Introduction to the Coral Reef Ecosystem

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Introduction to the Coral Reef Ecosystem

- A. Coral Reefs in Crisis
  - How many of you have dived or snorkeled on a living coral reef?
    Many of us who have cannot help but notice that coral reefs in the Florida Keys and all over the world are beginning to show rapid signs of deterioration..
  - What is the cause of it?
    (Human impacts are placing unnatural stresses on the fragile and bologicially diverse coral reef ecosystems of the world, leading to a proliferation of coral diseases and the loss of acres of living coral. Many of these coral gardens will never recover unless we act now to reverse this decline through education and good public policy.)
- Objective
  - The goal of this coral reef ecology course is to raise the awareness of students, residents, visitors and people all over the world to the fragility and importance of the coral reef ecosystem, in order to increase awareness and protection and avoid or reduce direct human impacts on coral reefs.
  - To increase appreciation of such a beautiful ecosystem, the most biologically diverse marine ecosystem on earth.
- Main Points
  - By the end of this course a student should be able to:
    - Describe the two most important food sources for coral polyps.
    - Cite the importance of the symbiotic algae living within the coral polyps

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Geological History Of The
Florida Keys

- Florida Keys
  - Lower Keys - Big Pine Key to Key West
  - Middle Keys and Upper Keys - SE end of Big Pine Key to key Largo

Geological History Of The Florida Keys

- **Florida Keys**
  ☆Extends from North Key Largo to the Dry Tortugas.
  ☆Protected on the west by mainland and Florida Bay and on the south and east by lagoon and coral reefs.
  ☆Coral reefs lie about six miles off shore and parallel the many islands or keys comprising the Florida Keys.
  - **Lower Keys**
    Big Pine Key to Key West
    - Most of the islands are the remains of old coral reefs with the exception of those comprising the Lower Keys which were formed by "shifting sand shoals" or "tidal sand bars". These sand bars were shaped by strong tidal currents, flowing back and forth between the Florida Bay and the Atlantic Ocean, between 125,000 and 2000,00 Years Before Present (YBP).
  - **Middle Keys and Upper Keys**
    SE end of Big Pine Key to Key Largo
    - Formed by corals and calcareous algae.
    - At 125 YBP, sea level was 20 to 50 feet higher than present level; most of Florida was under water.
    - At 100,000 YBP, sea level started dropping. It eventually dropped down to 300 feet below present level --> reef dies and formed coral rock.
    - Gradual erosion processes inflicted by air, sun, wind, rain and wave action caused the sand shoals to solidify, the reefs to flatten, and to slowly slope down towards the receding sea level.
    - At approximately 15,000 YBP (glacial period between 20,000 and 10,000 YBP), sea level started rising again at an approximate rate of 4 feet per 1,000 years.
    - Sea level stabilized at approximately 5,000 YBP.
    - Coral started growing again on top of the remains of ancient reefs.
    - Ancient reefs and sand shoals of 125,000 YBP laid the foundation for today's reef and land distribution.

Biology Of Corals

- What Is Coral?
  - Definition
  - Classific
  - Requirements
  - Distribution
  - Types
- Internal Structure
  - Skeleton
  - Soft Tissue

Biology Of Corals

- **What Is Coral?**

  ☆Some corals are solitary (only one polyp), such as the Flesh Disk Coral

  ☆Most species form colonies composed of hundreds or thousands of polyps covering a stony skeleton of calcium carbonate (hard corals), or a soft skeleton composed of a protein/calcium carbonate material (soft corals). This living tissue forms a very thin sheet of cells over the skeleton and measures less than 1/16" in thickness

  - Definition - A soft living organism, called a polyp, which secretes a skeleton of calcium carbonate; closely related to sea anemones.
    Some corals are solitary (only one polyp), such as the Flesh Disk Coral

    Most species form colonies composed of hundreds or thousands of polyps covering a stony skeleton of calcium carbonate (hard corals), or a soft skeleton composed of a protein/calcium carbonate material (soft corals). This living tissue forms a very thin sheet of cells over the skeleton and measures less than 1/16" in thickness

  - **Classific**
    Phylum:
    Cnidaria - All organisms belonging to this phylum are characterized by the presence of: Tentacles, Nematocysts (stinging cells), Central Digestive Cavity, Radial Symmetry

    Class:
    Hydrozoa - Portuguese-man-of-war, Fire Coral, Hydroids, Siphonophores

    Schvphozoa - Jelly fish (medusea)

    Anthoza - Sea anemones and corals

    Subclass:
    Octocorallia - Sea whips, Sea feathers, Sea plumes, Other gorgonians

    Zooantharia

    Order:
    Actinaria - anemones

Zooanthiniaria - carpet anemones

Scleractina - true stony corals

- **Requirements**
  - Clear, shallow and warm waters with temperatures ranging between 75 F (23.8 C) and 85 F (29.4 C). However, in the Florida Keys, corals may grow at temperatures as low as 64 F (17.7 C).
  - At temperatures greater than 90 F (32.2 C) growth stops
- **Distribution**
  Tropical waters of the world.

5. Types
   - Hard Corals (e.g. brain, elkhorn, staghorn, star, pillar coral, etc.)
   - Soft Corals (e.g. gorgonians or sea fans, sea whip, sea feather, etc.)
   - False Corals (e.g. fire coral, sea mats)

- **Internal Structure**
  - **Skeleton**
    - Deposited at the base of the polyp. A single polyp's skeleton is referred to as corallite or coral cup. polyp absorbs calcium from sea water and, through a biochemical process, it continuously secretes aragonite (a form of $CaCO_3$) at it's base. This causes an upward growth of the polyp. When the polyp divides horizontally (budding --> addition of a new polyp in conjunction with new skeletal material) it leads to horizontal growth.
    - Growth Rate
      - Slow for massive corals (e.g. star coral and brain coral) --> 1/8" (.32 cm) - 3/4" (1.9 cm) per years.
      - Faster for branching corals: (e.g. elkhorn, or staghorn coral) --> 8" (20.32 cm) per year (upward or terminal growth).
  - **Soft Tissue**
    - Composition: Two layers of cells and an amorphous layer between them. Upper end of polyp is open and crowned with a ring of tentacles surrounding a mouth -like opening.
    - Tentacles: Have specialized stinging cells called nematocysts which shoot dart-like barbs that capture and stun small animals (like zooplankton). it is covered with microscopic cilia and a thin layer of mucus.
    - Mouth: Leads to the stomach cavity, which is infolded longitudinally. These enfolding are called Mesenteries, where the gonads are present and where digestion takes place. The free ends of these partitions present long filaments called mesenterial filaments, which can be extruded through the mouth or openings through the body wall. these play an important role in the digestive process.
    - Adjacent polyps: Are frequently interconnected by the living tissue containing extensions of the gastrovascular cavity.
    - Living tissue: Also responsible for depositing skeleton between polyps.
    - Zooxanthellae: Microscopic algae which lives in large numbers inside the coral tissue and represents one of the most interesting aspects of coral biology. They live, divide and conduct photosynthesis within cells of polyp and may represent up to 50% of polyp's body weight.
      ☆This is an example of a perfect symbiotic relationship --> the

association between two different organisms in which there is a mutual benefit from the relationship (to be discussed in the next section).

- **Nutritional Sources And Feeding Strategies**
  ☆There has been considerable controversy/discussion as to what is the main food source of corals (% of contribution is beyond scope of course).
  ☆The three most important nutritional sources are:
    - **By-Products Of Zooxanthellae Photosynthesis**
      - a. During process of photosynthesis plants use sunlight energy to transform water, minerals and carbon dioxide into oxygen and carbohydrates (sugars).
      - b. O2 and carbohydrates are essential elements in the metabolic processes of corals (Energy Production).
      - c. Strategy - Translocation: Process by which these essential elements are "leaked" by algae into the polyp's tissue which in turn absorbs and directly utilizes them towards its metabolism On the other hand, the polyp's "Waste Products",. such as urea, which is a rich source of nitrogen, and CO2 (essential elements in the algae's nutritional requirements), are absorbed and metabolized by the algae. Besides playing an important role in coral nutrition the zooxanthellae is also essential in the process of skeleton deposition. The poly, on the other hand, also provides protection for the algae.
    - **Zooplankton**
      - a. Define and explain zooplankton and phytoplankton--> floaters; some are able to swim short distances.
      - b. Distribution:
        - 1. World Oceans, lakes and rivers.
        - 2. Present diurnal vertical migration - migrate to the bottom of the reef during the day and back to the surface at night. Why? Hypothesis:
          ☆Avoid predators.
          ☆Save energy on colder bottom water.
          ☆Seek food.
      - c. Strategy:
        - 1. Being primarily carnivores, zooplankton play a very important role in coral nutrition.
        - 2. Suspension Feeding: Corals are sometimes wrongly referred to as filter feeders. They trap food suspended in the water two methods:
          ☆Tentacles sense chemical and mechanical signals, activate nematocysts, stinging and capturing prey. Tentacles withdraw and cilia helps bring immobilized prey down to digestive cavity (best seen at night using light).
          ☆Mucus: Polyps may release mucus in the form of thin sheets over the whole colony or in strands or sheets into the water. Plankton, bacteria, organic debris get stuck to it and, through the help of cilia present on the tentacles, the mucus is brought back into digestive cavity where it gets digested. Scientists have found mucus to present a rich fauna of organisms thus making it an excellent food source, not only for corals, but for other organisms as well. Mucus is also used to get rid of sediments that settle on top of the colony.

- **Dissolved And Particulate Organic Material**
  - a. Dissolved organic molecules, such as glucose and certain amino acids, can be absorbed from water through the polyp's body wall by means of tiny fuzzlike projections, called "microvili" (Kaplan, 1982, p. 106) - Source: Leakage of organic molecules from decomposing animals and plants.
  - b. Particulate organic particles, such as bacteria, decomposing organic matter and fish fecal material (detritus) are directly ingested by the polyp (Barnes and Mann, Fundamentals of Aquatic Ecosystems, 1980, p. 87)
  - c. "Gastrovascular cavity of some species of colonial corals are interconnected, thus food obtained by one polyp can be transported throughout it's own body or to other polyps;> (Kaplan, p. 62)
  - d. Strategy
    - 1. Absorption: by microvilli on polyp's body wall, by mesenterial filaments.
    - 2. Suspension Feeding: by tentacles, by mucus strands. Interesting Observation: The latest scientific studies show a unique relationship between the percentage of nutritional contribution by each food source and corresponding polyp sizes. The most widely accepted theory states that species with large polyps obtain a higher percentage of their nutritional needs from zooplankton. large polyps are more efficient raptorial feeders than small tentacled species, for example the Montastrea cavernosa (large polyp species) can only meet 10% to 20% of its daily nutritional needs from zooxanthellae. Many large-polyped coral species partially or fully retract their tentacles during the day, and then fully expand them at night. In contrast, small-polyped corals maintain their tentacles fully extended both in daylight and at night. Species with very small polyps, such as Gorgonians, seems to satisfy most of their nutritional needs from byproducts of zooxanthellae, since they are relatively inefficient at capturing zooplankton. By maintaining their tentacles extended at all times, they are able to increase the percentage of surface area exposed to sunlight. This behavior maximizes the photosynthetic capacity of the host algae, and provides the added benefit of allowing the polyps to capture zooplankton at night.

- **Methods Of Reproduction, Propagation, And Growth**
  Corals exhibit both sexual and asexual reproduction and various methods of fertilization.
  - **Asexual Reproduction (Budding)**
    - a. Method which allows for colony growth by the continuous division of pre-existing polyps into BUDDS.
    - b. Two Types:
      - 1. Intratentacular (referred to as fission). The oral disk invaginates to produce a new mouth within the parental ring of tentacles.
      - 2. Extratentacular (referred to as BUDDING). The new mouth is produced outside the parental ring of tentacles.
    - c. New budding polyps form on the horizontal axis.
    - d. New polyps may appear anywhere in the tissue between the polyps. Mouth forms first followed by a ring of tentacles.
    - e. Some species exhibit both traits.
  - **Sexual Reproduction**

- a. Method which allows for the formation of new colonies
- b. Two types of colonies
  - 1. Hermaphroditic colony
    ☆Polyps have both male and female gonads, (e.g. elkhorn coral) producing ripe eggs and sperm in the same polyp.
    ☆However, many times the eggs and sperm mature at different times, thus inhibiting self-fertilization.
    ☆Fertilization may be external; (brooders), which is rare, or external (broadcasters).
  - 2. Gonacharistic (unisexual colony)
    ☆When all polyps of a colony are male or female (e.g. pillar coral).
    ☆Fertilization may be external or internal;.
    ☆Sex may change with age.
- c. What triggers spawning? In Australia the major trigger is the moon phase (New Moon). Spawning seems to begin one or two nights after the full moon in late spring or early summer.
- d. Egg fertilization is internal (brooders) for most species. The sperm swims into the mouth of the female polyp, eggs are fertilized and become a planulae - ciliated and oval-shaped larvae. Upon reaching maturity it swims clear of the female polyp. It may swim for 2 to 3 weeks before settling on the bottom (which must be hard, clean, silt- and algae-free), becoming polyps and starting a new colony. Note: Under the low nutrient conditions of tropical waters, corals will naturally out-compete algae. However, when nitrogen and phosphorous, the main limiting nutrients for algae growth, are artificially introduced into the ecosystem, the delicate ecological balance is altered. The algae will rapidly reproduce and take over substrates that otherwise would be colonized by new coral recruitment.
- e. Some species exhibit external fertilization (broadcaster): eggs and sperm shed into the water column.

- **Growth**
  - a. Involves the production of new polyps coupled with the continuous deposition of skeletal material
  - b. Two types:
    - 1. Non-Branching: if growth is mainly upward (skeleton addition) and horizontal (budding), massive coral heads will form (e.g. boulder corals -- brain and star corals).
    - 2. Branching: if growth and polyp formation is mainly terminal (at the tips), branching type colony will form (e.g. elkhorn and staghorn corals).
- **Propagation**
  ☆Fragmentation -- natural process in which broken pieces of a colony may re-attach by cementing themselves tot he bottom and forming a new colony. This is a common in branching species of stony corals.
- **Growth Requirements**
  ☆In order for corals to grow and reproduce, ocean water conditions must fall within certain physical, chemical and biological parameters:
    - 1. Temperature -- 75 F (23.8 C) to 85 F (29.4 C) (Florida Keys water temperature can be as low as 64 F (17.7 C)). At temperatures less than 75 F and greater than 85 F, corals start to experience stress.

        - 2. Light Penetration -- need shallow and sediment/algae-free waters.
        - 3. Salinity -- 34 to 37 ppt (normal for sea water)
        - 4. Food Supply -- Zooplankton, etc., from open ocean and within lagoon.
        - 5. Nutrient concentrations -- Nitrogen & Phosphate must be low.
        - 6. Pollutants , Silt and Sediments -- must be low.

Coral Reef Ecosystem

Coral Reef Ecosystem

Most biologically diverse marine ecosystem in the world
Ecosystem -- Ecological system formed by several interrelated communities
Ecology -- Study of the relationship between living organisms and their environment
Composition -- Composed of four main communities (in the context of the Florida Keys System):

- 1. Hammock Forest Community
    - a. Location
        - 1. Where the reef ecosystem starts: on upland (dry land) locations situated behind the mangrove forests that lie along the shores of the Keys.
        - 2. Most of the forest was destroyed in the late 1800's for ship and boat construction as well as for fruit and vegetable cultivation. Destruction of the community continues for real estate development.
    - b. Composition
        - 1. Composed of over 200 different species of tropical hardwood trees, shrubs, vines and other plants (mahogany, ironwood, gumbo limbo, tamarinds, bromeliads, orchids).
        - 2. Large hammocks today are limited to very few areas in the extreme southern tip of Florida and Florida Keys such as: North Key largo, Long key, Big Pine Key, Lower Matecumbe Key, Key Vaca and a few others.
    - c. Importance
        - 1. Protects the mainland soil from erosional forces and hurricanes; conserves scarce fresh water (crevices in limestone are filled with a spongy layer of humus which inhibits water from percolating away); filters atmospheric CO2; traps silt and sediment thus preventing erosion that otherwise would lower marine life quality.
        - 2. Decaying vegetation and thick humus contribute nutrients to itself, to the next community (the mangrove forest), and to the water by means of runoff. This natural and gradual input of nutrients into the aquatic

environment does not upset its delicate ecological balance, unlike the heavy input caused by human-related land activities
        - 3. Once cleared, nutrients are washed away and scrubby vegetation takes over. It may take 60 to 100 years for a mature hammock forest to grow back.
        - 4. Provides shelter, food, nesting and resting grounds for several species of animals such as: Woodrats, Cotton Mice, Woodpeckers, Pigeons, Snake Rate, Insects, Snails, Crabs, Butterflies, and Key Deer.
- 2. Mangrove Forest Community
  ☆One of the most productive ecosystems in the world.
  ☆The Florida Keys are surrounded by a fringe of mangrove forests growing in the transitional zone between the marine and terrestrial ecosystems. This plant community is adapted to living in saline, wet, and loose soil that is periodically submerged by tides.
    - a. Location
      ☆Grows on sheltered shores near bays, river estuaries (river mouths) and bordering coastal lagoons of tropical regions.
    - b. Composition
      ☆Composed of three species of trees: The seaward side is dominated by the Red Mangrove, followed by the Black Mangrove and then the White Mangrove.
    - c. Mangrove Species
        - 1. Red Mangrove trees are characterized by two types of branching aerial roots: "prop roots" which develop from the trunk, and "drop roots" which develop from branches. They also exhibit specialized breathing pores called "lenticel". These pores are present on aerial roots and on areas of the trunk just above the water-air interface. their main function is to facilitate the transport of oxygen down to the submerged roots. This root system acts as a support for the tree on the soft mud and helps trap sediments. Red Mangroves are referred to as "salt excluders". They have a physiological mechanism which inhibits the absorption of salt through their roots. Red Mangroves exhibit an interesting form of reproduction and propagation. The fertilized flower develops into an embryo and then into an elongated seed called a "Propagule". The propagule falls into the water and float vertically until it takes root in the muddy sediments of shallow waters. Both black and white mangroves follow a similar pattern of reproduction, propagation, and growth. However, the propagules of these trees are shaped differently.
        - 2. Clack mangroves occurs shoreward to red mangroves. Its leaves are which on the underside and are covered with excreted salt crystals. This species possesses "Pneumatophores", which are small,pencil-like vertical root which extend through the ground. These root shots are characterized by a spongy tissue of loose cells, and also exhibit lenticels. Such evolutionary adaptations enable trees to obtain oxygen directly from the air and also helps consolidate swamp sediments.
        - 3. White mangroves grow on elevated grounds above the high tide mark and behind red and black mangroves. The leaves are thick, succulent, rounded at both ends, and the same color on both sides. the root system resembles that of most terrestrial trees and seldom shows breathing roots. these trees are the smallest of the three mangroves species, and also exhibit lenticels at the base of their trouble. Note: Both black and white mangroves are referred to as "salt extruders:. In the process of water absorption from the saline environment, salt absorbed by the roots is

extruded in the form of salt crystals. White mangroves extrude these crystals through specialized glands at the base of their leaves, whereas black mangroves release unwanted salt through the bottom of their leaves.

- 3. Seagrass Bed Community
  ☆Is formed by extensive meadows of marine flowering grasses. They produce an extensive underground network of roots and stems, called "Rhizomes:, from which new shoots are sent up. They may propagate by means of fertilization or by re-establishment of broken pieces of the whole plant.
    - a. Location
      - 1. In shallow areas near shore (flats) of the Gulf's back country and across the bottom of Hawk's Channel Lagoon to the edge of the reef.
      - 2. Grow primarily in protects areas of bays and lagoons, where wave impact is minimal.
    - b. Composition
      - 1. Turtle grass, which has thin, flattened lance shaped leaves, and is responsible for the formation of extensive meadows.
      - 2. Manatee Grass, which has rounded leaves, occurs mixed with other grasses and rarely develops into meadows.
      - 3. Shoal Grass, which has thin and flat leaves, is a very important species in Monroe County, Florida. this grass is able to colonize areas highly disturbed with sediments, while the two other species are excluded by these adverse environmental conditions.
    - c. Importance
      - 1. Feeding grounds -- as blades and associated fauna area a rich food source for larvae and young of both fish and invertebrates, the habitat presents high species diversity such as: worms, crustaceans (crabs, mud and pink shrimp, lobster), mollusks (conchs), sea stars, sea horses, octopus, sea urchins, fishes, sea turtles, manatees, epiphytes, etc.
        ☆Studies have observed at least 113 species of algae growing on its leaves (Humm, 1964) and more than 130 species of animals, excluding fish, living on the community, Some of these animals are classified below:
        ☆Filter Feeders -- Burrow into bottom or attach themselves to blades; filter small decomposing particles from water (mollusks).
        ☆Deposit Feeders -- Forage along bottom feeding on detritus (crabs, shrimps, sea stars, urchins, and sea cucumbers)
        ☆Herbivores -- Feed directly on sea grass blades (manatees, urchins, sea turtles, and several species of fish -- parrot fish, surgeon fish). However, blades are fibrous and difficult to digest due to its high cellulose content. Researchers have not yet determined if these grazers are eating the grass for its nutritional value or for its epiphytes.
        ☆Carnivores -- Feed on small invertebrates and juvenile fish.
        ☆At dusk, many reef fish leave the sheltered reef and invade the turtle grass beds to feed on their blades (Parrot fish) or on small invertebrates (Grunts). At dawn, they return tot he reef.
      - 2. Nursery Grounds -- For the commercial pink shrimp, spiny lobster, gray snapper, sea trout, barracuda, grunts. The sea grass beds are considered the major nursery ground of the American Tropics.
      - 3. It is here that most of the nutrients produced in the mangrove are utilized.
      - 4. Shelter for several species of invertebrates.

        - 5. Prevention of Erosion -- Blades block and slow water flow thus helping trap and bind fine sediments together.
        - 6. Water Clarity -- Above process maintains water clarity, thus allowing the grass and zooxanthellae to process photosynthesis (--> coral growth)
        - 7. Nutrient Recycling -- Bacteria and Fungi break down blades and roots, making nutrients available to the organisms.
- 4. Coral Reef Community

  "The Living Coral Reef is one of the most diverse and complex communities in the world".

  The Florida Keys coral reef community presents approximately 107 species of corals (over 80% of all coral species of the tropical Atlantic) and over 500 species of tropical fish.

  The interaction and interdependence among all these organisms is so critical that many reef inhabitants cannot live outside the reef zone (e.g. Grunts).

  Sunlight, water, fish, invertebrates and plants play major roles in the sustaining and building of the reef:

  Sunlight --> Photosynthesis. Water --> Brings nutrients, O2, CO2. Fish --> Excrements help build and cement reef. Invertebrates and Plants --> Secrete calcium carbonate sediments that cement reef; food source; also grave the reef algae, creating space for corals to get established and grow.
    - a. Location
        - 1. From Dry Tortugas to Fowey Rock (S. Miami).
        - 2. Reef formations are found from 25 m to 13 km (7 miles) offshore.
        - 3. Depth: 3 feet to below 100 feet deep.
        - 4. Referred to as: "Florida Keys Reef Tract".
        - 5. Only living barrier reef community in the continental shelf of North America (3rd largest barrier reef in the world).
        - 6. Warm gulf stream water -- Florida Current -- plays a very important role in the existence and maintenance of these reefs. It brings nutrient-free (clean and clear) warm waters, plankton (food source) and recruitment of new species.
    - b. Composition
        - 1. This delicate community is not only composed of hard corals, but also of soft corals, sponges, fish, crustaceans, worms, snails, sea turtles, algae and many other organisms living in harmony with one another.
    - c. Importance
        - 1. Ecological Impact

          Storm Protection -- the reefs form a natural and self-repairing barrier that protects the lagoon and shore by absorbing the violent wave impact of ocean storms and hurricanes.

          Sand Production -- coral and calcareous algae are major sources of sand. Fish grazing on these organisms play an essential role in sand formation: and estimated 2 1/2 tons of sand per acre every year ("Our fragile Reefs", U.S. Dept. of Commerce, NOAA - from Laurie McLaughlin). This sandy sediment is fundamental for the growth of seagrass meadows (habitat for thousands of organisms) and the formation of sandy beaches along the shore.

          Food Production -- the reef community provides habitat, shelter, food and breeding grounds for many commercially valuable species such as lobsters, shrimp, groupers and snapper. Midchannel and offshore Patch Reefs also function as transitional habitats for species that migrate from

nearshore habitats (hardbottom and mangrove communities) to offshore reefs as they grow and mature.

- 2. Economic Impact
  ☆Tourism -- the economy of the Florida Keys depends primarily on the nearly 2 million tourists that visit the Keys and their coral reefs annually (divers, sport fisherman, sightseers, etc)
  ☆Fishing -- the coral reefs also support the fish that attract our local community of fisherman, the second most important economic and traditional force in the Keys.
  ☆Scientific Research -- being one of the most diverse and complex communities on the planet, it has attracted scientists and students from the world over to study and learn about its unique living and nonliving components.

- d. Types of Reefs
  - 1. Patch Reefs
    ☆Are linear of circular (dome shaped) in outline and found in waters 6 to 30 feet deep.
    ☆Found mostly along the seaward edge of Hawk Channel, but some are also present nearshore as well as in mid-channel.
    ☆HALO
    ☆Zone of barren sand around patch reefs and large coral head. It lacks sea grass due to grazing by black sea urchins and herbivorous fish. (parrot and surgeon fish).
    ☆Width of Halo represents the distance the fish feels safe for a quick retreat back to the reef.
  - 2. Barrier of Bank Reefs
    ☆Are typical elongated and form a narrow, linear, discontinuous arc from Miami all the way to the Dry Tortugas.
    ☆Occur mostly between the 3 and 35 foot depth contour. Reefs below 30 feet are occurring at depths after which the ocean floor has dropped off abruptly (at approximately 105 feet deep) are called deep reefs.
    ☆Halo is also present.

Reef Degradation

Reef Degradation

☆The Florida Keys Reef Tract is being impacted adversely by both direct and indirect human activities. The ecosystem has adapted to cope with naturally occurring events. However, short and long term stress on this fragile community are causing such a significant (perhaps permanent?) degree of damage to the reefs that it already affected the ecological balance of this

system. Besides that, it could eventually have a severe adverse impact on the economy of the Florida Keys, which is heavily dependent on the tourism and fishing industry for survival.

Natural Impacts

Major factors controlling coral reef development, community structure and species diversity:

- Hurricanes -- Fresh water stress; physical damage from waves; sedimentation stress.
- low Tides -- Hot water causes thermal stress --> coral expels Zooxanthellae --> may lead to death
- Cold Water Fronts -- Cause thermal stress (e.g. cold fronts from Florida Bay).
- Storms -- Fresh water stress; land and river run-off --> siltation; decreases salinity. (This last impact, however, is a rare event in the Keys)

Human Impacts

The accessibility and beauty of the Florida Keys coral reef ecosystem brings well over one million scuba divers, snorkelers, fisherman and boaters to our islands each year, This is approximately 10 times the number of tourists as the Great Barrier Coral Reef of Australia, which is ten times larger the Florida's reef.

The impact of these activities coupled with land-based processes such as shore development, farming, mining (phosphate industries), aerial spraying, sewage disposal, dredge and fill, etc., is placing a tremendous stress on the ecological balance of the reef, causing an unusually rapid decline of the system's overall health and ability to function

- Direct Impacts
    - Boat groundings and propellers damager corals and seagrasses, and injure marine mammals and turtles.
    - Anchoring is responsible for extensive damage *DAILY IMPACT*
    - Placement and recovery of lobster traps.
    - Flipping coral head by sports divers while capturing lobster.
    - Divers and snorkelers grabbing, stepping and standing on and kicking corals with fins and/or dragging their gear.
    - Hook and line fishing -- dragging, loss and discarded used line.
    - Commercial Fishery -- trap and gear loss (nets, lines, etc.).
    - Coral reef fauna collection.
    - Fish collection and chemicals used indiscriminately or in strong concentrations to stun fish may cause expulsion of Zooxanthellae and hurt invertebrate populations.
    - Irresponsible use of personal water crafts (e.g. near bird rookeries and over shallow flats during low tide).
    - Shore development -- marinas. channel dredging, land filling, sea wall construction --> leads to hammock and mangrove forests destruction.
    - Spear fishing removes large predatory species (tipping the balance).
    - Over-fishing can lead to the extinction of species (e.g. Queen Conch and the Jewfish).
- Indirect Impacts
    - Eutrophication -- excessive amounts of nutrients(nitrates and phosphates), the sources of which are:
        - Land and Boat sewage disposal (major problem): Septic Tanks, and Deep and Shallow Well Injection -- liquid sewage seeps through porous limestone directly into the fresh water aquifers, into canals, and eventually nearshore waters, where currents can transport it to the barrier reef.
        - Fertilizers -- landscaping, farming (e.g. South Florida area).

        - Cleaning products high in phosphates.
          ☆Stimulate plankton and benthic algal growth which reduces water clarity --> inhibits photosynthesis by sea grass and zooxanthellae, thereby decreasing skeleton production.
          ☆Stimulates growth of macroalgae algae, which competes for space with corals, and reduces oxygen concentration. Corals are at a competitive disadvantage under high nutrient concentration.
    - Pollutants -- are picked up from the water by the algae (crustaceans and mollusks as well) and introduced into the food chain by fish and invertebrates. The pollutants, which include heavy metals, hydrocarbons, pesticides, herbicides, PCBs. DDT are introduced by way of the following sources:
        - Engine exhaust and oil from boat engines accumulate inside bilges and are automatically pumped out.
        - Agricultural and urban gardening chemicals.
        - Land runoff (oil resides rom cars, etc.s)
        - Anti-fouling paints.
        - Waste disposal (such as batteries from lighthouses)
        - Toxic waste dumping.
    - Pathogens -- Disease scarring organisms may infect corals and associated fauna (bacteria and viruses). Source: Sewage.
    - Solid Waste Disposal -- Ocean dumping of trash such as plastic foam cups, aluminum cans, glass plastic bags and bottles, monofilament fishing line, six-pack connectors, cigarette butts. Turtles and other animals may confuse plastic bags for jelly fish and suffocate as they ingest them; fishing and trap lines get entangles around corals and slowly kill the polyps by continuously rubbing against them.
    - Sedimentation -- Most of the bottom of the Florida Keys are composed of very fine calcium carbonate silt. When these sediments are churned up for long periods of time, the water turns milky and inhibits photosynthesis by sea grasses and algae inside coral. Heavy sedimentation may bury corals, thus inhibiting their growth or killing them. The causes of such sedimentation include:
        - Construction of seawalls, canals, docks, and marinas.
        - Land-clearing
        - Boats running over shallow waters which disturb and suspend silts with propellers.
        - Snorkelers and divers kicking up sediment.

Stress-Related Signs
☆Deterioration of water quality

- Coral Bleaching
- Temperature and light related.
- When temperature reaches levels higher that 87 -89 degrees F, corals lose their symbiotic algae (gives coloration to coral) --> inhibits growth, stops calcification and may terminate reproduction.
- Affects: star coral, fire coral, elkhorn coral, soft coral and anemones. (e.g. Mat Anemone).

Blackband Disease

Caused by a microfilamentous blue/green algae in association with bacteria and other micro-organisms.

May start in dead parts of the colony and spreads very rapidly.

Eutrophication by phosphates, the main limiting nutrient for the blue/green algae, may be leading to an extremely high growth rate of this algae.

Affects: brain coral and star coral; sea plumes; sea fans.
All of the factors mentioned above are deteriorating the water quality and disturbing the delicate ecological balance of this remarkable ecosystem.