8.2 THREATS TO OCEANS AND COASTAL ECOSYSTEMS

College Board Topics 8.2, 8.4, 9.6, and 9.7

Related Reading: Chapter 16, especially pages 432 -437

Learning Objectives and Essential Knowledge

ENDURING UNDERSTANDING

STB-3

Human activities, including the use of resources, have physical, chemical, and biological consequences for ecosystems.

LEARNING OBJECTIVE

STB-3.B

Describe the impacts of human activities on aquatic ecosystems.

ESSENTIAL KNOWLEDGE

STB-3.B.1

Organisms have a range of tolerance for various pollutants. Organisms have an optimum range for each factor where they can maintain homeostasis. Outside of this range, organisms may experience physiological stress, limited growth, reduced reproduction, and in extreme cases, death.

STB-3.B.2

Coral reefs have been suffering damage due to a variety of factors, including increasing ocean temperature, sediment runoff, and destructive fishing practices.

STB-3.B.3

Oil spills in marine waters cause organisms to die from the hydrocarbons in oil. Oil that floats on the surface of water can coat the feathers of birds and fur of marine mammals. Some components of oil sink to the ocean floor, killing some bottom-dwelling organisms.

STB-3.B.4

Oil that washes up on the beach can have economic consequences on the fishing and tourism industries.

STB-3.B.8

Litter that reaches aquatic ecosystems, besides being unsightly, can create intestinal blockage and choking hazards for wildlife and introduce toxic substances to the food chain.

ENDURING UNDERSTANDING

STB-4

Local and regional human activities can have impacts at the global level.

LEARNING OBJECTIVE

STB-4.G

Explain the causes and effects of ocean warming.

ESSENTIAL KNOWLEDGE

STB-4.G.1

Ocean warming is caused by the increase in greenhouse gases in the atmosphere.

STB-4.G.2

Ocean warming can affect marine species in a variety of ways, including loss of habitat, and metabolic and reproductive changes.

STB-4.G.3

Ocean warming is causing coral bleaching, which occurs when the loss of algae within corals cause the corals to bleach white. Some corals recover and some die.

LEARNING OBJECTIVE

STB-4.H

Explain the causes and effects of ocean acidification.

ESSENTIAL KNOWLEDGE

STB-4.H.1

Ocean acidification is the decrease in pH of the oceans, primarily due to increased CO_2 concentrations in the atmosphere, and can be expressed as chemical equations.

STB-4.H.2

As more CO_2 is released into the atmosphere, the oceans, which absorb a large part of that CO_2, become more acidic.

STB-4.H.3

Anthropogenic activities that contribute to ocean acidification are those that lead to increased CO_2 concentrations in the atmosphere: burning of fossil fuels, vehicle emissions, and deforestation.

STB-4.H.4

Ocean acidification damages coral because acidification makes it difficult for them to form shells, due to the loss of calcium carbonate.

SUGGESTED SKILL

Concept Explanation

1.C

Explain environmental concepts, processes, or models in applied contexts.

SUGGESTED SKILL

Environmental Solutions

7.A

Describe environmental problems.

SUGGESTED SKILL

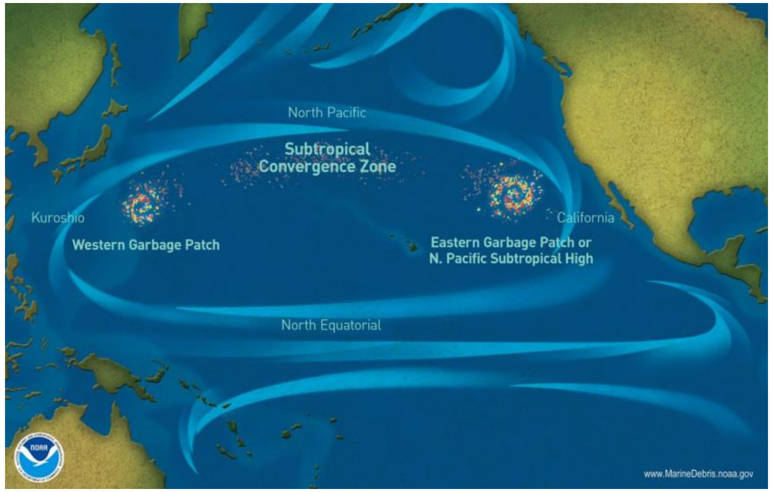
Mathematical Routines

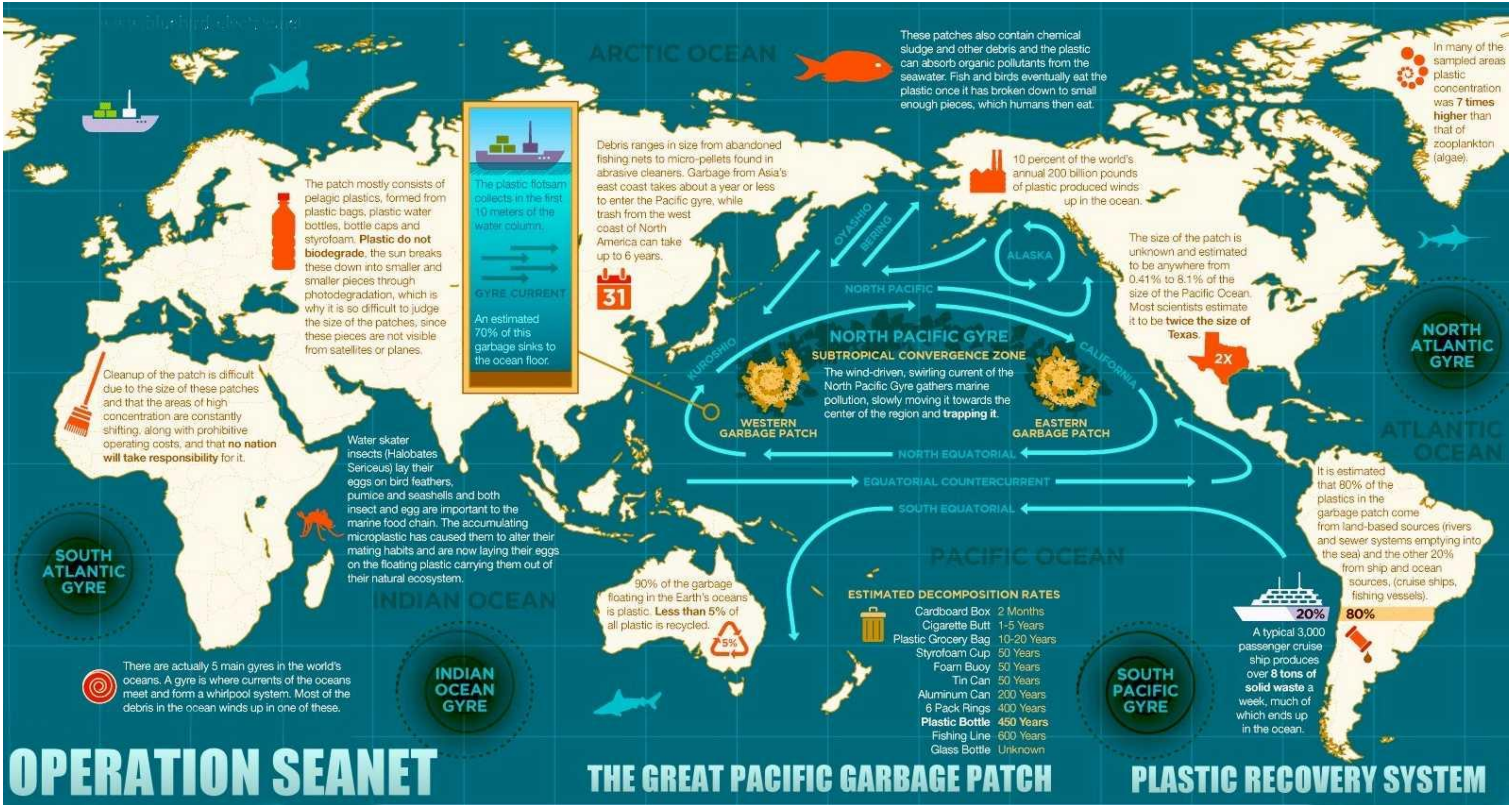
6.B

Apply appropriate mathematical relationships to solve a problem, with work shown (e.g., dimensional analysis).

Litter and Plastics

- Litter that reaches aquatic ecosystems is unsightly and endangers wildlife
  - Plastic debris is especially durable, often drifting for decades before breaking up into tiny pieces.
  - Like chemical pollutants, plastic and other forms of litter eventually washes out of watersheds and into oceans.
- Areas where circulating currents converge called ***gyres*** bring and trap plastic trash
  - The North Pacific Gyre contains the ***Great Pacific Garbage Patch***; an area larger than Texas where floating plastic bits outnumber organisms by a 6 to 1 margin
  - Mainly ***microplastics*** that are extremely difficult to collect.



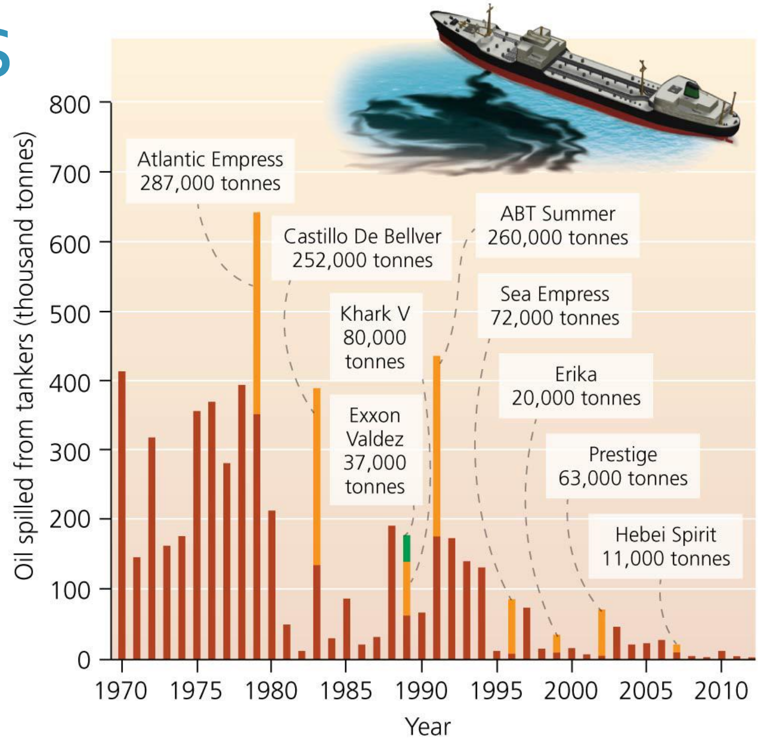

ARCTIC OCEAN
These patches also contain chemical sludge and other debris and the plastic can absorb organic pollutants from the seawater. Fish and birds eventually eat the plastic once it has broken down to small enough pieces, which humans then eat.
In many of the sampled areas plastic concentration was 7 times higher than that of zooplankton (algae).
The patch mostly consists of pelagic plastics, formed from plastic bags, plastic water bottles, bottle caps and styrofoam. Plastic do not biodegrade, the sun breaks these down into smaller and smaller pieces through photodegradation, which is why it is so difficult to judge the size of the patches, since these pieces are not visible from satellites or planes.
The plastic flotsam collects in the first 10 meters of the water column.
GYRE CURRENT
An estimated 70% of this garbage sinks to the ocean floor.
Debris ranges in size from abandoned fishing nets to micro-pellets found in abrasive cleaners. Garbage from Asia's east coast takes about a year or less to enter the Pacific gyre, while trash from the west coast of North America can take up to 6 years.
31
10 percent of the world's annual 200 billion pounds of plastic produced winds up in the ocean.
OYASHIO
BERING
ALASKA
NORTH PACIFIC
KUROSHIO
CALIFORNIA
The size of the patch is unknown and estimated to be anywhere from 0.41% to 8.1% of the size of the Pacific Ocean. Most scientists estimate it to be twice the size of Texas.
2X
NORTH ATLANTIC GYRE
NORTH PACIFIC GYRE
SUBTROPICAL CONVERGENCE ZONE
The wind-driven, swirling current of the North Pacific Gyre gathers marine pollution, slowly moving it towards the center of the region and trapping it.
WESTERN GARBAGE PATCH
EASTERN GARBAGE PATCH
ATLANTIC OCEAN
Cleanup of the patch is difficult due to the size of these patches and that the areas of high concentration are constantly shifting, along with prohibitive operating costs, and that no nation will take responsibility for it.
Water skater insects (Halobates Sericeus) lay their eggs on bird feathers, pumice and seashells and both insect and egg are important to the marine food chain. The accumulating microplastic has caused them to alter their mating habits and are now laying their eggs on the floating plastic carrying them out of their natural ecosystem.
NORTH EQUATORIAL
EQUATORIAL COUNTERCURRENT
SOUTH EQUATORIAL
It is estimated that 80% of the plastics in the garbage patch come from land-based sources (rivers and sewer systems emptying into the sea) and the other 20% from ship and ocean sources, (cruise ships, fishing vessels).
SOUTH ATLANTIC GYRE
PACIFIC OCEAN
INDIAN OCEAN
90% of the garbage floating in the Earth's oceans is plastic. Less than 5% of all plastic is recycled.
5%
ESTIMATED DECOMPOSITION RATES
Cardboard Box 2 Months
Cigarette Butt 1-5 Years
Plastic Grocery Bag 10-20 Years
Styrofoam Cup 50 Years
Foam Buoy 50 Years
Tin Can 50 Years
Aluminum Can 200 Years
6 Pack Rings 400 Years
Plastic Bottle 450 Years
Fishing Line 600 Years
Glass Bottle Unknown
20%
80%
A typical 3,000 passenger cruise ship produces over 8 tons of solid waste a week, much of which ends up in the ocean.
There are actually 5 main gyres in the world's oceans. A gyre is where currents of the oceans meet and form a whirlpool system. Most of the debris in the ocean winds up in one of these.
INDIAN OCEAN GYRE
SOUTH PACIFIC GYRE
OPERATION SEANET
THE GREAT PACIFIC GARBAGE PATCH
PLASTIC RECOVERY SYSTEM

Plastic debris endangers wildlife

- Marine plastics are estimated to cause the deaths of 100,000 marine mammals and 1 million seabirds each year.
- Wildlife mistake small pieces of plastic for plankton or fish eggs leading to ingestion.
  - One study showed plankton eating fish in the Great Pacific Garbage Patch had an average of 2.1 pieces of plastic their digestive system.
  - Another study attributed 40% of premature Albatross chick deaths to plastics regurgitated by the parents.
  - Ingestion of plastics can present choking hazards to wildlife and cause intestinal blockages.
- Plastics can have toxic effects on wildlife.
  - Plastics contain harmful substances (Bisphenol A and phthalates) which can leach into the digestive tracts of organisms.
  - Persistent organic pollutant's (POP's) such as dioxins and PCB's adhere to plastics and increase their toxicity.
- Plastics and other debris also pose the risk of entanglement, which can result in suffocation or exhaustion in wildlife.

Oil pollution comes from spills of all sizes

- **Non-point sources produce most oil pollution**
  - Natural seeps and small spills from private boats
- **About 30% of all oil and 50% of all natural gas come from seafloor deposits.**
  - North Sea and Gulf of Mexico have the largest deposits
  - Offshore drilling in some places is banned, especially where spills could harm valuable fisheries
- **In 2010 the *Deepwater Horizon* oil well exploded**
  - Spilled 1800 gallons/min for 3 months (≈ 670,000 metric tons total); hit coasts of four states on the gulf coast.



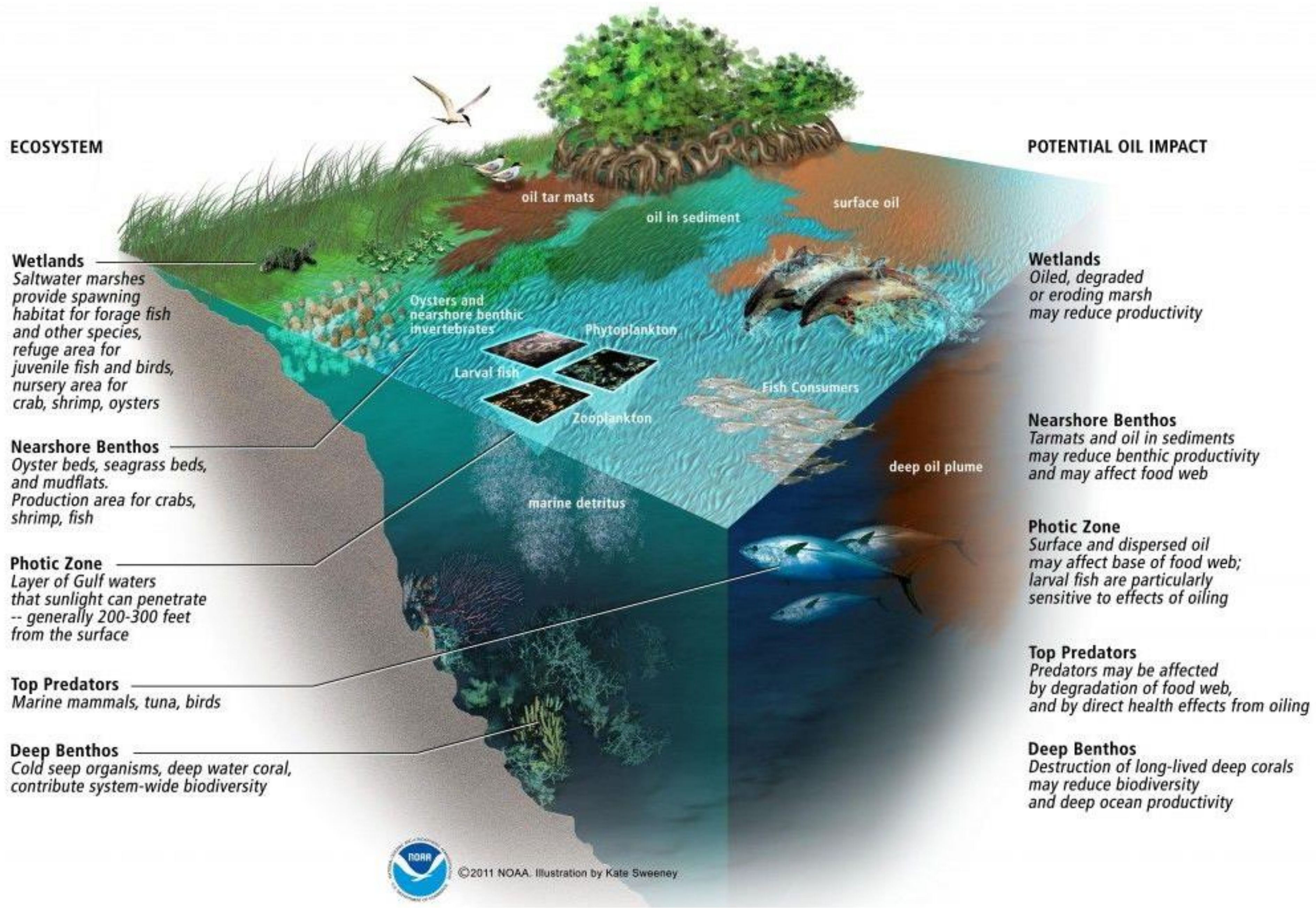
(c) Quantity of petroleum spilled from oil tankers, 1970–2012

- **In 1989 Exxon Valdez, a U.S. oil tanker, ran aground off the coast of Alaska**
  - largest tanker spill in U.S. History (37,000 metric tons)
  - Oil tankers are now required to have double hulls to prevent spills after sustaining damage.

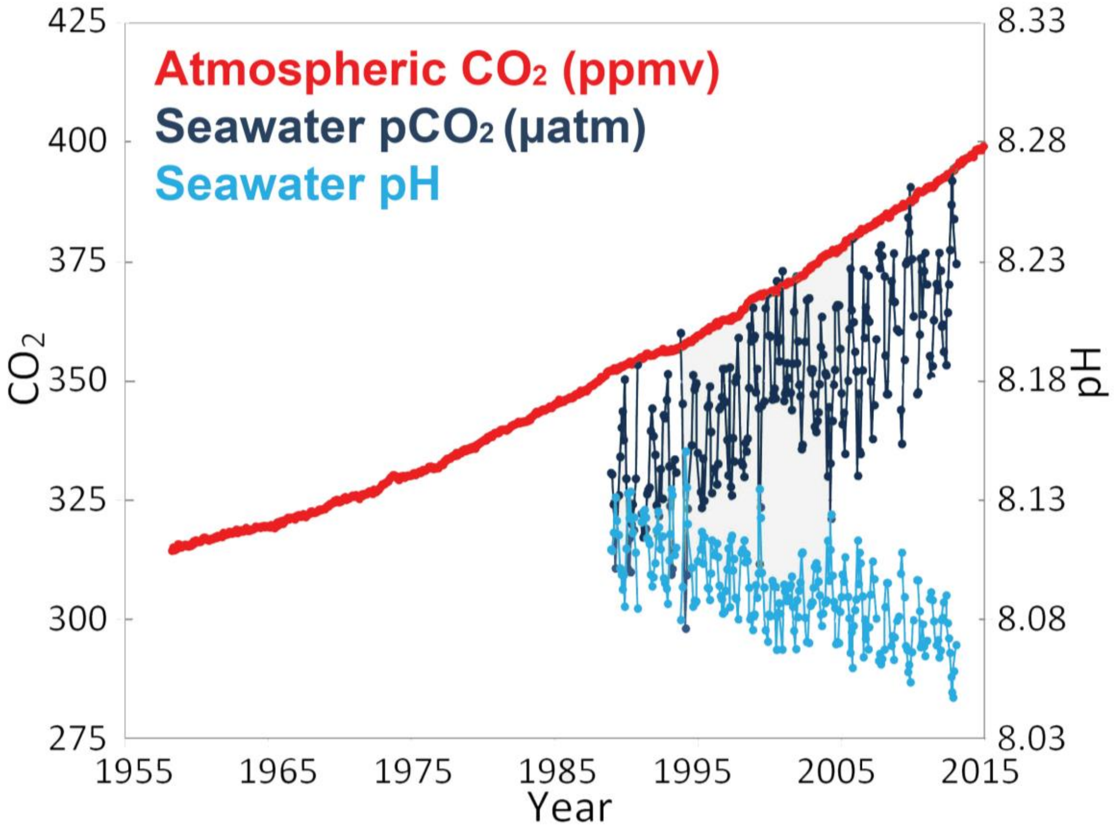
The impacts of oil spills

- **Organisms may be killed by smothering, ingesting, inhaling or absorbing oil**
  - Fish gills become coated, reducing gas exchange.
  - Birds may loose buoyancy as oil coats feathers.
  - Marine mammals become more prone to hypothermia.
  - Decreased light penetration reduces photosynthesis and undermines the base of marine food chains.

- **Preventing oil spills is easier than clean up.**
- Chemical dispersants
  - Break down oils into smaller droplets, diluting the concentration, and reducing its toxicity. Does not decrease volume of oil.
  - Tends to increase area affected by spill, but reduce the concentration; dispersants are toxic themselves.
- Microbes that degrade oil (“eat oil”)
- Burning oil off of the surface of the water
- Use of skimmers to collect oil on the surface and floating booms to keep it contained
- Using absorbent material (e.g. straw) to soak up the oil as it washes ashore
- Physically cleaning rocks and organisms along affected coast line

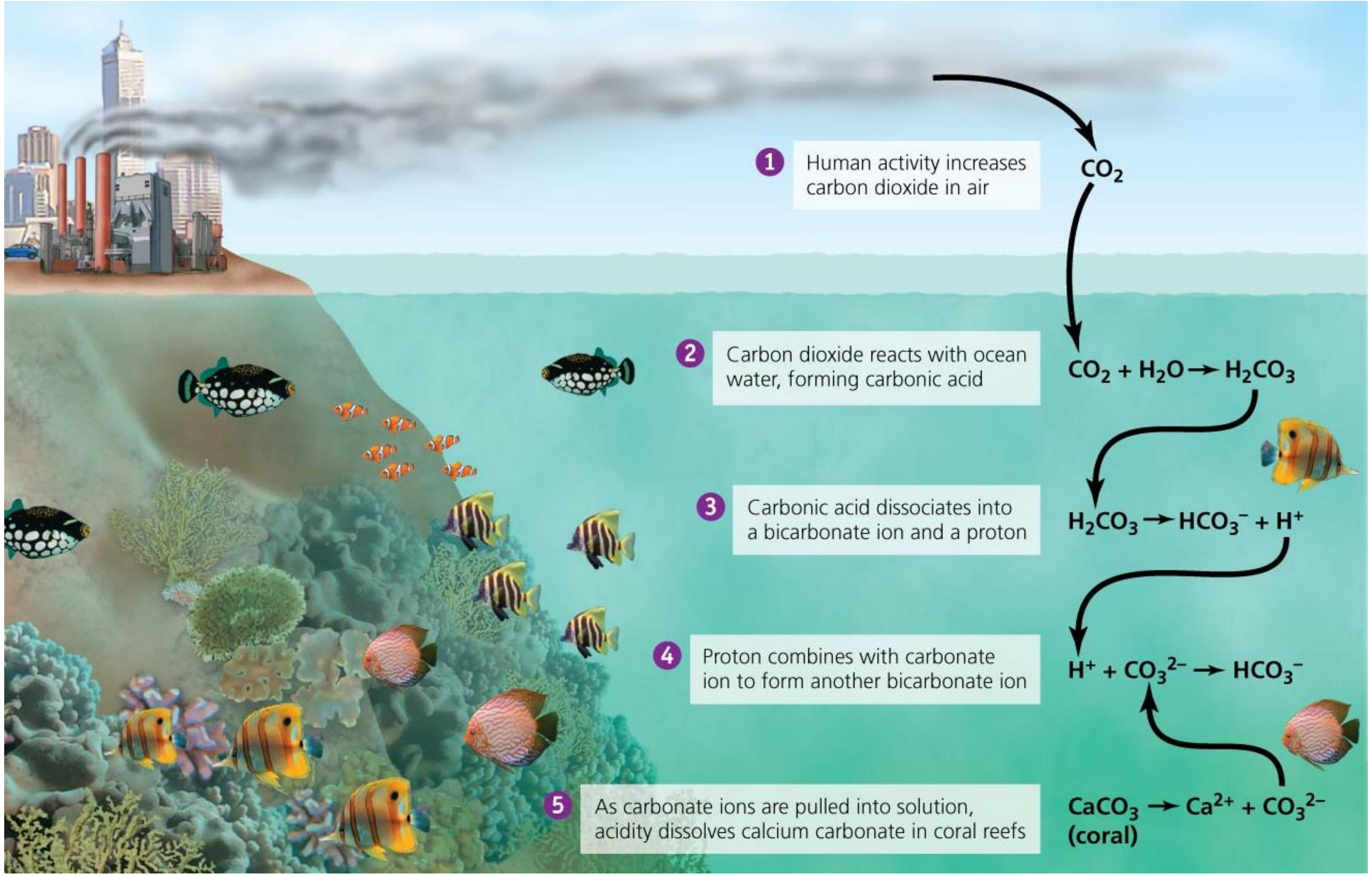

ECOSYSTEM
POTENTIAL OIL IMPACT
oil tar mats
oil in sediment
surface oil
Oysters and nearshore benthic invertebrates
Phytoplankton
Larval fish
Zooplankton
Fish Consumers
deep oil plume
marine detritus
Wetlands
Saltwater marshes provide spawning habitat for forage fish and other species, refuge area for juvenile fish and birds, nursery area for crab, shrimp, oysters
Nearshore Benthos
Oyster beds, seagrass beds, and mudflats. Production area for crabs, shrimp, fish
Photic Zone
Layer of Gulf waters that sunlight can penetrate -- generally 200-300 feet from the surface
Top Predators
Marine mammals, tuna, birds
Deep Benthos
Cold seep organisms, deep water coral, contribute system-wide biodiversity
Wetlands
Oiled, degraded or eroding marsh may reduce productivity
Nearshore Benthos
Tarmats and oil in sediments may reduce benthic productivity and may affect food web
Photic Zone
Surface and dispersed oil may affect base of food web; larval fish are particularly sensitive to effects of oiling
Top Predators
Predators may be affected by degradation of food web, and by direct health effects from oiling
Deep Benthos
Destruction of long-lived deep corals may reduce biodiversity and deep ocean productivity
©2011 NOAA. Illustration by Kate Sweeney

Increasing atmospheric CO_2 is altering ocean chemistry



- Burning fossil fuels and deforestation increase atmospheric CO_2.
  - As atmospheric concentrations increase, some of that CO_2 will diffuse into the oceans.
- Oceans have already absorbed a third of the excess carbon emitted to the atmosphere by human activities.
  - Oceans may be reaching their saturation point where they will not be able to absorb more CO_2
  - The rate of climate change would likely accelerate when this point is reached.
- Increased CO_2 in the ocean makes it more acidic.

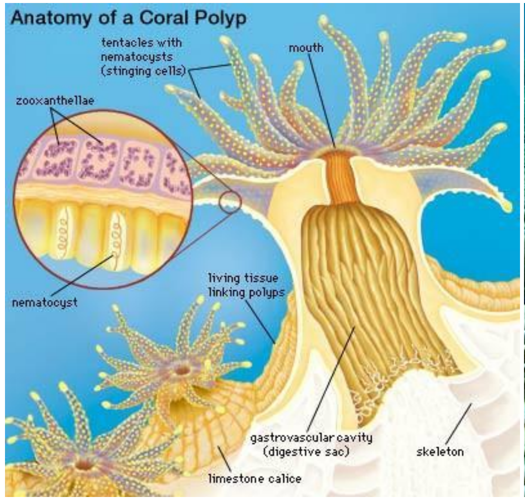
Ocean Acidification

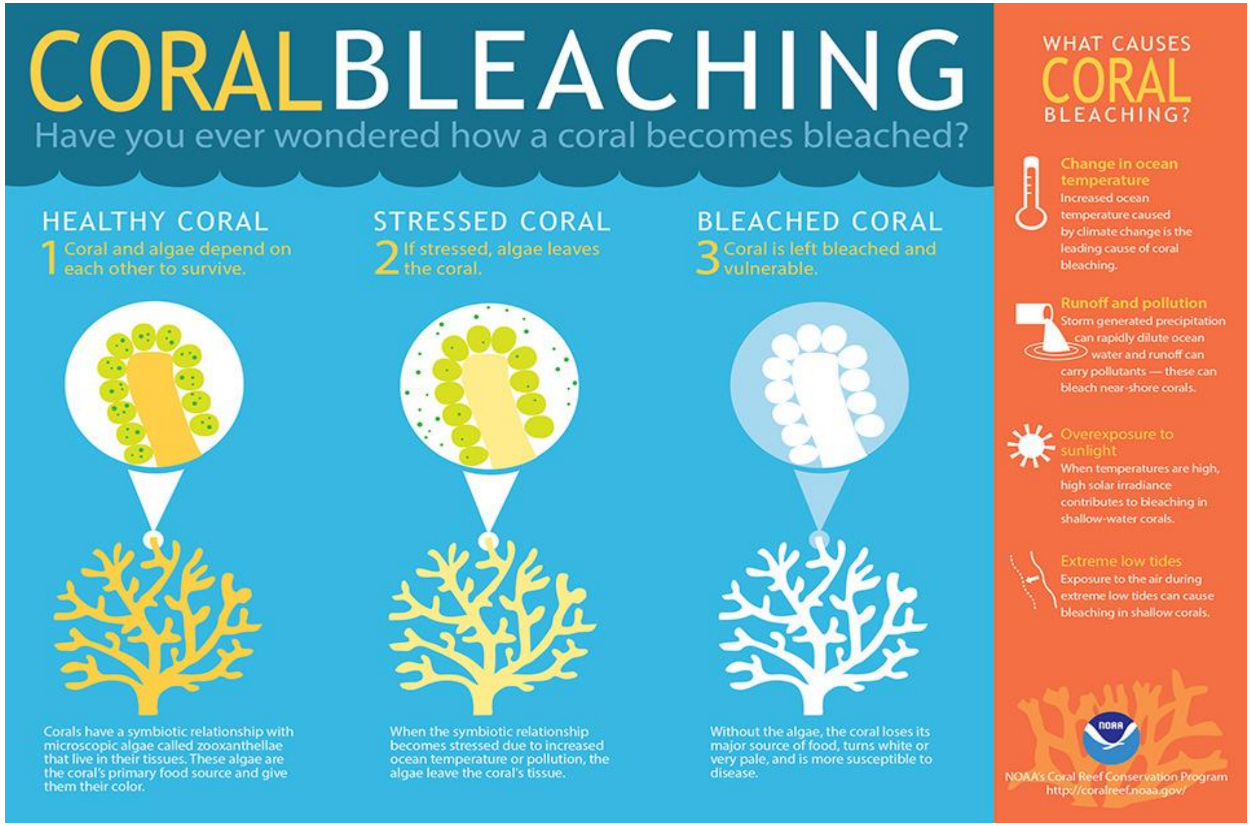


- ***Ocean acidification*** dissolves calcium carbonate ($CaCO_3$) shells and makes carbonate (CO_3^{2-}) less available for sea creatures (e.g., corals) to form shells.
  - Marine mollusks, many of which are commercially important species of shellfish, form shells from $CaCO_3$.
  - Coral reefs are made of the $CaCO_3$ skeletons of millions of coral polyps built on top of each other.
  - Acidification threatens the health of marine mollusks and coral reefs.

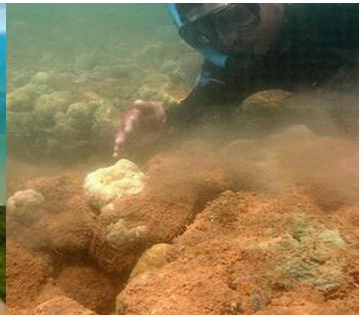
Coral Bleaching

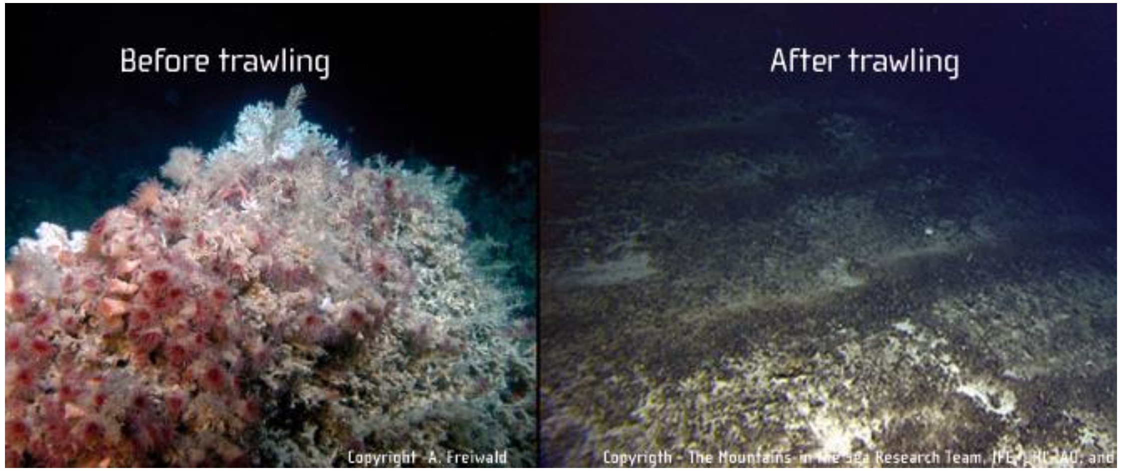
- Coral polyps contain photosynthetic zooxanthellae algae with whom they have a mutualistic relationship.
  - Coral polyps receive the majority of their nourishment from carbohydrates produced by the photosynthetic Zooxanthellae algae.
  - The coral skeleton provides a substrate for Zooxanthellae to anchor too and provides some protection to them as well.
  - Zooxanthellae algae is what gives living corals their color.
- Environmental stresses can cause Zooxanthellae algae to leave or be expelled from the coral polyp.
  - Warming oceans due to anthropogenic climate change.
  - Increased pollution in runoff can bleach nearby corals.





Additional threats to reefs





- Rising sea levels result in deeper waters over some coral, reducing the light reaching the reef and the photosynthetic Zooxanthellae algae.
- Agriculture, logging, mining, and construction are increasing sediment pollution in watersheds resulting in sediments increasing turbidity of coastal waters and smothering reefs as it settles onto the reef.
- Nutrient pollution can cause rapid growth of other forms of algae that smother reefs and increase turbidity.
- Destructive fishing practices such as bottom trawling or cyanide or dynamite fishing.
- Souvenir hunters, aquarists and the jewelry trade collect corals.

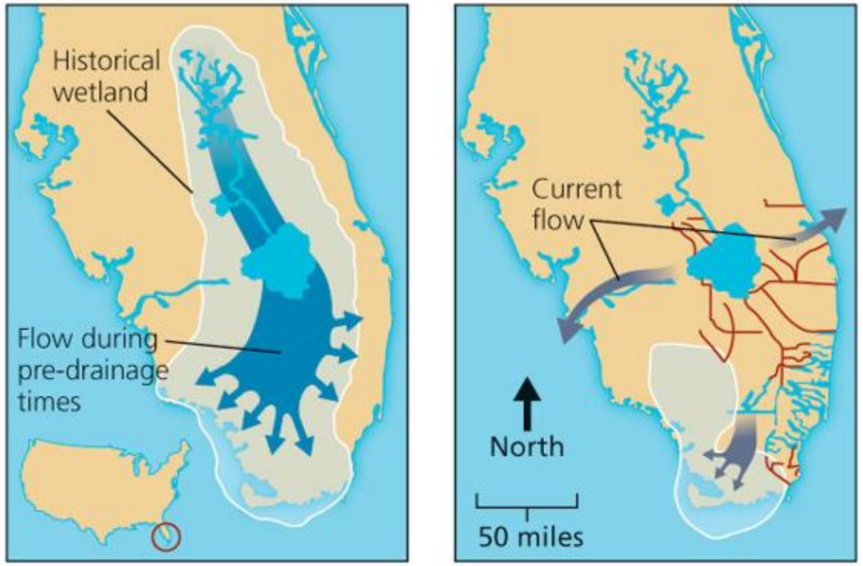
Coral Reefs provide ecosystem services

- **Supporting**
  - Coral reefs have the highest biodiversity of any marine ecosystem in the world in the world.
- **Regulating**
  - Reefs help slow incoming waves, reducing beach erosion.
  - Protects against storm surge and property loss / damage.

- **Provisioning**
  - Supports many subsistence fisheries around the world.
  - Multiple new drugs, derived from compounds in reef organisms are now being developed, with more likely as new species are discovered.
- **Cultural**
  - Attracts tourism which provides economic value to local communities.
  - Inspiration and aesthetic beauty

Wetlands

- ***Wetlands***: An area with soil submerged/saturated in water for at least part of the year, but shallow enough for emergent plants.
  - Wetland plants have adapted to living with roots submerged in standing water (cattails, lily pads, reeds)
- Ecosystem Services of Wetlands:
  - Supporting: H_2O filtration, biodiversity (many unique species), nutrient cycling
  - Regulating: groundwater recharge, absorb. of floodwater, CO_2 sequestration
  - Provisioning: habitat for animal & plant foods
  - Cultural: tourism revenue, fishing license, camping fees, ed/med research



a Historical flow regime **b** Current flow regime

- Threats to Wetlands:
  - Pollutants (nutrients (N/P), sediment, motor oil, pesticides)
  - Sea-level rise
  - Development - wetlands can be filled in or drained to be developed into homes, parking lots, or farms.
  - Water diversion upstream for flood control, agriculture, or drinking water can reduce water flow and dry up wetlands (ex: Everglades)
    - Dam construction for flood control / hydroelectric reduces the flow of water, sediments, and nutrients
  - Overfishing: disrupts food web of wetlands

Mangroves

- Mangroves are small trees with unique roots that grow in saline or brackish waters throughout the tropics.
  - Ecosystem Services:
    - Supporting: Biodiversity (habitat nursery), H2O filtration, Nutrient cycling
    - Regulating: Coastal protection and storm buffering, erosion control
    - Provisioning: habitat for juvenile commercial fish species, timber, fuelwood
    - Cultural: tourism, recreation, aesthetics

- Threats to mangroves:
  - Mangroves face many of the same threats as wetlands
  - Sea-level rise, development, pollution, overharvesting
  - Aquaculture, especially shrimp farming, poses an additional threat to mangroves, especially in southeastern Asia.

Video Resources

- Water Pollution
  - https://www.youtube.com/watch?v=GNGKsubYJ9U&t=1s