CHAPTER 11 LIFE IN THE WATER

Key Concepts

Major Concept (I) *One common method for classifying marine organisms is to place them in one of three categories based on their lifestyle and general habitat.*

Related or supporting concepts:

- The three basic categories of marine organisms are:
  a. plankton,
  b. benthos, and
  c. nekton.
- Plankton include both:
  a. plant-like organisms called phytoplankton, and
  b. animals called zooplankton.
- Plankton are organisms that float or drift with the currents. They have little or no mobility of their own.
- Benthos include the plants and animals that live on the bottom.
- Some benthos are attached to the bottom while others can move freely.
- Benthos may live either on top of or in the bottom sediment. Some move freely on the sea floor but burrow into the sediment for protection.
- Nekton are organisms that swim in the water column. There are only animals included in this category.
- The more standard taxonomic categories used by biologists to classify marine organisms are given in table 11.1 in your book.

Major Concept (II) *Plankton have little or no mobility of their own. They include both animals and plants, tend to exist in great swarms, and move with the currents.*

Related or supporting concepts:

- Plankton include organisms that have little or no mobility of their own and drift with the ocean currents. The plankton community includes both plant-like organisms called phytoplankton and animals called zooplankton.
- Some plankton, such as jellyfish and floating beds of kelp, are quite large. Jellyfish may be as much as 15 m (50 ft) long and kelp can be even longer.
- The smallest phytoplankton are less than 0.005 mm in diameter and must be collected with special filters.
- Zooplankton and phytoplankton that range in size between 0.07 and 1 mm in diameter can be captured with very fine mesh nylon nets and are referred to as net plankton.

Major Concept (III) *Most phytoplankton are small, single-celled plant-like organisms called algae.*

Related or supporting concepts:

- The individual phytoplankton cells may exist alone or they may join to form chains or groups. Regardless of the case, the cells are each independent and do not share any labor.
- The seaweed sargassum is the only large multicellular alga in the plankton group. It floats at the surface in a region of the North Atlantic called the Sargasso Sea.
- Large floating mats of sargassum provide shelter and food for many other organisms, some of which are unique to this environment.
- Two major types of phytoplankton are the diatoms (see fig. 11.2) and the dinoflagellates (see fig. 11.5).
- Diatoms have a yellow-brown pigment that masks the green color of the chlorophyll. This gives them the common name golden algae.
- Diatoms come in different shapes, some round and others elongate. The round diatoms float more easily and are found suspended in the water column. The elongate diatoms are often found on shallow sea floor and attached to floating objects.
- Diatoms populate cold water with high nutrient concentrations.
- Diatoms extract silica from the water to build cell walls. The silica-rich walls have pores that allow the plant tissue to interact with the water (see fig. 11.3).
- Diatoms must remain in the photic zone to survive. To increase their buoyancy they store food reserves as droplets of oil that lower their overall density.
- The rounded shape of most diatoms increases their surface area to volume ratio. This has two advantages:
    a. it increases their drag with the water and decreases their tendency to sink, and
    b. it increases the area over which they are exposed to sunlight and the nutrients and dissolved gas in the water.
- To further increase drag with the water some diatoms have spines or appendages.
- A very rapid increase in the density of diatoms is called a bloom. Sometimes their numbers can be so great that the water is discolored.
- A buildup of the skeletal remains of diatoms on the sea floor contributes to the accumulation of siliceous ooze. With time, organic matter that did not fully decompose may be buried and converted to oil.
- Dinoflagellates are peculiar organisms that photosynthesize like plants and ingest organic matter like animals. They can survive at lower light levels than diatoms.
- Dinoflagellates are red to green in color and have some mobility due to flexible, whiplike structures called flagella that they can use to beat the water.
- Although they can reproduce even more rapidly than diatoms in blooms, their numbers are more limited and they are not as important a source of primary productivity.
- Bioluminescence in some dinoflagellates gives them the common name fire algae.

- Coccolithophores are photosynthetic relatives of diatoms.
- Coccolithophores have outer calcareous plates (coccoliths) that disassemble when they die and contribute to calcareous sediments on the sea floor.
- In 1997 the water over most of the continental shelf in the eastern Bering Sea experienced a massive bloom of coccolithophores (fig. 11.4) that was attributed to:
    a. unusual climatic conditions,
    b. reduced cloud cover, and
    c. few storms resulting in abundant sunlight and above-average surface-water temperature.

Major Concept (IV) *Sudden, large blooms of certain species of dinoflagellates produce red tides. Some red tides are hazardous to fish and other organisms and can result in the poisoning of people.*

Related or supporting concepts:

- Red tides are caused by several different species of dinoflagellates (see fig. 11.6). Some species are poisonous while others are not.
- The red tides produced by toxic species are usually not harmful to shellfish feeding on them. The toxins will accumulate in the tissue of the shellfish, however, and those toxins can be passed on to people who eat the shellfish.
- Three diseases that can be passed on to people in this manner are:
    a. Paralytic Shellfish Poisoning (PSP),
    b. Neurotoxic Shellfish Poisoning (NSP), and
    c. Diarrhetic Shellfish Poisoning (DSP).
- The toxins produced by some species that cause PSP are very powerful nerve poisons. They can easily result in paralysis or death if the dose is high enough. One type of toxin is fifty times more powerful than strychnine.
- Cooking will not render the toxins harmless because they are not neutralized by heat.
- Cases of NSP occur less frequently and there have not been any reported deaths from it.
- The exact triggering mechanisms of red tides are not known but it appears as if they are increasing in frequency and severity (see fig. 11.7).
- Red tides appear most frequently in the spring and summer, following heavy rains that carry large amounts of nutrients, nitrates and phosphates in sewage and fertilizers, to the ocean in surface runoff.
- Other possible triggering mechanisms include:
    a. the dumping of ballast water by commercial vessels,
    b. the transfer of commercial shellfish stocks,
    c. high water salinity in the Gulf of Mexico,
    d. variations in temperature and light in water off the New England Coast, and
    e. the disturbance of bottom water where cysts, or resting cells, formed by the dinoflagellates collect.

- The toxins are thought to be a defense mechanism against predators.
- The dinoflagellate *Pfiesteria piscicida*, also known as the "cell from hell", was first identified in North Carolina in 1993. It has caused major fish kills in estuaries and coastal waters of the mid-Atlantic and southeastern United States. It has also been linked to human symptoms including sores, memory loss, nausea, respiratory distress, and vertigo.
- Not all red tides are toxic and not all red water is caused by the presence of dinoflagellates.
- The Red Sea's occasional red color is caused by large blooms of nontoxic photosynthetic bacteria that have red pigment.
- Toxic red tides in the Indian Ocean are caused by a photosynthetic bacterium, not a dinoflagellate.
- It is estimated that between 10,000 and 50,000 people are stricken with ciguatera poisoning each year from eating fish in tropical regions.
- There is no way to prepare fish affected by ciguatoxins that make it safe to eat.
- The symptoms of ciguatera poisoning are highly variable.
- There is some evidence that the ciguatoxins are produced by dinoflagellates. These toxins then make their way up through the food chain through herbivores and carnivores and may take as long as eight years to reach fish that are harvested for food.
- Another poison that affects marine organisms is domoic acid which is produced by diatoms and can become concentrated in shellfish that may be eaten by people.

Major Concept (V) *Zooplankton are the smallest animals in the oceans. They include both herbivores that feed on phytoplankton and carnivores that consume other zooplankton.*

Related or supporting concepts:

- Many zooplankton have limited mobility. While they may be able to dart short distances to capture prey or avoid predators, they are not able to swim against currents. A few zooplankton are shown in figure 11.8.
- In warm water with ample food supplies, zooplankton may produce three to five generations a year. In colder water where phytoplankton have a short growing season there may be only one generation produced each year.
- Zooplankton live in patches of high population density between areas with much lower population density. Turbulence and eddies in the water remove some individuals from the high population density patches and disperse them to the lower population density regions.
- Convergence zones and boundaries between water types concentrate zooplankton and attract predators.
- Some zooplankton migrate vertically in the water column, descending into dark water during the day to hide from predators and ascending toward the surface to feed at

night. The distance travelled varies between 10 m and 500 m (30 - 1500 ft).

- At night, upward migrating zooplankton may form dense layers of organisms that reflect sound and produce a false bottom reading on precision depth recorders. This is called the deep scattering layer (DSL).
- Two important members of the zooplankton are the foraminiferans and the radiolarians (see fig. 11.9). They are both single-celled, microscopic animals.
- The skeletal material of foraminiferans is made of $CaCO_3$ and the skeletal material of radiolarians is made of SiO_2.
- Radiolarian skeletons typically have spines. Examples are shown in figure 11.8. Structures called pseudopodia, or false feet, are used to capture diatoms and small protozoa.
- Both foraminiferans and radiolarians populate warm water.
- One of the most common types of zooplankton are small crustaceans, similar to shrimp, called copepods and euphausiids. Sketches of these animals are shown in figure 11.10. These animals:
    a. are both herbivores,
    b. reproduce more slowly than diatoms, doubling their population three to four times per year,
    c. make up over 60 percent of all zooplankton, and
    d. are a source of food for small fish.
- Copepods are smaller than euphausiids, while the euphausiids live longer and move slower.
- There are more copepods than any other kind of zooplankton in the oceans.
- The euphausiids are also known as krill. In Arctic and Antarctic water, krill are the primary food of baleen whales.
- Krill have been harvested commercially by the former USSR in the 1960s, and in later years, by Japan, Korea, Poland, and Chile. The largest harvests were obtained in the Antarctic summer of 1980-81.
- By 1996 only Japan, Poland, and the Ukraine were still harvesting krill and the catch was declining significantly.
- Krill is used as livestock and poultry feed. It has not been used successfully for human consumption because krill deteriorate too rapidly.
- An abundant carnivorous zooplankton is the arrowworm. They are found at all depths and are about 2 - 3 cm long. There are multiple species, some of which are restricted to specific water masses.
- Additional zooplankton include:
    a. pteropods (see fig. 11.10):
        i. which are small swimming snails or modified mollusks,
        ii. have a transparent, mobile appendage or wing,
        iii. some are herbivores and others are carnivores;
    b. ctenophores, or comb jellies (see fig. 11.11):
        i. that float near the surface,

ii. move by beating cilia in eight rows,
iii. vary in size from small to as much as 30 cm in length,
iv. which are all carnivores; and

c. jellyfish (see fig. 11.12):
i. which come from a group of animals called Coelenterates,
ii. some drift their entire lives while others are plankton only as juveniles and sink to the sea floor to live as benthos, similar to the sea anemone.

- One group of jellyfish that includes the Portuguese man-of-war, Physalia, and the by-the-wind-sailor, Velella, are actually colonial animals. These are composed of different types of organisms that live cooperatively, each having a specialized task such as reproduction, food acquisition, flotation, and defense.
- Organisms that spend their entire life as plankton are called holoplankton. Other organisms, called meroplankton, are plankton for only a part of their life span, usually as larvae, and later become nekton or benthos as adults.
- Meroplankton include oysters, clams, barnacles, crabs, worms, snails, starfish, fish, and others.
- Larvae are widely dispersed as plankton, thus reducing the problem of overcrowding in the area where they were formed.
- Marine organisms usually produce large numbers, sometimes millions, of eggs and only a few survive. The rest are an important food source for zooplankton and other animals.
- Figure 11.13 illustrates some common larval forms of marine organisms. You can see that they do not resemble the adult form.

Major Concept (VI) *Bacteria are abundant in the oceans and are important in a number of different ways.*

Related or supporting concepts:

- Bacteria are the smallest living organisms.
- Bacteria are single-celled organisms that reproduce by cell division every few minutes under optimal conditions.
- Bacteria are the most numerous organisms in the oceans. There are estimated to be 1 x 10^{29} bacterial cells in the marine environment.
- Bacteria are so numerous in the oceans that they cover all surfaces including decaying material, the sea floor, floating objects, and other organisms.
- Bacteria contribute to the decay and decomposition of organic material.
- Bacteria are a source of protein for planktonic larvae and single-celled protozoans.

Major Concept (VII) *Plankton are sampled using a variety of means, but the most commonly used method is a net similar to that shown in figure 11.15.*

Related or supporting concepts:

- Plankton can be collected using nets, water bottles, or submerged pumps that draw water through a filter.
- Nets are made with variable sized mesh, very fine mesh for phytoplankton and coarser mesh for large zooplankton.
- The net may be towed while the ship is underway or it may be lowered and raised vertically while the ship is on station.
- The volume of water that has been filtered to collect the sample is measured using a flow meter in the mouth of the net.
- If the net is towed, it has to be towed fast enough to catch the plankton but not too fast to inhibit the flow of water through the net.
- Sampling now often uses multiple-net systems where individual nets can be opened and closed on command from the ship.
- Multiple-net systems often include electronic sensors to measure salinity, temperature, water flow, light intensity, depth, and the angle of the instrument wire trailing away from the ship.
- A sample of the catch is examined to determine the types and respective numbers of plankton recovered.
- A measure of the number of organisms captured can be made by drying and weighing the sample or by using an electronic particle counter.
- The biomass can be determined by dissolving out the chlorophyll and measuring the concentration of the pigment.

Major Concept (VIII) *The nekton community is dominated by fish but includes squid, shrimp, reptiles, and mammals.*

Related or supporting concepts:

- There are about 5000 species of nekton.
- Nearly all nekton are vertebrates, meaning they have backbones. There are only two types of nekton that are invertebrates, the squid and a few species of shrimp.
- Squid (see fig. 11.16) spend a lot of time in deep water but migrate toward the surface at night. The use of video cameras on submersibles has allowed us to study squid in greater detail than ever before.
- Squid swim rapidly and have a wide range of bioluminescence and coloring. Their ability to change color, combined with their speed, makes them difficult prey and effective predators.
- Squid vary in size from a few centimeters long to the giant squid that can reach lengths of 20 m (65 ft).
- Fish dominate the nekton community.
- Fish can be found at any depth and distance from shore but they are not uniformly

distributed in the water.

- Fish are concentrated where their food supply is abundant. This is generally in zones of upwelling, shallow coastal regions, and estuaries.
- The numbers of fish generally decrease with increasing depth.
- Fish have different shapes that reflect their lifestyle. They may be:
    a. streamlined for fast swimming, like the tuna and mackerel,
    b. flat if they live on the sea floor, like halibut and sole, or
    c. elongate for life in rocks or soft sediment, like some eels.
- Fish use their fins for:
    a. turning and changing direction,
    b. locomotion,
    c. balance,
    d. changing depth, and
    e. stopping or braking.

Major Concept (IX) *Sharks and rays belong to a group called the cartilaginous, or non-bony, fish.*

Related or supporting concepts:

- Sharks and rays are different from other fish in that their skeletons are made of cartilage rather than bone (see fig. 11.17). This is the same material that makes your nose flexible.
- Sharks also have very abrasive scales, and teeth that are quickly replaced when they are lost and form up to seven rows in their mouth.
- Sharks have highly developed senses to help them in their search for food. They are able to detect chemicals in the water related to food sources in concentrations as low as one part per billion.
- Sharks can also detect vibrations or motion in the water that may signal an injured fish.
- Sharks also use an ability to sense electrical fields in their search for food as well as for a sense of direction related to the earth's magnetic field.
- There are more than 300 different species of sharks.
- The world's largest fish is the whale shark. It can grow to more than 15 m in length and feeds on plankton.
- Rays and skates are similar to sharks. They are flat and live near the bottom.
- Most rays are carnivores, feeding on crustaceans, mollusks, and other animals they find on the bottom. The manta ray is an exception; it feeds on plankton.
- Rays have large side fins and thin tails that may contain poisonous barbs.
- Some rays are able to generate electric shocks in the water for defense.
- Most sharks and rays bear their young live. They may be encased in a tough capsule as illustrated in figure 11.17.

Major Concept (X) *Commercially important fish species commonly inhabit shallow water and are fast swimming predators.*

Related or supporting concepts:

- Most fish harvested commercially are found at depths less than 200 m (600 ft).
- Some of the most important fish include relatively small species that are very abundant, such as:
    a. sardine,
    b. anchovy,
    c. menhaden, and
    d. herring.

  These fish feed on plankton and travel in large schools where the rate of primary productivity is high.
- Fish schools:
    a. range in size from a few individuals to thousands,
    b. may cover several square kilometers,
    c. have no single leaders,
    d. usually include only one species of fish of roughly the same size,
    e. change direction of travel frequently.
- Fish are able to maintain relative position with respect to one another by sensing motion in the water caused by their neighbors, in addition to wide-angled vision.
- Schooling probably promotes survival by decreasing the chances of a given individual being eaten and by keeping reproducing members of the species in close proximity.
- Commercially valuable bottom fish include:
    a. halibut,
    b. flounder,
    c. turbot, and
    d. sole.
- Two additional fish, perch and snapper, are found in shallow, nearshore areas. They are frequently called rock fish because they seek rocky areas for shelter.
- Examples of fish harvested from the open ocean include mackerel, pompano, swordfish, and tuna.

Major Concept (XI) *Relatively little is known about deep-water fish. Sampling the deep oceans is difficult and expensive, and the volume of water involved is enormous.*

Related or supporting concepts:

- Examples of known deep-sea fish are illustrated in figure 11.19.
- At depths of 200 - 1000 m (600 - 3000 ft) there is very little light. In this region there are large numbers of small luminous fish that school. Different species of Cyclothone

(see fig. 11.19) may well be the most numerous fish in the oceans.
- As you increase depth, the color of many fish changes from silver to black to match the light conditions and make it more difficult for predators to locate them.
- Many of these fish are bioluminescent.
- At great depths some fish use bioluminescent organs as lures to attract prey. Other adaptations include teeth that tilt backward into the mouth to trap fish and large jaws that can unhinge to swallow large prey.
- Most deep-water fish are small, between 2 and 30 cm (1 - 12 in) in length.
- These fish have a slow metabolism, breath slowly, and can go for long periods of time without feeding.

Major Concept (XII) *There are several different mammals that live in the oceans. They are all warm-blooded and breathe air.*

Related or supporting concepts:
- Some marine mammals spend their entire life in the water while others return to land to mate and give birth.
- All young are born live and are nursed by the mothers.
- Marine mammals include:
    a. whales,
    b. porpoises and dolphins (also known as the small whales),
    c. seals,
    d. sea lions,
    e. walruses,
    f. sea otters, and
    g. sea cows.
- Whales belong to the mammal group called cetaceans (see fig. 11.20 and table 11.3).
- Some whales have teeth while others have baleen that acts as a strainer (see fig. 11.20).
- Toothed whales include the killer whale, the sperm whale, and the porpoises.
- Baleen whales include the blue, finback, right, sei, gray, and humpback whales.
- Baleen whales take large volumes of water into their mouths and then expel it through the baleen. The baleen acts as a strainer that traps krill in the water.
- The gray whale has a different diet. Its primary foods are crustaceans and worms on the bottom.
- Historically, the whaling industry has concentrated on harvesting the "great whales"; including the blue, sperm, humpback, finback, sei, and right whales.
- The whaling industry has a long history, going back to the Norse between A.D. 800 and 1000.
- Various groups have hunted whales through time, including:
    a. in the 1500s the Basques of France and Spain,

b. by 1600 the Dutch, British, and Japanese,
c. the 1700s and 1800s saw whaling efforts by the United States, Great Britain, and northern Europeans including Scandinavia.

- By the end of the 19th century explosive harpoons and fast ships began to rapidly deplete the whale population. This continued into the 20th century.
- In the 1930s the blue whale was nearly hunted to extinction when only 4 percent of the original number of them still existed.
- The International Whaling Commission (IWC) was established in 1946. Its job is to set quotas on catches.
- In 1985 - 86, a moratorium on whaling went into effect.
- To assess stocks, Japan has practiced "scientific" or "research" whaling, harvesting 330 minke whales each year under IWC direction.
- Norway announced its intention to resume whaling in 1993 due to the large number of minke whales in the North Atlantic. It set its own catch limit at 289 whales.
- In 1994 the IWC voted 23 to 1 (Japan voting against with several abstentions) to establish a whale sanctuary in Antarctic waters below 55°S.
- In 2000 Japan extended its "scientific" hunt. Six vessels were used to hunt 160 minke whales, 50 Byrde's whales, and 10 sperm whales. It was the first harvesting of Byrde's and sperm whales since 1987.
- Iceland left the IWC in 1999 and plans to resume whaling in 2001.
- Native people of Arctic regions (Alaska, Greenland, and the former Soviet Union) are allowed to conduct subsistence whaling.
- In 1997 the Native American Makah tribe of Washington State received permission to harvest 5 gray whales from the annual limit of 140 gray whales harvested from the North Pacific for traditional subsistence needs. They harvested one gray whale in 1999.
- Seals, sea lions, and walruses are all pinnipeds (meaning feather-footed).
- Pinnipeds have four swimming flippers, as seen in the illustrations in figure 11.23.
- The pinnipeds spend a great deal of time on land and can be found at all latitudes.
- Seals and sea lions were hunted in the 19th and early 20th centuries, but they are under much less pressure now and appear to be coming back in numbers.
- Seals and sea lions face other problems now including pollution and a reduction in their prey due to commercial fishing.
- Manatees and dugongs, also known as sea cows, are members of the sirenia (see fig. 11.24). They are docile, large, and slow-moving. They are the world's only marine herbivorous mammals.
- Manatees populate the south Atlantic coastline and the Caribbean. Dugongs are native to Southeast Asia, Africa, and Australia.
- The dugong is in danger due to hunting and the manatee is under pressure due to the growing encroachment of civilization.
- Manatees are often killed by boat collisions. In this way 67 manatees were killed in Florida in 1998 and 82 in 1999.

- Manatees have also died from red tides and suffer from the loss of their habitat if Florida as salt marshes, sea grass beds, and mangrove areas are drained for development or otherwise destroyed.
- The Marine Mammal Protection Act of 1972:
    a. bans the harvesting or importing of marine mammals or products that come from them, and
    b. covers all U.S. territorial waters and fishery zones.
- Small numbers of marine mammals can be collected for scientific purposes with the proper permits and approval from the Marine Mammal Commission.
- Following passage of the Marine Mammal Protection Act, the numbers of some mammals have increased. While this is good in itself, it has also resulted in problems related to competition between animals and people for the same space. An example is the increase in harbor seals and sea lions along the west coast.
- Fecal material deposited by increasing populations of seals and sea lions has caused public health officials to prohibit recreational swimming and shellfish harvesting in some areas.

Major Concept (XIII) *There are four different kinds of marine reptiles: snakes, sea turtles, the marine iguana, and the gavial (see fig. 11.25).*

Related or supporting concepts:

- The gavial is a marine crocodile that lives in the Indian Ocean off the coast of India. It feeds on fish.
- The marine iguana has a flattened tail used for swimming and large claws for climbing out of the water onto coastal rocks. It inhabits the Galápagos Islands.
- Sea snakes inhabit the Pacific and Indian oceans in warm waters. They are not found in the Atlantic Ocean.
- Sea snakes are relatively diverse, with about fifty different kinds.
- Sea snakes are poisonous. They have flattened tails for swimming and nostrils on the top of the snout.
- Sea snakes can dive to 100 m and remain submerged for up to 2 hours. They feed on fish and bear their young live at sea.
- Sea turtles spend their lives at sea but return to land to lay their eggs.
- There are four types of sea turtles:
    a. the green turtle is herbivorous and can grow to 300 lb,
    b. the hawksbill feeds on reef sponges,
    c. the leatherback eats jellyfish and may weigh as much as 1400 lb, and
    d. the loggerhead consumes crabs, mollusks, and sponges and weighs between 150 - 400 lb.
- All marine turtles are migratory and may travel long distances between where they feed and where they lay their eggs.

- Turtle eggs incubate in the sand. After hatching, the young must make their way across the beach to the water. During this time they are easy prey for birds.
- The biggest threat to marine turtle survival comes from people who hunt:
    a. turtles for their;
        i. eggs and meat for consumption,
        ii. skin for leather, and
        iii. fat and oils for cosmetics, and
    b. Hawksbill turtles for tortoise shell that is used to make combs and jewelry, among other things.
- Eighty percent of all sea turtles in U.S. waters nest in Florida where habitat degradation is a serious problem. This degradation includes:
    a. beach lighting that frightens nesting turtles and disorients hatchlings,
    b. seawalls and bulkheads destroy nesting sites,
    c. the addition of sand in beach replenishment projects buries nests and changes the sand, and
    d. beach-cleaning machines can destroy nests.
- Regulations currently require shrimp fishermen to use Turtle Excluding Devices (TEDs). These are designed to allow the turtles to escape without releasing the shrimp.

Major Concept (XIV) *About 3% of the Earth's 8600 species of birds are considered marine species.*

Related or supporting concepts:

- Marine birds may spend their lives almost continuously at sea or they may go to the sea only periodically.
- All marine birds return to shore to nest.
- The most truly oceanic bird is the albatross of the southern oceans. It will spend four to five years at sea before returning to shore to nest.
- Wilson's petrel, the smallest of the Antarctic birds, flies 16,000 km (10,000 mi) to Labrador during the Southern Hemisphere winter.
- Penguins can not fly.
- Penguins swim in underwater flocks at almost 16 km/hr (10 mi/hr).
- Other large fishing birds include pelicans and cormorants.
- Gulls and terns are found all over the world.
- Puffins, murres, and auks are found in the North Atlantic, North Pacific, and Arctic. They are heavy-bodied, short-winged, and short-legged birds.
- Shorebirds are usually migratory and may travel in groups of thousands and hundreds of thousands of individuals.
- Marine bird habitats are under increasing pressure from growing human incursion in coastal areas and pollution. In addition, natural events such as landslides in nesting

areas and EL Niño

Major Concept (XV) *Careful regulation of fisheries is required to guarantee their long-term survival. Overfishing can drastically reduce the numbers of a given species and destroy the fishing industry for that species.*

Related or supporting concepts:

- The United Nations Food and Agriculture Organization (FAO) keeps track of world fish catch.
- With increased demand and improved technology, the world marine fish catch has increased significantly in the 4 decades from the 1950s through the end of the 1980s:
    a. 1950 - 21 million metric tons
    b. 1985 - 76 million metric tons
    c. 1989 - 86 million metric tons
- With the beginning of the 1990s however, there was an initial decline in the total tonnage followed by a increase once again:
    a. 1990 - 83 million metric tons
    b. 1992 - 83 to 84 million metric tons
    b. 1996 and 1997 - 86 million metric tons
- Over-fishing is a problem of global scale.
- The FAO estimated in 1997 that:
    a. 44% of world fish stocks are being fully exploited,
    b. 16% are overfished,
    c. 6% are depleted, and
    d. 3% are recovering slightly.
- The U.S. Office of Fisheries Conservation Management estimates that 41% of the species in U.S. waters are overfished.
- In 1992 Canada effectively shut down its cod fishing industry because of overfishing and Iceland was warned that its cod fishing industry may collapse unless annual catch is reduced by 40 percent. In 1993 the U.S. closed all parts of its cod fishery.
- The North Atlantic swordfish catch has declined 70 percent from 1980 to 1990 and the average weight of individual fish has fallen from 115 to 60 lb.
- The western Atlantic adult bluefin tuna population dropped 80% between 1970 and 1993. The Gulf of Mexico population has dropped 70% since 1975 and the Mediterranean population had declined by 50%.
- As traditional fisheries decline more pressure is placed on other species to satisfy demand. One example is shark.
- The shark catch has increased dramatically in recent years. Shark sales in the United States have increased from 3000 metric tons in 1985 to an average of 6000 metric tons annually in the 1990s.
- The Asian demand for shark fin soup supports an industry in which only the fins are kept and the bodies are thrown back into the sea.

- Overfishing is decimating shark populations in all the oceans.
- The shark fishery is particularly fragile due to the shark's low reproductive rate, their slow growth, and the long time it takes them to reach sexual maturity.
- Increased fishing and environmental degradation can combine to threaten fisheries. This has happened to the Peruvian anchovy fishery with the occurrence of El Niño (see fig. 11.29), and the salmon industry of the Pacific Northwest and Alaska as a result of the degradation of the freshwater environments where they spawn.
- In general, the cost of commercial fishing is increasing and the quality of the fisheries is decreasing.
- There has been some success in creating new fisheries. One example involves North Pacific bottom fish that are processed to remove fats and oils. The fish is then used to produce a high protein product called surimi that can be flavored to mimic crab, shrimp, and scallops.
- The demand for different marine products often depends on the country where they are sold. In the United States the most popular products are whole fillets and fish steaks. This drives the commercial fishing of high-cost fish such as salmon, swordfish, and halibut.
- Fish that are inadvertently caught while fishing for other species are referred to as incidental catch or by-catch. These fish are often simply dumped dead at sea. In other cases the incidental fish are saved and marketed separately.
- It is estimated that 27 million tons of incidental catch is discarded at sea annually.
- The annual shrimp harvest is 1.8 million tons and results in a by-catch of 9.5 million tons.
- Each year there are an estimated 40,000 sea turtles caught by longline fishing as incidental catch with an estimated mortality of 16,800 (42%). Shrimp trawlers catch more than 45,000 turtles with and estimated mortality of 12,000 (28.5%)
- Alaskan trawlers for pollock and cod discard some 25 million pounds of halibut, worth about $30 million, along with salmon and king crab because they are prohibited from keeping or selling it.

Major Concept (XVI) *Fish can also be raised in controlled environments as a crop in a process called mariculture or aquaculture.*

Related or supporting concepts:

- This was first done in China about 4000 years ago.
- Mariculture is relatively common in China, Southeast Asia, and Japan. This involves both fresh and salt water.
- Mariculture is labor intensive and most operations are small, run by individual families.
- Monoculture involves single species of fish. Polyculture makes more efficient use of

ponds by including bottom and surface feeding fish.

- Only about 2% of the fish used in the United States comes from mariculture. The principal species raised are trout, nearly 100 percent, and catfish, about 50 percent.
- The following characteristics are important to make a species economically attractive:
  a. the juveniles should be hardy and thrive in controlled conditions,
  b. they should gain weight rapidly,
  c. they should eat inexpensive and readily available food,
  d. they should demand a high price from the consumer, and
  e. they should reproduce readily in captivity.
- Aquaculture has nearly tripled its output in the last decade.
- One third of the salmon consumed world wide come from salmon pens. The world's largest salmon producers are Norway (46%), Chile (22%), Scotland (13%), and Canada (7%).
- Aquaculture research is focussing on new fish species for marketing in the next decade including mahimahi, Atlantic cod, Atlantic halibut, and redfish.

Key Terms and Related Major Concepts

At the back of the chapter in your book there are a number of key terms. You should be able to find the following terms referenced in the major concept indicated in parentheses.

plankton(I,II)	copepod(V)	invertebrate(VIII)
benthos(I)	euphausiid(V)	vertebrate(VIII)
nekton(I)	krill(V)	pinniped(XII)
algae(III)	baleen(V)	manatee(XII)
diatom(III)	pteropod(V)	dugong(XII)
dinoflagellate(III)	mollusk(V)	surimi(XV)
bloom(III)	ctenophore(V)	incidental catch(XV)
flagella(III)	cilia(V)	mariculture(XVI)
red tide(IV)	coelenterate(V)	aquaculture(XVI)
deep scattering layer(V)	colonial(V)	monoculture(XVI)
foraminiferan(V)	holoplankton(V)	polyculture(XVI)
radiolarian(V)	meroplankton(V)	ocean ranching(XVI)
crustacean(V)	larvae(V)	sea ranching(XVI)

Test Your Understanding With The Following Questions:

FILL IN THE BLANK

1. The free swimmers of the oceans are called _____.
2. Most phytoplankton are single-celled plants called _____.

3. _____ are also sometimes called golden algae.
4. A rapid increase in population of plankton is known as a _____.
5. A false bottom record produced by upward migrating zooplankton at night is called the _____ _____ _____.
6. False feet on some zooplankton are called _____.
7. Animals without backbones are called _____.
8. Shark skeletons are made of _____.
9. Large groups of fish are called _____.
10. Marine _____ are warm-blooded air breathers.

TRUE - FALSE

1. Some species of zooplankton can reproduce three to five times in a single year under optimum conditions.
2. There are over 1000 species of sharks.
3. Most valuable bony fish live in the upper 200 m of water.
4. Some of the largest marine organisms feed directly on some of the smallest marine organisms.
5. Pinnipeds are marine mammals.
6. Sea snakes are found in all ocean basins.
7. Overfishing is the only significant threat to marine fisheries.
8. Trout are popular in United States mariculture.
9. Phytoplankton migrate downward at night.
10. Krill are zooplankton.

MULTIPLE CHOICE

1. Which of the following are zooplankton?
    a. diatoms
    b. foraminiferans
    c. radiolarians
    d. b and c
    e. all of the above
2. Bottom fish are typically:
    a. slower than surface fish
    b. have brighter colors
    c. are poisonous
    d. are larger than surface fish
    e. more likely to be streamlined
3. Which of the following is a baleen whale?

a. blue
b. finback
c. right
d. humpback
e. all of the above

4. Sea turtles:
    a. lay eggs on land
    b. are herbivores
    c. are migratory
    d. a and c
    e. all of the above
5. Manatees:
    a. are hostile and defend their territory vigorously
    b. lay eggs in shallow water
    c. are docile
    d. live in Southeast Asian waters
    e. are carnivores
6. For a species to be economically viable for mariculture:
    a. the young should be hardy
    b. it should be inexpensive to raise
    c. it should command a high price
    d. it should reproduce readily in captivity
    e. all of the above
7. Approximately what percent of the United States fishery products are acquired by mariculture?
    a. 10
    b. 2
    c. 7
    d. 14
    e. 21
8. Which of the following are invertebrates?
    a. turtles
    b. squid
    c. reptiles
    d. mammals
    e. fish
9. Possible triggering mechanisms for red tides include:
    a. temperature changes
    b. variations in light
    c. high salinities
    d. heavy runoff of nutrients following large rains
    e. all of the above
10. Daily vertical migration of zooplankton may cover distances of:

a. 10 - 500 m
b. 1 - 5 m
c. 300 - 1000 m
d. 1 - 2 km
e. 1500 - 2600 m

Answer Key for 'Key Terms' and 'Test Your Understanding'

FILL IN THE BLANK

1. nekton
2. algae
3. diatoms
4. bloom
5. deep scattering layer
6. pseudopodia
7. invertebrates
8. cartilage
9. schools
10. mammals

TRUE - FALSE
1.T 2.F 3.T 4.T 5.T 6.F 7.F 8.T 9.F 10.T

MULTIPLE CHOICE
1.d 2.a 3.e 4.d 5.c 6.e 7.b 8.b 9.e 10.a