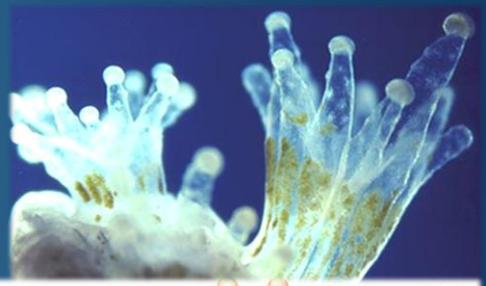
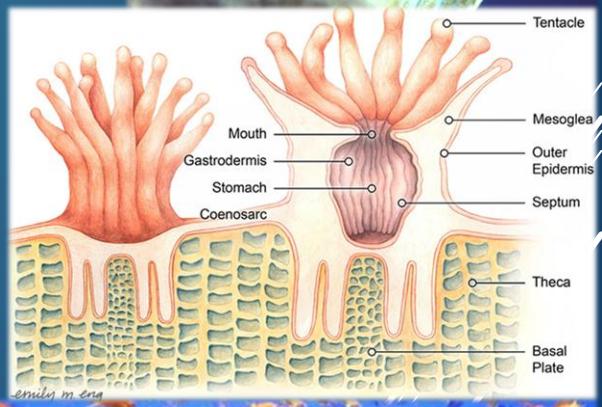
Human Impact on Coral Reefs

Ice ages have come and gone.
Coral reefs have persisted.
Sylvia Earle

What is a Coral?

- Corals are ancient animals related to jellyfish and anemones.
- An individual coral is known as a polyp, a very small and simple organism consisting mostly of a stomach topped by a tentacle-bearing mouth.
- The tentacles are for defense and capturing food (plankton and other small creatures) and are equipped with venomous barbs.
- The end opposite the tentacles, the base, is attached to the substrate.



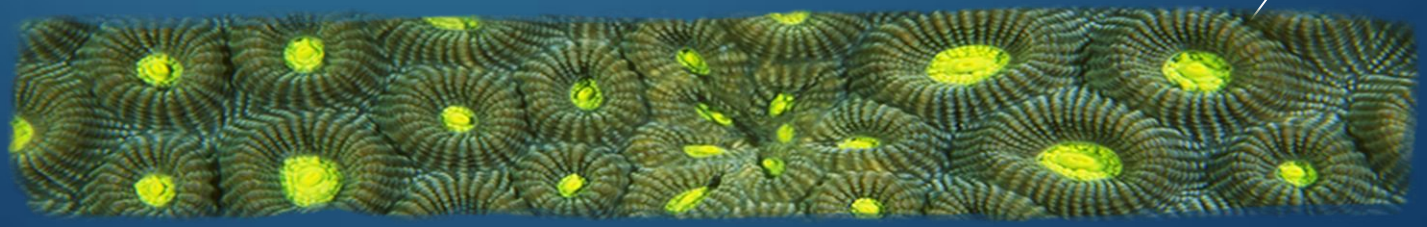


Coral Colonies

- Thousands of identical polyps live together in a coral colony. Individual coral polyps within a colony are connected by common tissue.
- Each polyp excretes a calcium carbonate exoskeleton for protection.
- As polyps die, new polyps grow on top of and next to the dead ones, contributing to the gradual slow growth of the coral reef.

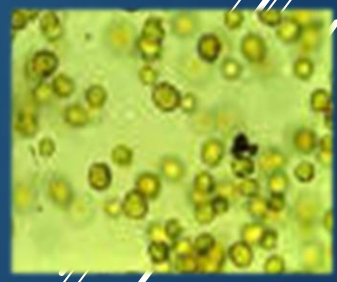
Coral Reefs

- Over long periods of time, the skeletons of many coral colonies add up to build the structure of a coral reef.
- Coralline algae cement corals together, and various mollusks contribute their hard skeletons as well.
- Some corals build up their structure at a rate of less than an inch per year, while faster growing corals may grow at rates of 6 inches per year.



Coral and Algae

- Reefs require a solid surface or platform on which to grow.
- They only occur in shallow areas that are reachable by sunlight because of the relationship between coral and algae.
- Microscopic algae live inside coral. Nutrients supplied by these algae from their photosynthetic processes allow the corals to grow and reproduce quickly enough to produce reef structures. They also give corals their distinctive colorations. Reciprocally, coral provide algae with protection and access to sunlight.



Coral and Algae

- The need for sunlight and a solid surface restrict reef building corals to the shallow rocky waters of the tropics.
- In many ways, reef-building corals are animals that act like plants – they stay in one place and get some of their energy from the sun.
- Everything You Ever Wanted to Know About Coral Reefs, in a Four-Minute Video
- Interactive Reef

Biodiversity

- 32 of the 34 recognized animal Phyla are found on coral reefs compared to 9 Phyla in tropical rainforests
- Coral reefs contain 25% of the world's marine fish species.
- About one-third of all marine fish species live part of their lives on coral reefs, that's at least 5,000 different species of wildlife.
- Sponges, starfish, gastropods, sea worms, eels, crustaceans, mollusks, jellyfish, sea anemones and turtles are among the most commonly seen non-fish species.

Biodiversity

- Reefs in the Florida Keys, for example, hold at least 45 species of stony coral, 37 of octocoral, 5 of sea turtles, 500 of fish, about 1,700 of mollusks and hundreds of species of sponges.
- Southeast Asia is considered the global epicenter of marine diversity, the earth's coral triangle. Its over 38,000 square miles of coral reefs (34% of the world's total) are home to over 600 of the 800 reef-building coral species in the world.

Symbiotic Relationships

- The coral reef is an intricate ecosystem and contains a diverse collection of organisms.
- Many species – fish, invertebrates, algae and microorganisms – make their homes on and around coral reefs.
- Many have symbiotic relationships that make the coral reef ecosystem successful.
- As we saw previously, algae supply nutrients and oxygen to coral and coral provide access to sunlight, carbon dioxide and protection to the algae.

Symbiotic Relationships

- Boring organisms such as sponges, worms and bivalves; along with grazers such as parrotfish and sea urchins break down coral skeletons. Borers and grazers usually attack dead coral. The resulting sediment settles into spaces in the reef.
- Coralline algae and minerals cement the dead organic matter, stabilizing the reef structure.
- Sponges provide shelter for fish, shrimp, crabs, and other small animals that come in a variety of shapes and colors.

Smiley sponge: Sponges suck in seawater via small holes on their sides and expel the filtered water through large holes.

Symbiotic Relationships

- Bryozoans encrust the reef. These microscopic invertebrates form branching colonies over coral skeletons and reef debris, cementing the reef structure.
- The banded coral shrimp is an example of a cleaner shrimp. It removes parasites and dead skin from reef fish.
- Some species of wrasses, colorful cigar-shaped fish, are also cleaners and set up cleaning stations along the reef. When a larger fish aligns itself at one of these cleaning stations, a cleaner wrasse removes parasites from the fish.

Two Banded Coral Shrimp

Symbiotic Relationships

- Both schooling and solitary fish are essential residents of the reef ecosystem. They play a vital role in the reef's food web, acting as both predators and prey. Their leftover food scraps and wastes provide food or nutrients for other reef inhabitants.
- Parrotfish use chisel-like teeth to nibble on hard corals. These fish are herbivores and eat the algae within the coral, grinding the coral's exoskeleton to get the algae. They also defecate sand. A single parrotfish can produce about five tons of sand per year.

Queen parrotfish eating algae

Symbiotic Relationships

- Due to their symbiotic relationships, the loss of any one of the reef species can have serious consequences for the reef as a whole.
- Conversely, if coral reefs decline, populations of fish and other animals that rely on coral reefs for food and shelter may decrease as a result.

A cleaner shrimp rids a moray of parasites at a reef cleaning station. The shrimp is in little danger since predation ceases almost completely at cleaning stations.

- symbiotic relationship: two different species living together
- mutualism: both species benefit
- commensalism: one benefits, the other is neither helped nor harmed
- parasitism: one benefits the other is harmed

Factors Correlated with Healthy Coral Reef Growth

- water temperature: 68° to 82° F
- clear water: Corals are sensitive to sediments, which can create cloudy water blocking out the sun and can be deposited on corals harming polyps.
- clean water (low inorganic nutrient concentrations): Wastewater and pollution discharged into the ocean can contain too many nutrients, causing seaweed to overgrow the reef.
- vigorous water motion: Reef development is generally more abundant in areas that are subject to strong wave action. Waves carry food, nutrients and oxygen to the reef; distribute coral larvae; and prevent sediment from settling on the coral reef.

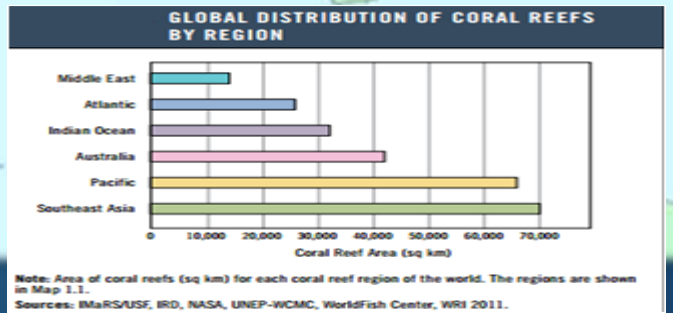
Factors Correlated with Healthy Coral Reef Growth

- substrate: a solid surface or platform to provide stability
- salinity and carbon dioxide: Precipitation of calcium from the water is necessary to form a coral polyp's skeleton. This requires warm water, low carbon dioxide and high salinity (32–35%) (which is why corals don't live in areas where rivers drain fresh water into the ocean).
- water acidity: pH of 7-8 ... The calcium carbonate shells of corals and other marine animals dissolve in acidic water.
- water depth: Building corals are generally found at depths of less than 150 feet, where sunlight can penetrate.

Location

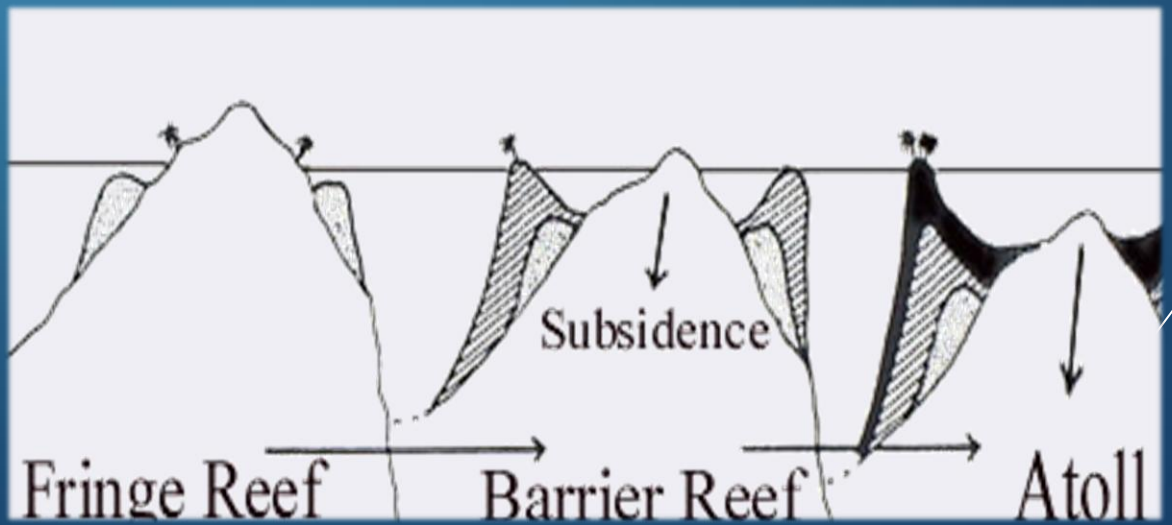
- Coral reefs are confined to a broad band roughly covering the tropics and circling most of the planet. Corals can also be found farther from the equator in places where warm ocean currents flow out of the tropics.
- The majority is found in the Indo-Pacific, which stretches from the Red Sea to the Central Pacific.
- Coral reefs are usually found in shallow areas at a depth of less than 150 feet.
- However, some coral reefs extend even deeper, up to about 450 feet deep.
- Despite the importance of coral reefs to life in the ocean, all existing coral reefs add up to less than 1% of the sea floor – an area about the size of France.

Global Distribution of Reefs

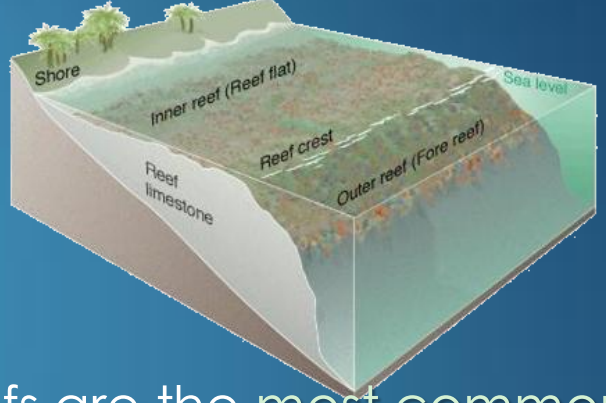


Types of Coral Reefs

- fringing reefs
- barrier reefs
- atolls
- patch, bank or platform reefs



Fringing Reefs




South Pacific island

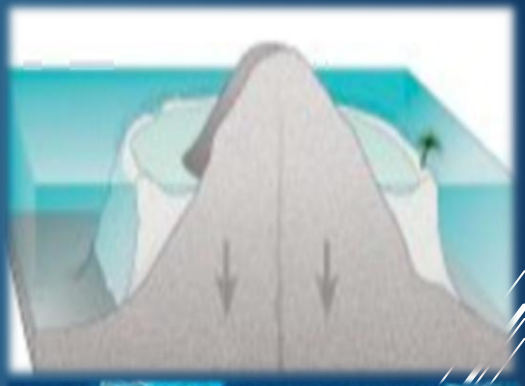

Cayman Islands


The Maldives

- Fringing reefs are the most common type of reef and develop from the simple upward growth of a calcium carbonate platform from a shelf along the coastline. Fringing reefs occur close to land but often extend out to sea for long distances.
- Corals grow quickly to the surface and produce a shallow platform which is usually around the level of the lowest tide.
- Offshore, growth is slower. Typically there is a sharply defined edge, the reef crest, beyond which there is a steeply shelving reef front dropping to the ocean floor.
- Fringing reefs are commonly found in the South Pacific, Hawaiian Islands and parts of the Caribbean.

Barrier Reefs

- Typically these are old structures rising up from a deeper base farther out from the shoreline, a well defined coral zone separated from land by a lagoon (a shallow area with a sandy floor, patch reefs and patches of seagrass).
- Some have their origins as fringing reefs but take on a new stage of growth when the shoreline they are associated with subsides (submerges or is flooded by rising sea levels).
- The barrier reefs continue to grow upward on their own but deeper water fills in between the reef and the shoreline and a lagoon is formed.



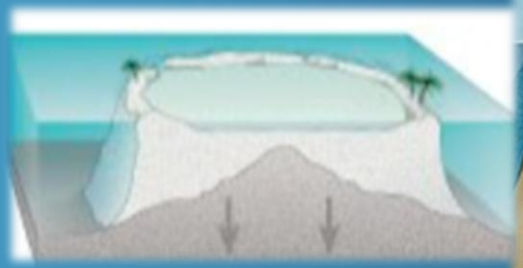
Barrier Reefs

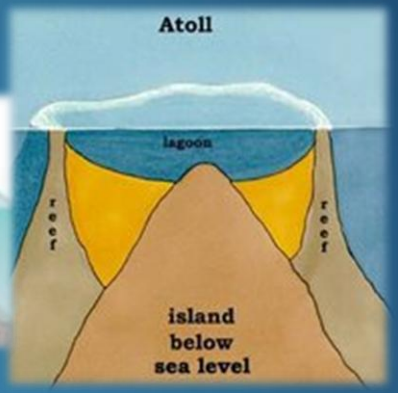
- Barrier reefs are common in the Caribbean and Indo-Pacific. The Great Barrier Reef off northern Australia in the Indo-Pacific is the largest barrier reef in the world. This reef stretches more than 1,240 miles.
- Sometimes it is hard to tell the difference between fringing reefs and barrier reefs. One of the things that separates these two is the depth of the lagoon in the area near shore. Barrier reefs have at least some deep portions; fringing reefs do not. Another major difference is that barrier reefs tend to be much farther away from shore than fringing reefs.

The Great Barrier Reef

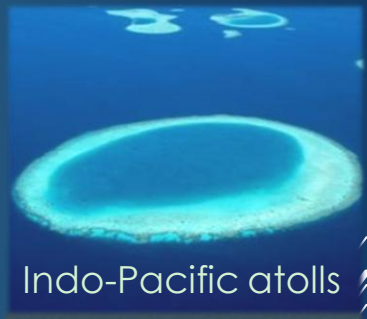
Belize Barrier Reef with Great Blue Hole, a vast perfectly round underwater sinkhole, near the center

Atolls





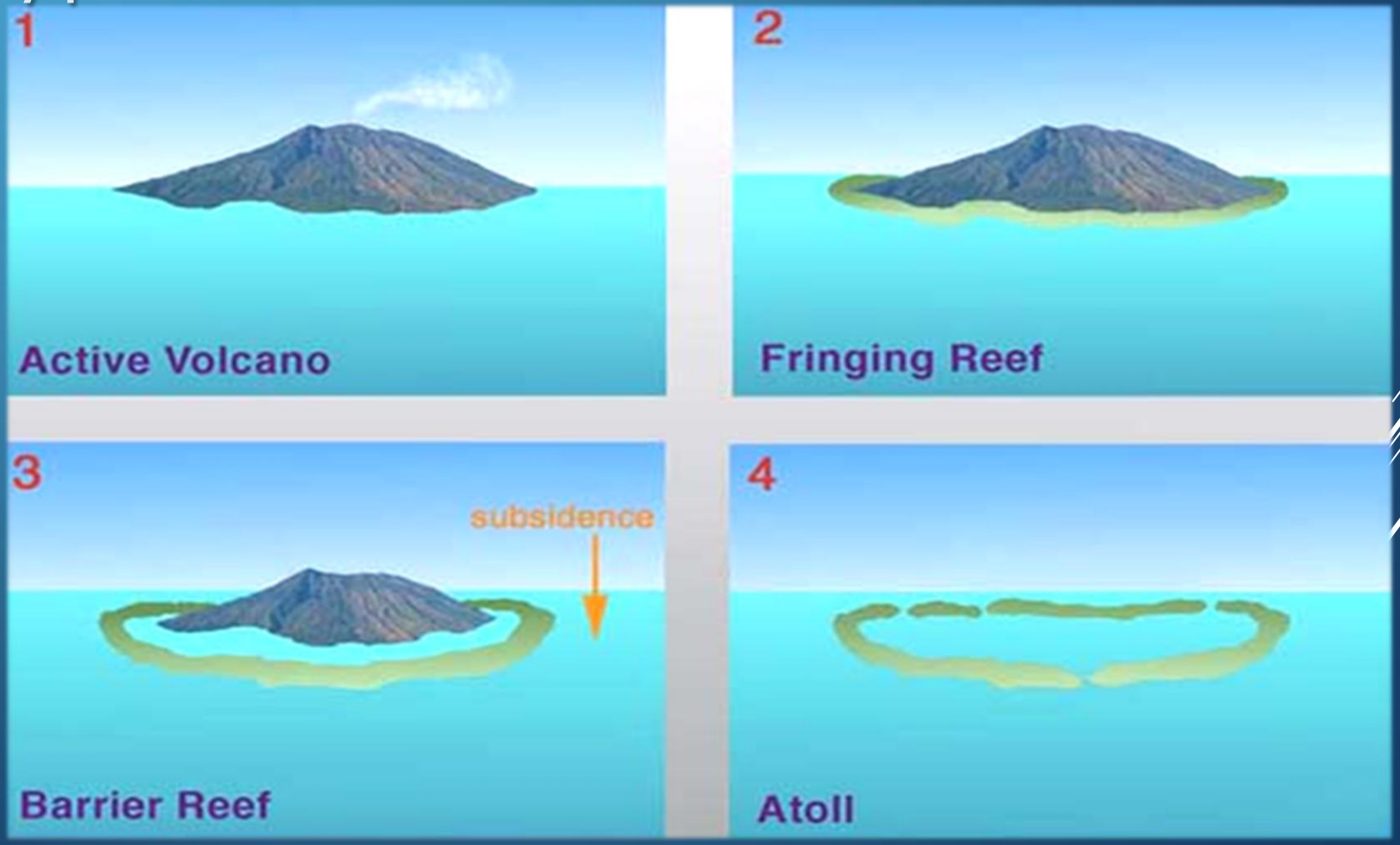
- Atolls are unique structures, typically circular and enclosing a large and often very deep lagoon.
- They are usually found in oceanic locations, far away from the continental shelf.
- They initially form as fringing reefs around isolated, usually volcanic islands. If these island subside, the reefs continue to grow, first forming a barrier around the sinking island, but finally forming a single ring of coral once the island disappears completely beneath the sea. The result is several low coral islands around a lagoon.
- Atolls commonly occur in the Indo-Pacific. The largest atoll, named Kwajalein, surrounds a lagoon over 60 miles long.


Indo-Pacific atolls


Kure Atoll


The Maldives

The Connection Between Types of Coral Reefs



Watch a great animation clip of how an atoll forms.

Patch, Bank or Platform Reefs

- Bank or platform reefs are simple physical structures formed a number of ways.
- As reefs, they have no physical link to a coastline and do not have the clear shape of a barrier reef or atoll.
- Larger or submerged reef structures of this type are also referred to as shoals.
- Patch reefs are small, isolated reefs that grow up from the open bottom of the island platform or continental shelf. They usually occur between fringing reefs and barrier reefs. They vary greatly in size and they rarely reach the surface of the water. Patch reefs are more properly considered regular micro-scale reef features of all three of the other reef types.

bank reef, or shoals

Numerous patch reefs form part of the fringing reef system bordering a tropical island shore.

Benefits of Coral Reefs

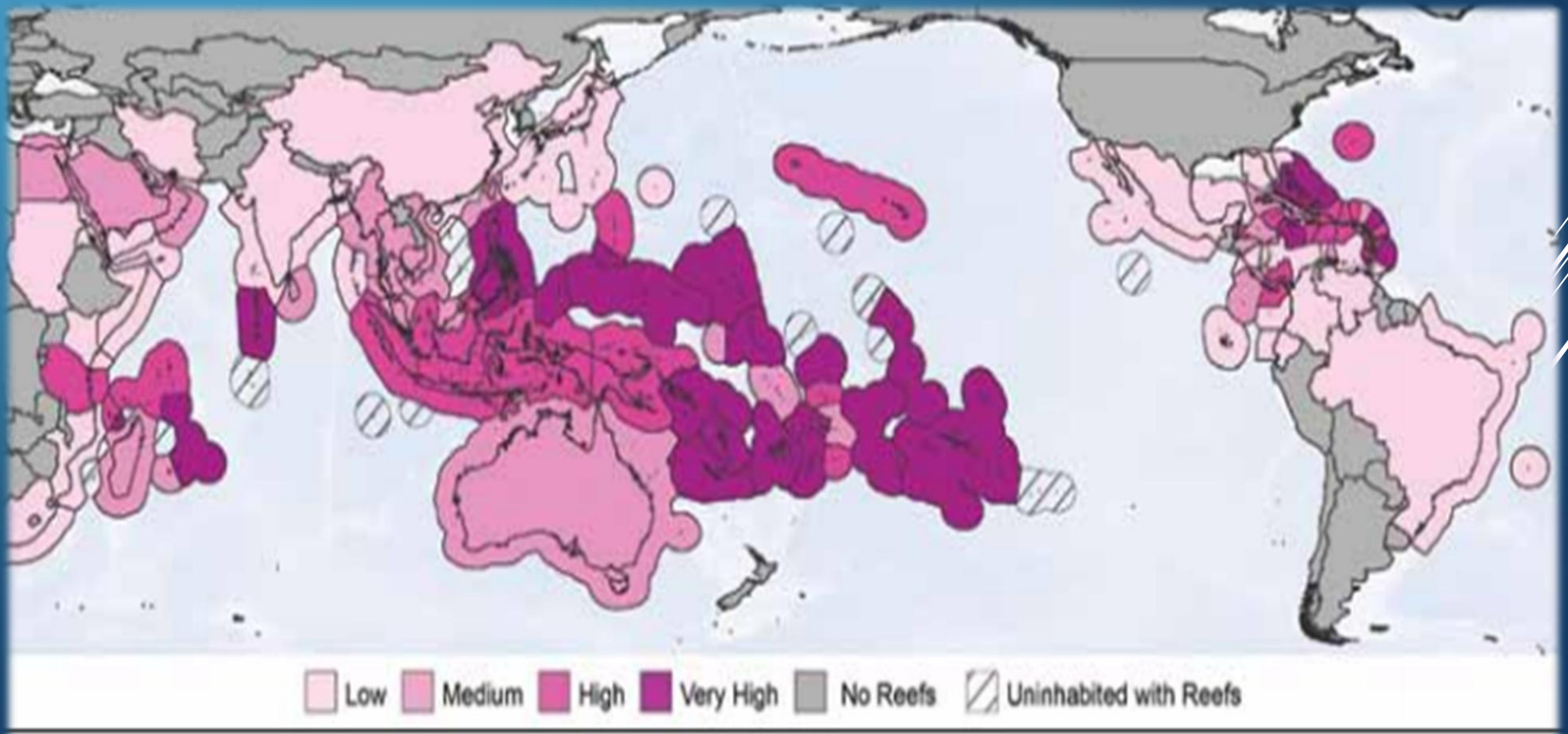
- wildlife habitats: function as nurseries, and feeding and breeding grounds for countless species
- coastline protection: from storms and erosion
- new land
- food: Properly managed, coral reefs can yield an average of 15 tons of fish and other seafood for under half a square mile per year.
- income: provide employment for millions of people
- tourism income


Indonesian fisherman

Benefits of Coral Reefs

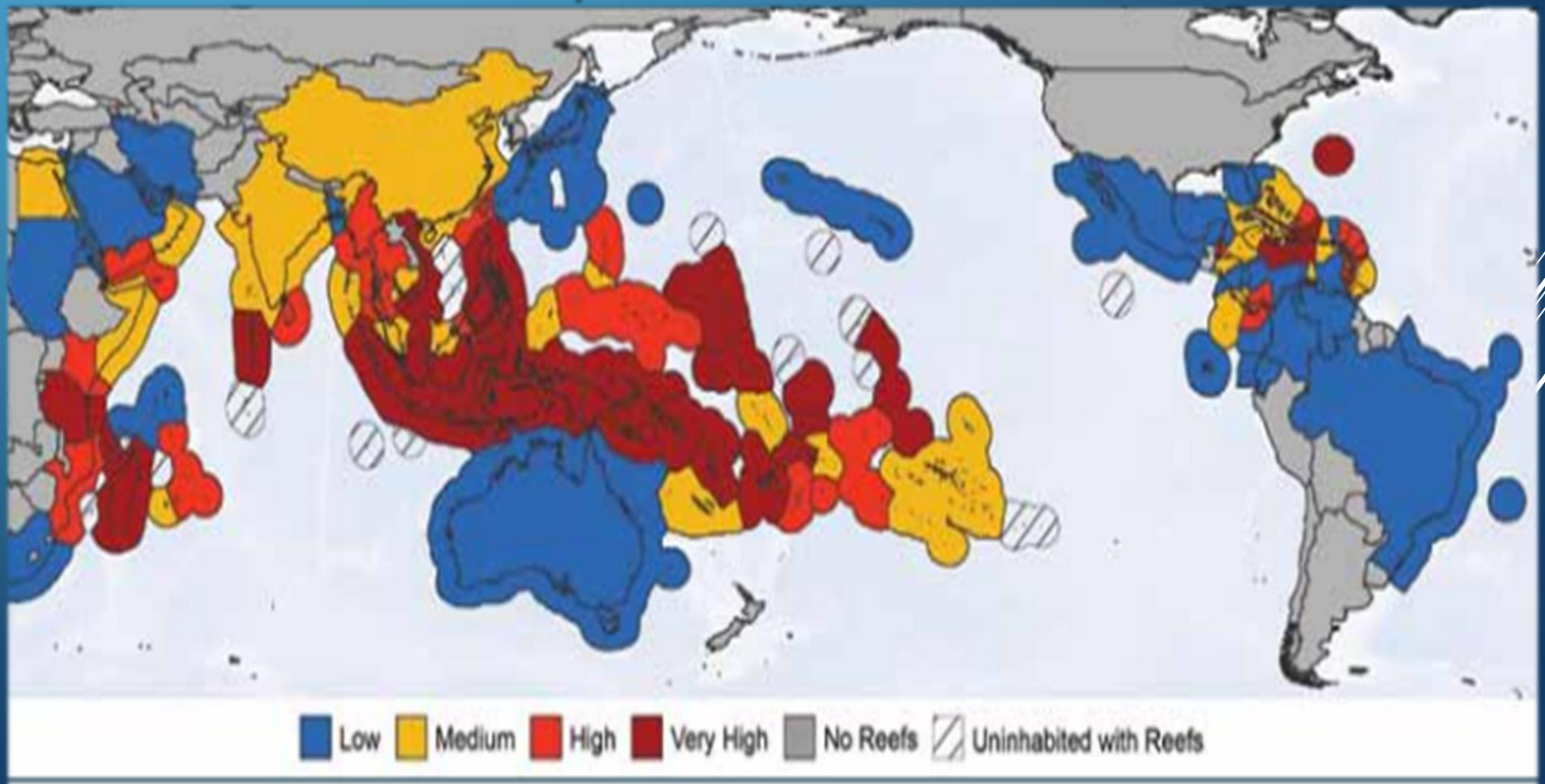
- recreational opportunities
- sources of drugs and medicines: Many corals have already provided a number of medical break-throughs in HIV and cancer treatments.
- Coral skeletons are often used as bone substitutes in reconstructive bone surgery.
- remove and recycle carbon dioxide from the air
- more recent uses: food additives and toiletries, research and education, jewelry and art, marine aquarium specimens, cement and other building supplies

Social and Economic Dependence on Coral Reefs



Note: Reef dependence is based on reef-associated population, reef fisheries employment, nutritional dependence on fish and seafood, reef-associated export value, reef tourism, and shoreline protection from reefs. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles. Reef territories that are only inhabited by military or scientific personnel are not included.

Social and Economic Vulnerability to Reef Loss



Notes: Vulnerability is based on exposure to reef threats, reef-dependence, and adaptive capacity. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles.

Precarious Position

- While coral reefs are the most spectacular of underwater environments, they are also the most fragile. Because of their narrow range of tolerance for environmental conditions, coral reefs are especially sensitive to damage from both natural and human causes.
- 20% of coral reefs were lost and an additional 20% were degraded in just the last several decades of the 20th century.
- 75% of remaining reefs are currently threatened. Even some of the most remote and pristine reefs are losing species.
- 2003: According to research, coral cover dropped 80% in the previous three decades.
- 2006: Researchers estimated that 30% of the world's coral died and another 30% were severely damaged in the previous 50 years.

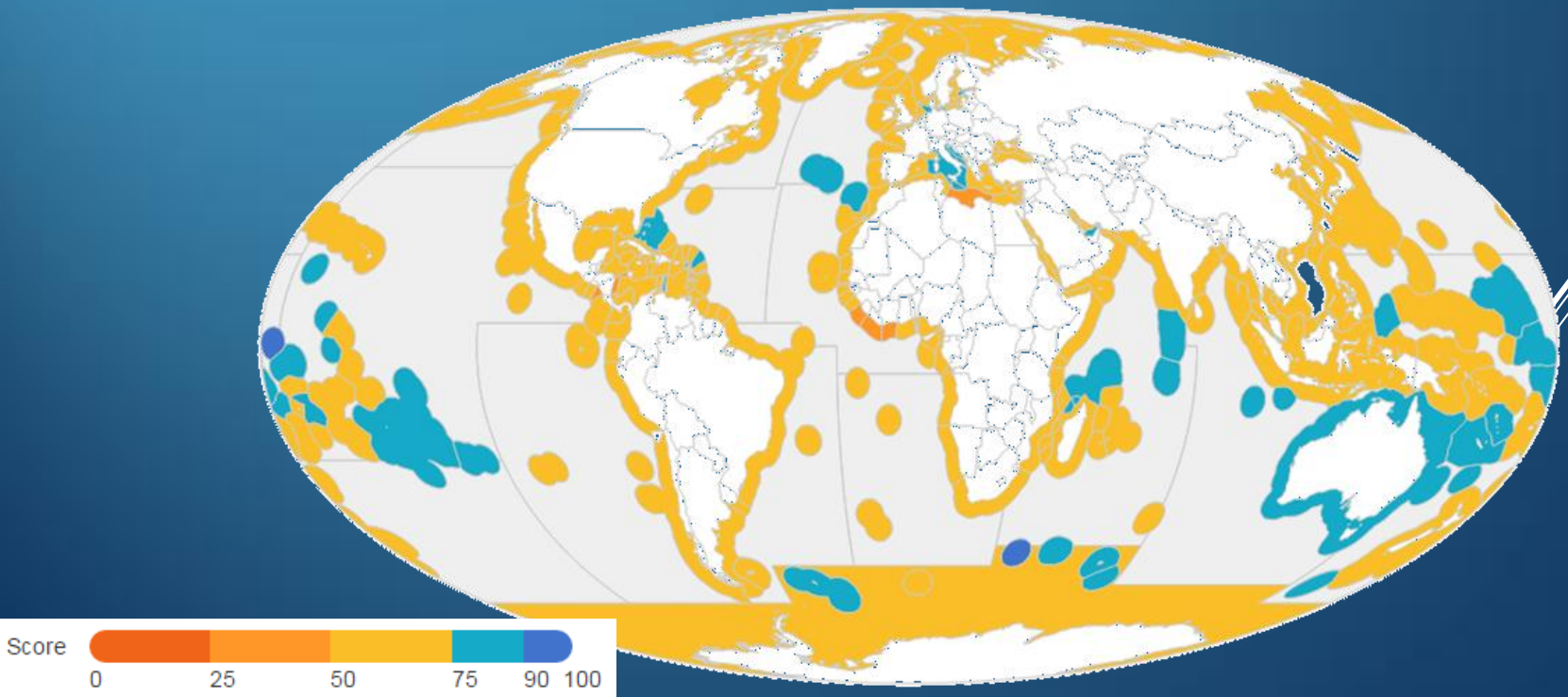
Precarious Position

- A new study shows that coral reefs, and the organisms that live in them, are "healthiest in both the richest, most well developed areas and in the poorest, most under-developed ones." Right in the middle of the socioeconomic spectrum is where corals suffer most.

- Most problems with coral reefs are human problems.
- At middle levels of development, people have enough infrastructure to be destructive, but they don't have enough infrastructure to have alternatives.
- Scientists have said that as much as 95% of Jamaica's reefs are dying or dead.
- Indonesia and the Philippines hold 77% of Southeast Asia's coral reefs and nearly 80% of threatened reefs.

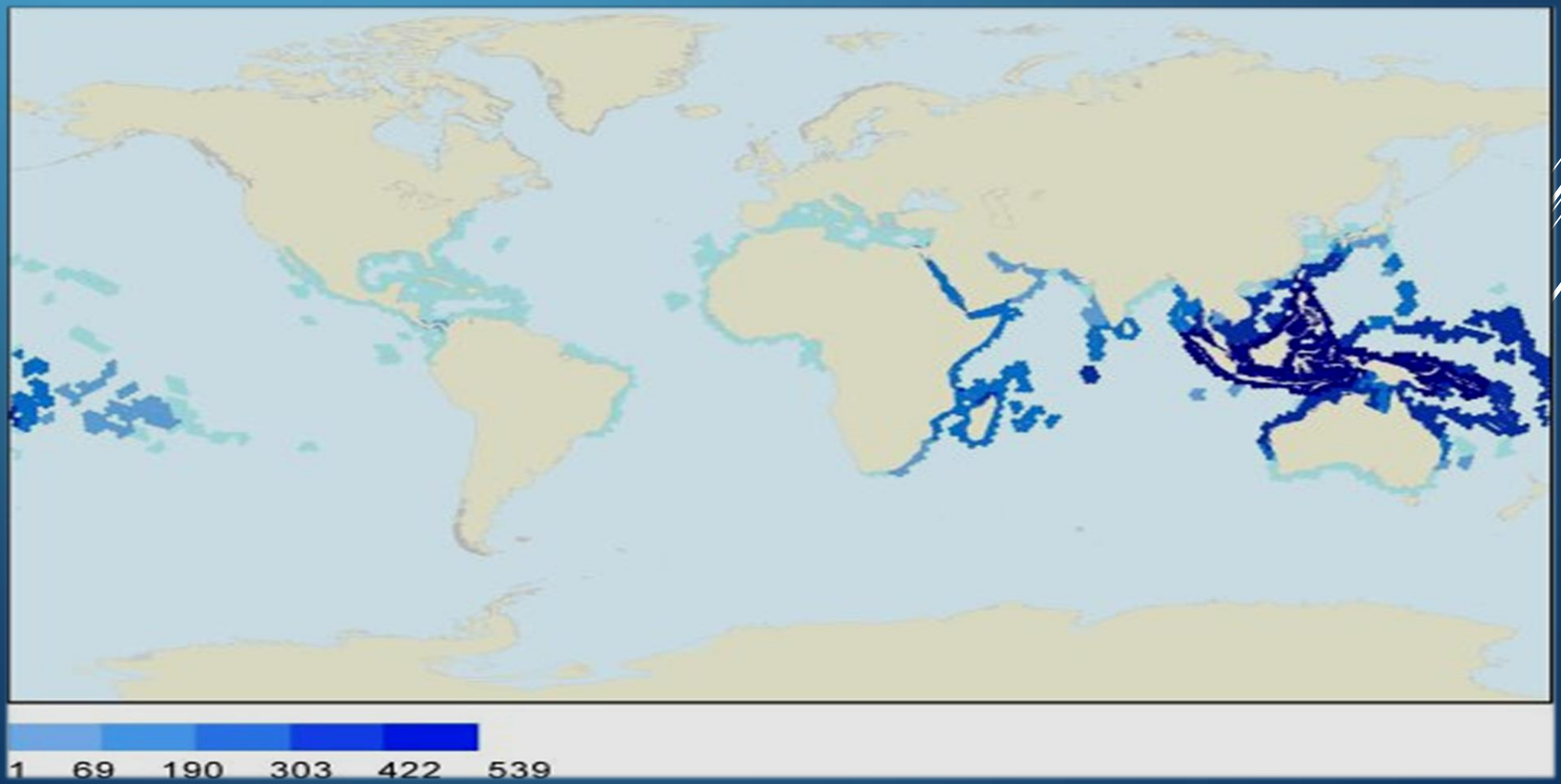
The Ocean Health Index

The Ocean Health Index identifies people as part of a human-ocean ecosystem. The Index is the first assessment tool that scientifically measures key elements from all dimensions of the ocean's health -- biological, physical, economic and social -- to assess how sustainably people are using the ocean.

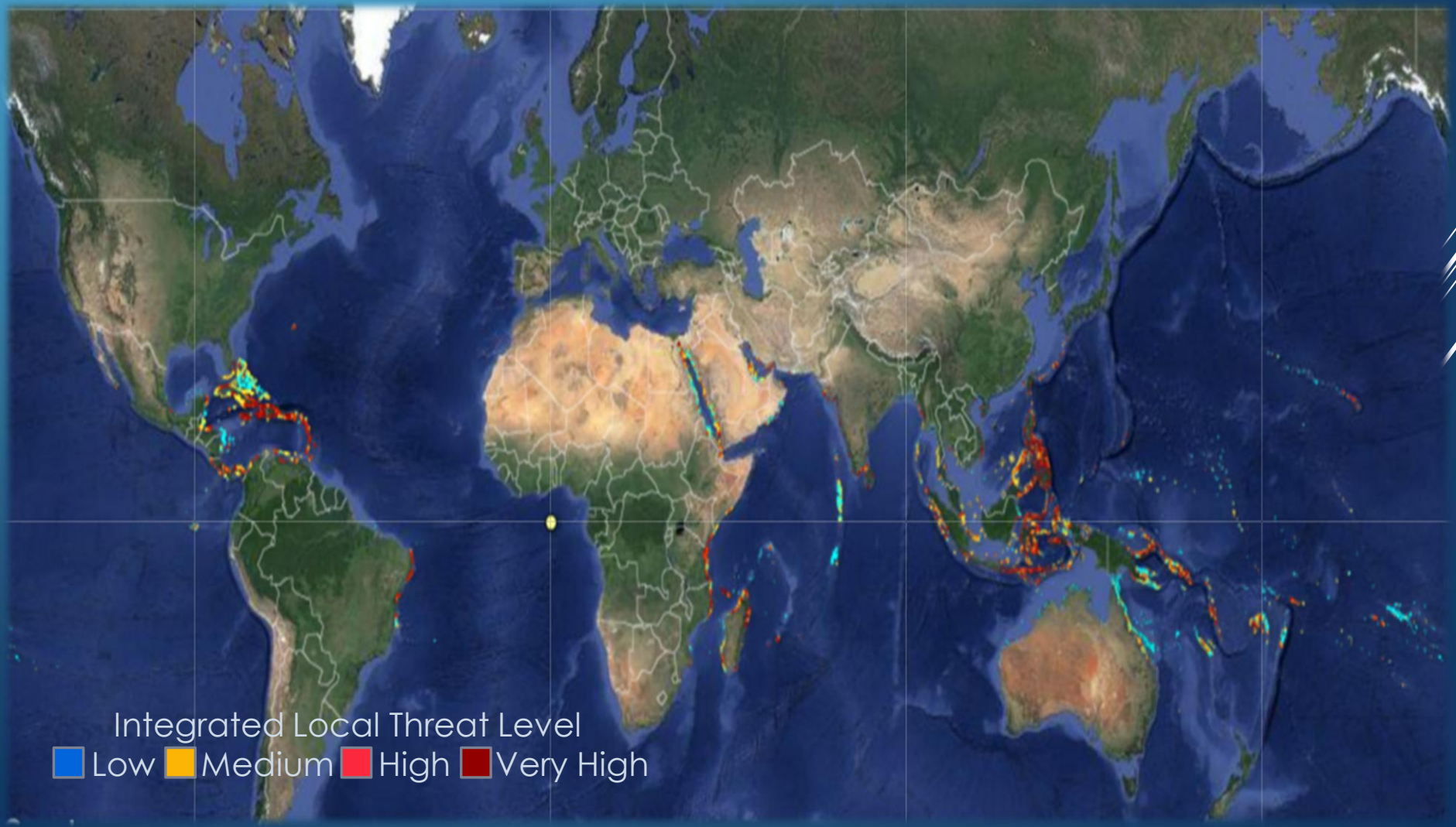


Threatened Coral Richness (Number of Species)

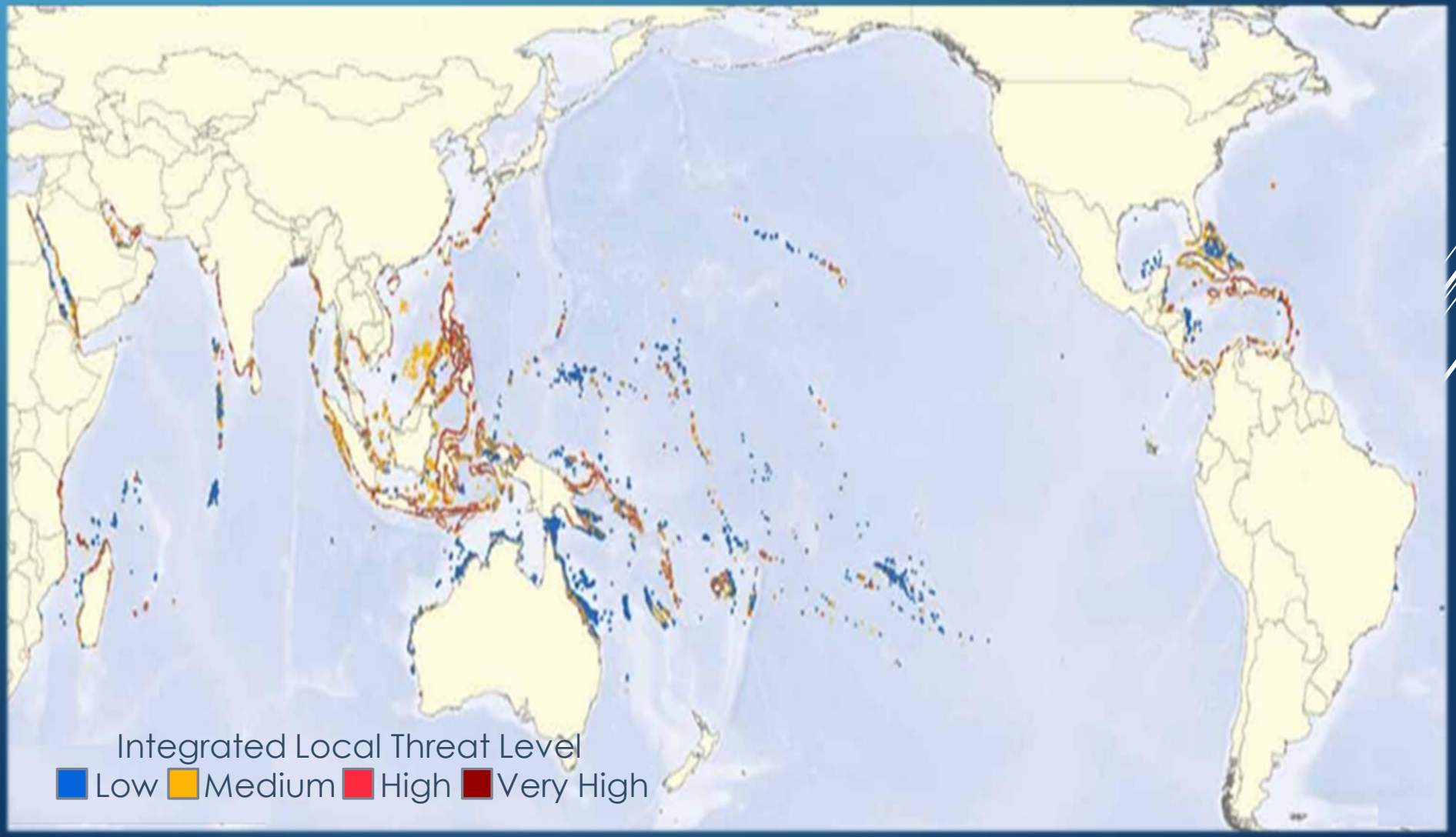
Shows the threats that coral reef species face around the world.



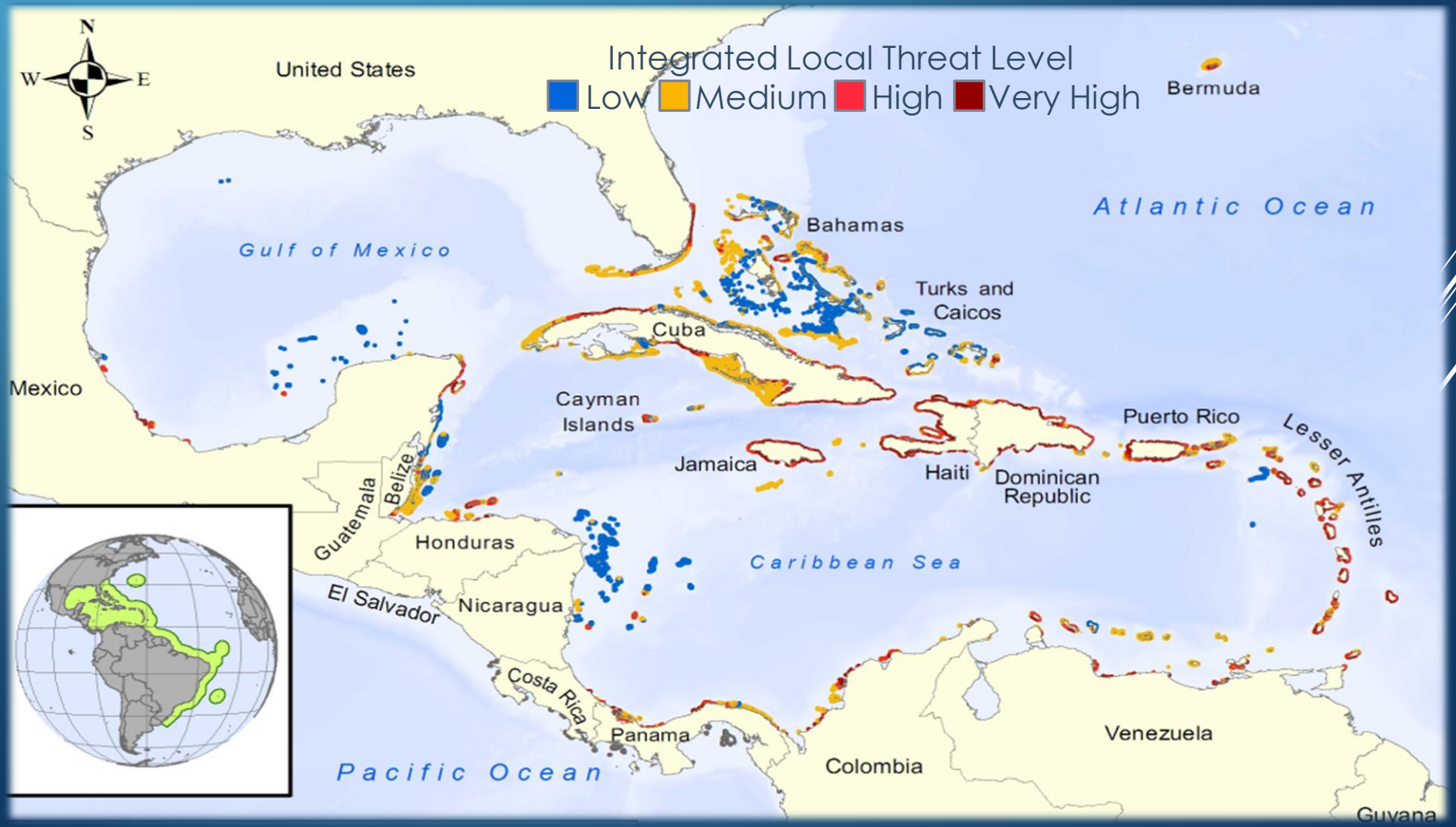
Coral Reefs Classified by Threat from Local Activities



Reefs at Risk: World View

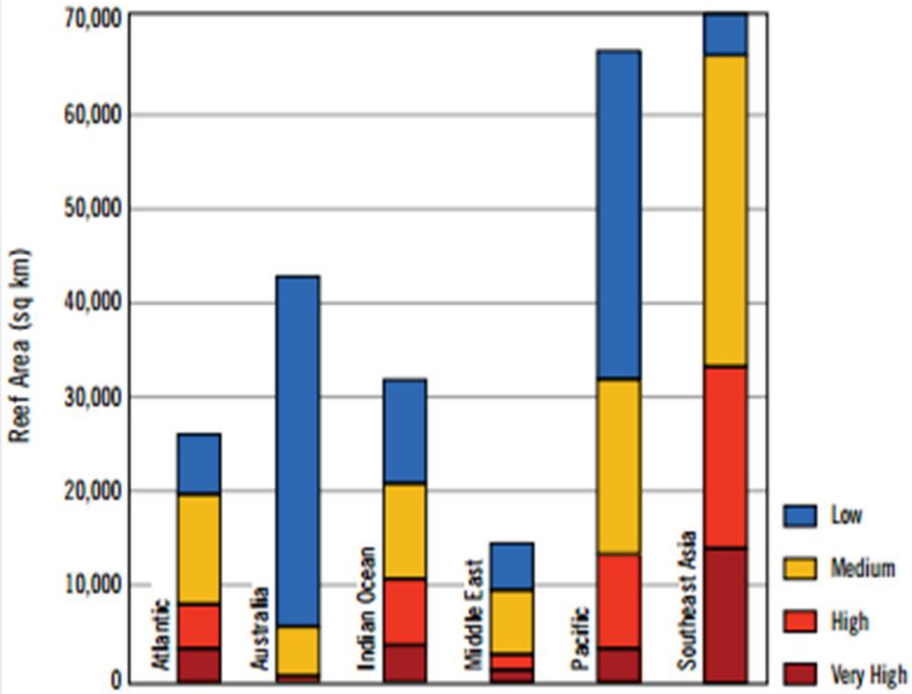


Reefs at Risk: Atlantic View



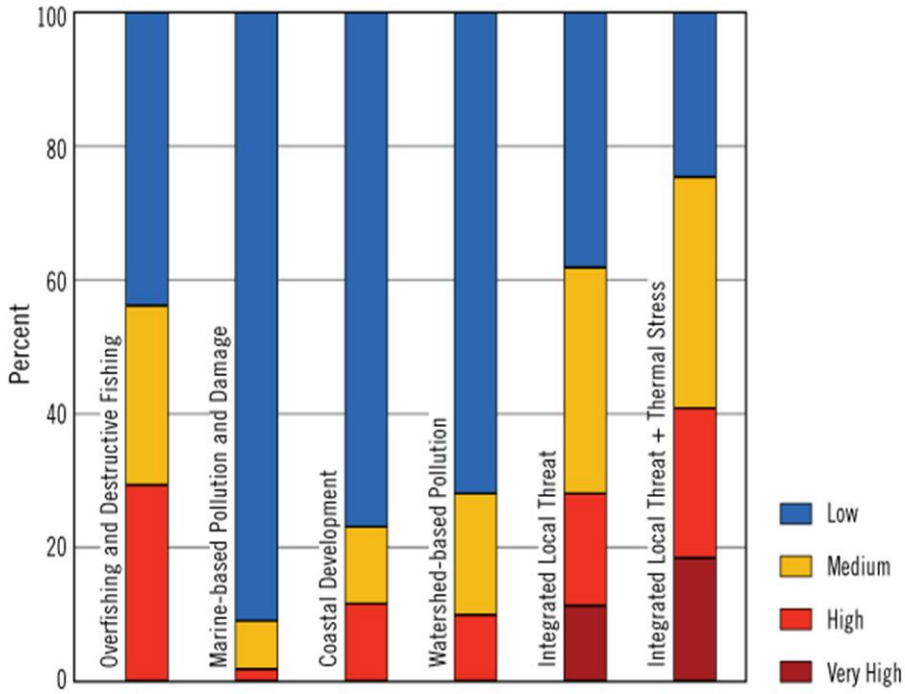
Reefs at Risk: Local Threats

Integrated Local Threats (by area of reef)



Note: Amount of reef area (in sq km) in each region classified by integrated local threat.

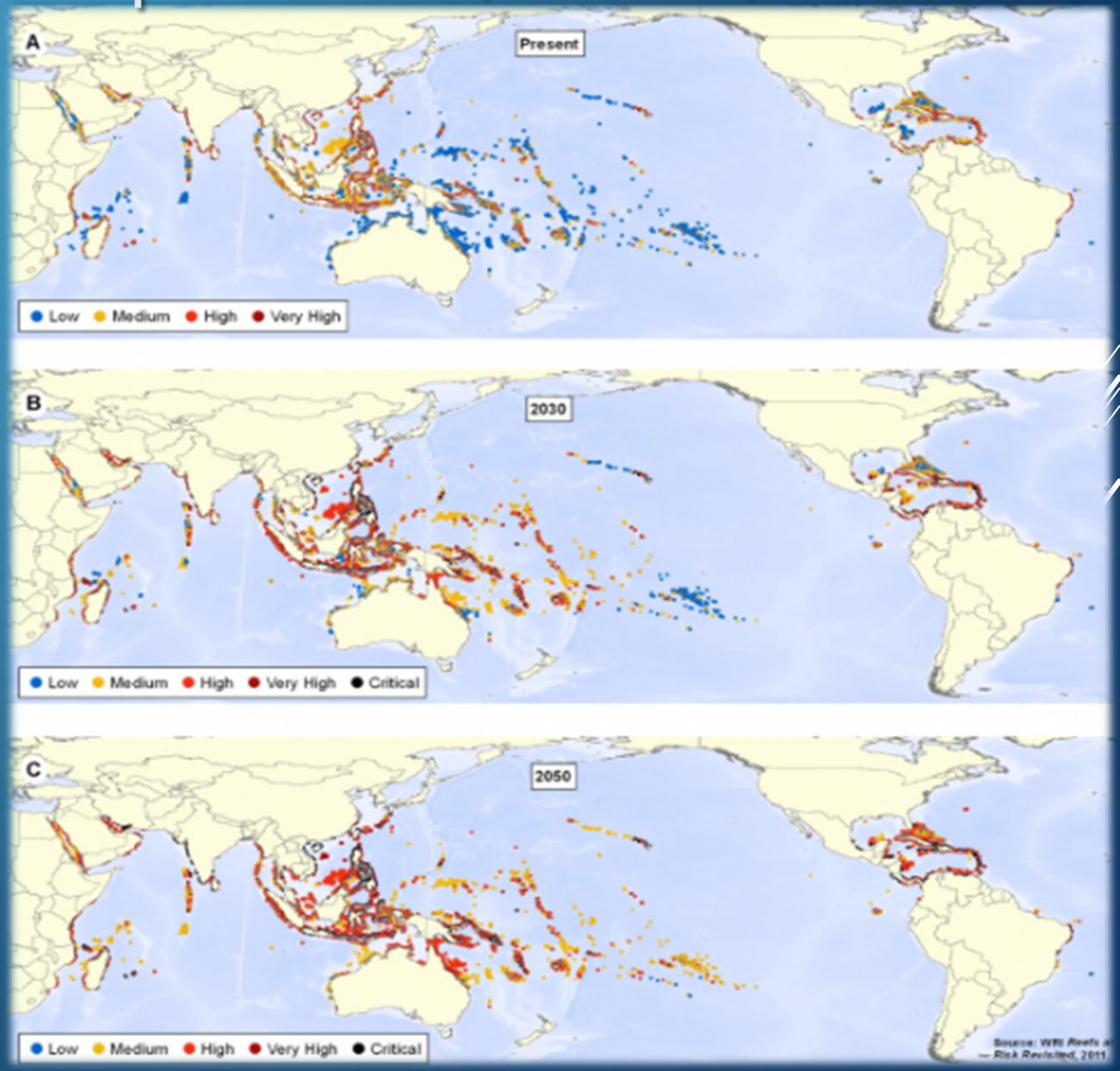
Individual Local Threats



Note: The first four columns reflect individual, local threats to the world's coral reefs. The fifth column (integrated local threat) reflects the four local threats combined, while the sixth column also includes past thermal stress.

Reefs at Risk: present, 2030, 2050

Map A (top) shows reefs classified by present integrated threats from local activities (coastal development, overfishing/destructive fishing, marine-based pollution, and/or watershed-based pollution). Maps B and C show reefs classified by the same combined with projections of thermal stress and ocean acidification for 2030 and 2050, respectively.



Top 10 Emerging Threats to Coral Reefs

Global Change Threats	• Coral bleaching caused by elevated sea surface temperatures due to global climate change • Rising levels of CO^2 • Diseases, plagues and invasives linked to human disturbances in the environment
Direct Human Pressures	• Over-fishing (and global market pressures) including the use of damaging practices (bomb and cyanide fishing) • Sediments from poor land use, deforestation and dredging • Nutrients and chemical pollution • Development of coastal areas for urban, industrial, transport and tourism developments, including reclamation and mining of coral reef rock and sand beyond sustainable limits
The Human Dimension — Governance, Awareness and Political Will	• Rising poverty, increasing populations, alienation from the land • Poor capacity for management and lack of resources • Lack of political will and oceans governance

Natural Sources of Coral Reef Stress


Wolf volcano on Isabela Island

- intense and damaging storms
- volcanic eruptions
- natural stream and river runoff: contributes to increased sedimentation and decreased salinity
- exceptionally low tides: can expose reefs to the atmosphere for prolonged periods
- El Niño and La Niña: both involve ocean water temperature change

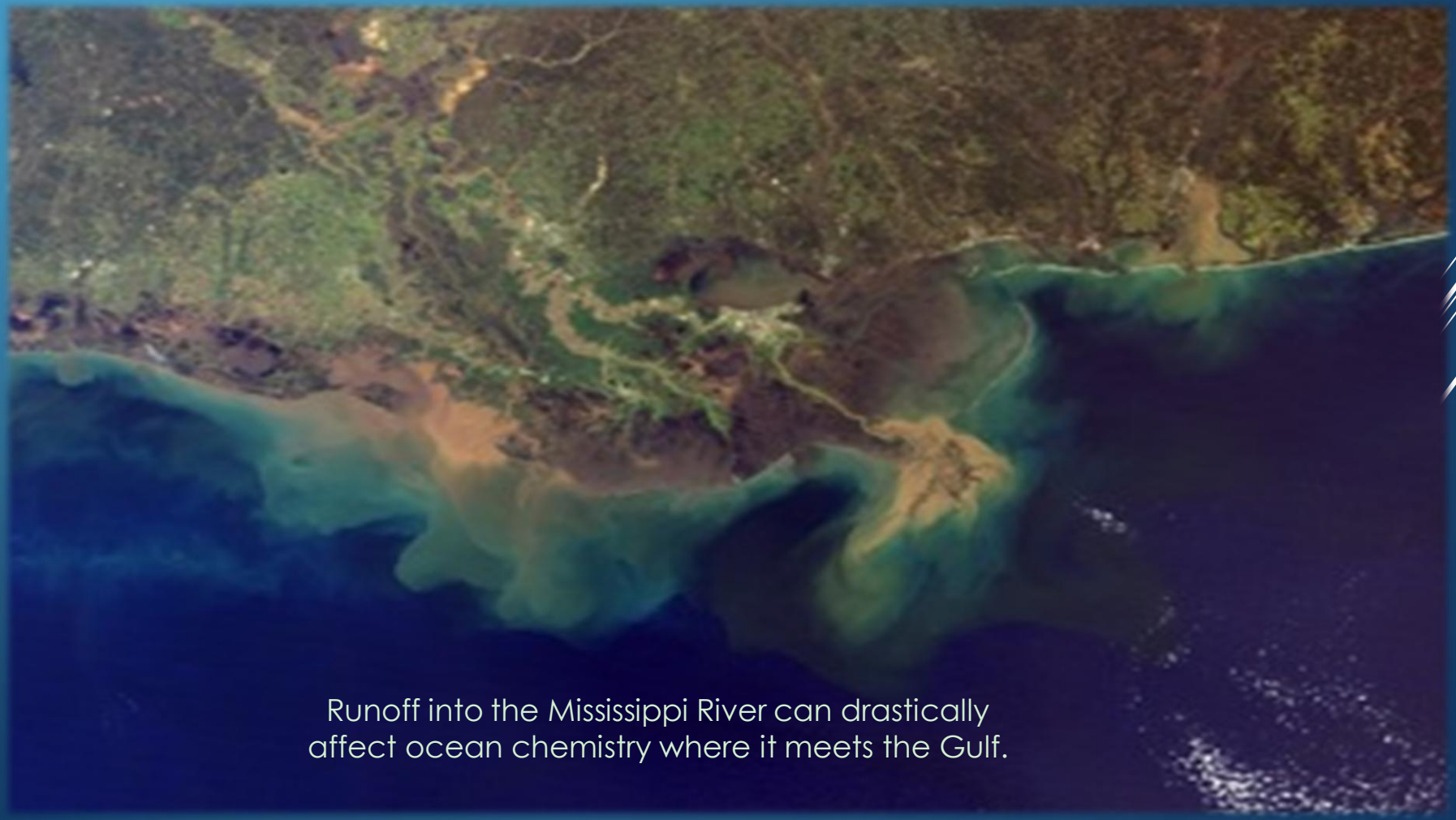
Natural Sources of Coral Reef Stress

- predator population explosions: massive outbreaks of predatory starfish, the crown-of-thorns starfish (COTS), resulting in dead reefs, the almost total absence of larger food and game fish and potentially affecting even deep-sea fish populations through a breakdown in the food chain
- diseases and biological infestations: generally occur in response to biological stresses … Frequency of coral diseases has increased significantly over last 10 years causing widespread mortality due perhaps to deteriorating water quality.

Natural Sources: Storm Wave Damage

Natural Sources: Storm Damage

Natural Sources: Stream and River Runoff

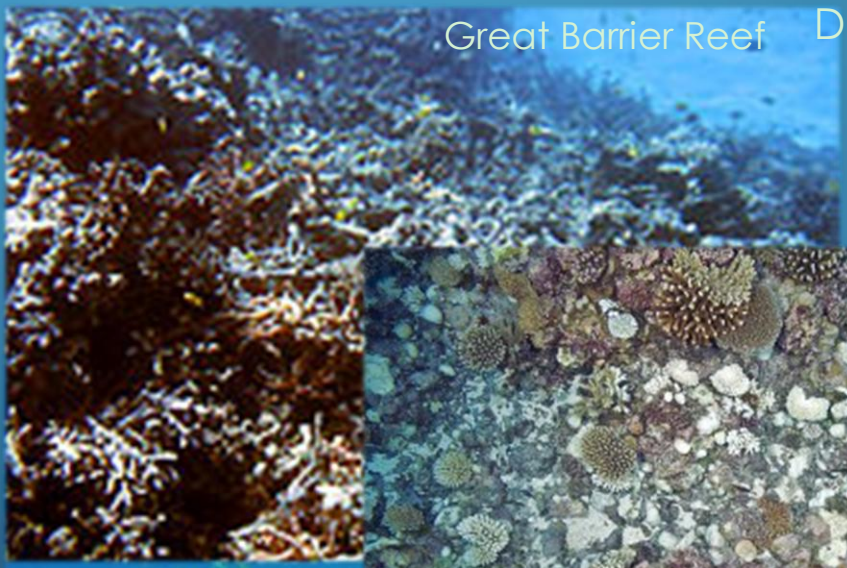


Runoff into the Mississippi River can drastically affect ocean chemistry where it meets the Gulf.

Natural Sources: Exceptionally Low Tides

low tide exposed reef
Malakula Vanuatu

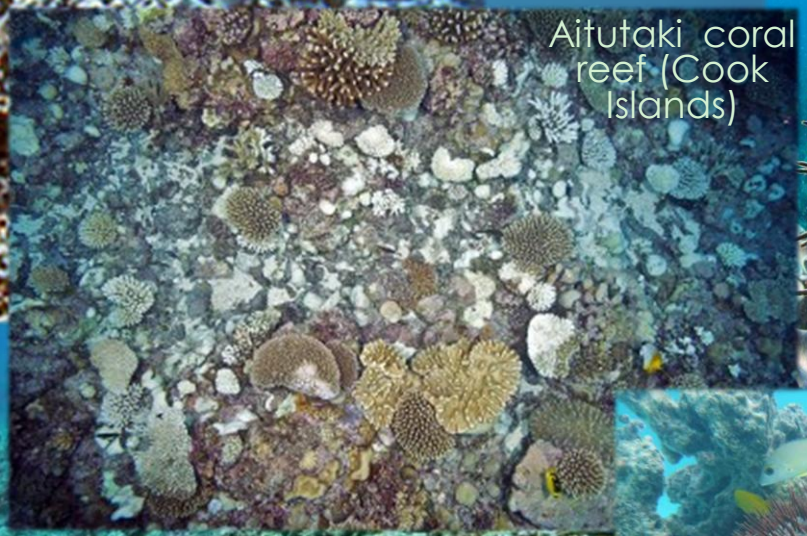
Natural Sources: Predator Population Explosions



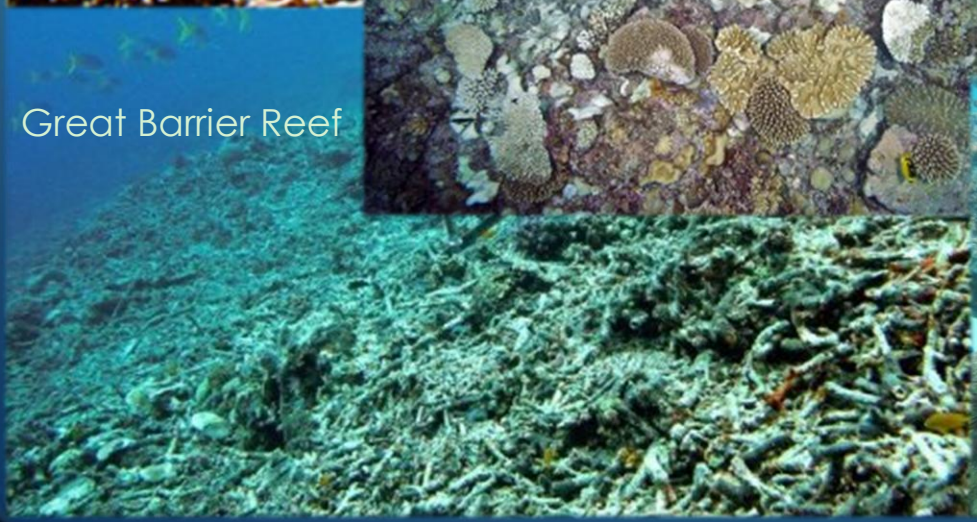
Great Barrier Reef

Damage that COTS can do to a reef system in just a short amount of time

Crown of Thorns starfish



Aitutaki coral reef (Cook Islands)



Great Barrier Reef

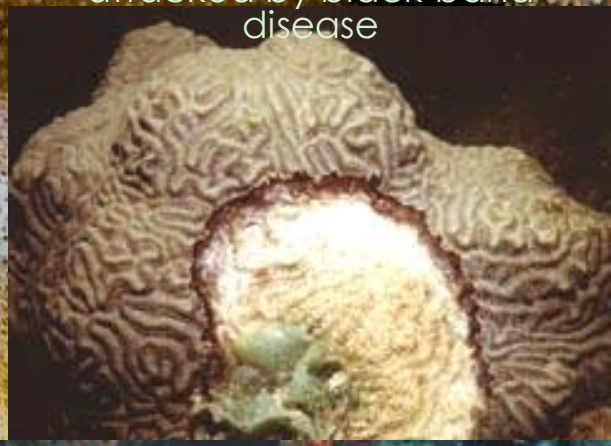
COTS on coral (lower right corner shows uneaten coral; upper right shows coral skeleton).

Natural Sources: Diseases and Biological Infestations

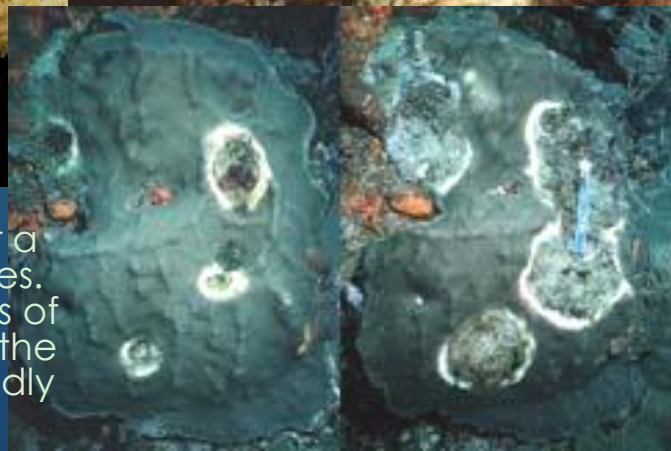
Some diseases appear as discolored bands, spots or lesions on the surface of coral. Over time, these expand over the coral's surface consuming the living tissue and leaving the stark white coral skeleton in their wake.

Other diseases cause large patches of living coral tissue to slough off, exposing the skeleton beneath. Once exposed, the coral's limestone skeleton can be a fertile breeding ground for algae and encrusting invertebrates.

The colonization and overgrowth of the exposed coral skeleton by foreign organisms often results in the health of the entire colony taking a downward spiral from which it seldom recovers.



large brain coral is being attacked by black-band disease



Yellow-band disease can rapidly spread over a coral, destroying the delicate underlying tissues. On the left is a massive coral in the early stages of attack by yellow band disease. On the right is the same coral several weeks later. Note how rapidly the area of destroyed tissue has expanded.

Local Human Sources of Coral Reef Stress

- sewage discharges and agricultural runoff: Fertilizer runoff and untreated sewage introduce added nutrients to coastal ecosystems. These elevated nutrient levels promote algae growth.
  - High concentrations of algae or solid sewage can overwhelm and smother polyps. Under normal conditions, herbivorous fish and some invertebrates keep the algae population balanced.
  - May lower water salinity making it difficult for polyps to form exoskeletons.
  - Increased nutrients may cause crown-of-thorns populations to flourish.

Local Human Sources of Coral Reef Stress

- thermal effluents: Power generating plants use enormous amounts of water to cool condensers and then discharge the now-heated water back into the environment causing increases in water temperature.
- ocean pollution: poisons coral polyps, takes on many forms including oil slicks, pesticides and other chemicals, heavy metals and garbage
- sedimentation from poor land use practices: Soil that settles on reefs smothers coral polyps and blocks out the sunlight needed for corals to live.
- Introduced / invasive species: In the absence of natural controls, the damage caused by invasive species can be devastating.

lionfish

Local Human Sources of Coral Reef Stress

- destructive fishing practices (resource extraction practices): More than 80% of the world's shallow reefs are severely over-fished.
  - overharvesting: sometimes rely too heavily on certain species causing some reef fish to be severely overharvested and damaging the reef ecosystem
  - dynamite fishing: use dynamite to kill and capture fish which destroys the reef framework itself
  - cyanide fishing: Collectors for pet and food trades dump poisons like cyanide or bleach into the water to stun fish and make them easier to capture, killing many fish, corals and reef wildlife, and degrading the reef habitat itself.

Local Human Sources of Coral Reef Stress

- mechanical damage: physical impacts from ship groundings and anchor, pipeline and cable damage ... Careless handling of nets, lines, and lobster traps has led to reef damage. Divers and snorkelers that sit or stand on or handle corals can injure the delicate polyps. Dropped boat anchors can gouge the reef and crush corals.
- global aquarium trade: Over collecting leads to local extinctions, disrupted mating systems and fewer fish on the reef.
- coral mining and souvenir trade: created an international market for coral skeletons, shells, sponges and other reef animals ... Coral skeletons are used as aquarium decorations or fashioned into jewelry and sculptures.

Local Human Sources of Coral Reef Stress

- coastal development and dredging: Habitats can be destroyed or disturbed by dredging activities and the dumping of waste materials. Greater amounts of fresh water, nutrients and sediment can reach the reefs causing further degradation. Nutrient-rich water causes fleshy algae and phytoplankton to thrive in coastal areas in suffocating amounts known as algal blooms. Coral reefs are biological assemblages adapted to waters with low nutrient content, and the addition of nutrients favors species that disrupt the balance of the reef communities.
- eutrophication: a common phenomenon in coastal waters and the ecosystem's response to the addition of artificial or natural nutrients ... In contrast to freshwater systems, nitrogen is more commonly the key limiting nutrient of marine waters so nitrogen levels have greater importance in salt water.

Local Human Sources of Coral Reef Stress

- military and nuclear testing: excessive noise, explosions, oil and fuel spills, wreckage and debris, damage to reef structure, siltation from construction and dredging, waste management practices, recreational activities, species introductions, nuclear destruction of habitats
  - Coral Reef Conservation Guide for the Military
- unsustainable tourism: Tourism generates vast amounts of income for host states. Where unregulated however, tourism pressures can cause damage to the very environment upon which the industry depends.

Local Human Sources: Sewage Discharge and Agricultural Runoff

- ecological consequences
  - phytoplankton bloom reduces light penetration and promotes growth of filter-feeding bio-eroders
  - benthic seaweeds overgrow and smother corals

Local Human Sources: Nutrients and Algae Growth

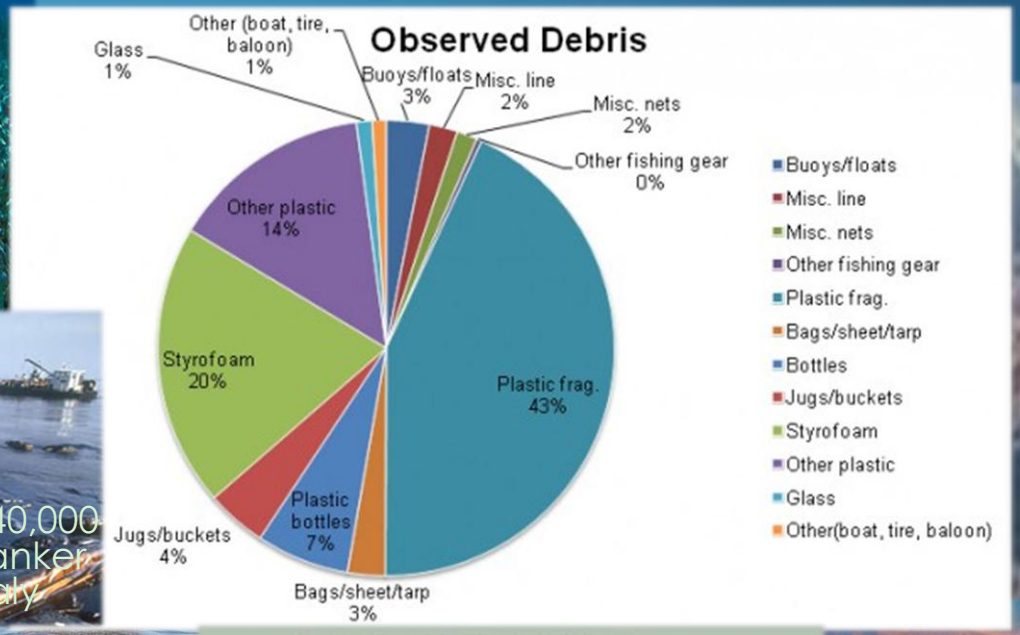
dead coral covered with sediment and turf algae in the Gulf of Mannar.

Local Human Sources: Other Wastes

Local Human Sources: Toxic Chemicals

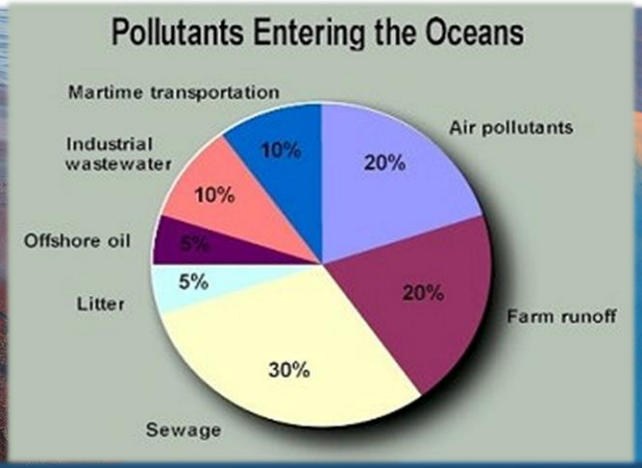
Industries dump waste such as oil, fertilizers, solid garbage and toxic chemicals.

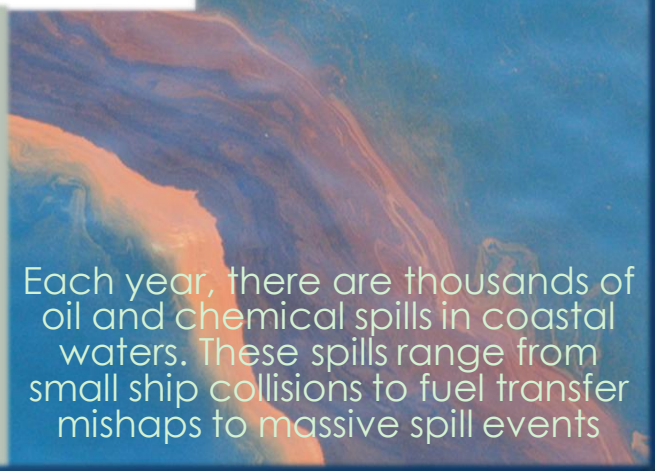
efforts to contain the 140,000 tons of oil spill from a tanker that exploded off Italy



California oil spill caused by ruptured pipeline

560,000-1,400,000 barrels of oil leak into the Gulf of Mexico every year.

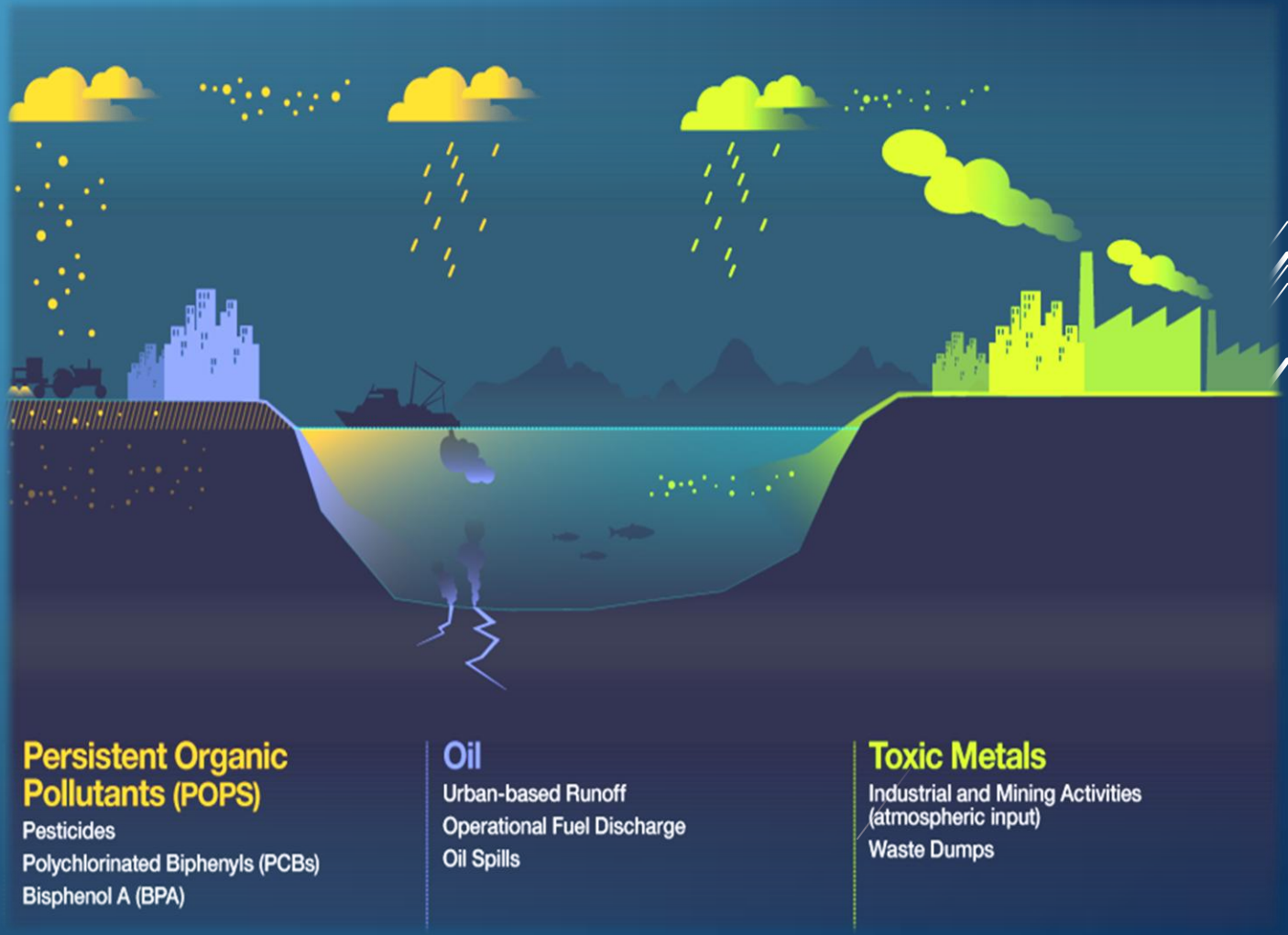




Each year, there are thousands of oil and chemical spills in coastal waters. These spills range from small ship collisions to fuel transfer mishaps to massive spill events

Local Human Sources: Toxic Chemicals

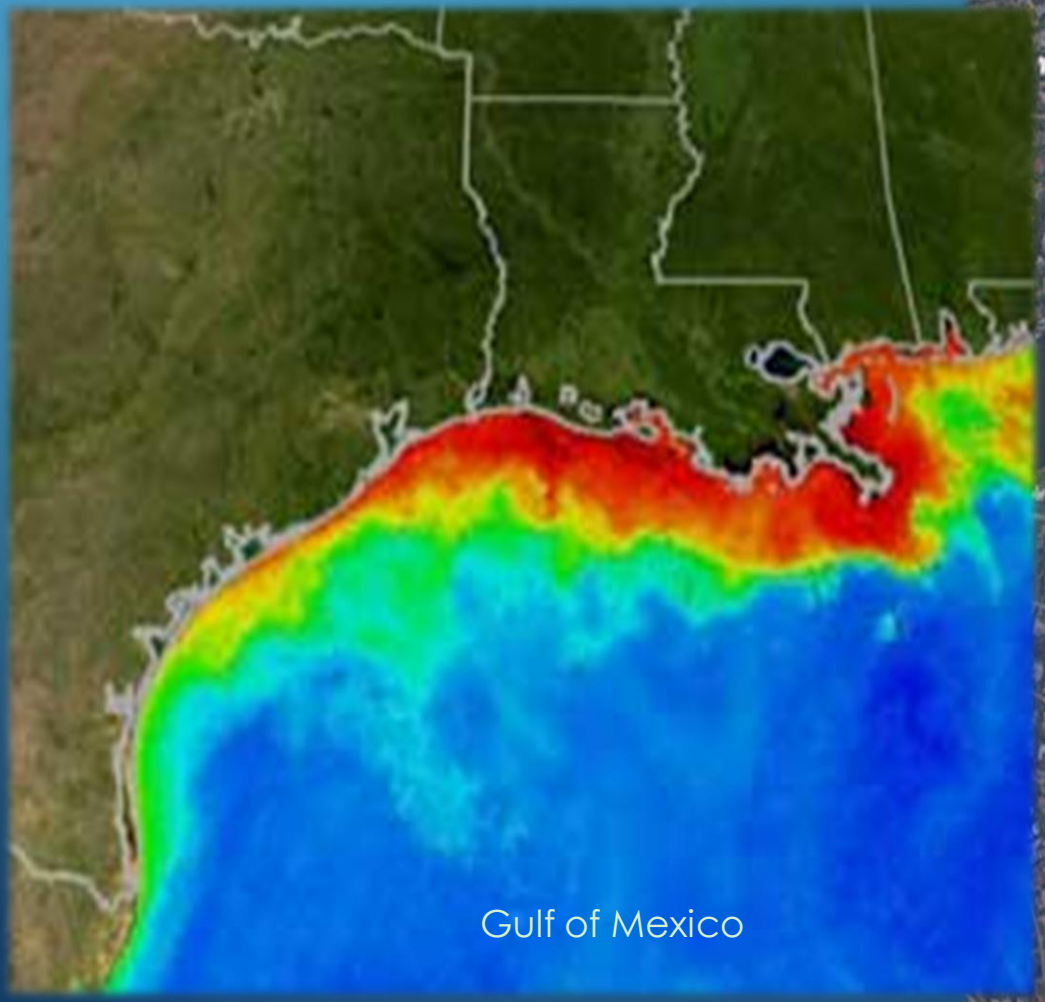
More than 100,000 chemicals are used commercially and many enter the marine environment via atmospheric transport, runoff into waterways or direct disposal into the ocean. Three general categories of chemicals are of particular concern in the marine environment: oil, toxic metals and persistent organic pollutants.



Local Human Sources: Nonpoint Source (NPS) Pollution

- … caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters
  - sediments from coastal urban and agricultural development
  - nutrients from detergents, fertilizers, leaky septic tanks and domesticated animals
  - pesticides (home use, agricultural and golf courses)
  - automobile wastes such as combusted motor oil, tire rubber, brake pad dust, coolant, etc
  - waste water from swimming pools and aquaculture ponds

Local Human Sources: NPS Pollution



Local Human Sources: Sediment Runoff


Tijuana River, Mexico


Rio Loco River, Puerto Rico


Rio de La Plata, Argentina

Local Human Sources: Sediment Plume Entering the Ocean

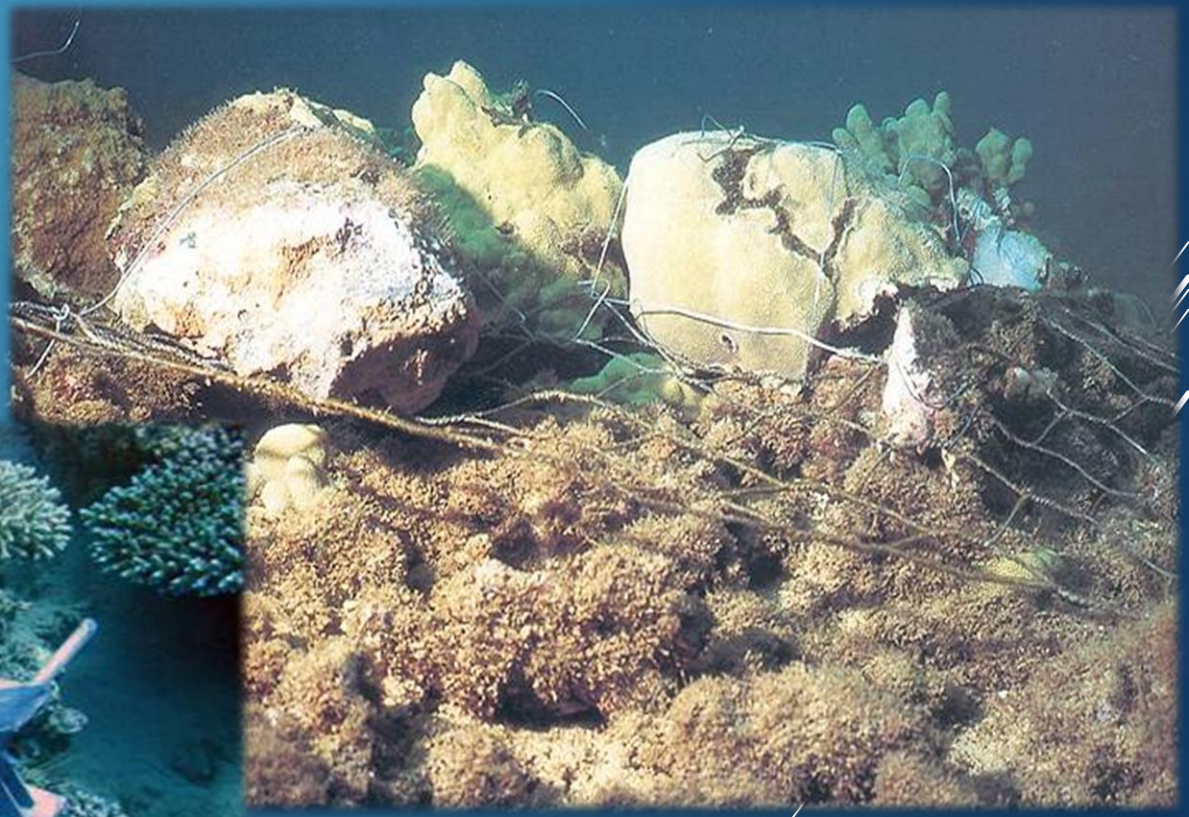
Local Human Sources: Corals Smothered in Sediment

Local Human Sources: Introduced Species

Local Human Sources: Destructive Resource Extraction Practices

- overfishing
- use of dynamite to catch fish
- use of bleach or cyanide to catch fish
- breakage of coral to remove fan worms
- collection of live coral or rocks

Local Human Sources: Mechanical Damage



Local Human Sources: Mining of Reef Limestone

Local Human Sources: Coastal Development

Local Human Sources: Dredging

Local Human Sources: Loving a Reef to Death

- walking on reefs
- diver damage
- fish feeding
- excessive recreational use

Global Human Sources of Coral Reef Stress

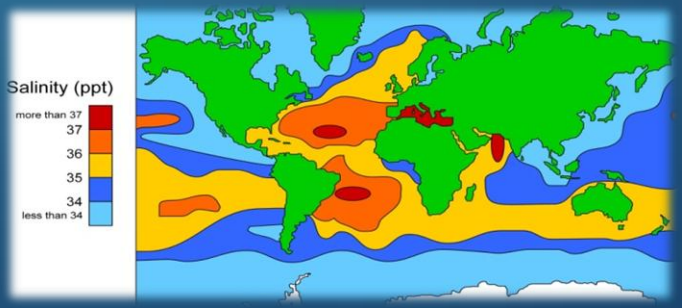
- rising seawater temperature due to climate change: one of the most serious causes of stress to corals throughout the world
  - Higher than normal temperatures (1-2 degrees), pollution, and exposure to air breaks down the relationship between corals and their symbiotic microalgae and the plant cells are ejected.
  - The algae are what give corals some of their bright colors. When this happens, corals appear white or bleached. Just one degree above the typical summer max is enough to bleach many corals.
  - If the temperature is too high for too long, corals and their microalgae are unable to recover. Over the past 30 years, bleaching has become more frequent, intense and widespread. This has led to massive die offs of corals throughout the world.

Global Human Sources of Coral Reef Stress

- excessive carbon dioxide and ocean acidification: has emerged as another potentially serious threat to coral reefs … Traditionally, corals have removed excess carbon dioxide from the atmosphere. However, the amounts of carbon dioxide in the atmosphere have gone beyond what corals can uptake, and the oceans are becoming more acidic as higher amounts of carbon dioxide dissolve into the water. Increasing acidity reduces corals' ability to construct their calcium carbonate skeletons. The ocean's acidity has increased by 25% percent over the past 200 years. Acidic conditions dissolve coral skeletons, which make up the structure of the reef, and make it more difficult for corals to grow. If left unchecked, scientists estimate that the oceans could become 150% more acidic by the end of this century, making it very hard for corals to grow at all.

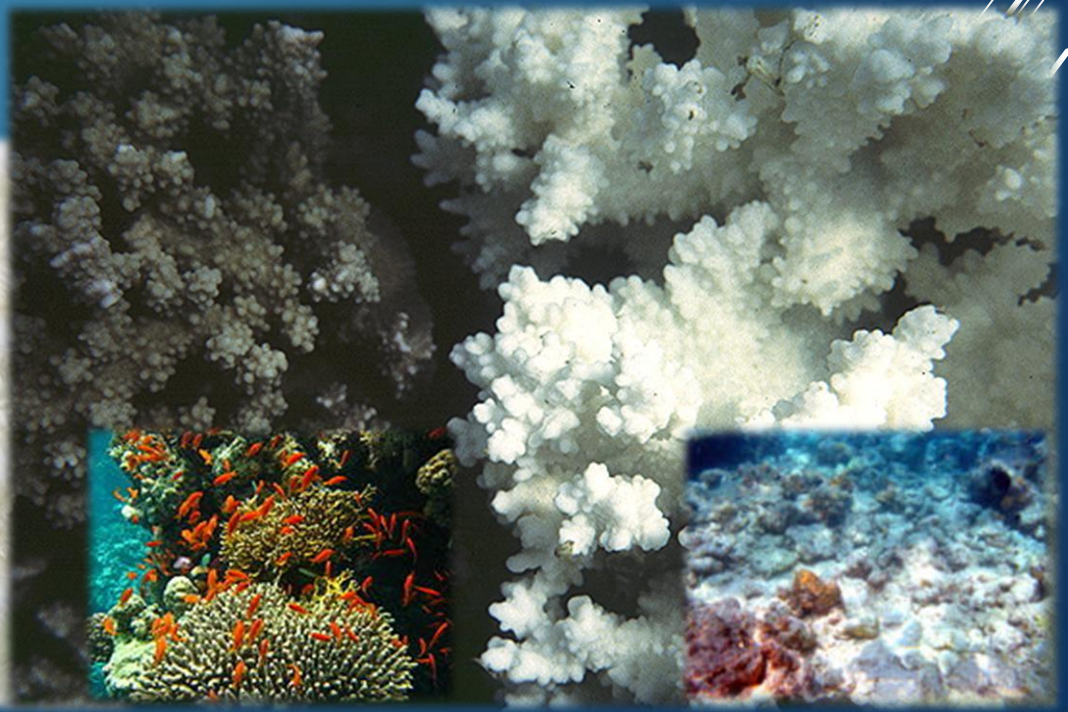
Global Human Sources of Coral Reef Stress

- warmer ocean temperatures: allow corals to become sick more easily, and allow disease-causing organisms to grow faster
- rise in sea level: would decrease the amount of available sunlight
- ozone depletion: increases intensity and nature of ultraviolet radiation, which in turn damages coral in shallow areas
- salinity changes: Corals require a salinity of 25-35 ppt for their skeleton-forming process. Weather changes due to global warming threaten to lower the ocean's salinity levels.



Global Human Sources: Coral Bleaching

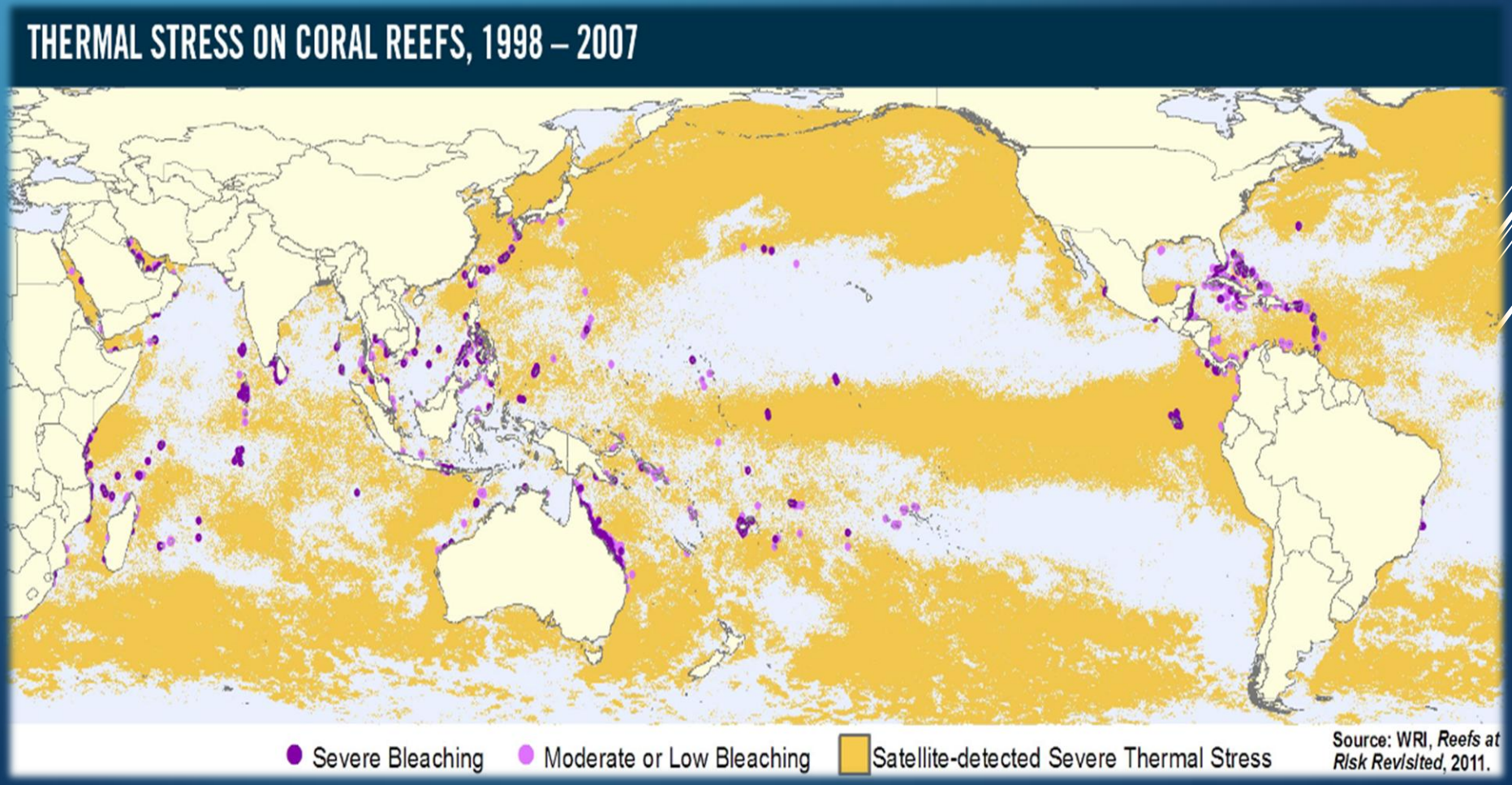
Coral bleaching results in white, dead-looking, coral. Healthy coral, by contrast, is very colorful and rich with marine life.



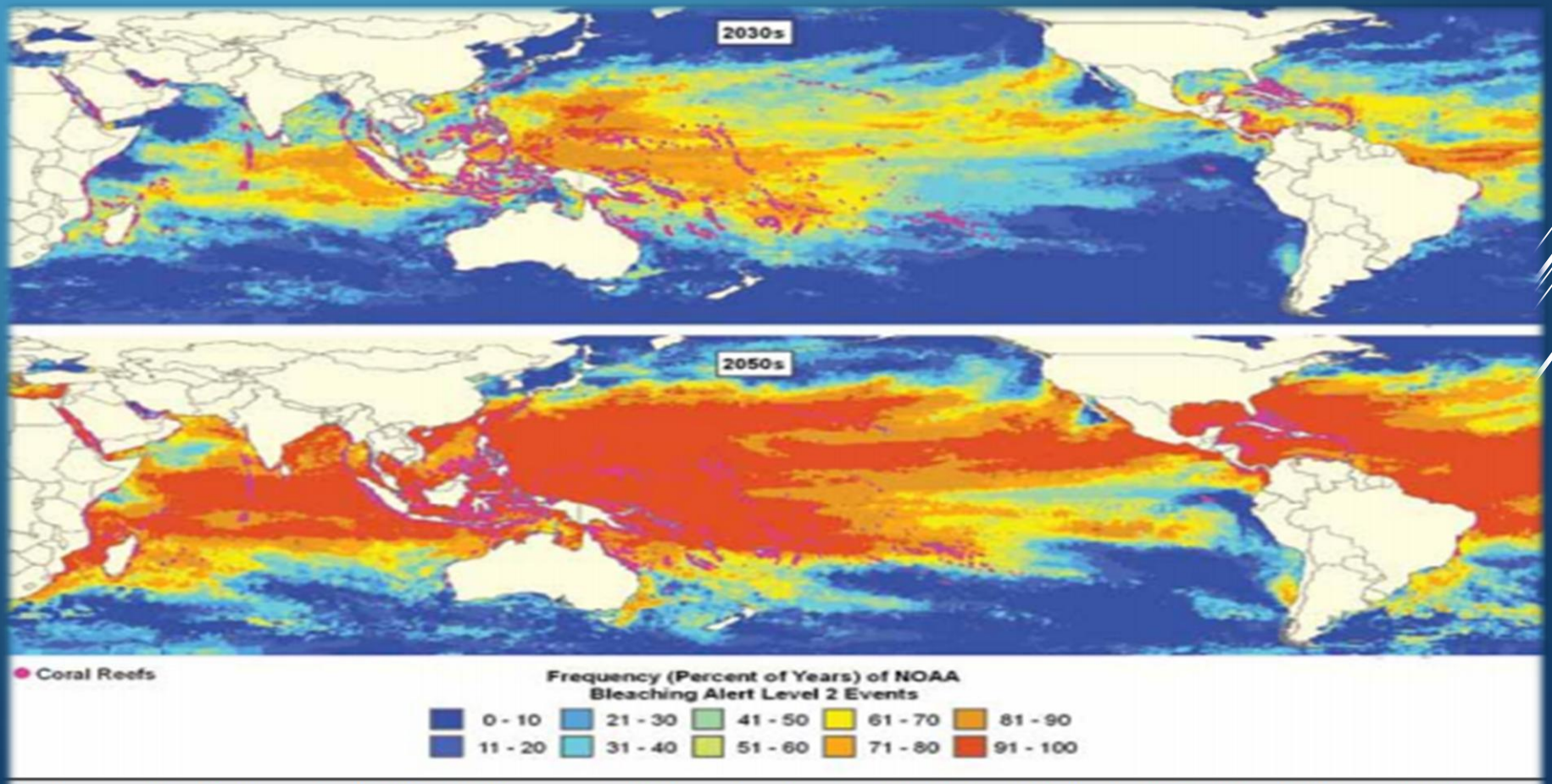
Global Human Sources: Causes of Coral Bleaching

- unusually high or low temperatures
- unusually high or low salinity
- high amounts of visible or ultraviolet light
- sedimentation
- high levels of nutrients (sewage, etc)
- high levels of toxins (pesticides, etc)

Global Human Sources: Coral Bleaching

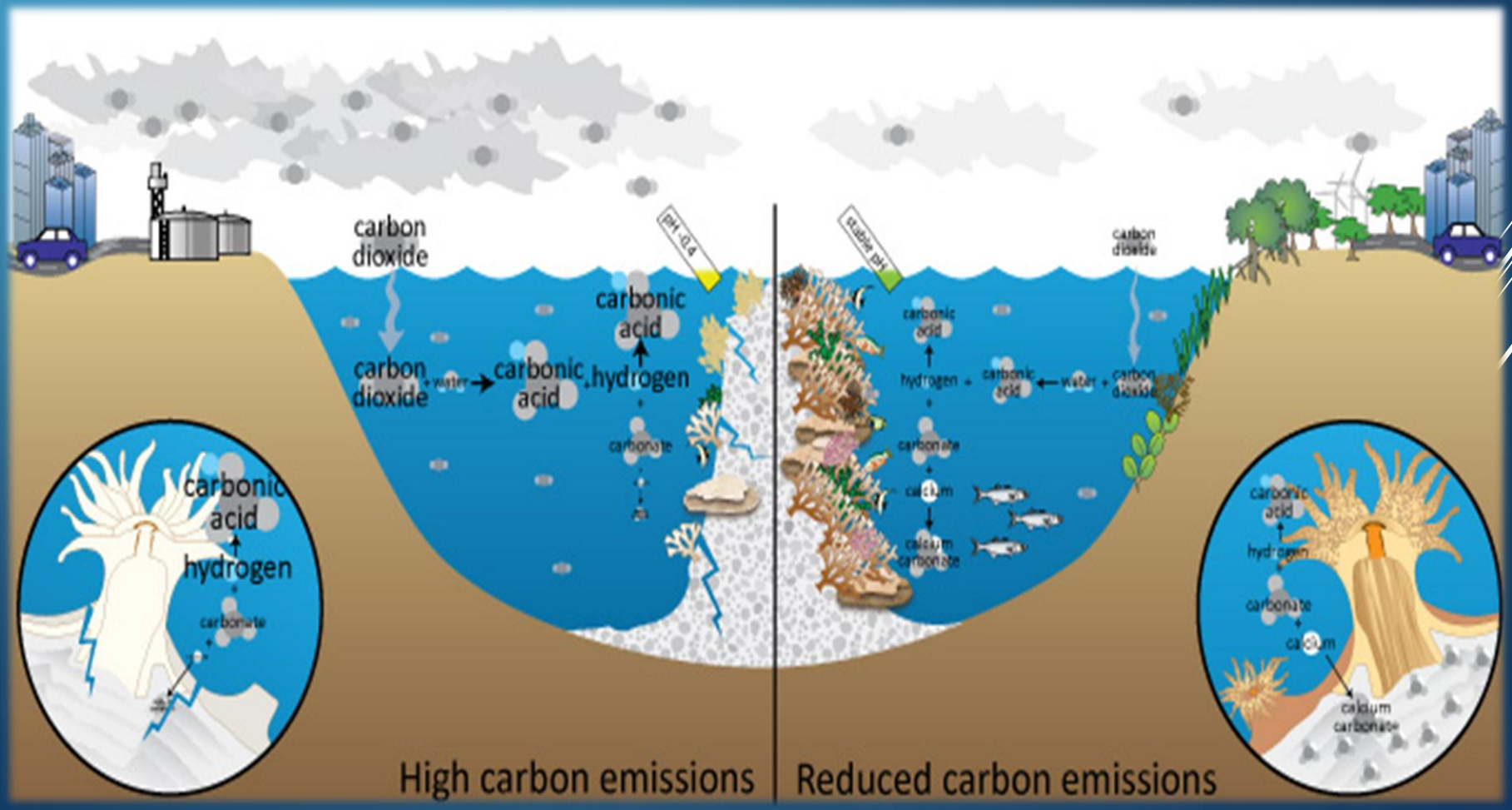


Global Human Sources: Coral Bleaching: 2030s, 2050s

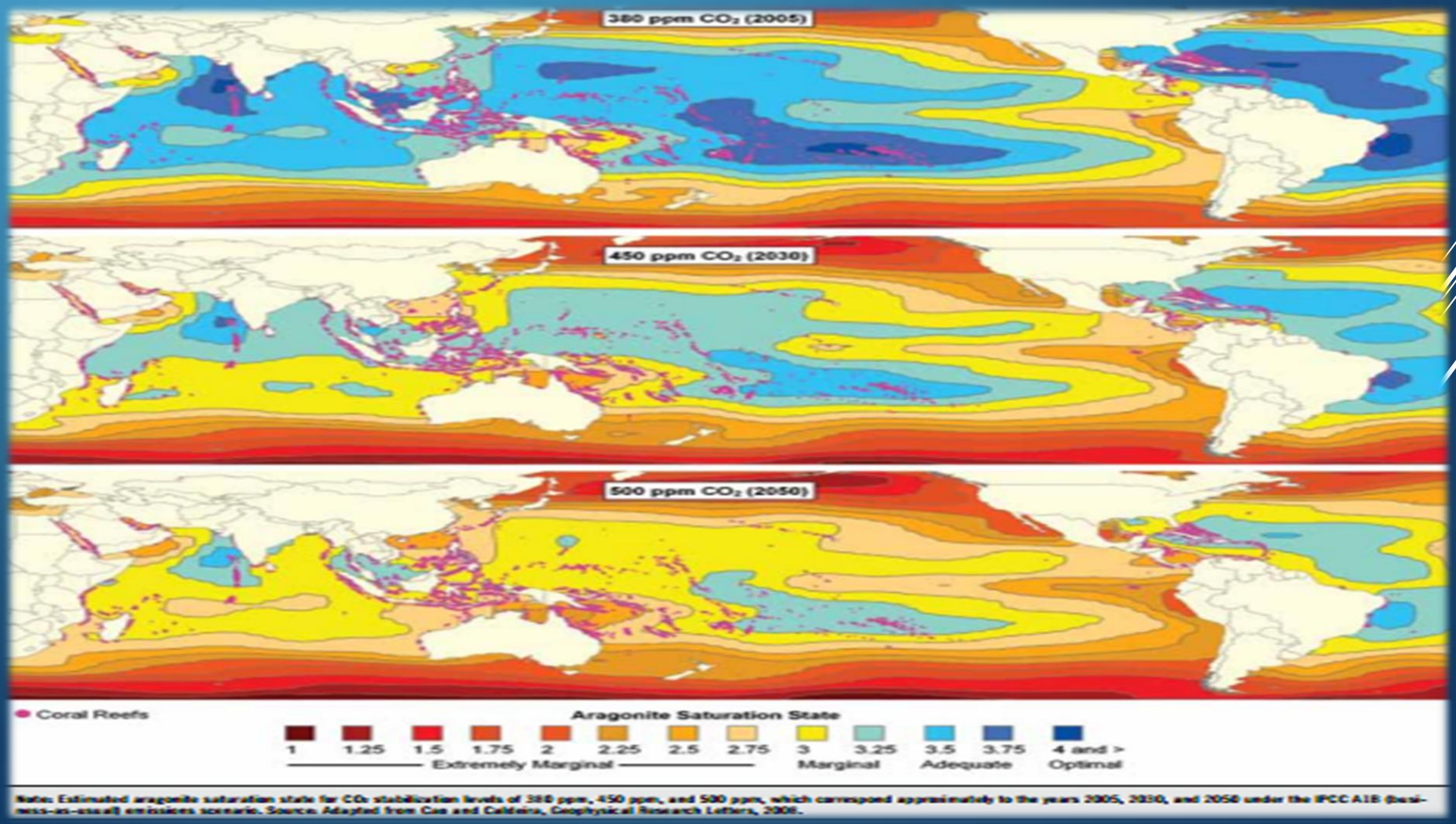


Note: Frequency of future bleaching events in the 2030s and 2050s, as represented by the percentage of years in each decade where a NOAA Bleaching Alert Level 2 is predicted to occur. Predictions are based on an IPCC A1B ("business-as-usual") emissions scenario and adjusted to account for historical temperature variability, but not adjusted by any other resistance or resilience factors. Source: Adapted from Donner, S.D. 2009. "Coping with Commitment: Projected thermal stress on coral reefs under different future scenarios." PLoS ONE 4(6): e5744.

Global Human Sources: Excessive Carbon Dioxide



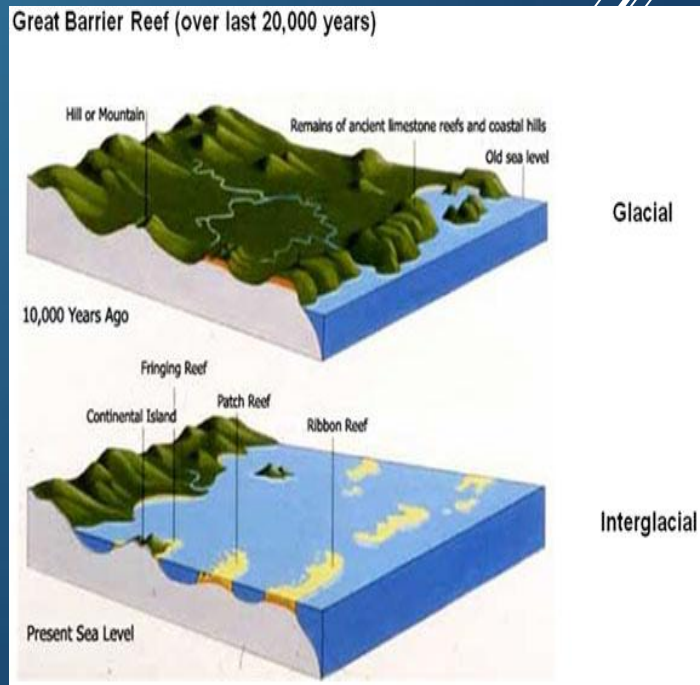
Global Human Sources: Ocean Acidification



Note: Estimated aragonite saturation state for CO_2 stabilization levels of 380 ppm, 450 ppm, and 500 ppm, which correspond approximately to the years 2005, 2030, and 2050 under the IPCC A1B (business-as-usual) emissions scenario. Source: Adapted from Cao and Caldeira, Geophysical Research Letters, 2008.

The Consequences of Coral Reef Stress

- outright mortality of coral tissues
- breakage of coral colonies
- bleaching
- diseases
- slower growth
- competitive exclusion by other organisms
- increased reef erosion



Protecting Coral Reefs: National and International Regulations

- The US prohibits the removal or destruction of corals from all areas of the continental shelf within a 3-mile limit.
- The Florida Fish and Wildlife Conservation Commission prohibits the collection of living or dead stony corals or fire corals within Florida waters.
- The collection of hard corals is banned in Hawaii, Guam and Puerto Rico.
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates the international trade of certain animals and plants. More specifically, the Convention regulates the import, export, re-export and introduction from the sea of certain plants and animals based on their vulnerability.

Protecting Coral Reefs

- The establishment of marine sanctuaries or preserves may help ensure the availability of this ecosystem in the years to come.
- The Australian government established the Great Barrier Reef Marine Park in 1975 to manage and protect a large part of the reef. In addition, the Great Barrier Reef was designated as an UNESCO World Heritage Site in 1981, providing further protection to this 1,430 mile-long coral reef system.
- In US waters, the NOAA National Marine Sanctuary system is composed of 14 federally-protected underwater regions, including more than 150,000 square miles of ocean and Great Lakes waters. Several are sanctuaries that protect corals and coral reefs.

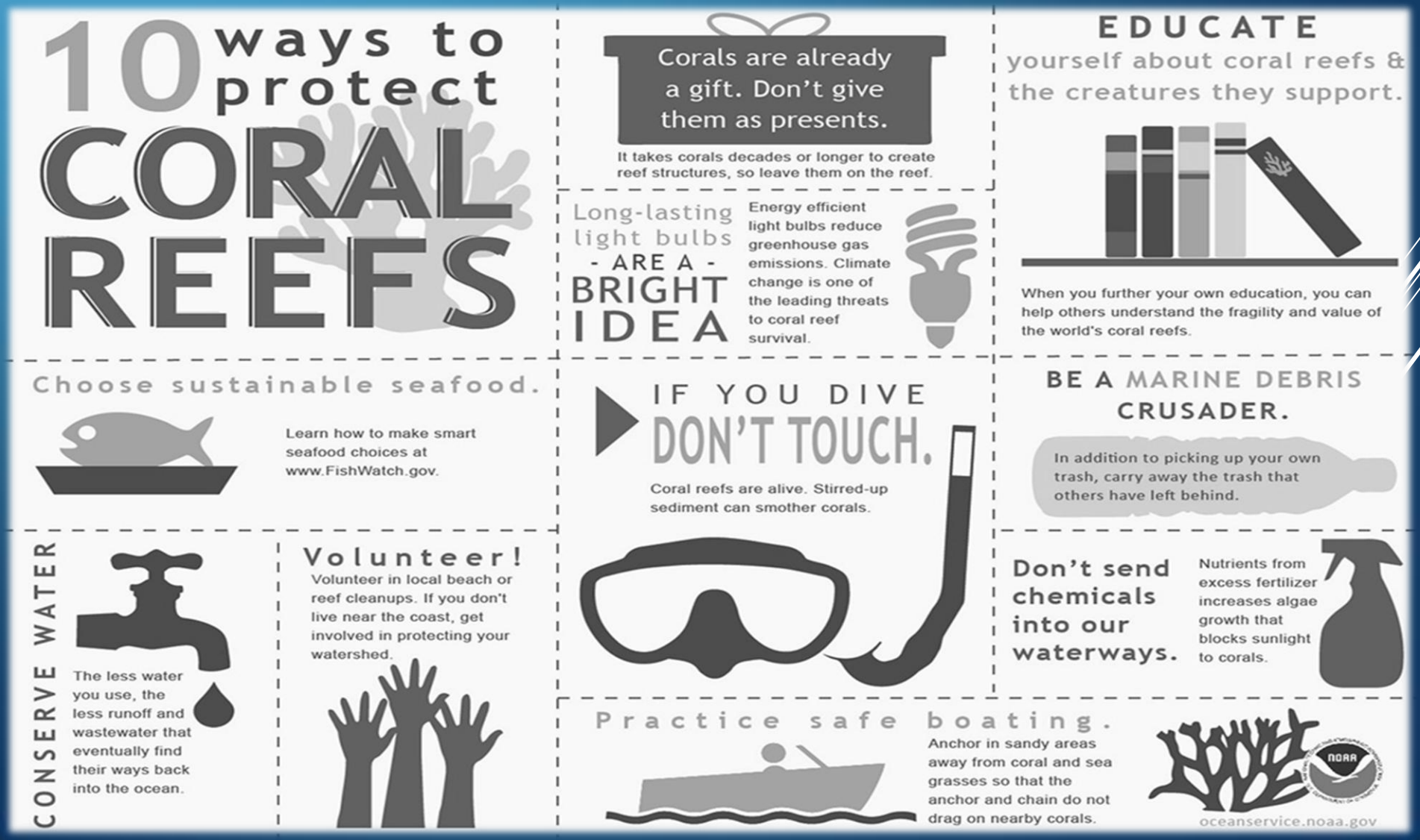
NATIONAL MARINE SANCTUARIES

coral reef ecosystem off Swains Island in the National Marine Sanctuary of American Samoa

Protecting Coral Reefs

- Education:
  - Don't sit on, stand on or even touch live coral.
  - Boaters should take care with anchors and when navigating around coral reefs.
  - Don't collect dead or living coral.
  - Only purchase aquarium fish that have been aquarium raised or from a Marine Aquarium Council (MAC) certified retailer.
  - Support sustainable fisheries by only eating seafood certified by the Marine Stewardship Council (MSC).
  - Help reduce carbon dioxide emissions into the Earth's atmosphere and, eventually, the oceans.

Protecting Coral Reefs



The End