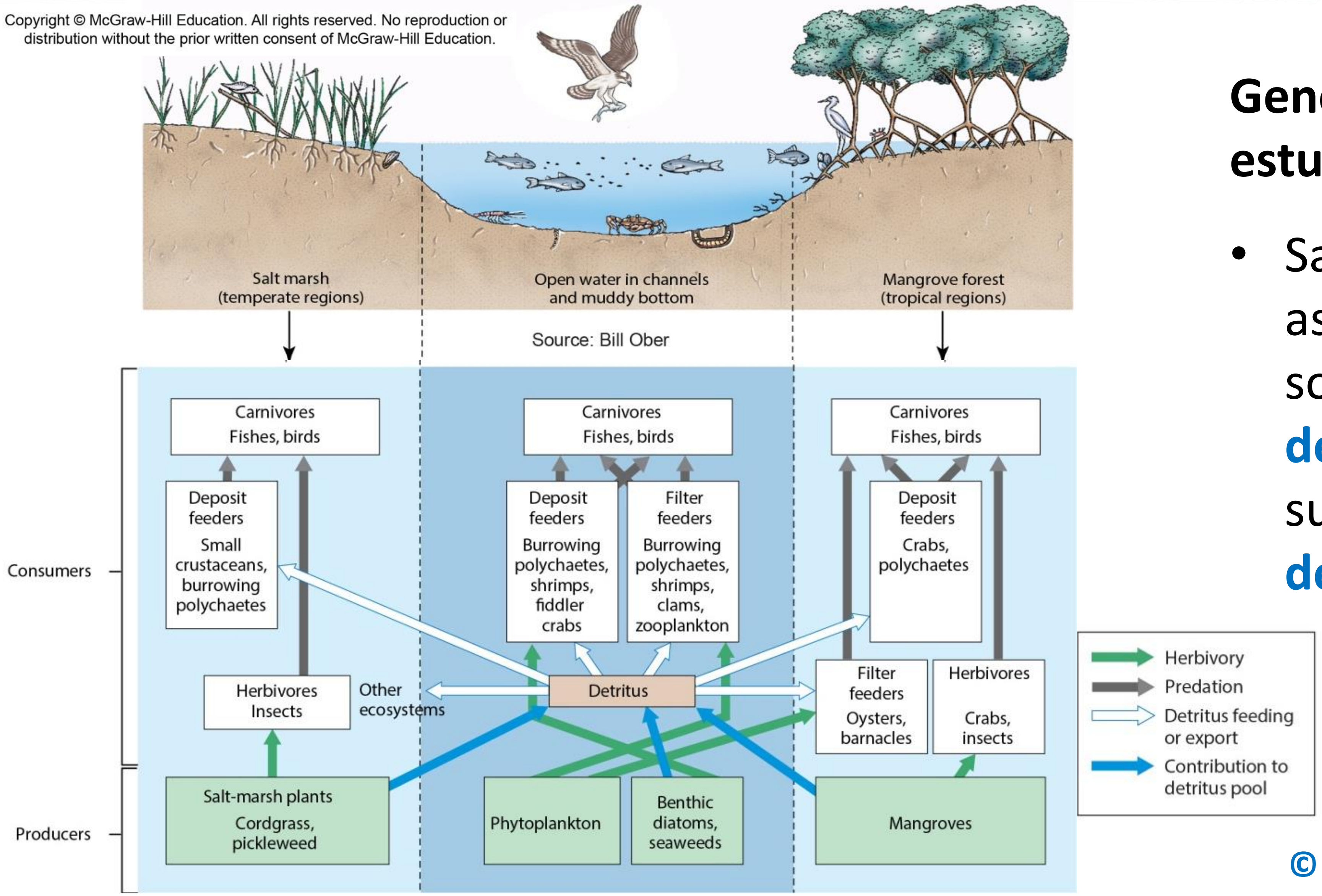
©Bianca Lavies/Getty Imagess

Mangrove Forests – Habitats to Many Species

Seaweeds, sponges, oysters, sea anemones, barnacles, and many other types of organisms live **attached to the roots** of the red mangrove (*Rhizophora mangle*).

©Charlie Arneson

Estuarine Food Webs – Salt Marshes & Mangroves



Generalized food webs in estuarine ecosystems

- Salt marshes, mangroves, as well as terrestrial sources contribute to the **detritus** pool that supports abundant **deposit and filter feeders**

Summary – Salt Marshes & Mangroves

Estuarine communities – rich biodiversity, providing food and shelter for many organisms

	Salt Marshes	Mangroves
Vegetation	Grassy	Short trees & shrubs, some species with prop roots
Geographic distribution	Cold, temperate & subarctic regions	Warm, tropical & subtropical regions
Substrate	Soft, muddy bottoms	Soft, muddy bottoms
Organisms	Deposit & filter feeders, grazers, some infauna	Deposit & suspension feeders, some epifauna attaching to mangrove roots

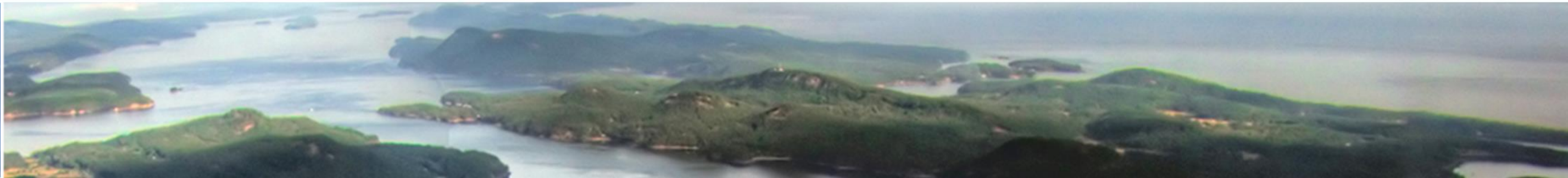



Image: NOAA

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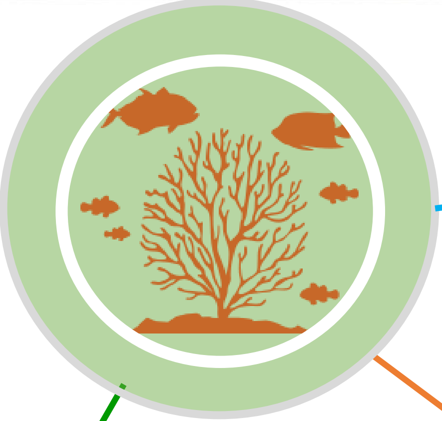
Coastal Eutrophication

Marine Ecosystems – The Subtidal, Estuaries, and the Intertidal



Subtidal Zone

Always submerged

- ❑ Unvegetated Areas
- ❑ Kelp Forests
- ❑ Seagrass Beds
- ❑ Coral Reefs

Coastal Eutrophication

- ❑ Harmful Algal Blooms & Effects
- ❑ *Noctiluca Blooms*

Intertidal Zone

***Not always* submerged**

- ❑ Rocky Shores
- ❑ Sandy and Muddy Shores

Estuaries

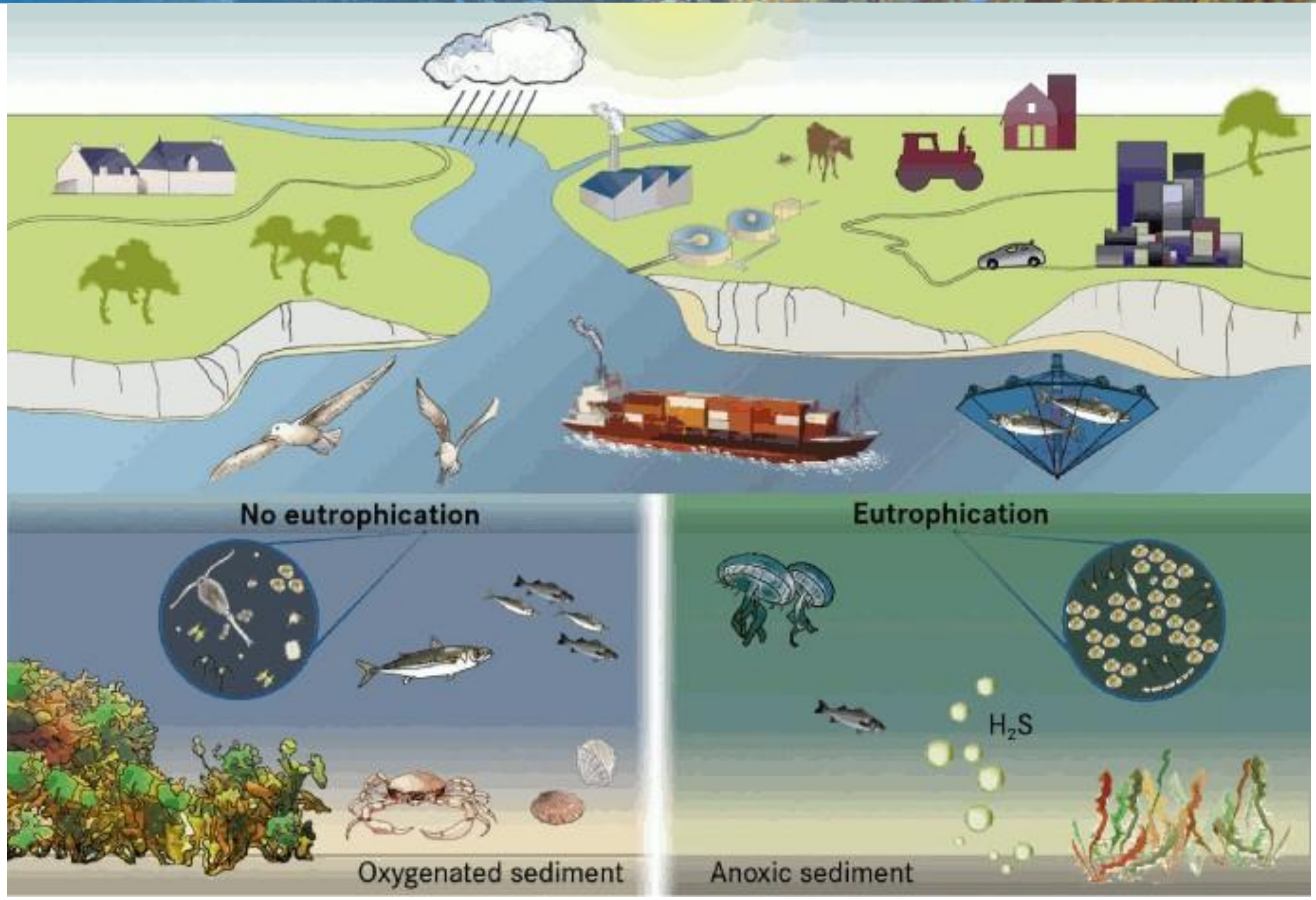
Where rivers *meet* the sea

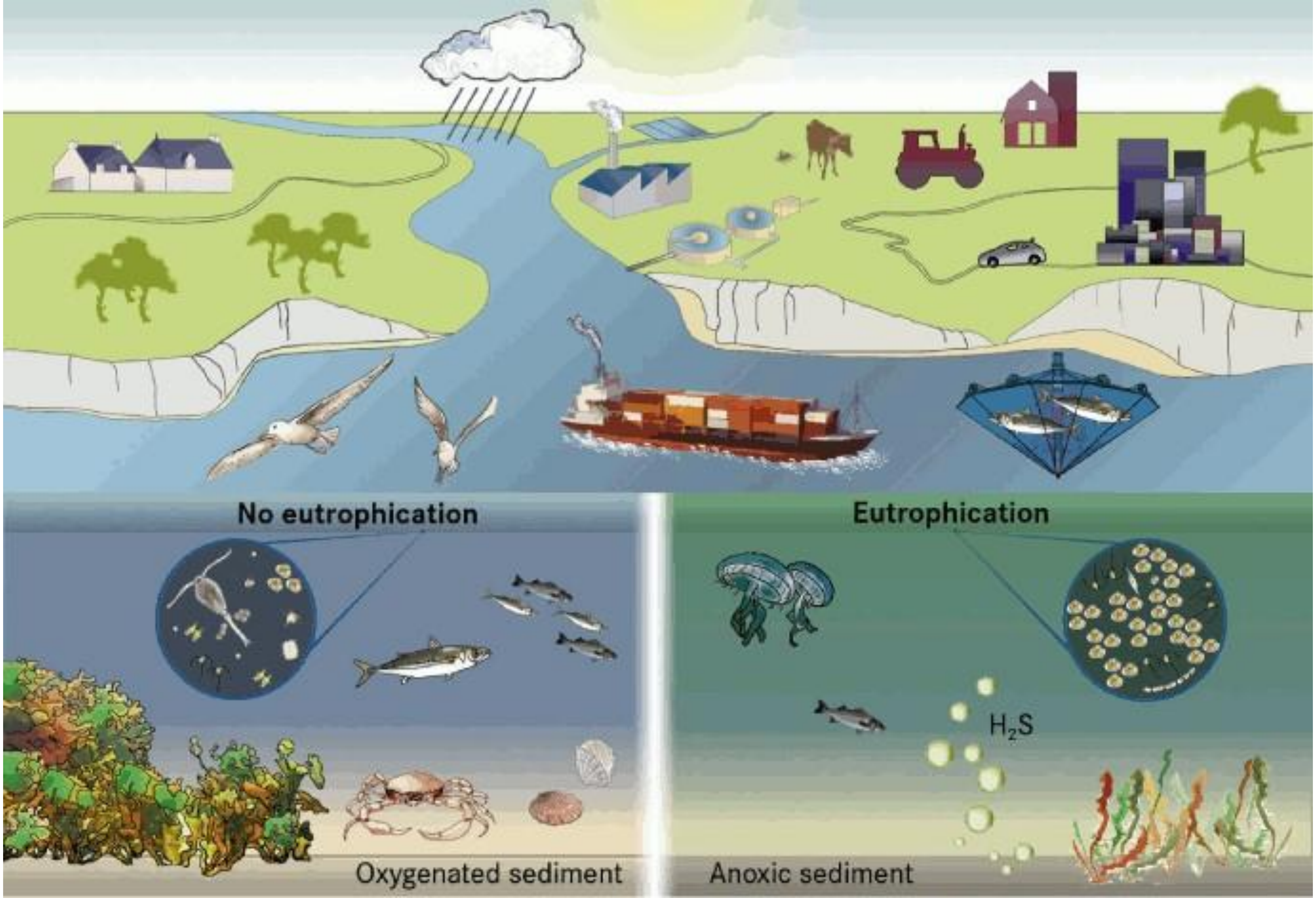
- ❑ Salt Marshes
- ❑ Mangroves

What is Coastal Eutrophication?

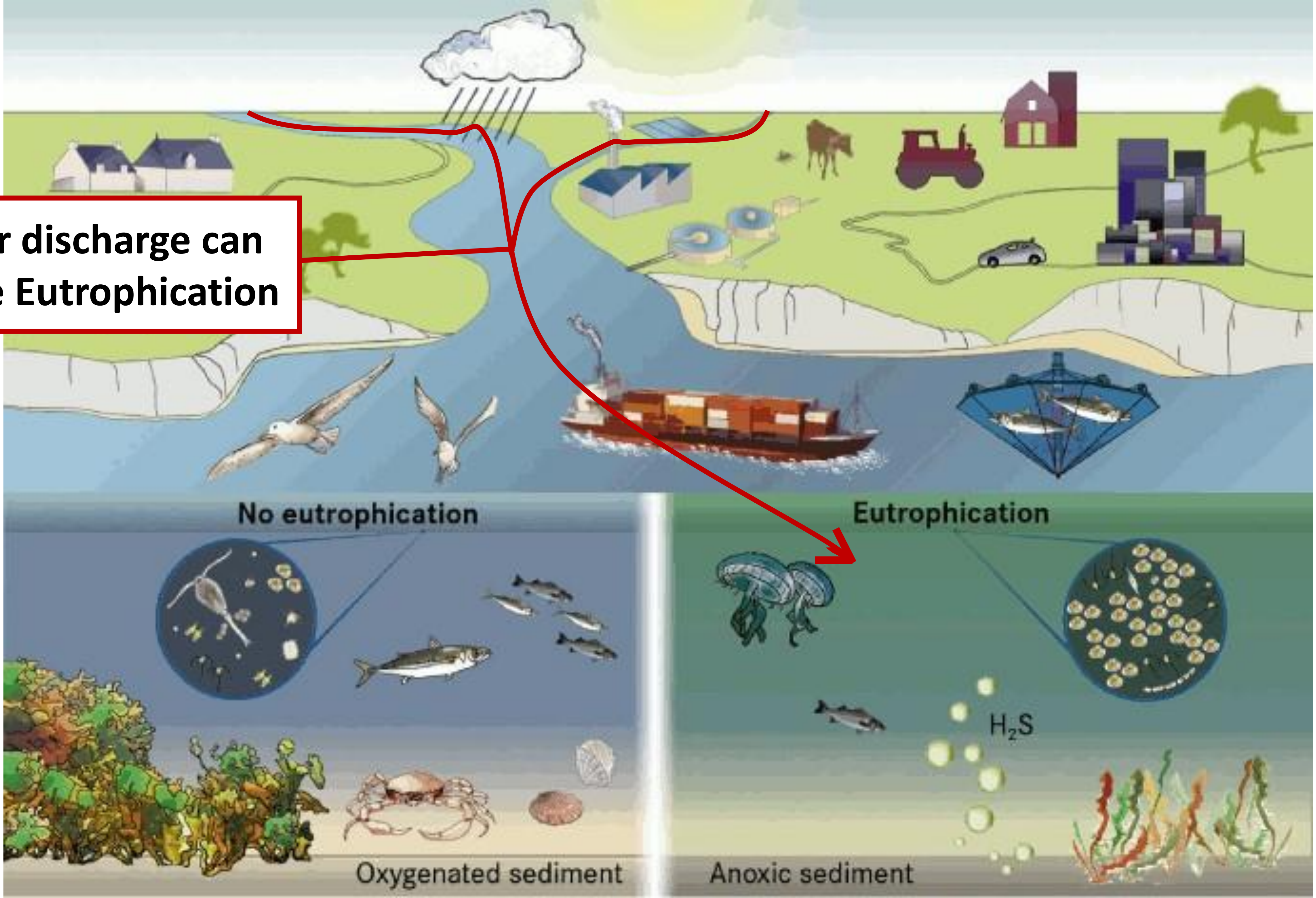
- **Coastal Eutrophication is over-enrichment of water** with nutrients that leads to adverse affects of water quality and marine life.

- **Effects of Coastal Eutrophication**
  - Harmful Algal Blooms
  - Dead Zones (Hypoxia)
  - Fish Kills



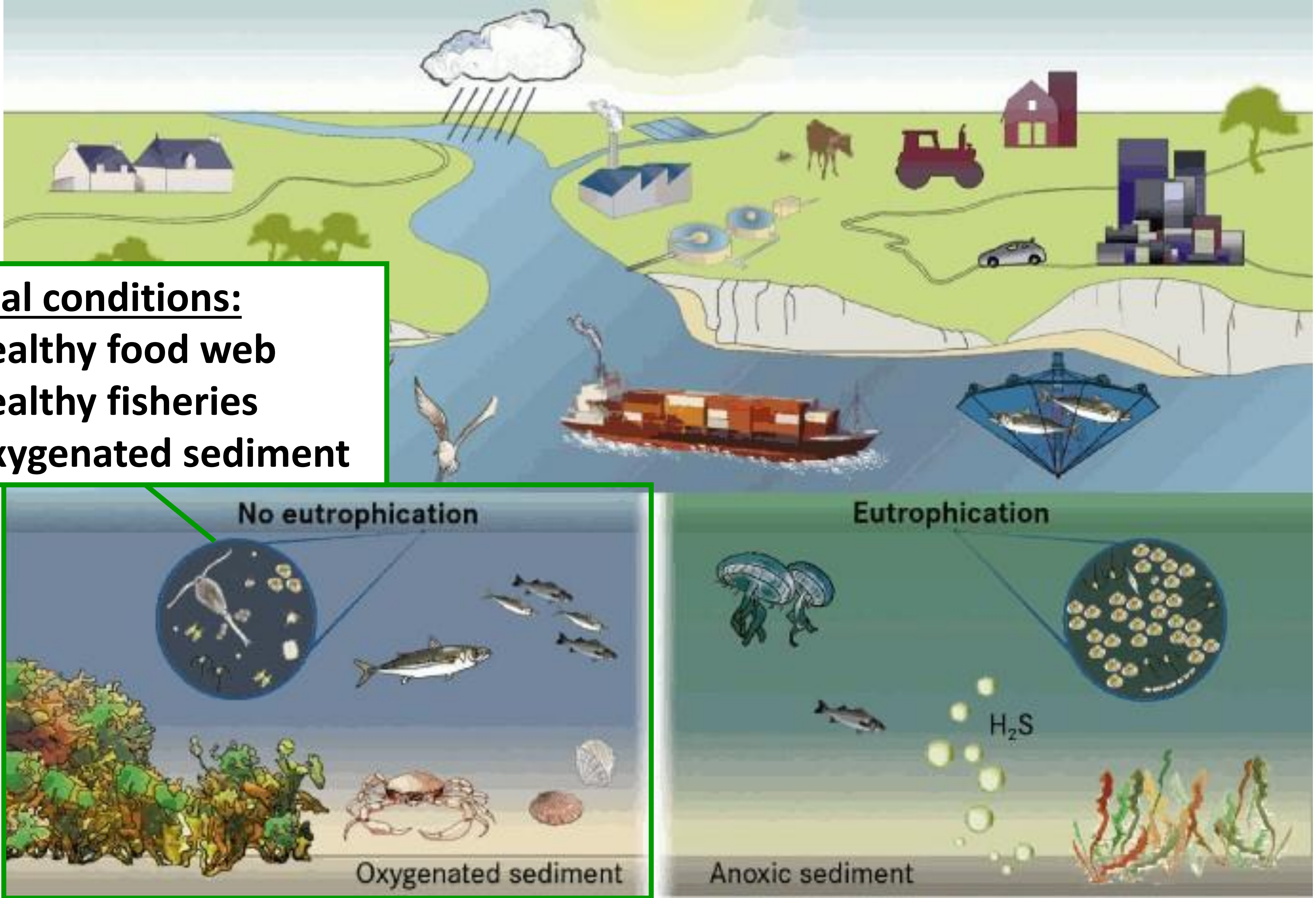

No eutrophication
Eutrophication
H_2S
Oxygenated sediment
Anoxic sediment

River discharge can cause Eutrophication



Normal conditions:

- Healthy food web
- Healthy fisheries
- Oxygenated sediment

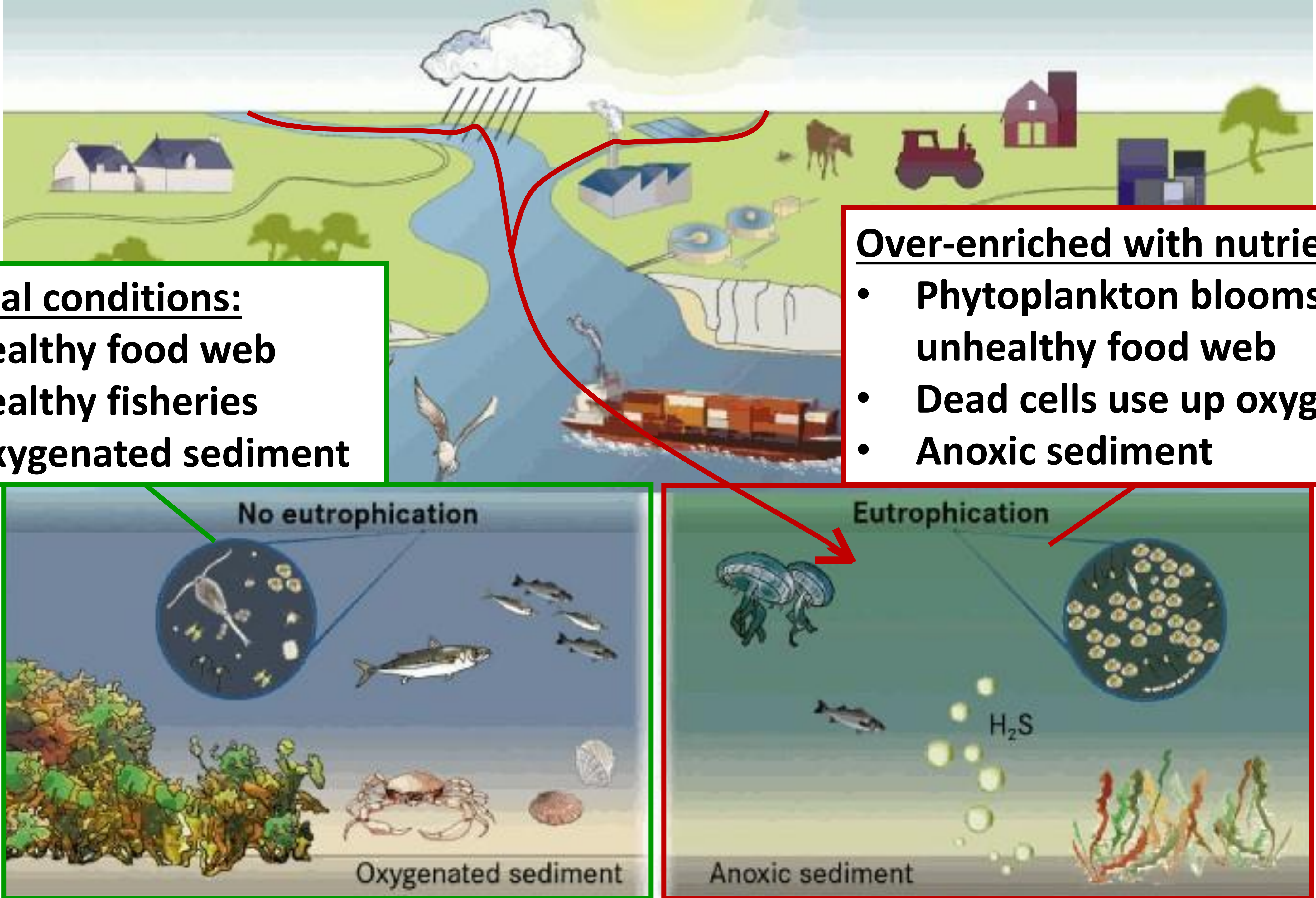


Normal conditions:

- Healthy food web
- Healthy fisheries
- Oxygenated sediment

Over-enriched with nutrients:

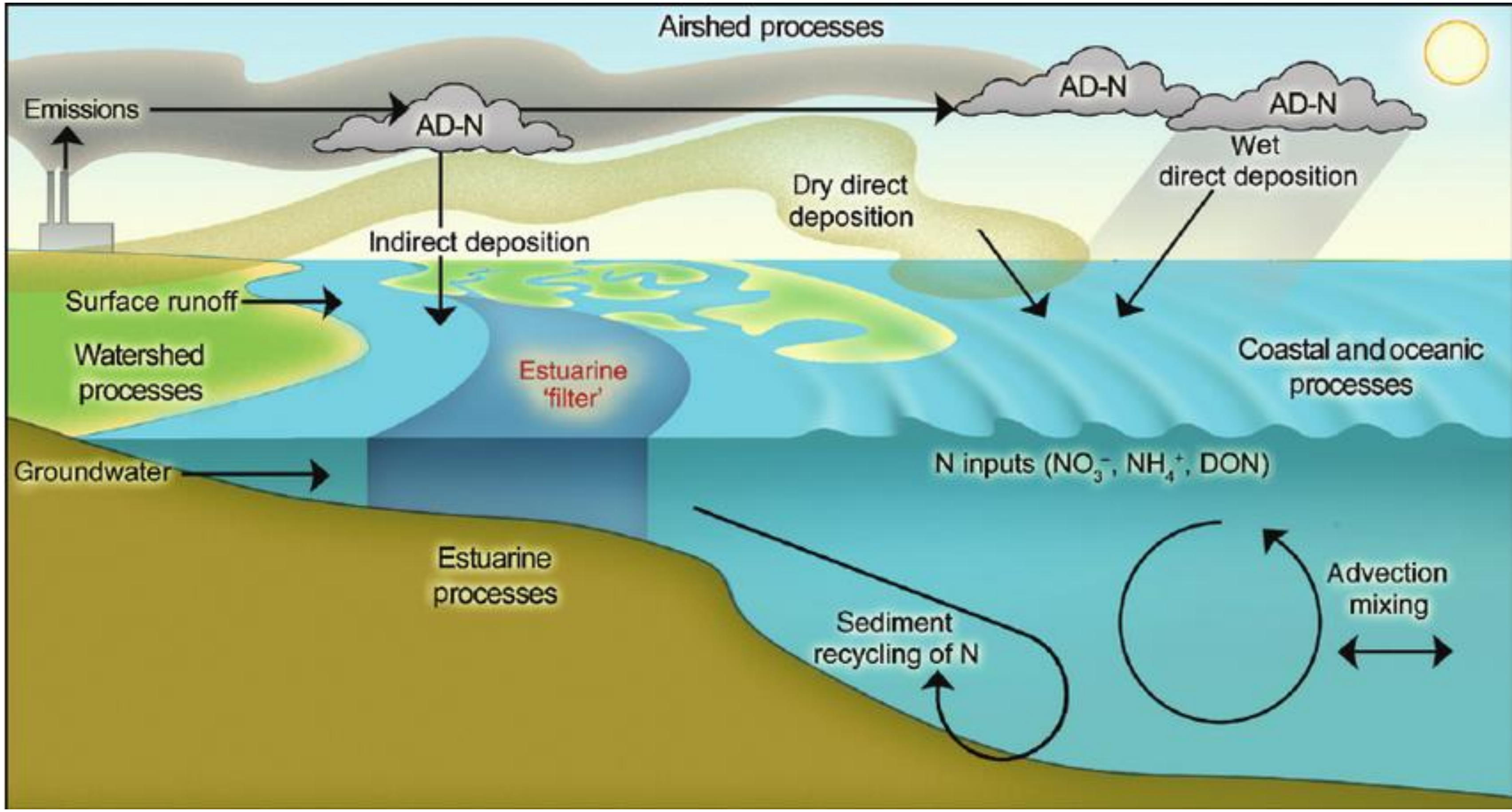
- Phytoplankton blooms & unhealthy food web
- Dead cells use up oxygen
- Anoxic sediment



Causes of Coastal Eutrophication

Nutrient loading of coastal waters is caused by **increased inputs of nutrients** from

- Activities in the **upstream catchment**
- **Atmospheric** deposition
- **Groundwater** input
- **Local effluents**
  - **Runoffs** from farmland and urban centers



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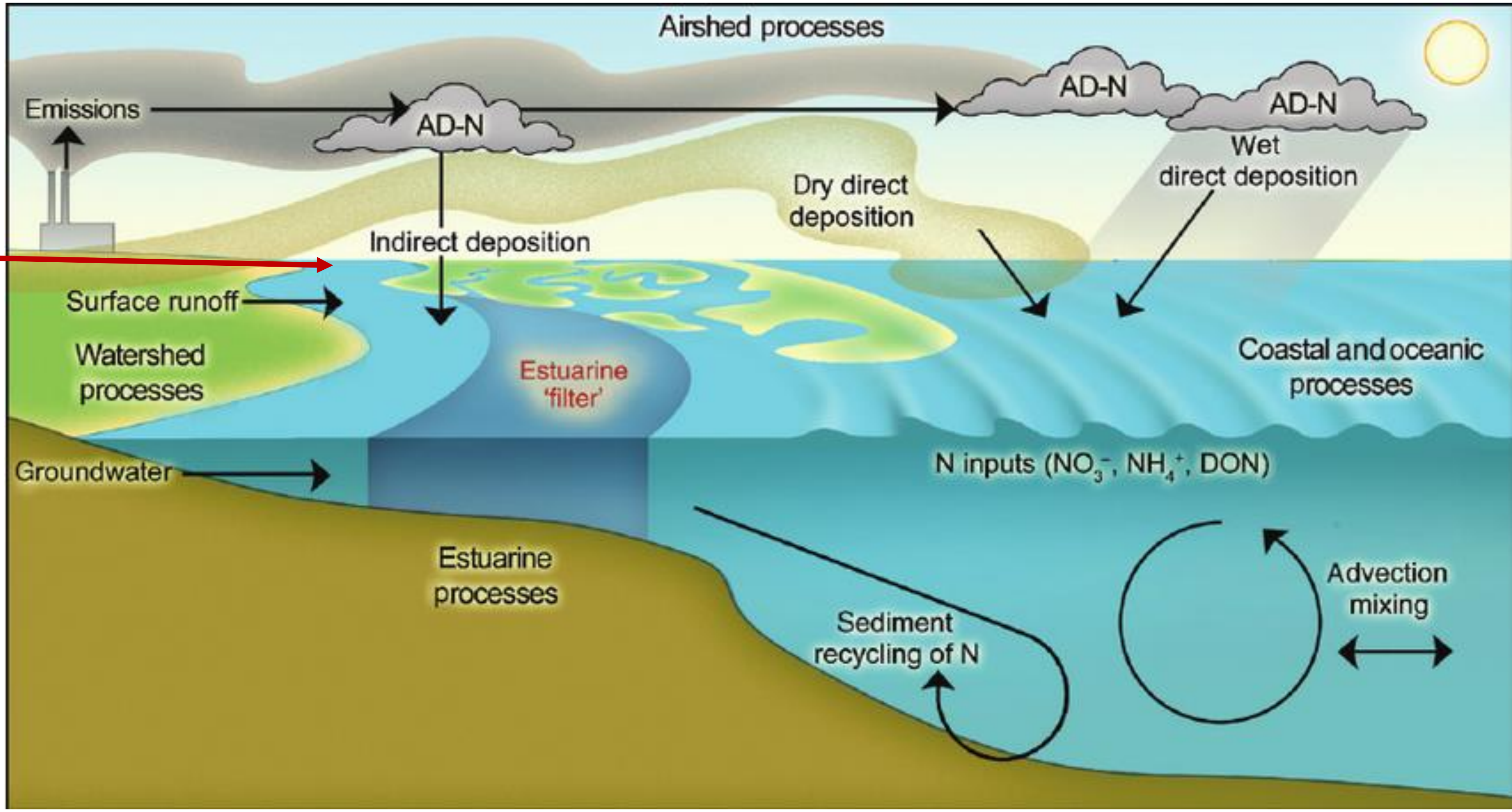

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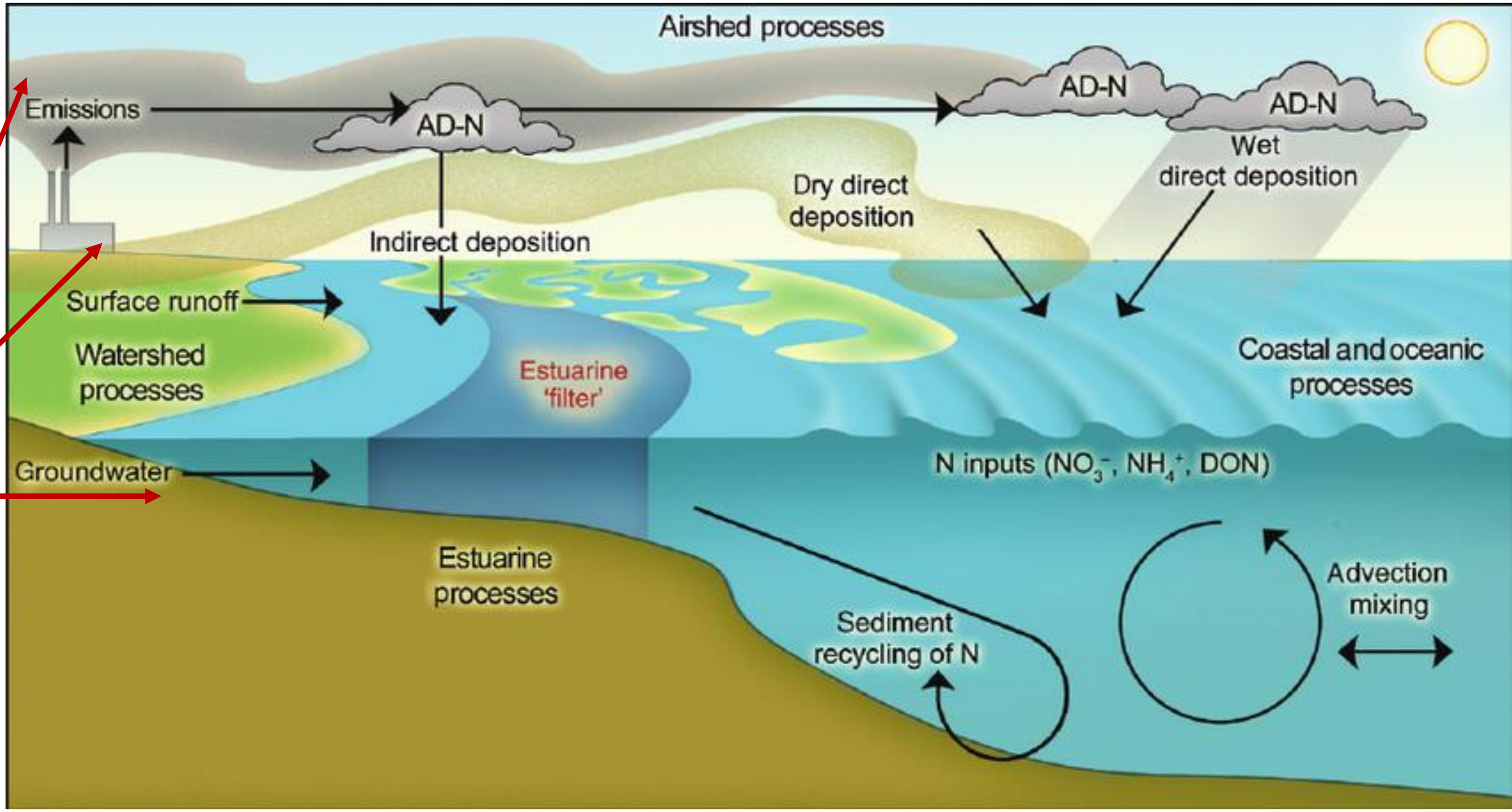

Different Types of Phytoplankton Blooms

Phytoplankton Blooms occur under favorable conditions – a rapid increase or accumulation of algae in marine ecosystems. Can block sunlight and cause oxygen depletion in water.

- **Harmful Algal Bloom (HAB)** – Toxic
- **Noxious Algal Bloom** – Annoying (e.g. mucus)
- **Exceptional Algal Bloom** – Dense, otherwise harmless
- Usually caused by **dinoflagellates**, although some **diatoms** have been known to cause **HABs** (i.e. prymnesiophytes, coccolithophorids, chrysophytes)

Phaeocystis **Bloom**

Image: Wikipedia

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Phaeocystis Bloom

Image: Wikipedia

Algal Bloom – A Serious Problem Caused by Eutrophication

Algal blooms in representative estuarine and coastal waters.

(Upper row, left to right)
Cyanobacterial bloom in the St. John 's River Estuary, Florida (courtesy: J Burns); dinoflagellate red tide, coastal Pacific Ocean, Japan (courtesy: ECOHAB Program); cyanobacterial bloom in the lagoonal Neuse River-Pamlico Sound, North Carolina (courtesy: H Paerl).

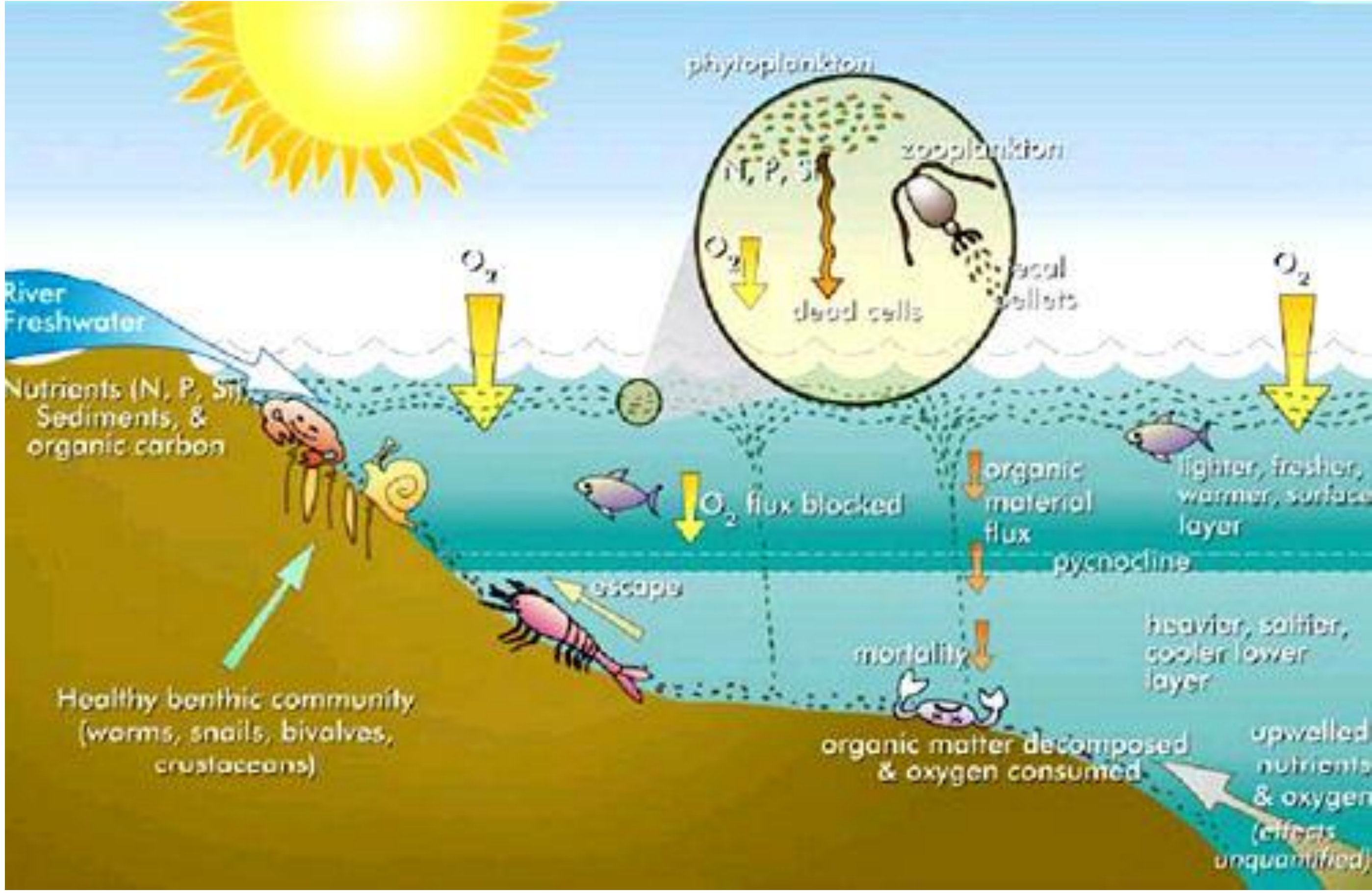
(Middle row)
Mixed algal bloom, Orielton Bay, Australia (courtesy: ECOHAB Program); near-shore dinoflagellate bloom, W. Florida (courtesy: Florida Department of Environmental Protection); cyanobacterial bloom, Lake Ponchartrain, Louisiana (courtesy: J Burns).

(Bottom row)
Cyanobacterial bloom in the Baltic Sea near the Finnish coast (courtesy: Finnish Institute of Marine Research); dinoflagellate bloom, Pamlico Sound, North Carolina (courtesy: P Tester); dinoflagellate red tide in coastal waters near Hong Kong (courtesy: K Yin).

Eutrophication Leads to Coastal Water Hypoxia (Dead Zones)

Eutrophication leads to bottom water hypoxia in coastal seas

Image: epa.gov



Hypoxia, or oxygen depletion, is an environmental phenomenon where the concentration of **dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms**, commonly defined as a concentration of dissolved oxygen less than 2 mg/L (2 ppm).

Eutrophication Leads to Coastal Water Hypoxia (Dead Zones)

Eutrophication leads to bottom water hypoxia in coastal seas

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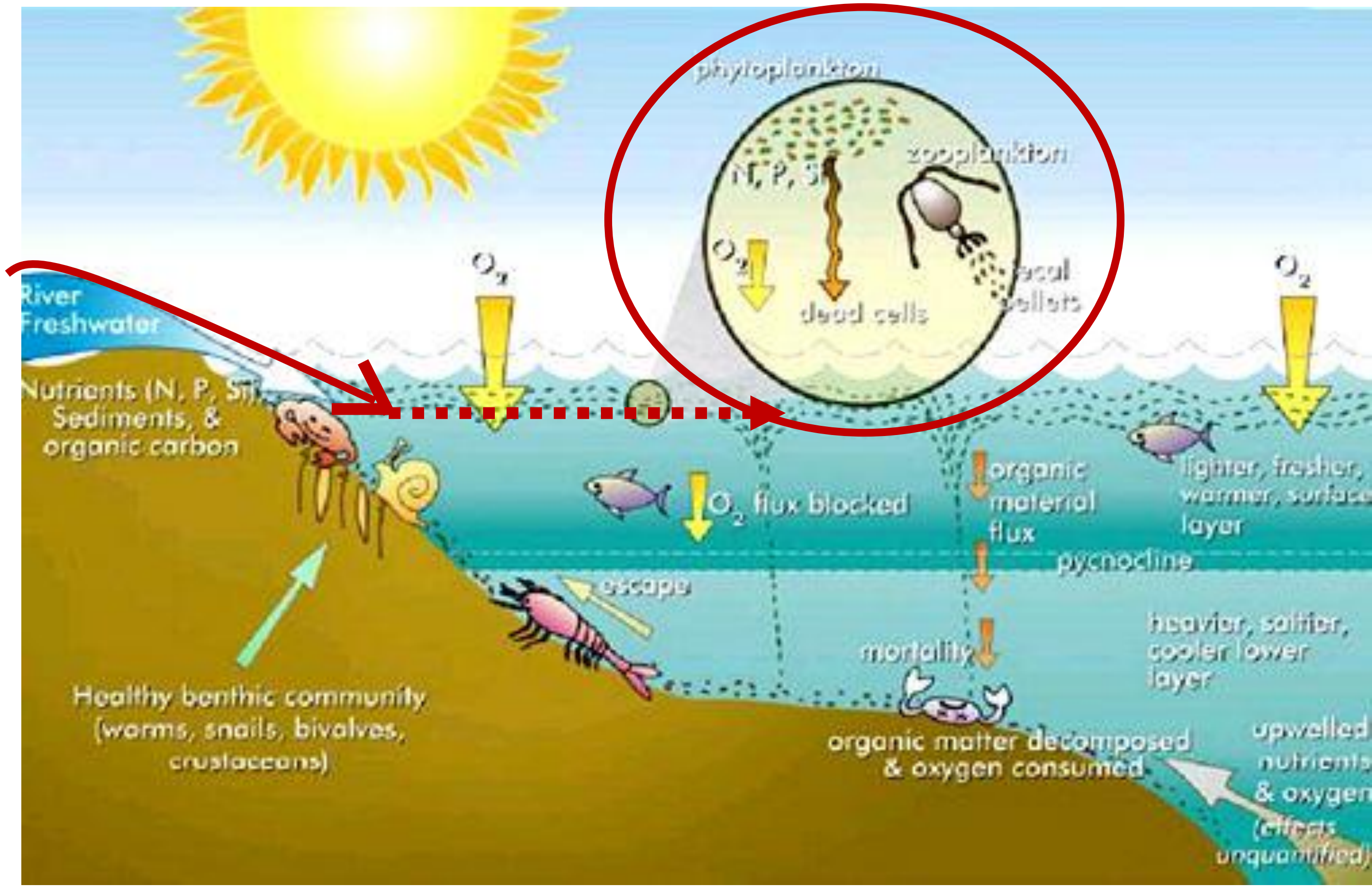

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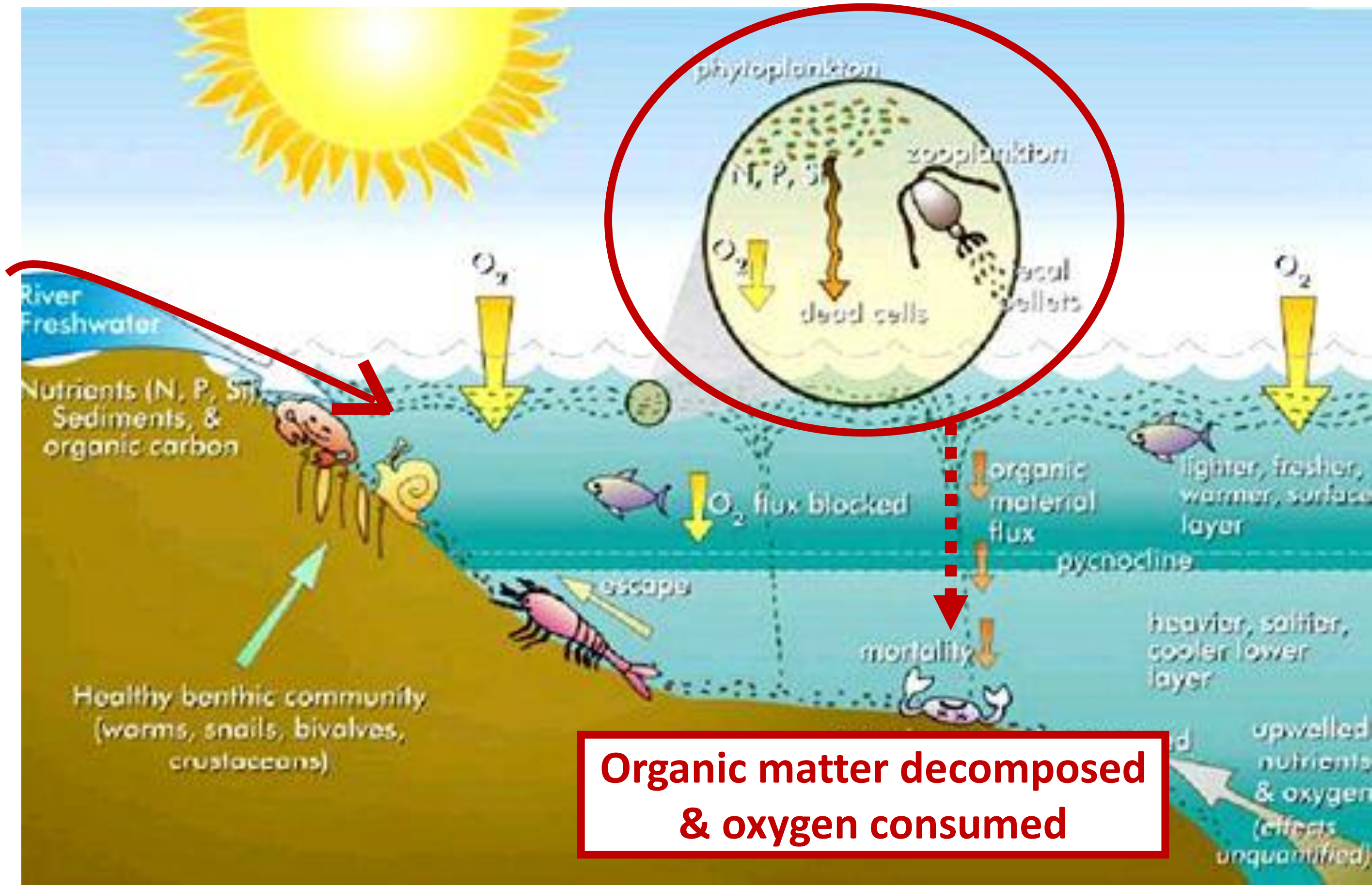

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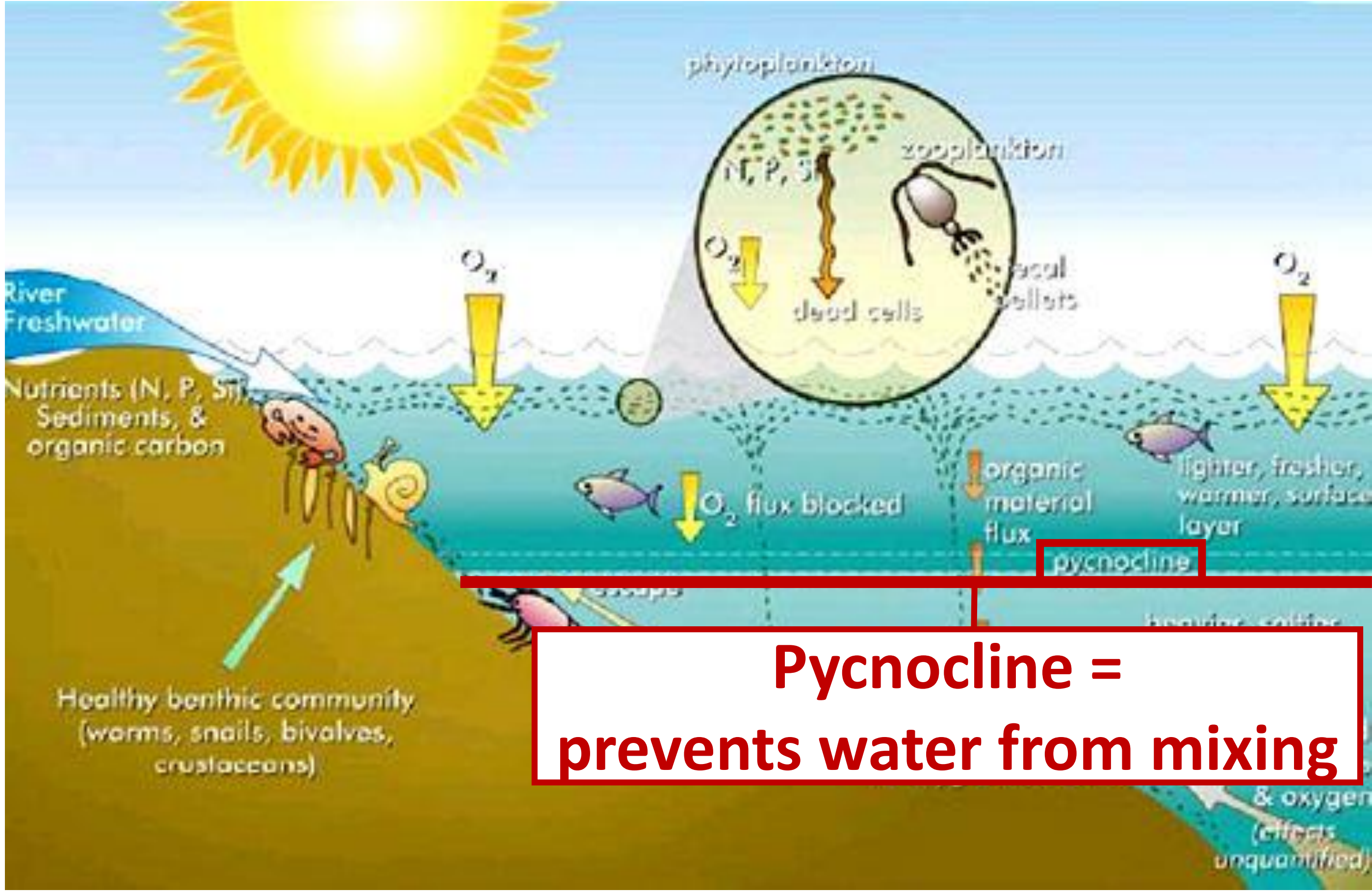
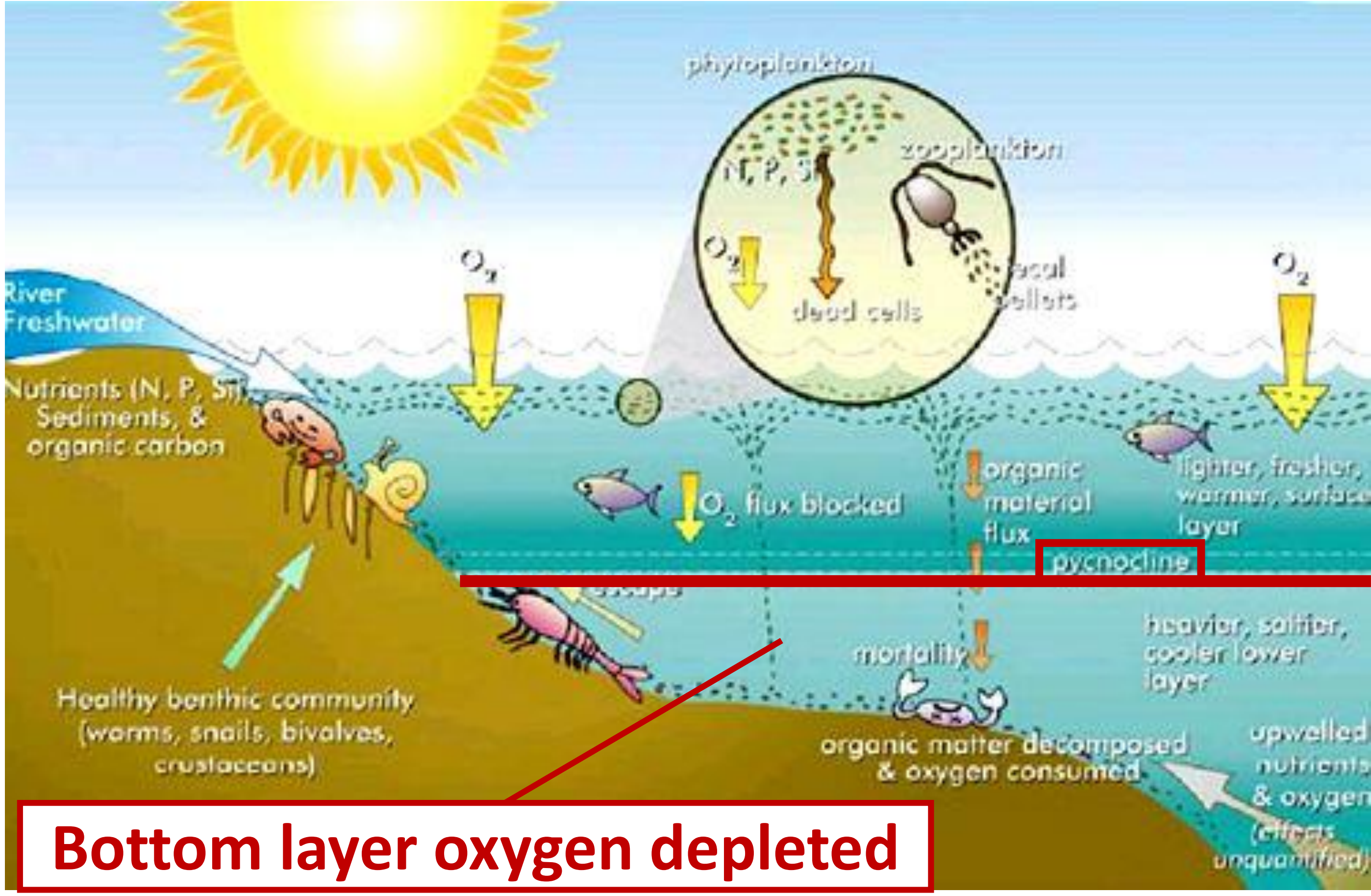


Eutrophication Leads to Coastal Water Hypoxia (Dead Zones)

Eutrophication leads to bottom water hypoxia in coastal seas

Image: epa.gov



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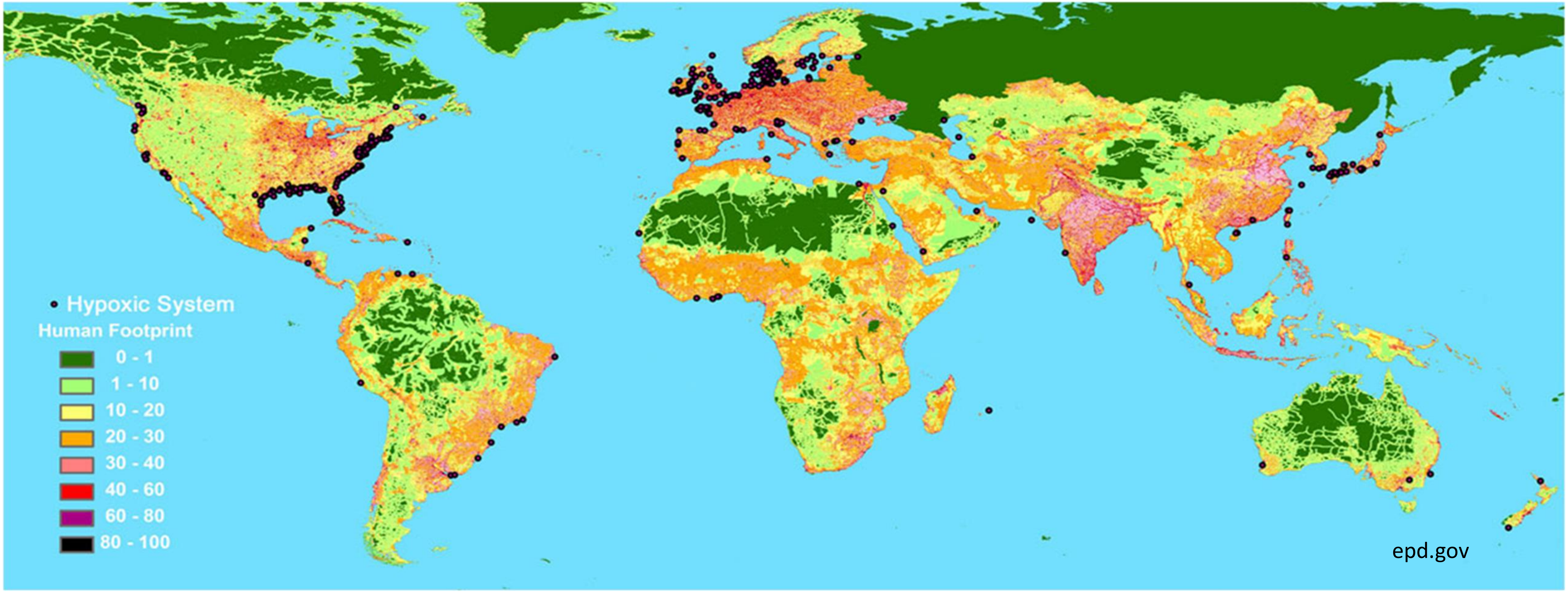
“Dead Zones” Threaten Marine Life

Dungeness Crabs washed up on a beach in Oregon after **suffocating in low-oxygen waters**.

Image: Elizabeth Gates, courtesy of PISCO

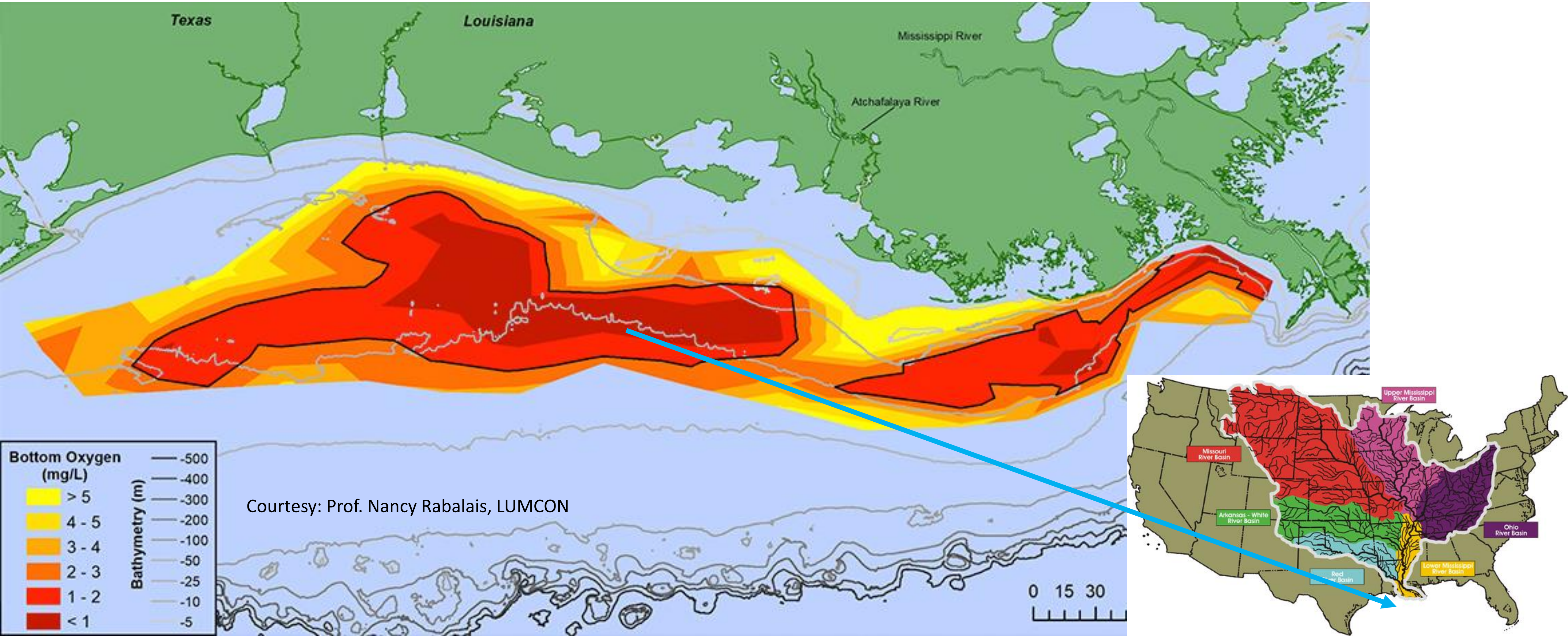
“Dead Zones” around the World

Increasing eutrophication around the world is leading to higher numbers of hypoxic waters or ‘dead’ zones, threatening pelagic and benthic marine life.



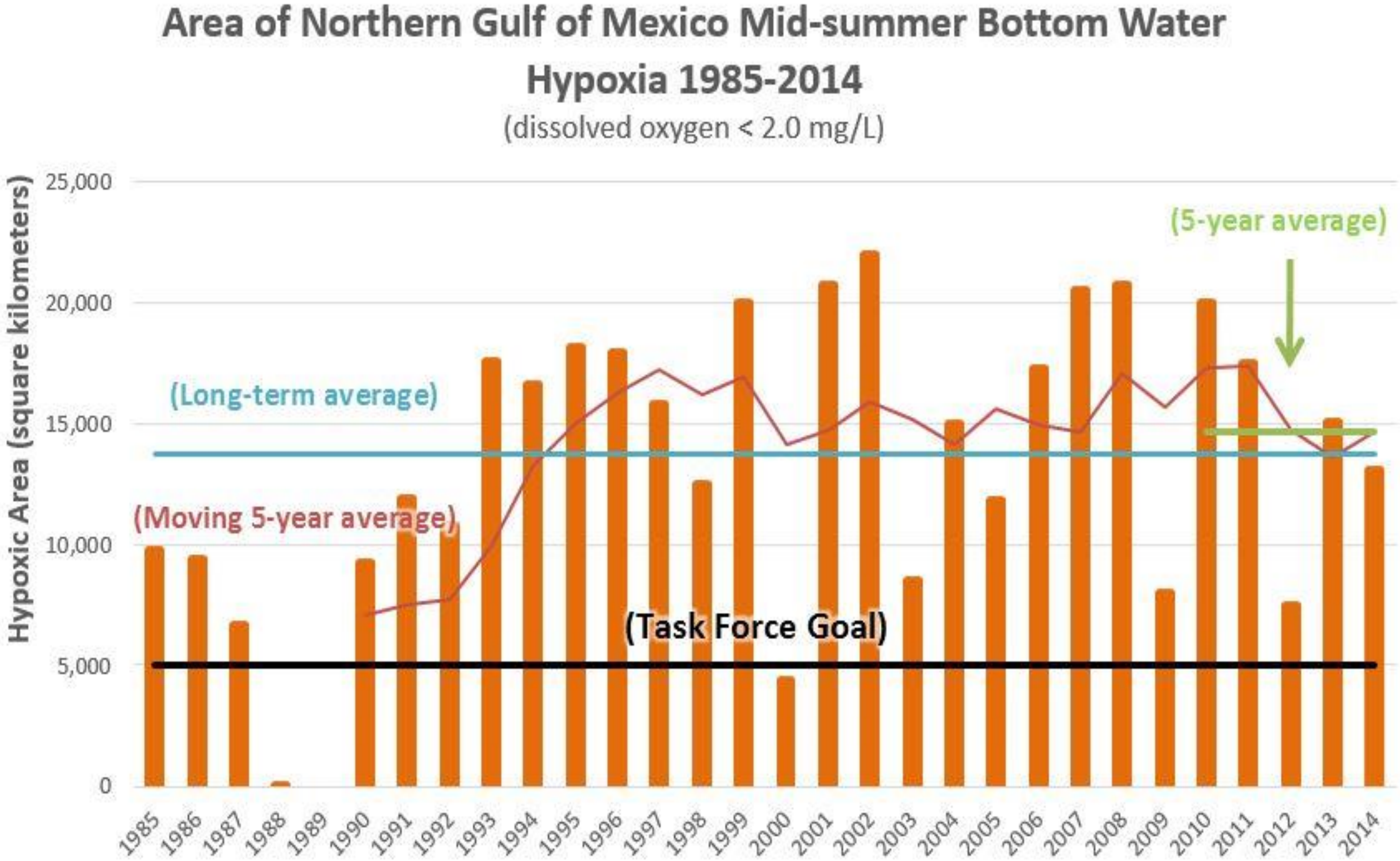
Northern Gulf of Mexico “Dead Zone”

One of the **largest and most studied** hypoxia zones in the world.



Courtesy: Prof. Nancy Rabalais, LUMCON

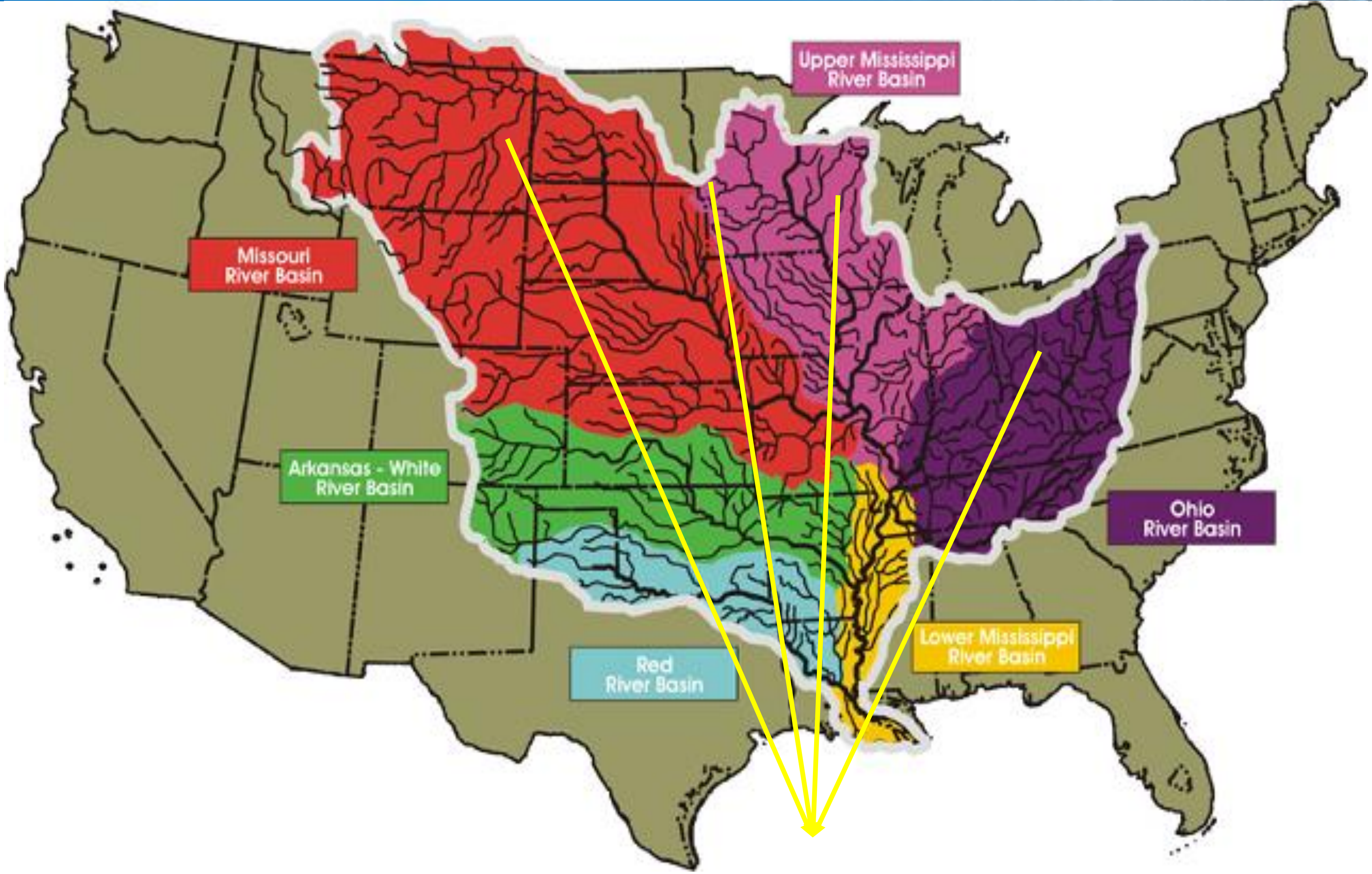
Northern Gulf of Mexico "Dead Zone"



There is annual monitoring of hypoxia affected areas in the Northern Gulf of Mexico.

Affected areas remain large in recent years.

Runoff from Mississippi River



Runoff from farms and cities drains into Mississippi River.

Runoff has high nutrients from fertilizers, waste water treatment plants, and other concentrations.

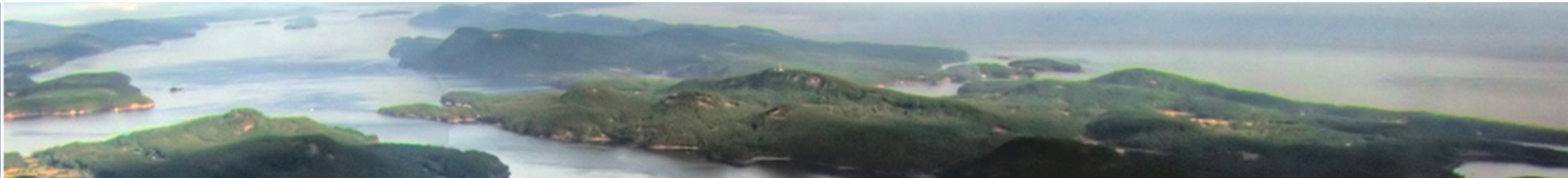
This **pollution** ends up in the Gulf of Mexico.

This Mississippi River discharge has been blamed as the **cause of the phytoplankton bloom and the subsequent oxygen depletion in the bottom layer** due to the degradation of **sinking organic matter** and water column stratification.

Summary – Coastal Eutrophication

- **What is Coastal Eutrophication?**
  - the excessive loading of nutrients to the coastal water fuels massive blooms of phytoplankton, which can cause adverse effects in the marine ecosystem.

- **What are the effects of nutrient overload and fast organism growth?**
  - **Harmful Algal Blooms (HABs):** Rapid increase of phytoplankton blooms with toxins
  - **Hypoxia (dead zones):** Oxygen is so low that it cannot sustain marine life
  - **Fish kills:** HABs and hypoxia cause die off of marine life



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Effects of Harmful Algal Blooms (HABs)

HABs – Also Called Red Tides

Plankton blooms occur under favorable conditions. **A sudden increase in phytoplankton biomass** can cause harmful effects including **poisoning and deaths of fish and other marine vertebrates.**

- The term **Red Tide** is most widely used. It is used when such blooms **alter the ocean color**; there are also **Brown Tide** and **Green Tide**.
- Red Tide can also be formed by "**animals**" e.g. **ciliates.**
- **Not all red tides are harmful**, so the term **Harmful Algal Blooms (HABs)** is used to describe plankton blooms that produce **toxins.**
- **Red tides and Harmful Algal Blooms can be used interchangeably**

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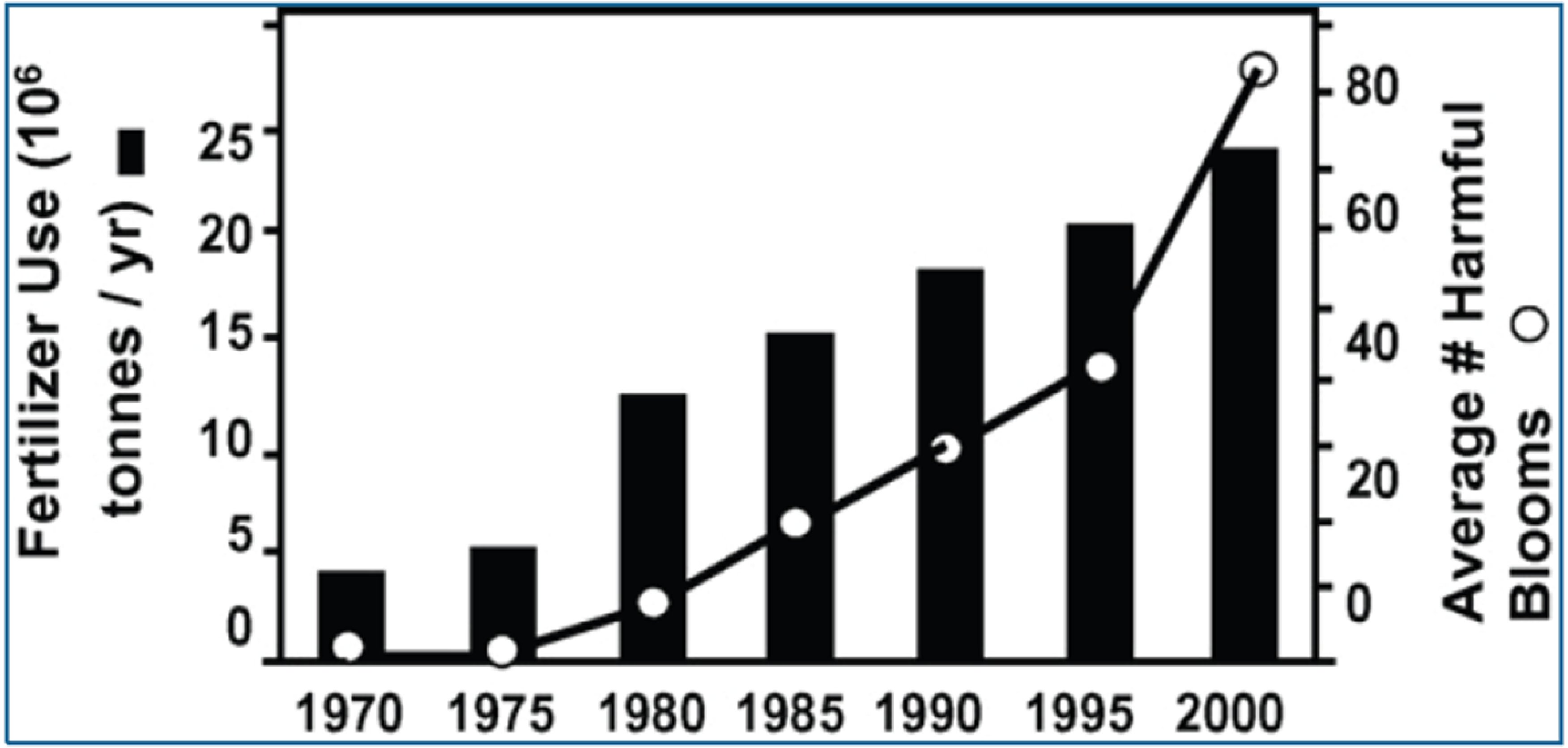
The *Enteromorpha prolifera* (a macro green alga) bloom in Qingdao

Red Tides – Linked to Eutrophication

Red Tides vs. Fertilizers in China Seas



The recent **increase in HAB events** off the coast of China is **related to the increase in the use of nitrogen-based fertilizer** over the past two decades. (Heisler *et al.* 2008)

HABs – Global Impacts

- **HABs cause major economic and health losses**
  - U.S. – On average, $49 million loss per year
  - Often much higher for short time ($50 million to Maryland in a few months in 1997)
  - Hong Kong (2007) – major beach closure
  - Hong Kong (1998) – 90% of farmed fish killed, HK$250 million loss (new species: *Karenia digitata*)

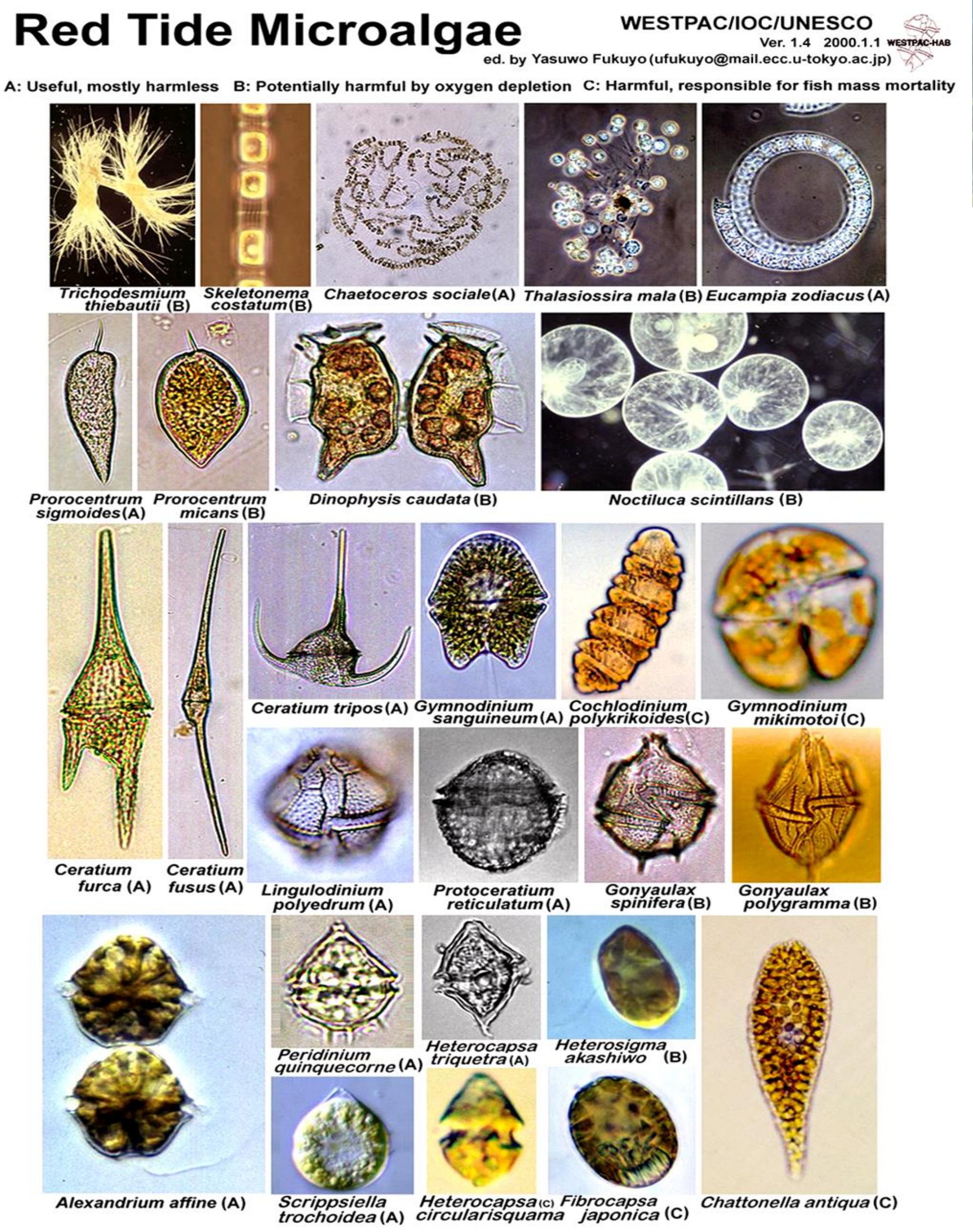
- **Suggestions – HABs have been *increasing* globally**
  - Both in **frequency** and **intensity**
  - Some global increases are due to better reporting and some real increases

Image: https://www.abc.net.au/news/2019-06-19/

Examples of HABs

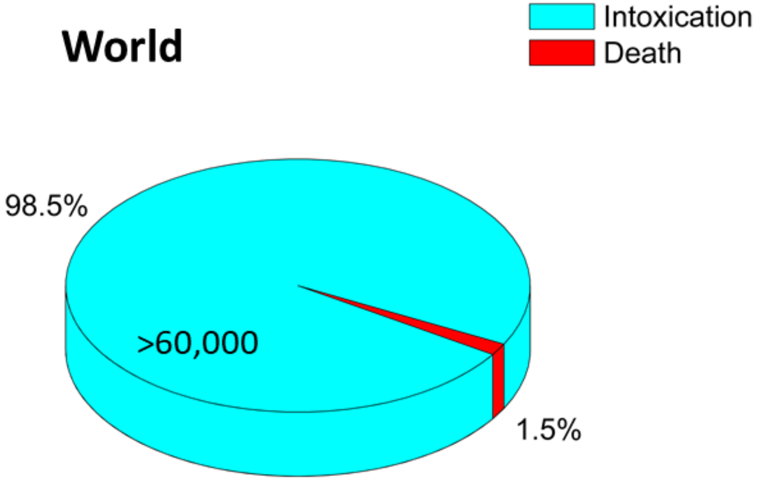
- **Dinoflagellates are the most common red tide forming species**, but other taxa, including diatoms and cyanobacteria, can also form red tides.

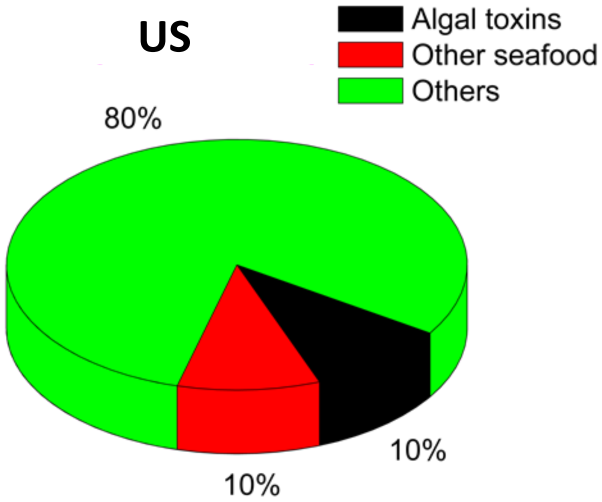
- Many species are toxic.

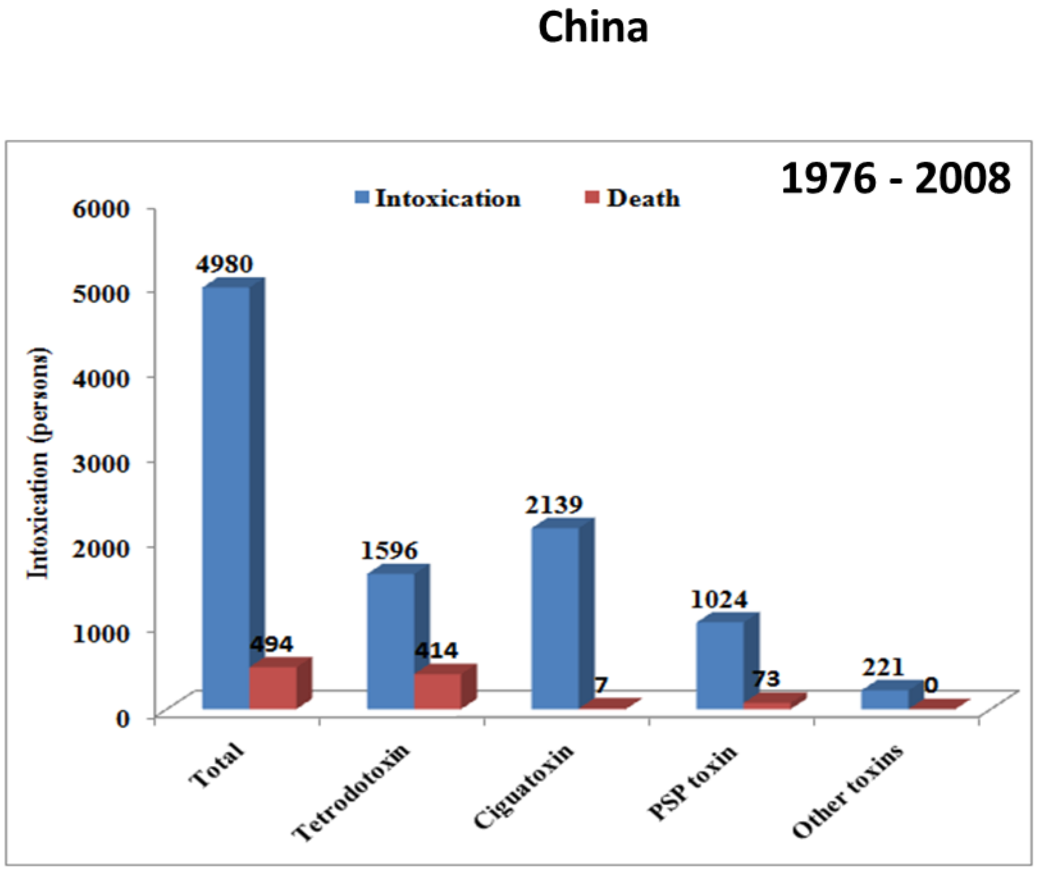


Algal Biotoxins can cause food poisoning

Seafood contaminated by toxic blooms can make you *sick*, while some can be *fatal*.



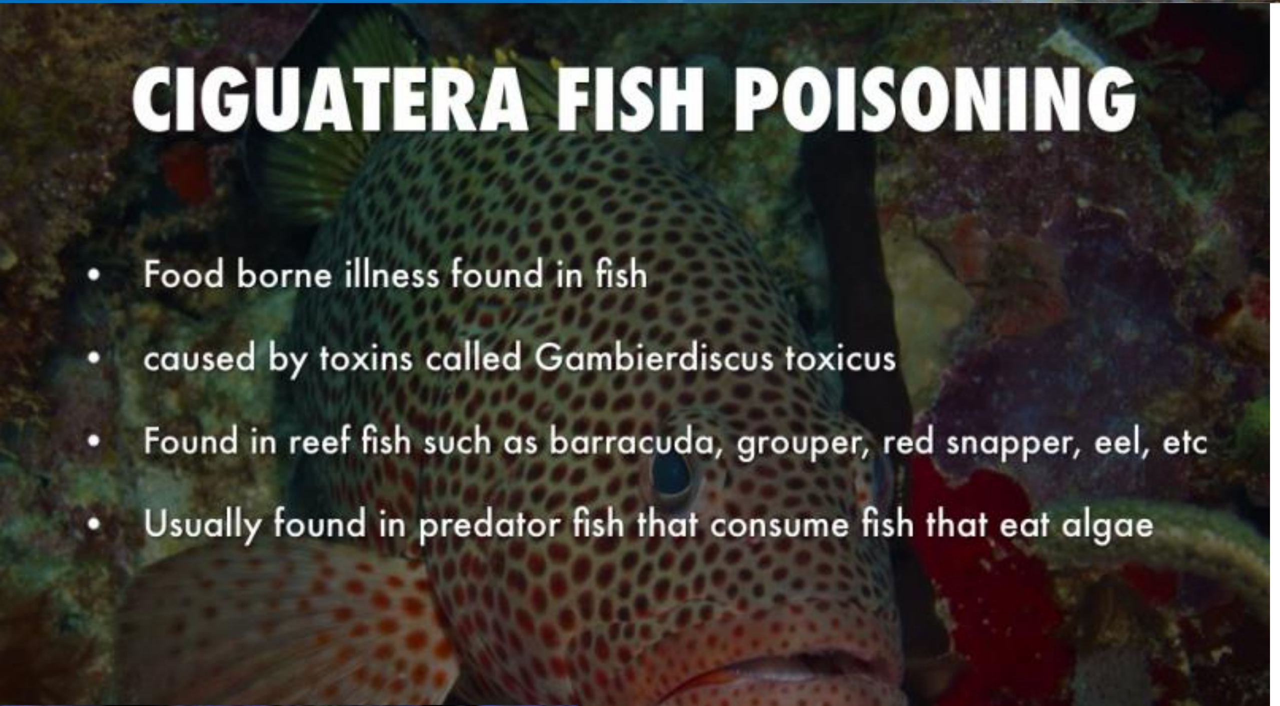


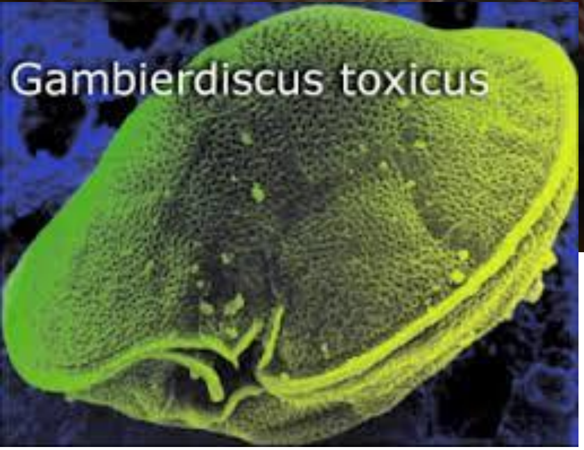


Source: Dolah et *al.* (2000), GEOHAB (2012)

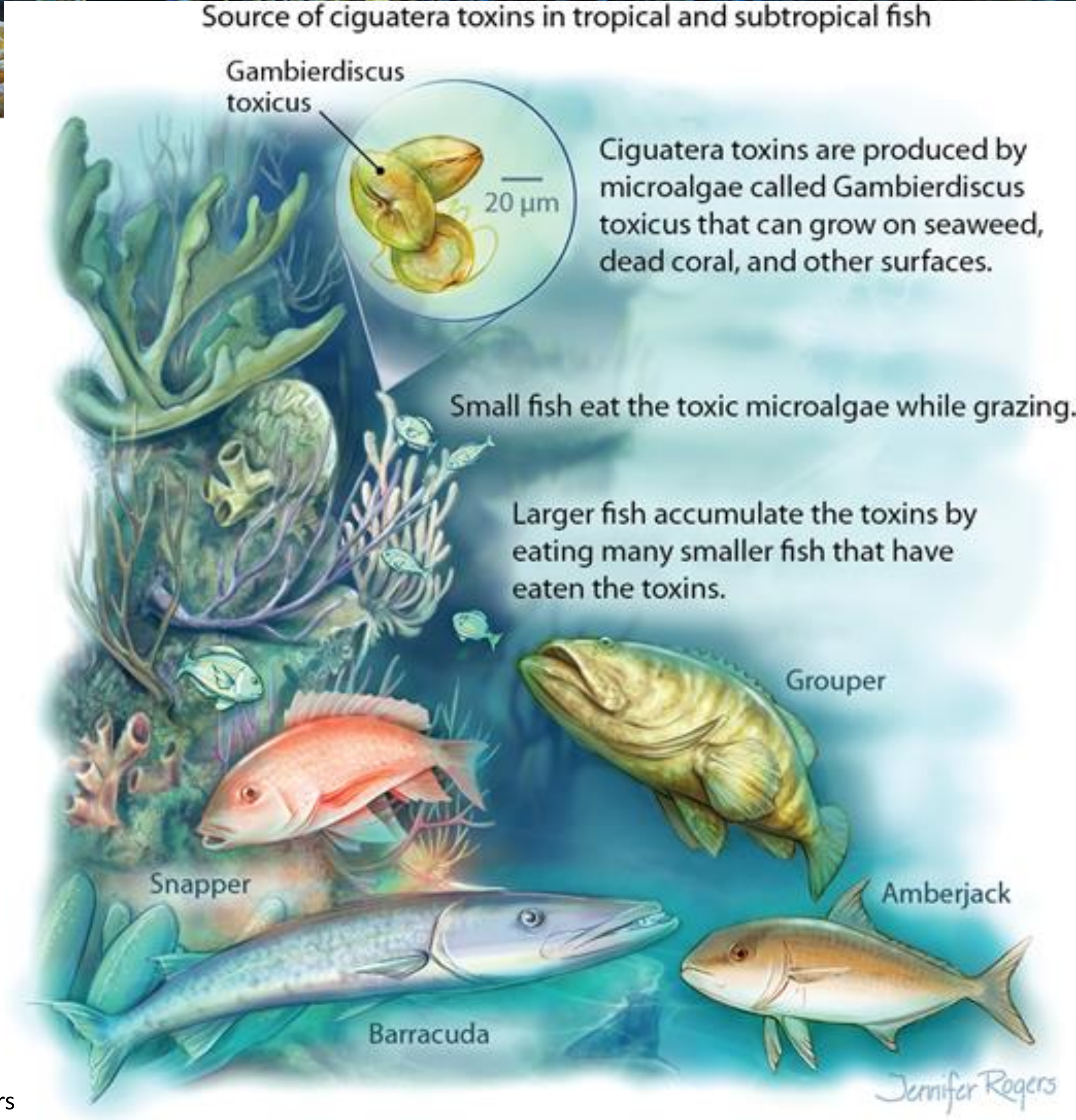
Syndrome	Causative organisms	Toxins produced	Route of acquisition	Clinical manifestations
Ciguatera fish poisoning (CFP)	*Gambierdiscus toxicus* (benthic) and others	Ciguatoxins	Toxin transfer up the marine food chain; illness generally results from eating large, carnivorous reef fish	Acute gastroenteritis, paresthesias and other neurological symptoms
Paralytic shellfish poisoning (PSP)	*Alexandrium* spp, *Gymnodinium catenatum, Pyrodinium bahamense* var. *compressum* and others	Saxitoxin family	Eating shellfish harvested from affected areas	Acute paresthesias and other neurological manifestations; may progress rapidly to respiratory distress, muscular paralysis and death
Neurotoxic shellfish poisoning (NSP)	*Gymnodinium breve, G. brevisulcatum* and others	Brevetoxins	Eating shellfish harvested from affected areas; toxins may be aerosolized by wave action	Gastrointestinal and neurological symptoms; respiratory and eye irritation with aerosols
Diarrhetic shellfish poisoning (DSP)	*Dinophysis* spp.	Okadaic acid and dinophysistoxins (DTXs)	Eating shellfish harvested from affected areas	Acute gastroenteritis
Azaspiracid shellfish poisoning (AZP)	*Protoperidinium crassipes*	Azaspiracids	Eating shellfish harvested from affected areas	Neurotoxic effects with severe damage to the intestine, spleen, and liver tissues in animal tests
Amnesic shellfish poisoning (ASP)	*Pseudo-nitzchia* spp.	Domoic acid and isomers	Eating shellfish (or, possibly, fish) harvested from affected areas	Gastroenteritis, neurological manifestations, leading in severe cases to amnesia (permanent short-term memory loss), coma, and death
Possible estuary-associated syndrome	*Pfiesteria piscicida* and other *Pfiesteria* spp.	Unidentified	Exposure to water or aerosols containing toxins	Deficiencies in learning and memory; acute respiratory and eye irritation, acute confusional syndrome

Ciguatera Fish Poisoning





Gambierdiscus toxicus



Courtesy: Jennifer Rogers

Summary – Harmful Algal Blooms (HABs) & Red Tides

- **What are Red Tides?**
  - The term Red Tide is used when such blooms alter the ocean color.
  - The term Red Tide and HABs can be used interchangeably.

- **What are the impacts of HABs?**
  - Not all algal blooms are harmful, but most of them cause food web interruption, oxygen depletion, loss of biodiversity, and poisoning and deaths of fish and other marine vertebrates.
  - In some cases, it could cause severe economic loss and threaten public health.

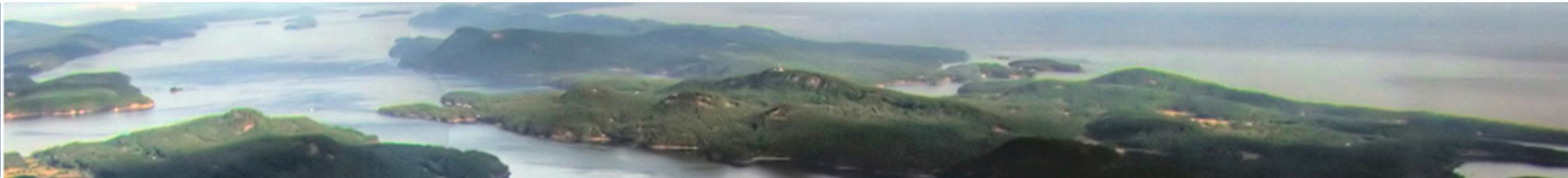


Image:
New York Times (23 Jan 2015)

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Noctiluca Blooms – A Case Study

Noctiluca Red Tide around the World

NEWS › HONG KONG

Hong Kong in bloom: stunning photos of 'Sea Sparkle' on city's shores

Long-exposure pictures taken by the Associated Press show a mesmerising luminescence from the marine plankton Noctiluca scintillans, triggered by water pollution along Hong Kong's seashore

Staff Reporters

PUBLISHED : Friday, 23 January, 2015, 2:21pm
UPDATED : Friday, 23 January, 2015, 5:58pm

Source: New York Times

A red tide stains Repulse Bay Beach
(Image: South China Morning Post)

珠海出现蓝色荧光海滩 被确认为夜光藻赤潮（图）

2015年01月13日 14:22　来源：珠海特区报　参与互动(0)　6

11月25日，深圳大梅沙海域赤潮 新华社发

Red Tides in Hong Kong

- More red tides occurred in the **eastern waters** than in the western waters
- **Less favorable conditions for phytoplankton blooms in western waters:** water is more turbid (cloudy, less sunlight) and more dynamic.
- ***Noctiluca scintillans*** is the **most common** species of red tides **in Hong Kong waters**

Distribution of *Noctiluca* blooms recorded in Hong Kong waters from 1980 to present.

Source: AFCD, HK

>28%

紅潮種類在不同水質管制區的分佈狀況(1980 – 2014)

種類	發生次數 吐露港及赤門	大鵬灣	東部緩衝區	牛尾海	將軍澳	維多利亞港	南區	西北部	西部緩衝區	后海灣	總數
Noctiluca scintillans	68	69		62			59	6	9		273
Skeletonema costatum	23	3		1	3	9	13	3	10	2	67
Mesodinium rubrum	8	9		11	1		18	7	3	2	59
Gonyaulax polygramma	23	8		16			6	1			54
Prorocentrum minimum	45	1							1		47
總數 : 95種	413	152	1	143	7	14	155	31	31	13	960

註: 一次紅潮可由多個種類引發

數據來源: 漁農自然護理署及環境保護署

(HKEPD, 2014)

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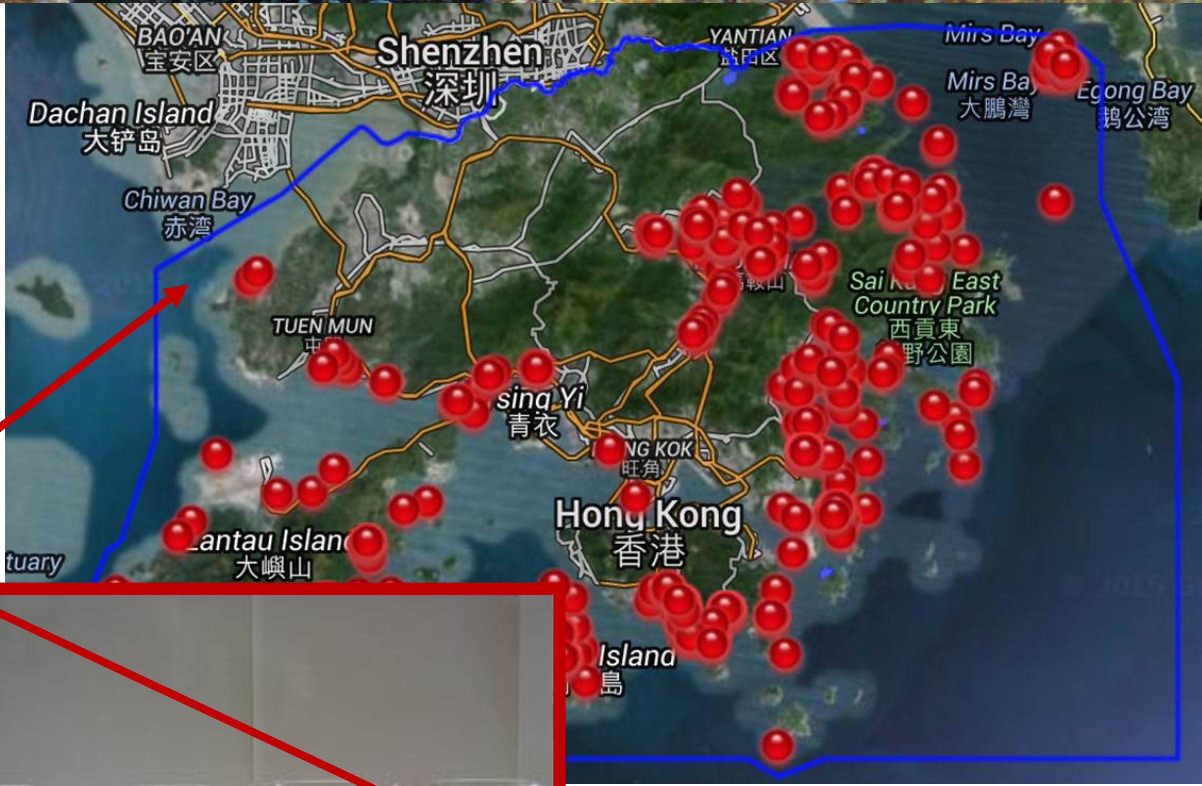

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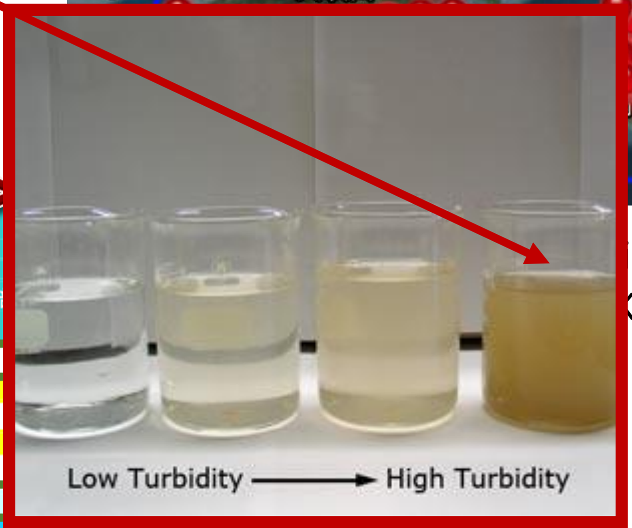

(HKEPD, 2014)

Red Tides in Hong Kong

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- ***Noctiluca scintillans*** is the **most common** species of red tides **in Hong Kong waters**

(HKEPD, 2014)

Red Tide off HKUST (8 Feb 2019)

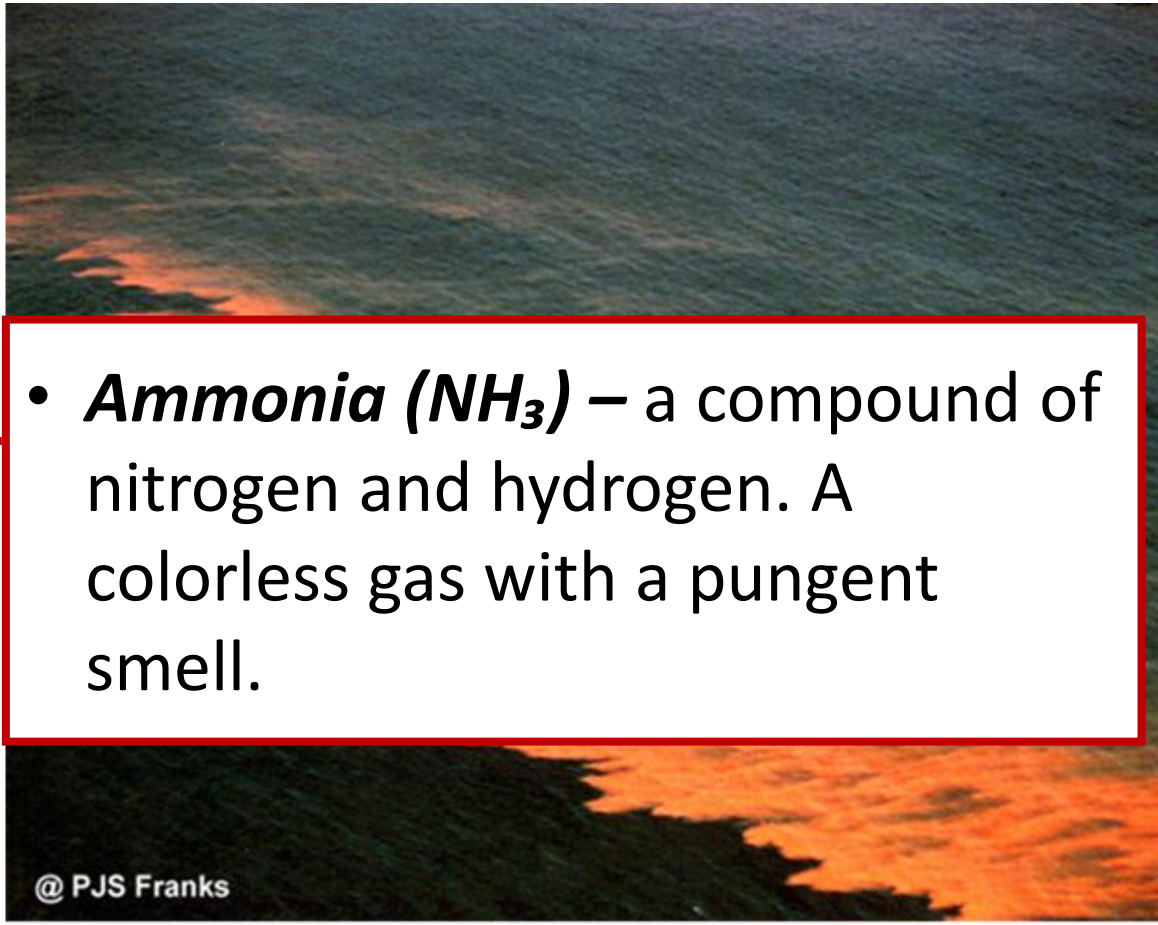
Courtesy: Dr. Isaac Cheung

Environmental Impacts

- Discoloration of water
- Oxygen depletion
- Potential ammonium toxicity
- Interruption of food web structure

Environmental Impacts

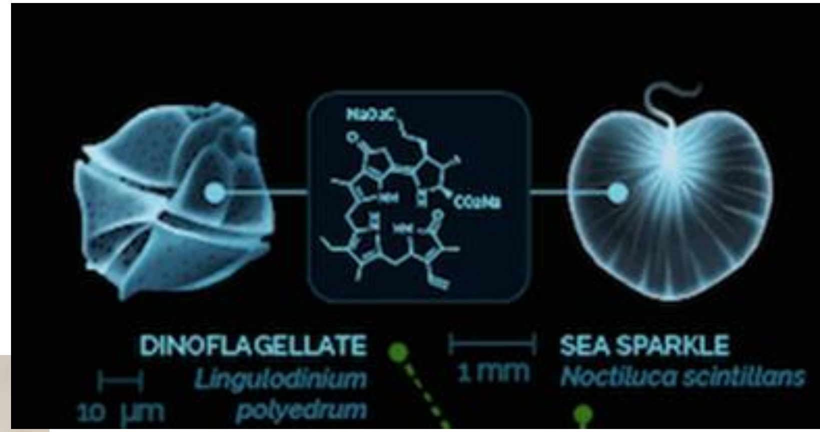
- **Discoloration of water**
- **Oxygen depletion**
- **Potential ammonium toxicity**
- **Interruption of food web structure**

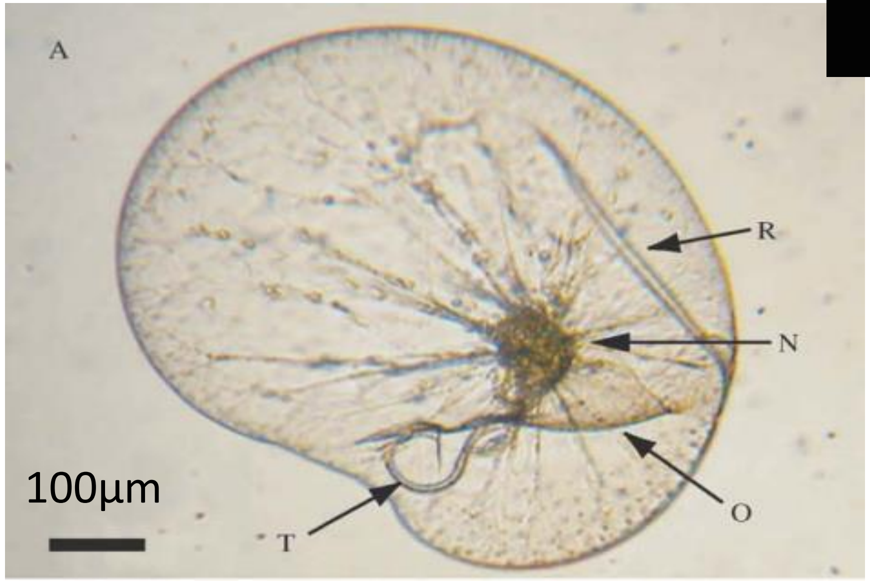


- ***Ammonia (NH_3)* –** a compound of nitrogen and hydrogen. A colorless gas with a pungent smell.

What are *Noctiluca scintillans*?

1. Heterotrophic dinoflagellate
2. Large size (100 - 2,000 µm)
3. Positively buoyant
4. High feeding flexibility
5. Bioluminescence

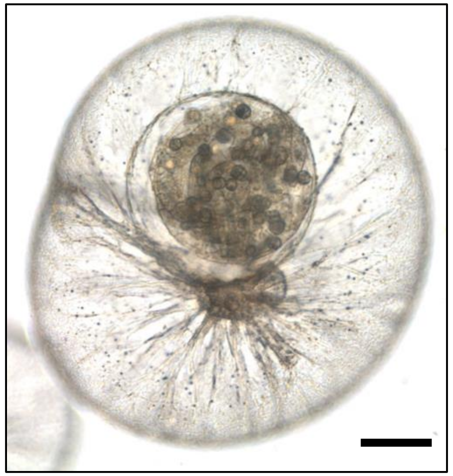




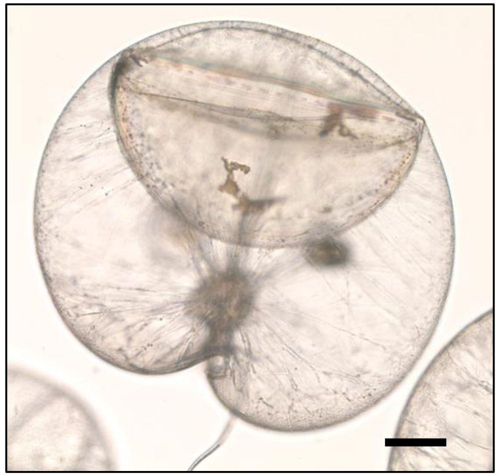
Mature trophont of *Noctiluca scintillans*.
R: rod organ; O: oral pouch; T: tentacle; N: nucleus
(Fukuda & Endoh 2006)

Noctiluca as a Predator

Small diatom



Large diatom



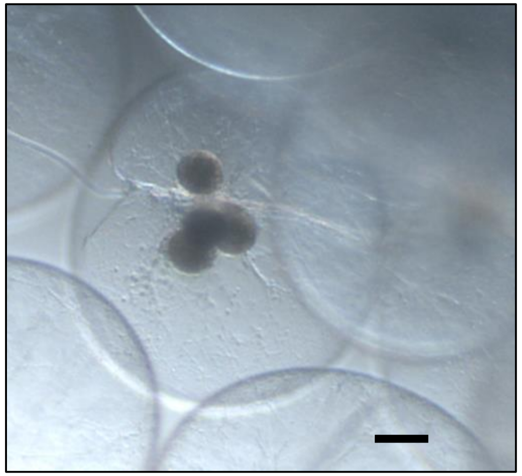
Trichodesmium sp.

Detritus

Tintinnid

Copepod

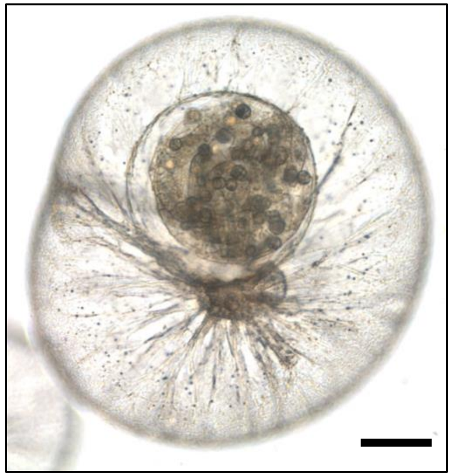
Copepod egg



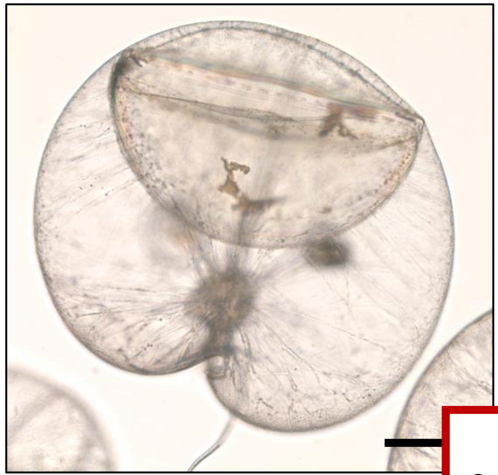
Copepod fecal pellet

Noctiluca as a Predator

Small diatom



Large diatom



***Trichodesmium* sp.**

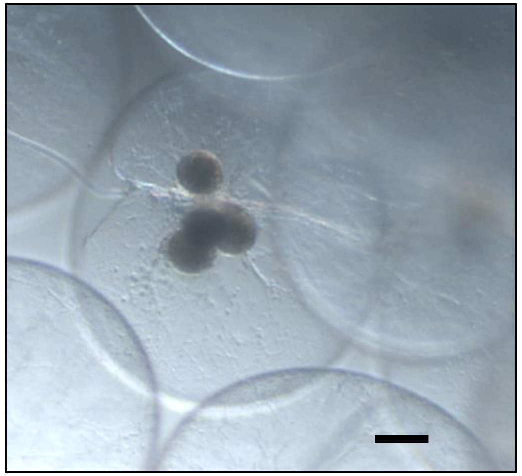
Detritus

- ***Copepods* – microscopic crustaceans**

Tintinnid

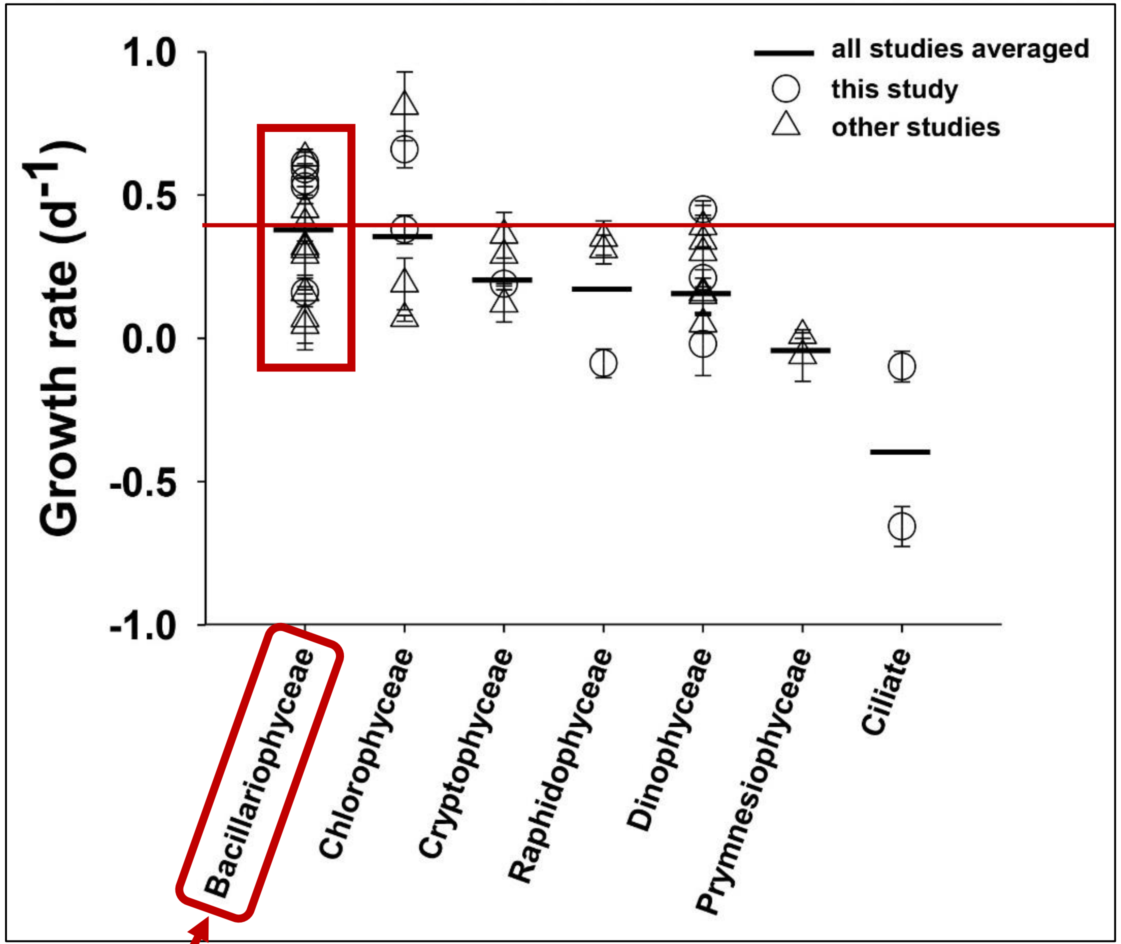
Copepod

Copepod egg



Copepod fecal pellet

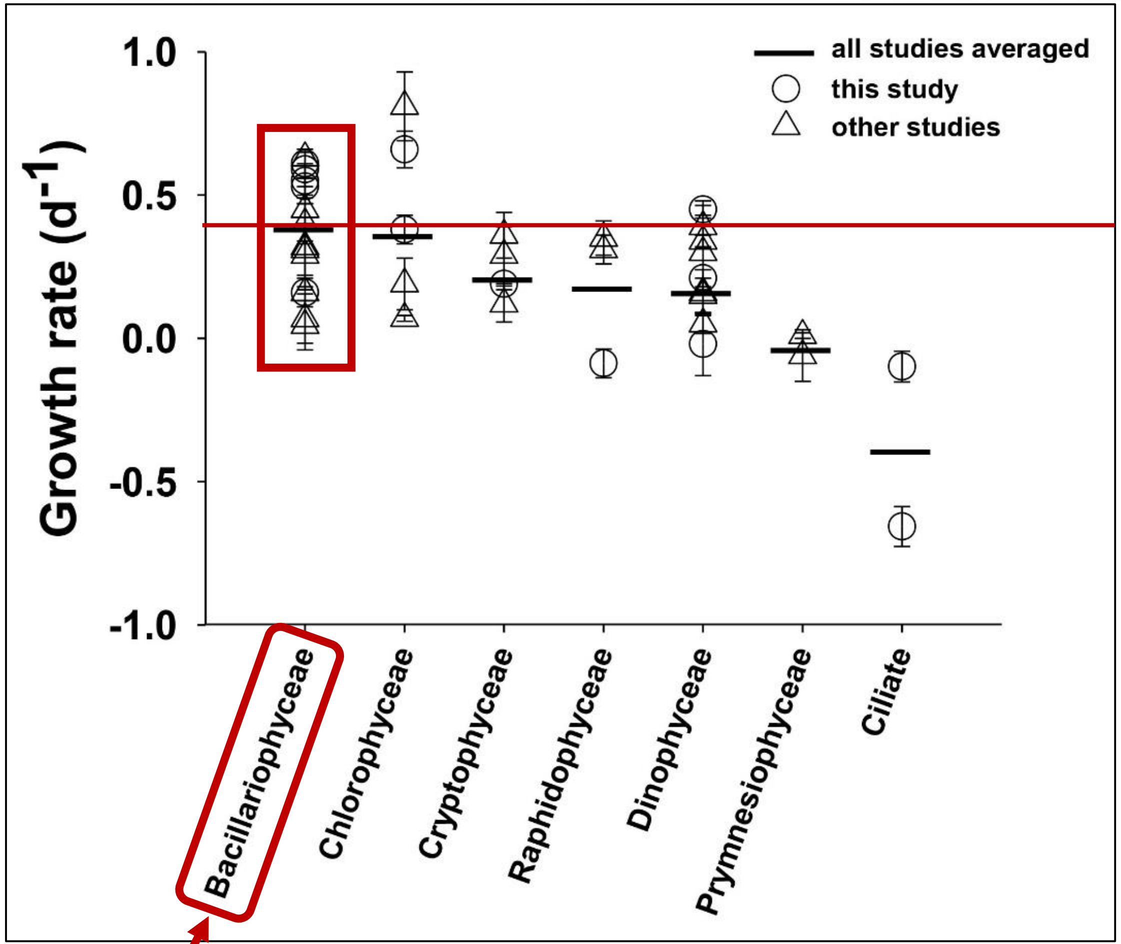
Diatoms – The Most Favorable Food of *Noctiluca*

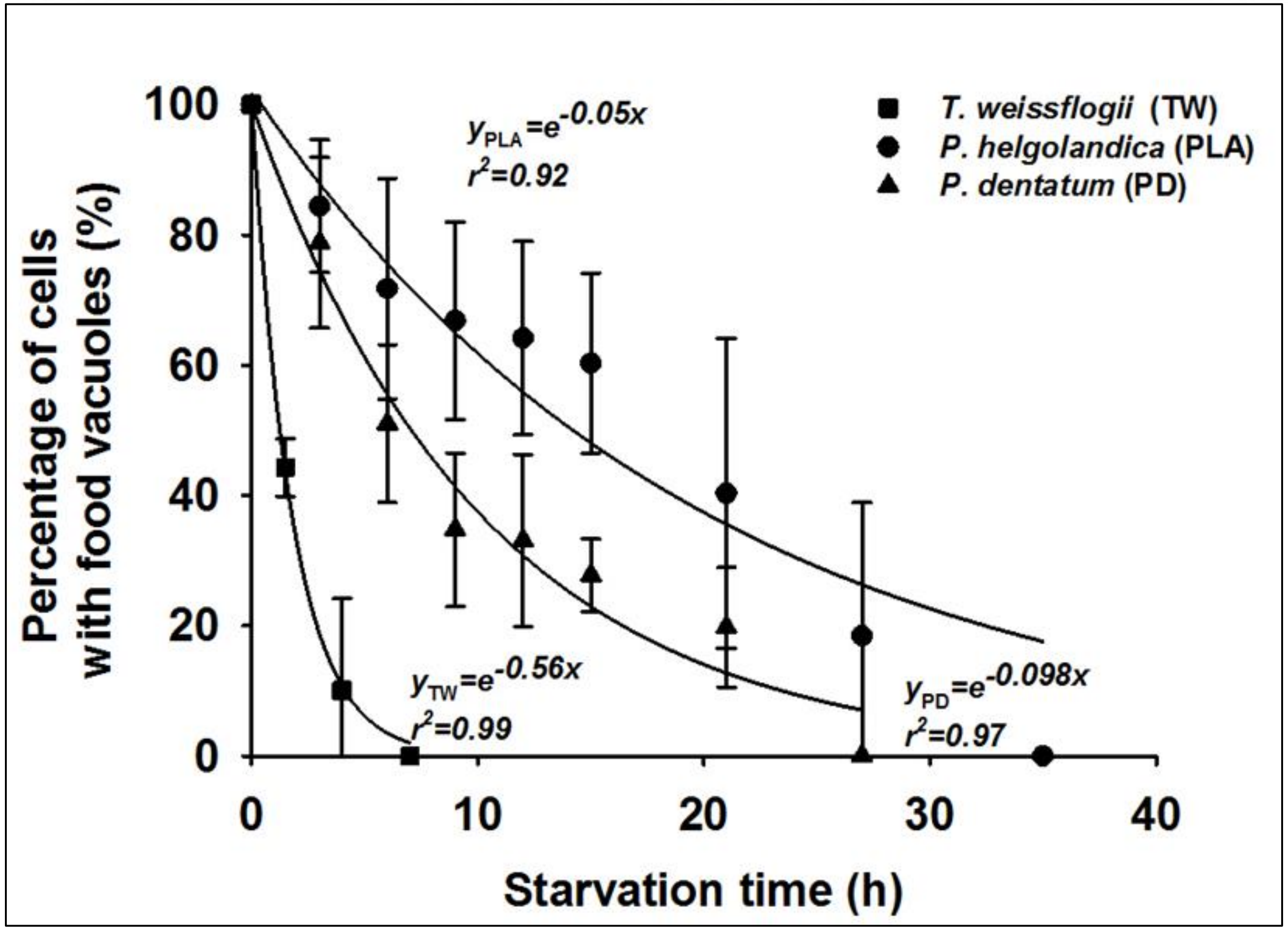


Higher growth rates on diatoms and chlorophytes

Zhang *et al.* (2015, 2016)

Diatoms – The Most Favorable Food of *Noctiluca*



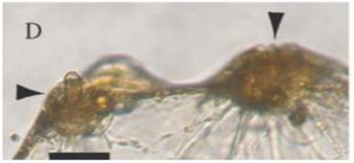


Higher growth rates on diatoms and chlorophytes

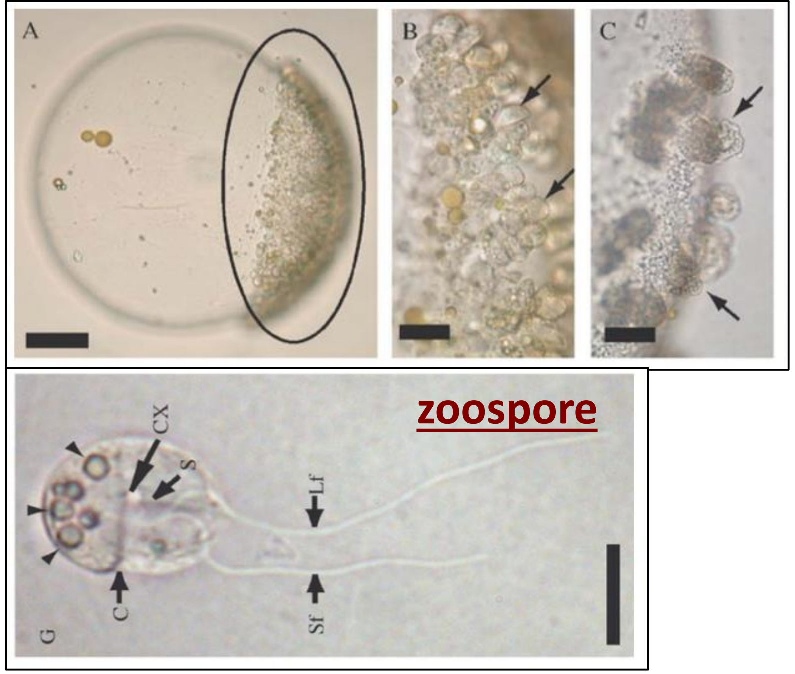
Digest diatoms faster than other prey

Zhang *et al.* (2015, 2016)

Noctiluca – Sexual Reproduction under Suitable Environmental Conditions



Process of gametogenesis
(sexual reproduction)

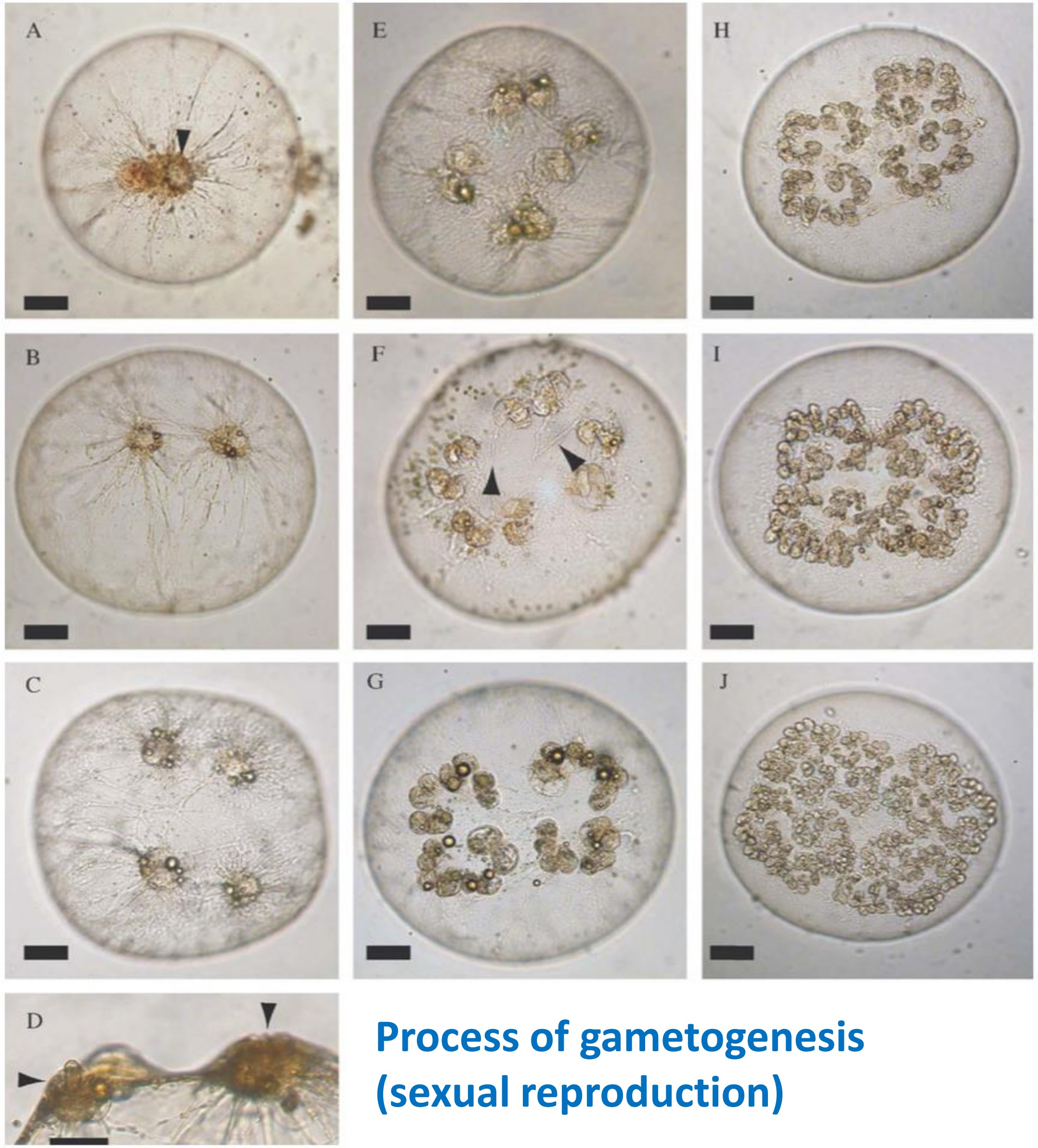


Maturation of gametes (eggs)

Process of *Noctiluca's* sexual reproduction

Fukuda (2006)

Noctiluca – Sexual Reproduction under Suitable Environmental Conditions



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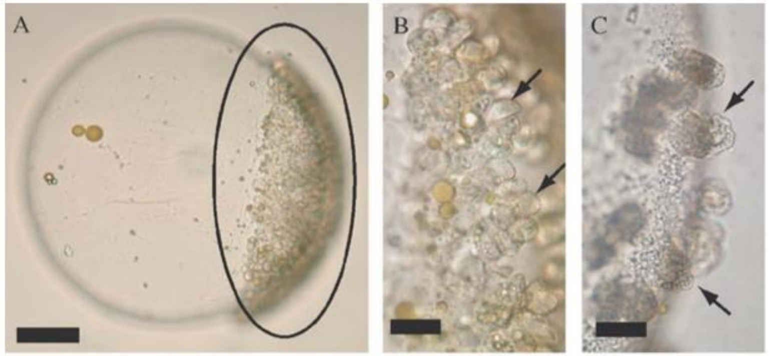
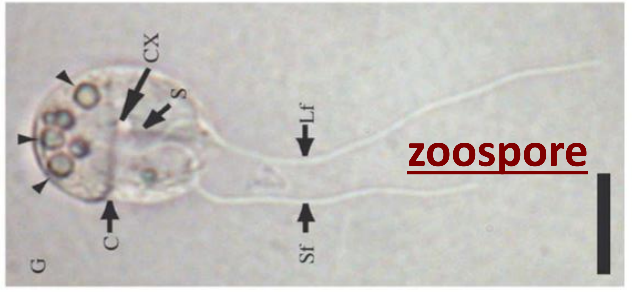




Maturation of gametes (eggs)

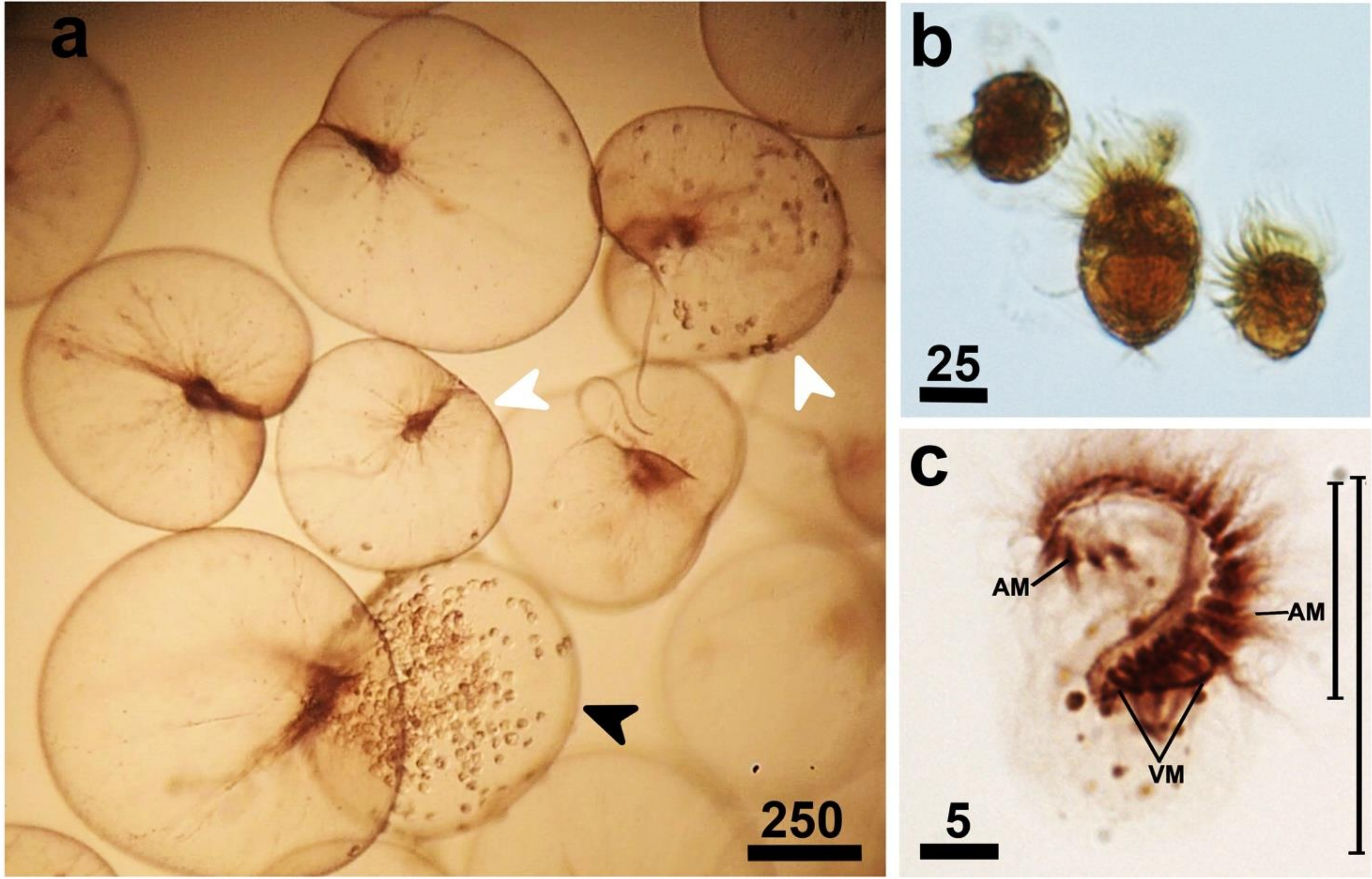
Process of *Noctiluca's* sexual reproduction

Fukuda (2006)

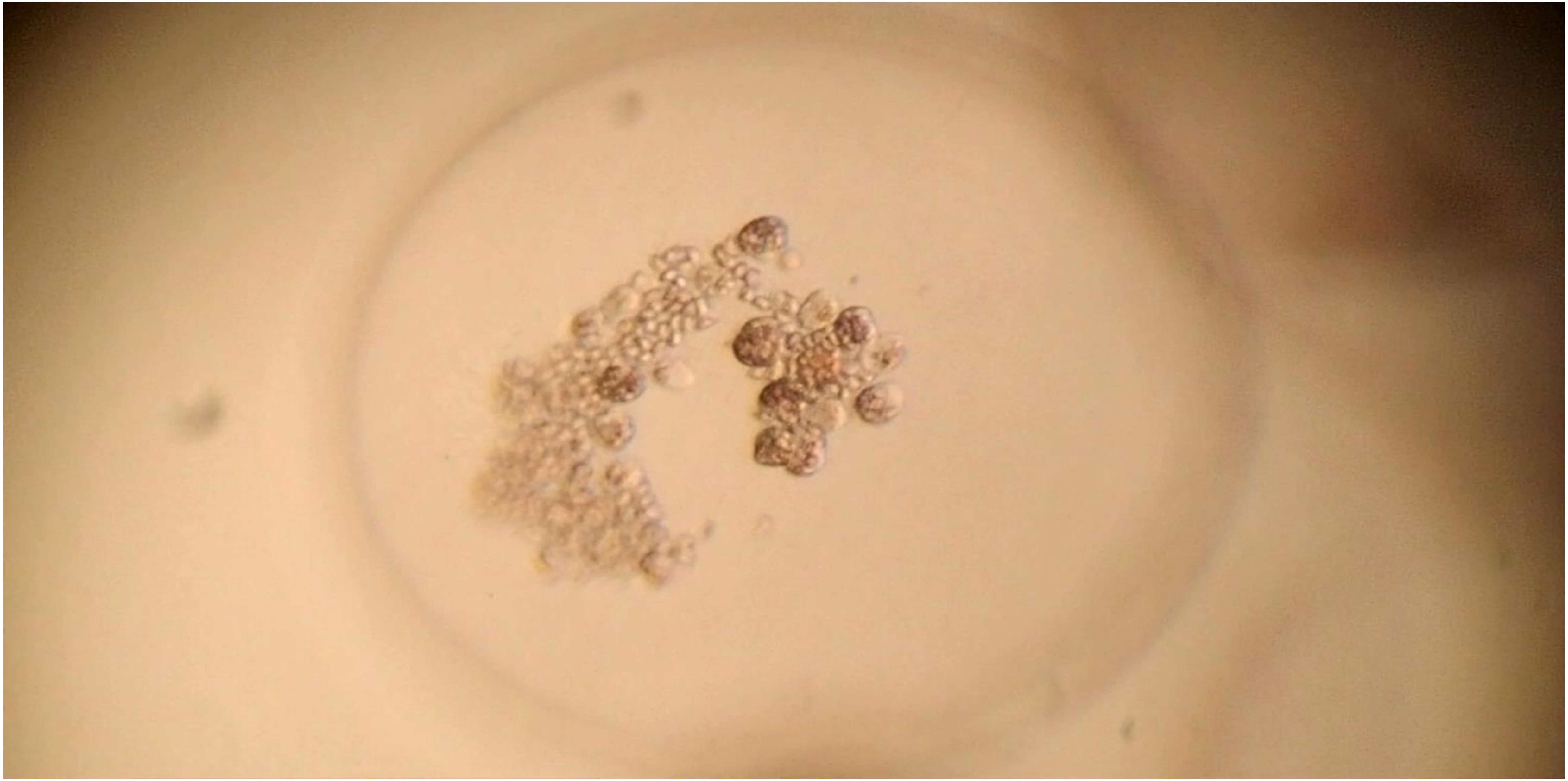
- Can go through sexual reproduction
- Sexual reproduction can produce thousands of gametes (eggs)
- One gamete will produce one Noctiluca cell

Noctiluca – An Atypical "Prey" for Ciliates

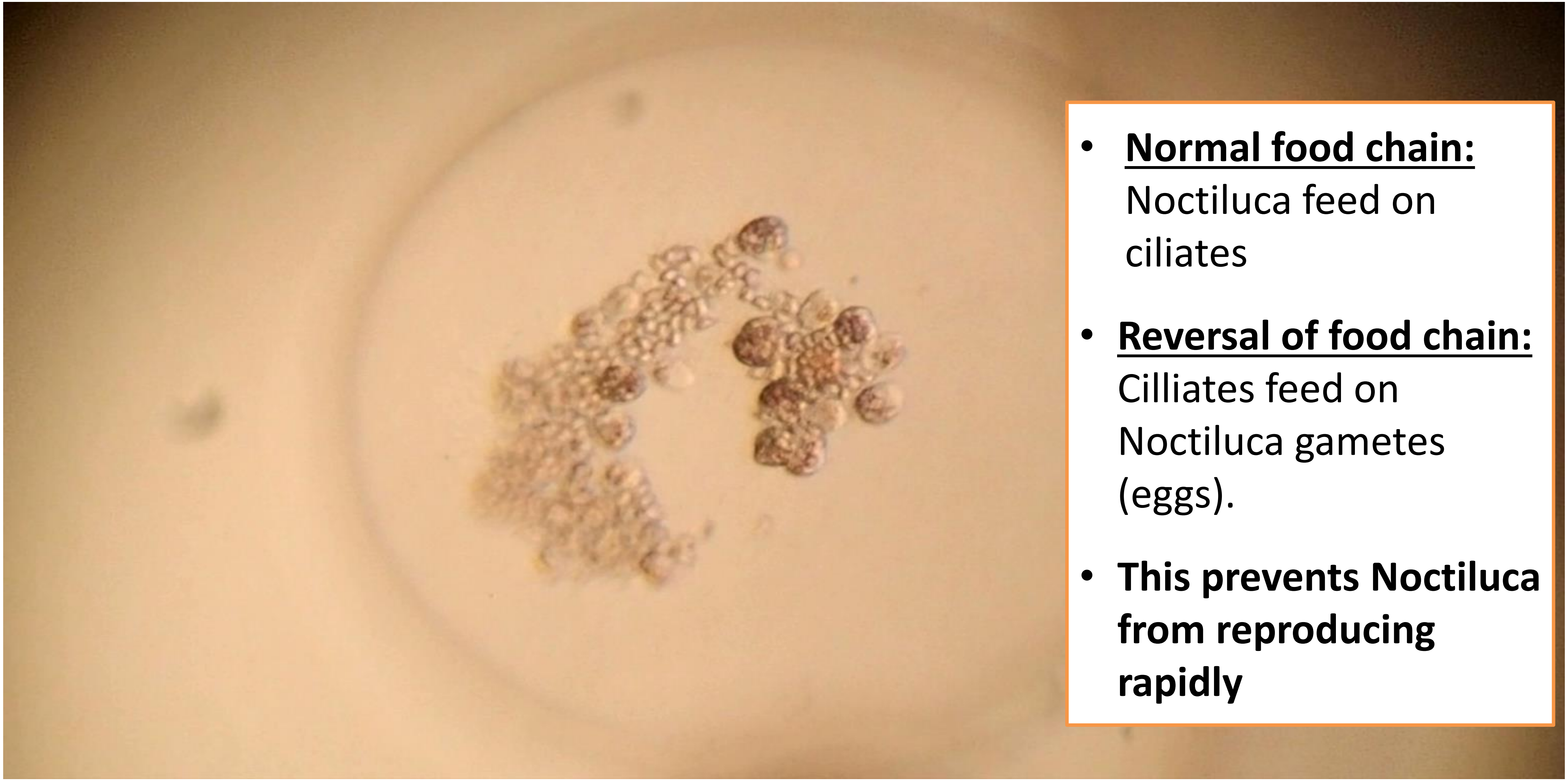
Noctiluca **and swimming organisms**



Strombidium hongkongense swarming on or around gametogenic (black arrow) and vegetative (white arrows) *Noctiluca* cells.



Ciliates feeding on progametes (like eggs) of *Noctiluca.*



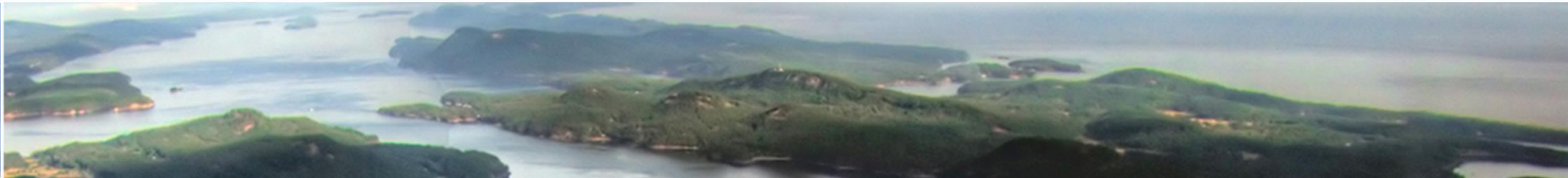
- **<u>Normal food chain:</u>** Noctiluca feed on ciliates
- **<u>Reversal of food chain:</u>** Cilliates feed on Noctiluca gametes (eggs).
- **This prevents Noctiluca from reproducing rapidly**

Ciliates feeding on progametes (like eggs) of *Noctiluca.*

Summary – *Noctiluca* Red Tides

- **What are *Noctiluca scientillans?***
  - A bloom-forming heterotrophic dinoflagellate – the most common red tide species in HK
  - Can cause oxygen depletion, have ammonium toxins and interrupt food web
  - A **predator**, eating everything available, but its **most favorable food is diatoms**
  - Go through sexual reproduction under certain environmental conditions

- **Prof Liu's research team recently discovered that one ciliate species can feed on the progametes of *Noctiluca*, which may reduce the effectiveness of sexual reproduction as a survival or blooming strategy for *Noctiluca*, and potentially shorten the durations of *Noctiluca* blooms**



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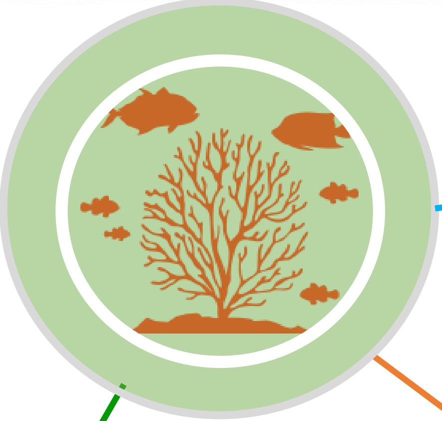
Overall Summary:

Marine Ecosystems – The Intertidal, Estuaries & The Subtidal

Marine Ecosystems – The Subtidal, Estuaries, and the Intertidal



Subtidal Zone

Always submerged

- ❑ Unvegetated Areas
- ❑ Kelp Forests
- ❑ Seagrass Beds
- ❑ Coral Reefs

Coastal Eutrophication

- ❑ Harmful Algal Blooms & Effects
- ❑ *Noctiluca Blooms*

Intertidal Zone

***Not always* submerged**

- ❑ Rocky Shores
- ❑ Sandy and Muddy Shores

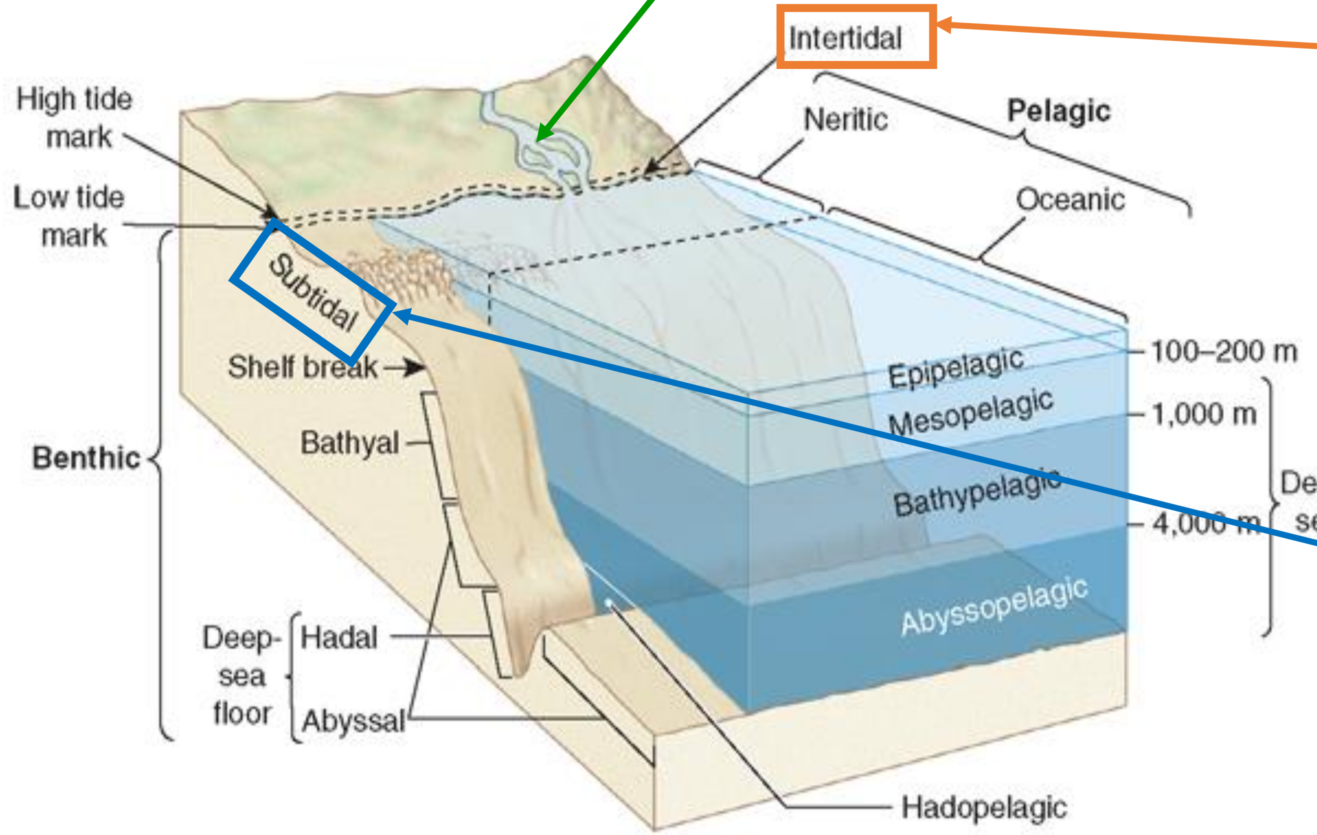
Estuaries

Where rivers *meet* the sea

- ❑ Salt Marshes
- ❑ Mangroves

Some Subdivisions of the Marine Environment

- **Estuaries**
  - Partially enclosed coastal regions where **fresh water from rivers meets and mixes with seawater**



- **Intertidal Zone (Littoral Zone)**
  - At the boundary between land and sea
  - **Under water at high tide, exposed to air at low tide** (i.e. exposed to air at least once a day)
  - The only part of the marine environment that faces **regular exposure to air**

- **Subtidal Zone (Sublittoral Zone)**
  - Below the low tide level to edge of continental shelf (shelf break)
  - **Always submerged** (even at the lowest of low tides)

Subtidal and Intertidal

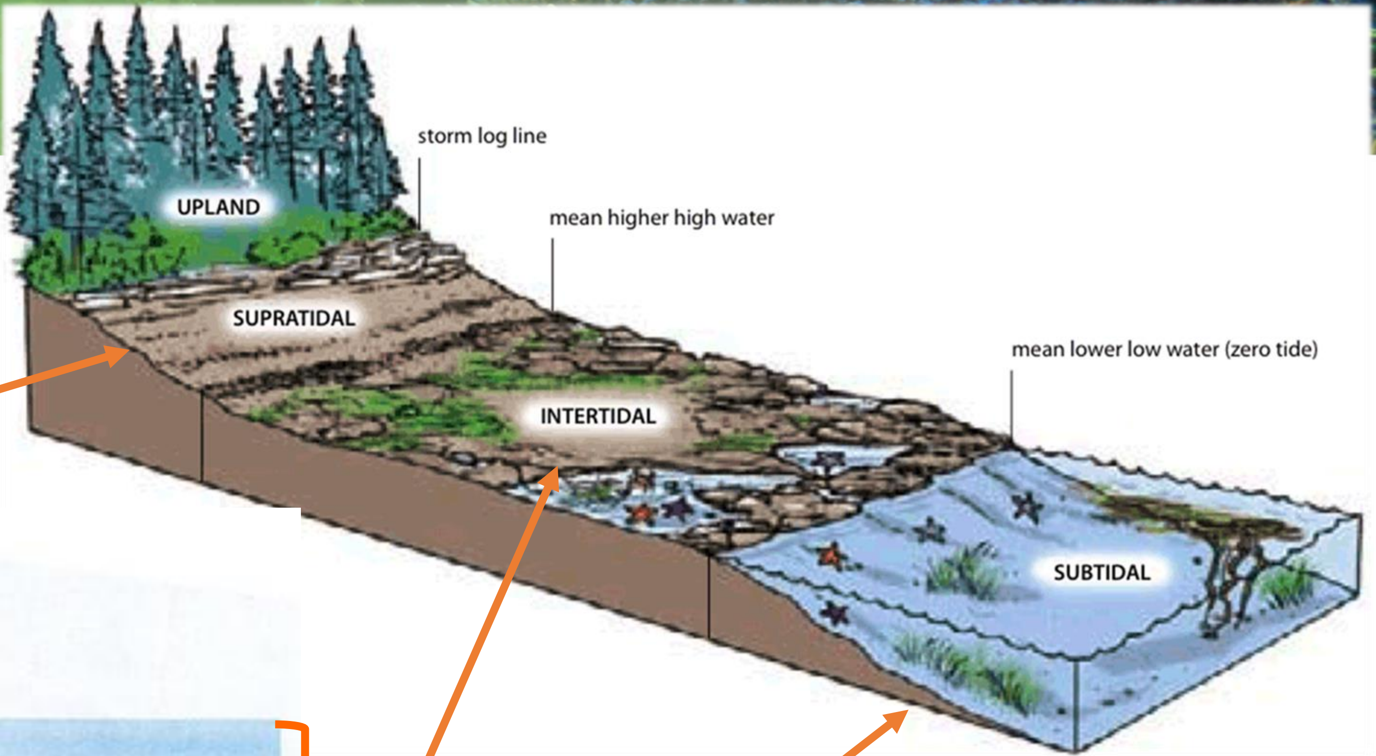


Image: Geocaching.com

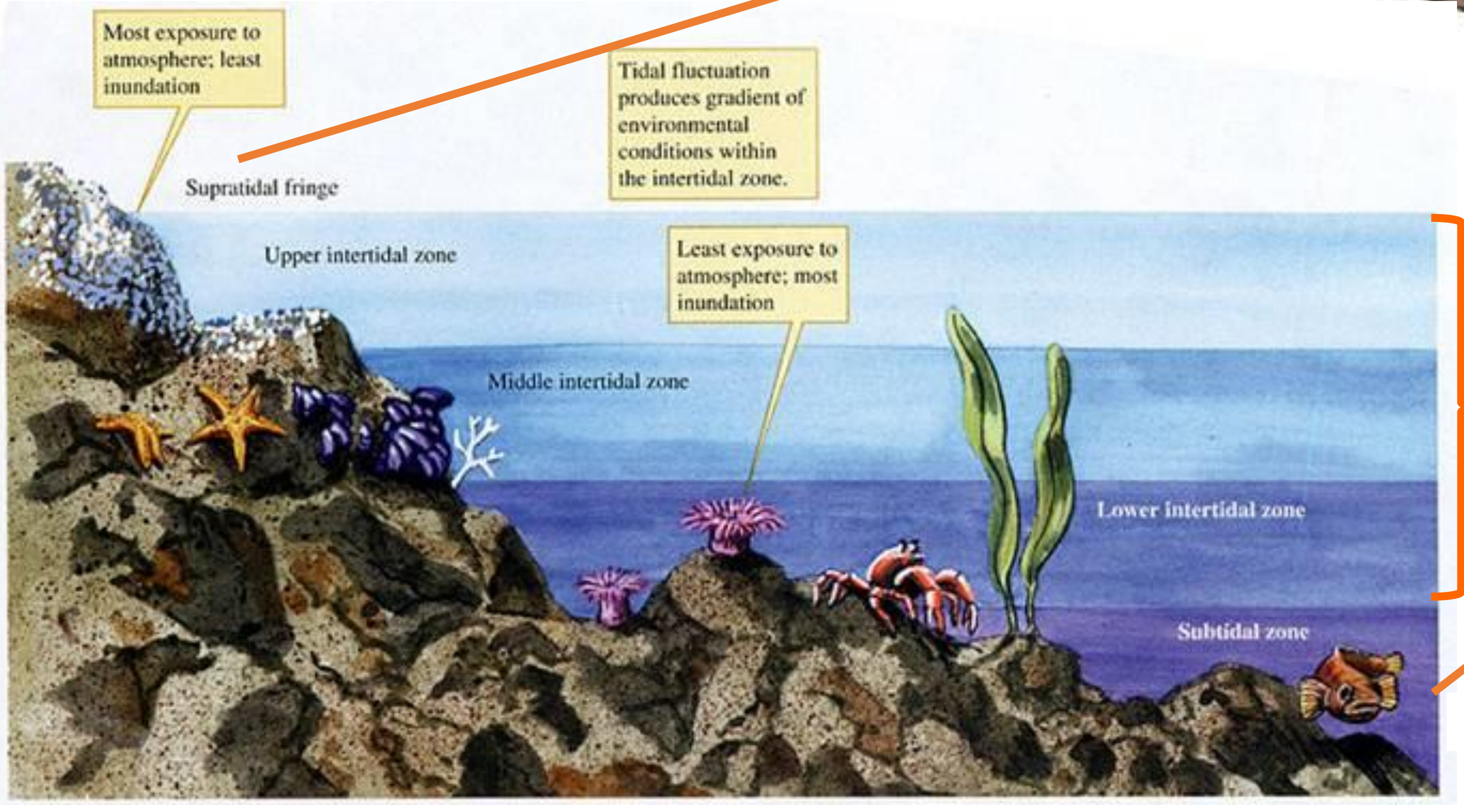


Image: South China Normal University

Summary

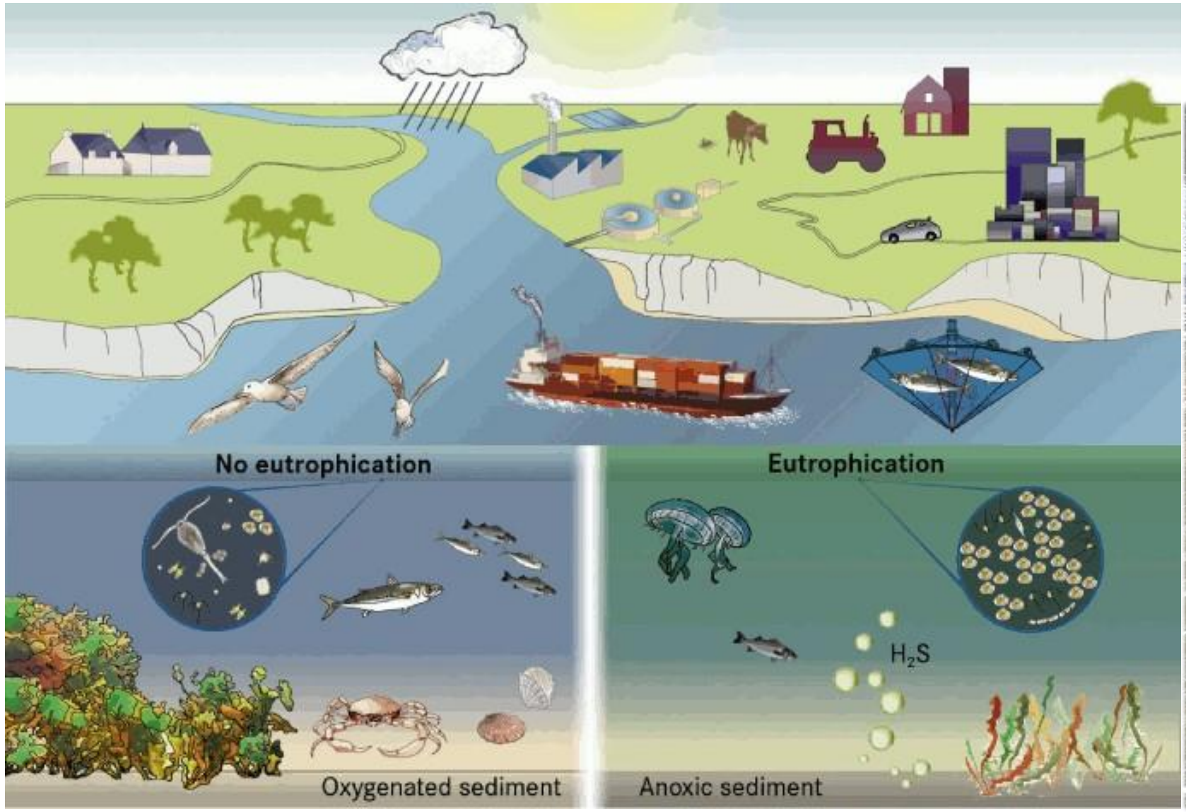
Coastal, intertidal and subtidal zones have valuable biodiverse marine ecosystems but most vulnerable to human impacts.

- **Subtidal (always submerged):**
  - **More stable environment** than intertidal because it is always submerged
  - **Kelp Forests** – hard bottoms; **Seagrass Beds** – mostly soft bottoms
  - **Coral Reefs** – one of the most biodiverse and productive ecosystems on Earth
- **Intertidal (submerged at high tides, exposed at low tides):**
  - **Unstable environment:** drastic changes in desiccation, temperature, salinity, & O_2 in different sediment types, etc.
  - **Rocky Shore Challenges:** Limited space; upper limit – physical challenges, lower limit – biological challenges
  - **Muddy Shore Challenges:** Anoxic conditions
- **Hard Bottoms:** More wave action; rocky; **epifauna** more abundant; organisms **attach** to the hard substrates
- **Soft Bottoms:** Less wave action; muddy; **infauna** more abundant; organisms usually **burrow**; deposit and suspension feeders; food web centered around detritus
- **Estuaries – where rivers (fresh water) meet the sea**
  - **Habitats:** Mudflats, Salt Marshes, Mangroves
  - **Special adaptations** (e.g. mangrove roots)

Coastal Eutrophication & Harmful Algal Blooms (HABs)

Coastal Eutrophication

- Caused by **human activities**
- Leads to **serious environmental problems and health problems** (e.g. HABs, hypoxia, fish kills, food poisoning)



Why are These Topics Important?

- After learning the basics of marine life, this Module presents students with an ecological tour of the **diversity and beauty of the major marine ecosystems**, as well as some insights on **why these ecosystems are important to the wildlife and humans**.

- **Human impacts:** Habitat degradation, pollution, overfishing, urban development

- **Climate change:** Sea level rise, global warming, increase in extreme weathers

- **More studies need to be done**