Additionally, some assignments will be used to teach students computer skills.

STANDARDS: This unit will cover portions of California State Standards for High School Marine Biology: Cell Biology 1b and 1f ; Ecology 6a, 6b, 6c, 6d, 6e, 6g and Evolution 7d, 8b.

UNIT LESSONS: Instruction will utilize power point presentations, reading assignments, lecture notes, worksheets, a field trip, and hands on labs and activities.

UNIT OUTLINE:

I. What is a Coral Reef?

A. One of the most beautiful and fascinating natural environments; variety surpasses anything else the sea has to offer
    1. 100's of different fishes, plants and inverts
    2. multi-hued coral colonies branch in all directions
    3. sponges, sea fans, and other strange animals adorn the reef surface, providing even greater color and variety
    4. also outlandishly colored fishes drift and dart through the surrounding turquoise waters

B. Coral reefs are limestone structures formed by the skeletons of tiny sea-anemone-like animals and are the largest things on earth built by an organism

C. Distribution: found in tropical seas throughout the world
    1. Indo-Pacific: enormous area spanning SE Asia through Polynesia and Australia, and East across Indian Ocean to Africa. By far the largest and richest in species. Highest density of species there; which is 4 x's that found in the Caribbean.

polyps that are quite small (few exceed a pencil width in diameter). They are like small anemones that secrete a calcium carbonate base; tentacles are covered with nematocysts.

B. Polyps grow in groups called colonies
    1. each succeeding generation builds its home upon the foundation of skeletons left by the last
    2. colonies attach to other colonies

C. Growth factors: depth of water, amount of light, water movement, temperature and water clarity affect the way in which a coral colony grows; corals are naturally long-lived but are intolerant of changes
    1. corals require a water temperature of 22˚C (72˚F) or more so they are only found in the tropics
    2. reef-building corals are limited to growing no deeper than 50m (164') as they need sunlight
        a. they need sunlight because within the living tissue of the polyp are tiny plant cells called zooxanthellae
        b. causes tissue to look brownish

D. Zooxanthellae fix sugar (photosynthesis) and corals use it for nutrition (up to 90% of energy used by coral comes from algae); deeper forms of coral intake more plankton.
    1. zooxanthellae receive nutrients and a place to live from the coral
    2. so corals are a composite organism - part animal and part plant

E. Life history of coral polyps
    1. Food: regularly feed on small creatures floating by, captured by sticky stinging tentacles.
        a. feeding usually occurs at night as tentacles would be bitten off by fish during the day; tentacles are withdrawn into the protection of a hard skeleton formed by the polyp (limestone).
        b. digested food can go to their neighbors (which are clones) and is transported by cilia.

survive they quickly turn into an adult and bud off many exact duplicates of itself; compete with its neighbors for food, space, light, etc.

3. Growth
    a. some can grow 10 cm/yr; brain coral only .5 cm/yr
    b. reef-building corals (as opposed to Octocorals) live in colonies which vary in growth form by species (brain corals, boulder corals, elkhorn and staghorn are examples)
    c. colonies exhibit 3 basic growth forms: branching, massive, and plate-like
4. soft corals too; no rigid skeleton; made of heavy proteins with spicules; sea fans; do not build reefs - are called Gorgonians or Octocorals
5. some algaes also form limestone skeletons and contribute to the solid framework of the reef; fleshly algaes are eliminated by urchins, abalone, or waves; coraline algae can withstand these predators.
6. upon the limestone base grows an assortment of sponges and other plants and animals giving the reef great complexity.

F. Formation of Fringing Reefs, Barrier Reef, and Coral Atolls

1. form from differing stages of sinking undersea volcanoes
2. Hawaiian Islands show this as the oldest islands (volcanoes) are at the Northwest end of the chain; Hawaii (youngest) has a fringing reef; Kauai has a barrier reef; past this is a totally sunk island and an atoll.
3. guyots are flat top seamounts that have sunk below the surface; flat because of wave erosion
4. why don't interiors of Atolls fill in? no or few nutrients (or plankton) on the interior so no coral growth; reefs don't exist close to shore as erosion and sediments make the water too cloudy; corals cannot tolerate sedimentation or freshwater.

B. The Lagoon: the protected waters behind the crest; found here are patch reefs, coral sand, seagrass beds, and mangroves

1. Patch Reefs: isolated coral islands surrounded by sand and grass
    a. may be composed of few or many different kinds of corals
    b. big or small (averaging 20-70 meters in diameter); round to oval
    c. best places in the world for snorkeling
    d. notable feature is a bare sand 'halo' that surrounds the base of the reef for a distance of 1-2 meters (figure)
2. Seagrass: group of marine plants found in the calm waters of the lagoon
    a. structurally simple; little shelter above the grass blades
    b. animals active during the day are mainly small inverts and fishes that rely on concealment; either camouflage or burrowing
    c. long-spined sea urchins restrict their feeding here to nighttime
    d. occasional sea turtle or trunkfish, otherwise a 'night spot'
    e. most fish that feed at night in the seagrass take shelter on the reef by day. Wastes rich in nitrate remain on the reef establishing a vital transfer of nutrients that promotes growth of reef plants and corals
    f. also serves as a home for juvenile reef fishes; they can find shelter
        1) continued growth makes them vulnerable; so they must move or die
        2) many perish to predators never reaching the reef to mature or reproduce
        3) a fortunate few successfully relocate to a bigger shelter

5 functions of the seagrass community:

1) filter runoff and prevent sediment loading onto corals
2) provide surface for attachment (sites are limited)

limiting factor: anything that prevents a population from growing

e. falling leaves and nesting birds add nutrients enhancing plant growth
f. mangroves are pioneers in land building by trapping sediments

C. The Reef Face: seaward side of the reef drops off rapidly forming the reef face
1. Upper Zone consists of gentle slopes; large number of coral species; abundance of Staghorn coral; usually extends to 3-20 meters in depth
2. Lower Zone extends from 20 meters to waters too poorly lit to permit coral growth
a. usually dominated by mountainous star coral
b. forms ridges with sand channels or grooves; spur-and-groove formations run perpendicular to shore
c. marine life changes rapidly with depth

D. Hardgrounds: second type of low reef habitat
1. low platform of limestone covered with a living carpet of sponges, soft corals, and encrusting plants and animals but few reef-building coral
2. limestone platform is what remains of an ancient worn down reef
a. provides sites for attachment
b. waving sea fans and colorful fishes abound

To understand the coral reef environment, one must realize it is composed of an intricate mixture of different, yet interrelated places occupied by a wide variety of living things.

IV. Coral Reef Ecology

A. Essential terms and concepts
1. Ecology: branch of biology that deals with the distribution and abundance of living things. It involves complex interactions between many factors.

- Consumers (various levels, 1°, 2°, 3°) which convert the energy in organic materials into chemical energy that can be used for metabolism.
- Detritus chain which deals with the decomposition of once living creatures.

1. Primary Producers: forms the energy-nutrient base upon which all higher levels depend.
    a. consists of those organisms that are capable of performing photosynthesis (plants).
    b. convert sunlight and inorganic substances into living tissues.
2. Primary Consumers: the community members that feed directly on living plants: consists of herbivores
3. Secondary Consumers: community members that kill and eat other living animals
    a. consists of carnivores; some omnivores
    b. most reef fishes, all corals, and a variety of invertebrate animals

C. The Role of Plankton
1. coral reef ecosystems are affected by the water movements about the reef, as they deliver the food to the corals
2. water movements change seasonally and daily - this can bring about changes in clarity, temperature, salinity, sediment levels, and kinds and amounts of plankton.
3. reef planktivores remove as much as 60% of the plankton

D. The detritus chain or why the earth is not covered with a thick layer of dead plants and animals.
1. scavengers: some sharks (will also feed on live prey)
2. assortment of inconspicuous, often microscopic, organisms
3. decomposers release the nutrients back into the environment to be taken up again by plants to start new growth
4. nutrient cycling is essential

V. Major Categories of Reef Life

A. Plants: algae and seagrasses
1. algae can be attached to the seafloor (benthic) or drifters (phytoplankton)
2. seaweed (benthic algae): 3 main types determined by photosynthetic pigments - green, brown, and red
3. White light absorption* - red wavelengths filter out first; at depth only the longer green and blue wavelengths remain.
4. algae contain pigments specialized to best use sunlight at different depths
    a. green algae (red-absorbing) are most common in shallow water
    b. red algae (blue-absorbing) may be found 100's of feet deep in clear tropical waters
    c. brown algae (yellow-green absorbing) like intermediate depths
    d. these are general distribution patterns however and all 3 types may be found on a shallow reef
5. seagrasses (in the lagoon) evolved from land plants and have a vascular system and produce flowers

B. Invertebrates: animals without a backbone make up most of the animals in the sea; there are 26 major divisions (phyla) of animals but only 1 has a backbone; 6 phyla are particularly well represented on coral reefs
1. **Sponges**: are a colorful group; may be quite large and some can contain an entire scuba diver
    a. feed by creating currents that draw in seawater through tiny pores to filter bacteria and plankton
    b. seemingly harmless, some use chemical warfare to bore their way into coral heads
    c. one to be cautious of and not to touch is the fire sponge
    d. spicules provide structure, support, and protection
2. **Cnidarians** (jellies, corals, sea anemones, octocorals)

4. **Echinoderms**: spiny-skinned animals (sea stars, urchins, sand dollars)
    a. sea stars prey on mollusks
    b. brittle stars are nocturnal predators but also scavenge
    c. sea cucumbers feed mainly on detritus mixed in the sediments and
       must process enormous quantities of sediment
    d. sea lilies are common in deeper waters of the reef face
    e. sea urchins are common and actively forage on vegetation at night while hiding in crevices by day
5. **Mollusks**: varied group (snails, clams, squids and octopi)
    a. snails are slow moving grazers but some are predatory
    b. clams and scallops depend upon heavy shell for concealment and to keep predators at bay, but the are heavily hunted by fishes and sea stars
    c. they are active filter feeders that pump water through strainers
    d. squids and octopi have a well-developed nervous system with large brains and eye much like our own
        1) masters of color change and are well camouflaged
        2) octopi are benthic creatures, while squid are open water hunters of fish and shrimp
6. **Crustaceans**: (shrimp, crabs, lobster)
    a. some are scavengers, some predators, some omnivores
    b. many shrimp are "cleaners" and gain food by removing parasites from fish or inverts; can clean inside the mouth of a barracuda and won't be harmed
    c. crabs and lobster are tasty

VI. Ecology of Reef Fishes

A. Fish
1. anatomy
2. senses: sight, hearing, taste, touch, lateral line
3. neutral buoyancy

a. Bold contrasting patterns serve to destroy the outline of a fish and prevent recognition of its shape.
b. Colors that accurately picture the hiding place.

2. Advertisement: may be an advantage in warning others that the area is occupied, thereby reducing the need for physical conflict.
    a. Warning colors tend to be bold and color combinations are the most visible: red and black, yellow and black, red and white.
    b. anemone fish build up mucus so they don't get stung; anemones without anemone fish would be eaten by turtles; with anemone fish, turtles will be bitten in the eyes as it approaches; mutualism.
3. Mimic coloration: some fishes take on the color pattern of a toxic fish even though it is not toxic.

D. Feeding Structures: mouth, teeth, and jaws vary greatly among reef fishes. Some take in plankton, some bite off polyp tentacles, scrape algae, capture and swallow other fish, or grasp and crush shells.

VII. General Ecology

A. Reproduction and Dispersal
1. usually timed with the best feeding opportunities for the larvae.
2. or, spawning is synchronized with predictable currents that may carry the offspring to the same reef where they were spawned.
3. individuals may produce 100,000's of eggs with each spawning. Usually these are broadcast into the plankton community.

B. The Use of Space: Distribution and Abundance Patterns
1. most reef fishes are not scattered about randomly, but rather tend to be more common in certain places.
2. usually related to food and shelter.
3. larger scale climatological or oceanographic processes may limit
4. some species may be absent if their planktonic larvae have a difficult time reaching a reef.

4. herbivores have different teeth and digestive tracts than meat eaters.
    a. plant cells have a strong cell wall made of cellulose and requires greater initial mechanical breakdown and extensive chemical processing than does the use of animal cells.
    b. have large flat grinding teeth, capable of crushing the tough cell walls, and have a relatively lengthy digestive tract to allow for slow digestion.
5. carnivores
    a. have sharp pointed or blade-like teeth, adapted for seizing and holding prey or for piercing and tearing.
    b. have a short digestive tract as animal cells may be digested more quickly.
6. feeding behaviors differ too.
    a. herbivores must spend a good deal more time feeding than meat eaters to obtain the same amount of energy and may graze throughout the day
    b. carnivores may concentrate feeding to relatively short periods.

VIII. Fish Ecology: grouped by the type of food resources used although many fishes feed upon several sources (plants, plankton, invertebrates, fish).

A. **Plant and Plankton Feeders**: Three families are common: parrotfishes, surgeonfishes, damselfishes

1. <u>Nomadic Browsers</u>
    a. Parrotfishes are the largest and most colorful
        1) beak-like mouth parts are used to scrape and bite algae from coral surfaces; they defecate sand
        2) secrete a mucous cocoon to enclose themself in as they sleep at night; masks their scent from eels
        3) all are born female; supermales are determined from these; there is also a midphase
        4) form mixed feeding aggregation with blue tangs

vegetable gardens
2) may kill polyps in a small area to allow for settlement and induce growth of their favorite algae
3) aggressively defend their territories against herbivores but not carnivores

3. Fish That Eat Plankton
   a. must distance themselves from the immediate shelter of the reef
      1) windy side of reef or island gets the brunt of the oncoming plankton; the further out from the reef the plankton feeding fishes are, the more plankton they get
      2) however, if they get too far away they will be eaten by tunas, jacks, sharks, or other predatory fish.
   b. safety in numbers and rely on speed; sleek lines; color patterns are often monochromatic blue or silver to reduce their chances of being detected; also sharp eyesight, keen reactions, small protrusible jaws
   c. some damselfishes, blue chromis and sergeant major
   d. creole wrasse is similar looking to the blue chromis with which it forms mixed aggregations
   e. yellow-headed jawfish lives in a small burrow and waits for plankton to come by; retreats tail first into its burrow
   f. daytime plankton feeders retire for the evening and are replaced by the "night shift", the cardinalfishes, squirrelfish and sweepers (all have large eyes)

B. **Hunters of Invertebrate Prey**: carnivorous prowlers of the seafloor called benthivores. They have many prey to choose from; best method to hunt them with is to pick a place and time to hunt, and then eat everything possible (generalist); although they are limited by their behaviors and feeding structures

1. Day Benthivores
   a. rule for invertebrates is to stay hidden during the day

1) puffers inflate themselves and have powerful toxins
2) filefish, porcupinefish, and triggerfish have stout spines
3) trunkfish have bony plates of external armor

h. rely on defenses not speed, and have developed odd shapes and unusual swimming styles with highly coordinated use of all their fins; they are beautifully adapted however their numbers are low

i. one small group uses cryptic habits and color, the seahorses, blennies (eat algae too), and gobies (cleaners of parasites)

j. wrasses are small cigar-shaped fishes; also start out as female; sleep under the sand

k. butterflyfishes and angelfishes nip off parts of large invertebrates

1) butterflyfishes nip worm and polyp tentacles; their mouths are highly adapted with fine brush-like teeth resembling surgical forceps; couples mate for life; often have an eye-spot (deflective) - predator must anticipate the prey's evasive reaction; if the tail is mistaken for the head, a predator will "lead" its target in the wrong direction; and an eyespot can direct an attack away from a vital area.
2) angelfishes nip sponges.

2. <u>Day Benthivores of Off-Reef Habitats</u>

a. mojarras, some wrasses, flatfish, and rays; few reef-dwellers venture out in the daylight because of potential large predators and few invertebrates expose themselves in the day, many have shells if they do (helmets, welks, conchs); so few feed this way

1) goatfishes use barbels on the chin to taste and touch prey in the sand
2) trunkfish are protected with armor and use jets of water to excavate prey
3) hogfish achieve safety through sheer size (large wrasse); have crushing jaws and teeth

c. squirrelfish, bigeyes, and some cardinalfish have large eyes with superior light gathering ability; reddish in color (looks black at night)

4. Few night-time benthivores feed on the reef

C. **Fish That Eat Other Fish**: are called piscivores. Smaller fish remain near the reef to receive safety and shelter but at twilight the predators have an advantage; their eyes work better than the day or night specialized eyes of the reef fishes. Dawn and dusk is a dangerous time for reef fishes. There are 3 strategies taken: pursuing (moving with visual contact), stalking (attack from a hovering or drifting position using stealth and camouflage), ambush (use disguise to make themselves seem part of the reef, to take prey by surprise from close range).

1. Pursuing Predators
    a. attack from considerable distance relying on sheer speed to run down a victim in open water; sharks, jacks, mackerels, and the yellowtail snapper. All are swift, sleek fishes that swim continuously and are capable of great bursts of speed
    b. all have efficient torpedo-shaped body; reduced drag in scales, fins, gill coverings; caudal fin is sickle-shaped to provide thrust and reduce drag at high speeds. Also have a very narrow caudal peduncle with lateral keel to aid in turning at high speeds.
    c. common examples are the jacks and yellowtail snapper.
        1) Small bar jacks move quickly through an area in small hunting packs
        2) mackerels patrol the reef face for stray fish and squid; ultimate speed machine
        3) yellowtail snapper are particularly common; are curious and will follow divers
        4) nurse sharks are most common and are nocturnal
2. Stalking Predators: barracuda, trumpetfish, houndfish
    a. typically have elongate bodies; presenting minimal profiles
    b. attack is short and swift
    c. caudal fin has a large surface area, providing rapid

shapes (not necessarily sleekness), camouflage and stillness until the victim is a gulp away
   b. have unusually large upturned mouths capable of creating a vacuum (inhaling-type predator) with disruptive coloration
   c. scorpionfish and toadfish have perfected disguises; dorsal spines of the scorpionfish have a strong neurotoxin
   d. flounder frequent reef areas; can change color patterns and bury itself slightly so that it springs from hiding with amazing swiftness to attack an unsuspecting victim

IX. Coral Reefs, Divers, and Conservation

A. Natural threats
1. modern coral reefs represent the products of millions upon millions of years of evolution and adaptation
2. storms and hurricanes may wreak havoc on reefs
   a. powerful waves topple large colonies and tumble them about, leaving a trail of destruction
3. sediments deposited among the living polyps smother them
4. injured areas are vulnerable to bacterial infections or colonization of fast growing algae
5. areas subjected to sediment laden waters (mouth of Amazon River)
6. long term temperature changes, or changing rainfall patterns; also changes in sea level can lead to the destruction and creation of reefs
7. coral bleaching; individual polyps spit out their symbiotic algae (for some reason); coral animal is clear so you look at white limestone; scientist brought a coral head into an aquarium and raised the temperature; coral ejects the zooxanthellae (maybe so because white absorbs less radiation);so did an experiment using ultraviolet radiation; actually it is any stress but is mostly temperature; corals require >72˚F over 85˚F then coral bleaching.
8. "Crown of Thorns Starfish"; are huge starfish with 15 arms and poison spines; their stomachs extend out to cover and engulf large

be immediately obvious

b. discharge of nutrient-rich waste water (sewage, fertilizers, pesticides) into marine environments may lead to explosive algal growth; thick algal mats can smother the reef
c. thermal pollution: power plant discharge of heated water is not the only threat; now global warming may threaten reefs
d. sedimentation: when land is stripped of natural vegetation through clearing and burning, rains will carry loads of sediments directly to the sea; urbanization of coastal areas often changes the water quality to quickly devastate large areas of reef. Corals vary in their ability to rid themselves of sediments.
e. overfishing: particularly using habitat-destructive methods; explosives are sometimes used to stun and kill fish; may shatter the reef structure; chemical poisons (including bleaches and soaps) is a common practice; aquarium suppliers.
f. boating: physical contact involving collision with or anchoring on live coral; flushing of bilges or dumping trash are common practice aboard many cruising yachts and other vessels.
g. divers and snorkelers: direct physical contact; much is inadvertent (can't control buoyancy); underwater photographers are the worst; some smash living creatures to attract fishes; spearfishing has become highly controversial and is an undesirable activity; near misses take chunks out of the living coral; fisherman may have to forcibly pull out fish, bracing against and crushing the corals; also continued removal of higher predators from reef areas leads to changes in composition to the ecosystem with unknown effects; sportfishing too; side-show approach of resorts providing something extra for their guests.

C. Solutions

1. to whom does the reef belong? How do we preserve the health of

ecological value have highly restricted use
5. zero-consumptive use zones; areas closed to commercial fishing; plan must include "buffer zones"
6. parks require money to staff; levying user fees is increasingly common
    a. this will insure quality reef diving far into the future
    b. local residents see regulation as an infringement of their birthrights
    c. oceans are our common heritage.
7. Taking an Active Role:
    a. Do Not -
        1) Physically contact the reef or its inhabitants
        2) Spearfish in reef areas
        3) Feed reef life
        4) Remove any part of the reef environment
        5) Raise clouds of sediments with your fins
        6) Leave behind any trace of your visit
        7) Continue to patronize or recommend reef-damaging dive operators
    b. Do -
        1) Insist that your dive boat be moored or anchored in areas free of live bottom
        2) Ensure that you and your buddy have all equipment securely and closely attached to your persons
        3) Request that all divers in your party respect these guidelines
        4) Patronize and recommend conservation-conscious dive operations
        5) Report observed damage and violations of law to the proper authorities

RESOURCES:

1. Pisces Guide to Caribbean Reef Ecology by William S. Alevizon. 1994.
2. National Audubon Society Field Guide to Tropical Marine Fishes by C. Lavett Smith. 1997.

3. Build a plankton and have a slow sinking contest
4. Students learn how to use Power Point and will do a presentation on an Invertebrate of their choice
5. Simulated coral reef quadrat inventory
6. Butterflyfishes dichotomous keying activity
7. Fish Printing activity; with anatomy properly labeled
8. Fish dissection lab and fish fry
9. Food Chains, Food Webs and Biodiversity activity using Coral Reef organisms cards of organisms at different trophic levels.
10. Using html, students will design a travel ad and brochure to a coral reef/snorkling/diving get-away of their choice
11. Sea Urchin Fertilization Lab

READING ASSIGNMENT: Castro and Huber, Chapter 9 - An Introduction to Ecology; Chapter 13 - Coral Reefs.

ASSESSMENT:

Unit test - on coral reef ecology
Travel Brochure:
Power Point Presentation:
Labs/Activities:
Review sheets and handouts: