CHAPTER 17 THE NEKTON: FREE SWIMMERS OF THE SEA

Objectives

1. To study the diversity and life styles of the marine organisms that swim freely in the oceans.
2. To look in some detail at representative members of the mammals, reptiles, squid, and fish that are included in the nekton.
3. To investigate commercial fisheries in the world's oceans.

Key Concepts

Major Concept (I) *Organisms that swim freely in the oceans belong to the group called nekton. Nekton move independently of currents and waves.*

Related or supporting concepts:

- Most nekton are fish but they include mammals, reptiles, birds, and squid.
- The mobility of nekton allows them to pursue prey and flee from predators.
- In general, nekton occupy the top levels of the food chain and include both herbivores and carnivores.
- In terms of size they range from small tropical fish to the blue whale, the largest creature ever to have lived on earth.

Major Concept (II) *The first group of nekton we will discuss are the mammals. These include whales, porpoises, dolphins, seals, sea lions, walruses, sea otters, sea cows, and the polar bear.*

Related or supporting concepts:

- Marine mammals are homeotherms (warm-blooded animals that maintain relatively constant body temperature by internal mechanisms) and air breathers.
- These creatures may spend their entire lives in the water or they may return to land to breed and bear their young.
- Mammals are born live and nursed by their mothers when young.

Major Concept (III) *Many marine mammals use sound to communicate with each other and also to picture their surroundings.*

Related or supporting concepts:

- Beneath the surface there is often little or no light to reveal objects. Consequently many mammals use sound to probe the environment. This is similar to our use of sonar. Mammals emit sounds that reflect off of objects and return. This process is called echolocation.
- Some mammals alter the frequency of the sounds they emit, using low-frequency sounds to probe large areas and high-frequency sounds to track specific nearby objects.
- Hearing centers in porpoise brains are highly developed while vision centers are less developed and it is believed they have no sense of smell.
- Mammals also use sound to communicate. One of the most remarkable examples of this is the "song" of the humpback whale that may last for up to thirty minutes.

Major Concept (IV) *Whales belong to the mammal group called cetaceans.*

Related or supporting concepts:

- Whales can be divided into those that have teeth and those that strain their food through structures called baleen or whalebone. The mouths of toothed and baleen whales are compared in figure 17.1.
- Toothed whales feed on squid, fish, and other mammals. These include the killer whale, the sperm whale, and porpoises.
- Baleen whales strain the water for krill and other plankton and include the blue, finback, right, sei, and humpback whales. The gray whale is also a baleen whale but it feeds mainly on bottom-dwelling crustaceans and worms. Humpback whales will circle an area with a high density of krill and expel air to create a screen of bubbles, after which they will swim through the area and feed.
- Whales typically migrate but the distance varies with the species. The California gray whale and the humpback whale both have distinct migratory patterns and travel long distances.
- California gray whales:
    a. feed in the Bering Sea and the Arctic Ocean in the summer, building up energy reserves of fat and blubber,
    b. migrate south to Baja California in December where they mate and give birth,
    c. live off their stored reserves of fat and blubber in the winter, losing 20–30% of their body weight in the process,
    d. travel northward again in February or March, traveling in small groups at about 5 knots, 24 hours a day, and
    e. complete this 18,000-km (11,000-mile) migration each year.
- Humpback whales:
    a. occur in three populations that remain independent from each other in the North Pacific, North Atlantic, and Southern Ocean, and
    b. spend winter months at high latitudes and summer months at low latitudes, breeding and birthing.
- Other whales such as the bowhead, beluga, and the narwhal remain in colder water throughout the year, migrating only short distances.
- The bowhead whale:
    a. spends nearly its entire life at the edge of the Arctic ice pack, and
    b. travels to the Bering Sea in winter months and the Chukchi and Beaufort Seas in summer months when the ice pack recedes.
- The narwhal:
    a. is found only in Arctic waters,
    b. is the most northerly whale, and
    c. are found along the east and west coasts of Greenland.

Major Concept (V) *The larger species of whales have been hunted for hundreds of years*.

Related or supporting concepts:

- The whaling industry has traditionally focused on the larger species of whales including the blue, sperm, humpback, finback, sei, and right whales.
- A brief chronological history of whaling includes:

A.D. 800–1000	Earliest recorded European whaling by the Norse, followed shortly after by the Basques of France and Spain.
1500s	Basque whalers had extensive whaling stations along the Labrador coast. This industry peaked in the 1560s and 1570s, employing 1000 people and producing 500,000 gallons of oil each year.
1600	Whaling began among the Dutch, British, and Japanese.

1868	The harpoon gun with an explosive harpoon was invented by a Norwegian.
1925	Large factory ships were added to whaling fleets to process whales at sea. This resulted in the rapid depletion of the whale population because of increased efficiency in harvesting operations.
1930s	The blue whale population had been reduced to less than 4% of its original size.
1946	The International Whaling Commission (IWC) was established by fifteen member nations. The IWC has no police powers, but it does recommend whaling limits and bans for some species as well as establishing whaling seasons.
1960s	Whale kills peaked (>50,000 in 1960 and >66,000 in 1962).
1970s	Commercial whaling was under such pressure that it was on the decline.
1979	The IWC placed a ban on whaling in the Indian Ocean and outlawed the use of factory ships.
1982	The IWC recommended a moratorium on whaling, except for dolphin and porpoise, to determine the status of whale populations. The moratorium began in 1985–86.
1993	Norway announced its resumption of whaling citing the large population of North Atlantic minke whales.
1994	At its 1994 meeting the IWC voted (23 to 1 with Japan dissenting and several abstentions) to create a whale sanctuary in Antarctic waters south of 55°S.
1997	The IWC granted permission to the Native American Makah tribe of Washington State to harvest five gray whales annually. The Makah's cited an 1895 treaty with the U.S. government granting them whale harvesting rights.
1999	Iceland left the IWC to resume whaling.
2000	Japan expanded its "scientific" harvesting of whales by taking 508 minke and 43 Bryde's whales. Norway harvested 487 minke whales.
2002	Japan unsuccessfully lobbied the IWC to receive approval to harvest an additional 50 minke and 50 sei whales.

- Populations of California gray whales have recovered and the populations of several other species appear to be increasing.
- The majority of whale species still have populations far below their estimated original numbers.
- The eastern North Pacific right whale was nearly exterminated during the 1940s–60s, and it is considered the most endangered of the large whales.
- There are a number of reasons that have been proposed for the slow recovery of whale populations including:
    a. the difficulty of finding mates in small populations,
    b. noise pollution in the oceans may interfere with whale communication,
    c. extensive krill harvesting,
    d. the global depletion of fish species, and
    e. pollution.

Major Concept (VI) *Dolphins and porpoises are small, toothed whales.*

Related or supporting concepts:

- In the open ocean they often travel in large schools.
- They can travel at speeds in excess of 30 knots.
- They are found in tropic and temperate waters.
- They occasionally will enter coastal brackish waters.
- A great deal of pressure has been put on dolphins and porpoises in the last 20 years.
- A 1990 U.N.-sponsored symposium reported that more than 1 million dolphins and porpoises are killed each year in fishing nets (often as unwanted by-catch).
- Two species are thought to be endangered; the Mexican porpoise and the black dolphin of the Chilean coast.

Major Concept (VII) *The pinnipeds, or feather-footed animals, are a group of mammals having four characteristic swimming flippers. These include seals, sea lions, and walruses (see figs. 17.5 and 17.6).*

Related or supporting concepts:

- Pinnipeds are true marine mammals but they spend time on land as well.
- These mammals have a wide range geographically from the tropics to polar regions.
- The true seals in this group lack external ears and cannot rotate their front flippers to support themselves on land. These include the common harbor seal, the harp seal of the northwest Atlantic, the Weddell and leopard seals of the Antarctic, and the elephant seals (a giant seal, the males can weigh as much as two tons).
- The northern fur seal and the sea lion have ears, longer necks, and front flippers that can support them as they "walk" on land.
- Some seals migrate long distances in the spring and summer for breeding purposes.
- During the 19th and early 20th centuries seals and sea lions were hunted extensively for fur and oil.
    a. Between 1870 and 1880 hunters reduced the northern elephant seal population to 100.
    b. By 1892 hunting is thought to have reduced the population of the Guadalupe fur seal of southern California to only 7 individuals. The current population is about 1500 due to conservation efforts by both the U.S. and Mexico combined with an amazing amount of luck.
    c. By 1910 the population of northern fur seals in the Pribilof Islands was down to only 200,000 to 300,000.
        1. Commercial sealing and the killing of females was banned in 1967–68.
        2. In 1967–68 the population was estimated at 2.5–3 million.
        3. The minimum estimate of the annual native subsistence harvest over the years 1986–1996 is 1600 seals (juvenile males only in the Pribilof Islands).
        4. The current population is estimated at about 1.1 million.
        5. There has been a long-term decrease in population since the mid-1950s which is thought to be due to a reduction in their food supply caused by large commercial fish harvests in the area.
    d. The white-fur pups of the Canadian harp seal were commercially harvested in eastern Canada for 150 years.
        1. Hunting was banned by the Canadian government following a collapse of the market due to international protests in the 1970s and 1980s
        2. The loss of the Atlantic cod industry has driven sealers back to hunting. The government set a quota of 250,000 seals in 1996, 1997 and 1998.
        3. The current population is estimated at 4 million.
- The walrus is distinct from the seals and sea lions. It has no external ears and hind flippers that it can rotate to walk on land.
- Both male and female walrus are equipped with tusks. They use their tusks to help haul themselves out of the water onto the ice. The tusks are also probably used to glide along the bottom as they search the sediment for food with their whisker pads.

- The walrus population before the 18th century hunting was 200,000 to 250,000 animals.
- The 1950 population had fallen to 50,000 to 150,000 animals. The last count taken was of 234,000 animals in 1985.
- The size of the walrus population is related to ice conditions, the availability of prey, hunting, and human disturbance.
- Over the last 36 years an average of 7,000 walrus have been harvested, but between 1992 and 1996 the average harvest dropped to 5,000 animals.

Major Concept (VIII) *Sea otters are relatively small mammals that differ from seals and whales by not having an insulating layer of blubber for warmth*.

Related or supporting concepts:

- Sea otters are related to river otters but are larger.
- Sea otters live in coastal waters and feed off of shellfish living on the bottom.
- Unlike seals and whales, sea otters have no thick insulating layer of blubber.
- Sea otters maintain their body temperature with soft, thick fur. In the 18th and 19th centuries otters were mercilessly hunted nearly to extinction for their pelts. Prime pelts sold for as much as $1000.00 each!
- The sea otter population was protected from hunting in 1911 and gradually began to come back.
- The Alaskan population is at a minimum of 100,000 and there are about 2,300 in California waters.
- A significant decline in the seal population in Alaskan waters has driven killer whales to begin feeding on sea otters.
- The declining seal population may be due to heavy groundfishing or environmental conditions such as the warming ocean temperatures that have occurred in the area since the mid-1970s.
- Since 1990 the otter population is thought to have been reduced by up to 90% in some areas due to predation by killer whales.
- Because otters are much smaller than seals, killer whales have to kill large numbers to get the same nourishment.
- The otters live near kelp beds and feed on sea urchins that graze on the kelp.
- As the otter population dwindles, the urchin population increases and they threaten to destroy kelp beds that are home to many other organisms.

Major Concept (IX) *Another important mammal group is the Sirenia, including manatees, and dugongs (see fig. 17.7).*

Related or supporting concepts:

- Manatees and dugongs are also known as sea cows.
- Manatees inhabit brackish coastal bays and waterways along the warm southern Atlantic coast and in the Caribbean.
- Manatees are frequently injured or killed by collisions with boats and wounds inflicted by propellers.
    a. Between 1979 and June 1992 more than 1700 manatees died along the Florida coast, 26% of them from boat collisions.
    b. In 1996, 600 manatees died. At least 158 of these deaths were due to neurotoxin poisoning during a red tide bloom of *Gymnodinium* (see chapter 16).
    c. There were 305 manatee deaths from all causes in 2002.
- The destruction of Florida's manatee habitat is increasing. Salt marshes, seagrass beds, and mangrove swamps are being drained and reclaimed for development.
- Dugongs live in the seas of Southeast Asia, Africa, and Australia. They have disappeared from much of the Indian Ocean and South China Sea due to degradation of habitat.
- The sea grass beds that dugongs depend on for food are being cleared for development and smothered by sediments eroding from land due to overgrazing and deforestation.
- Dugongs are also hunted for their tusks and killed or injured by boat propellers.
- These mammals are the world's only herbivorous marine mammals.

- The Steller sea cow is now extinct. It used to inhabit the shallow waters off the Commander Islands in the Bering Sea.
- These sea cows were slow-moving, docile, and unafraid of humans. Unfortunately they were not able to withstand human hunting pressure.
- The last known Steller sea cow was killed for meat in 1768.

Major Concept (X) *The polar bear is the top predator of the Arctic's marine food chains (fig. 17.8).*

Related or supporting concepts:

- Polar bears have a relatively long life span of 15 to 20 years.
- Polar bears are carnivores with dense fur and blubber for insulation.
- They feed primarily on ringed seals. In addition, they eat other seal species and whale and walrus carcasses.
- Polar bears travel 30 km (19 mi) or more over the ice each day. They are strong swimmers, capable of swimming continuously for 100 km (62 mi).
- Female bears make dens in drifted snow in October and November.
- The world's total population of polar bears is estimated at 25,000 to 40,000.
- They are found in the United States (Alaska), Canada, Denmark (Greenland), Norway (Svalbard Islands), and Russia.
- Russia and Norway prohibit all hunting of polar bears.
- The Marine Mammal Protection Act of 1972 (see Major Concept XI below) prohibits the killing of all marine mammals, including polar bears, except by native people for subsistence purposes.

Major Concept (XI) *In 1972, the Congress of the United States established the Marine Mammal Protection Act (MMPA), Public Law 92-522.*

Related or supporting concepts:

- The MMPA covers all U.S. territorial waters and fishery zones. It also includes all persons and vessels on the high seas that are subject to the jurisdiction of the United States.
- The act includes a ban on the taking and/or importing of any marine mammal or marine mammal product. An exception is made for Native peoples for the purposes of subsistence hunting and the creation of authentic native articles of handicraft and clothing.
- “Taking” is defined as the act of harvesting, hunting, capturing, or killing any marine mammal or attempting to do so.
- Individual marine mammals can still be taken for scientific purposes or public display under highly restricted circumstances.
- The MMPA has been so successful in U.S. coastal waters that in some instances the mammals and people are competing for the same habitats and resources.
- Since the act was passed, harbor seal and sea lion populations have increased 7–10% annually along the U.S. West Coast. These animals feed on fish that are commercially harvested.
- Seals and sea lions also deposit fecal matter in shallow beach areas that cause high levels of harmful bacteria in the water. This has led to the occasional closure of these areas to swimming and shellfish harvesting.

Major Concept (XII) *Approximately 3% of the 8600 species of birds are marine species. Many adaptations have allowed birds to successfully live in marine habitats. They are an extremely important group of consumers in marine food webs.*

Related or supporting concepts:

- Seabirds swim both at the surface and underwater using modifications to wings, feet and body shape.
- Marine birds use many techniques to remain warm, dry, and bouyant --or to control their buoyancy-- while under water.

- They can float easily because of fat deposits, light bones, and air sacs.
- Their feathers are waterproofed by an oily secretion called preen.
- Marine birds decrease their buoyancy during dives by exhaling the air in their lungs and air sacs and pulling their feathers close to their bodies to squeeze out trapped air.
- Birds that routinely swim underwater, such as cormorants and penguins, have thicker, heavier bones. Penguins also lack air sacks.
- Marine birds have excellent eyesight which is used not only for detecting their prey from above the water surface, but also while submerged.
- Birds have less developed senses of hearing and smell. Their least developed sense is taste.
- Birds have a very high metabolic rate and are voracious eaters feeding on fish, squid, krill, egg masses, bottom invertebrates, carrion, and garbage.
- They are most prevalent where food is abundant. Large bird populations often signal regions of high productivity.
- The albatross of the southern oceans is a truly oceanic creature. It spends four to five years at sea before returning to its nesting site. It has a wingspan of up to 3.5 m (11 feet).
- Seabirds can have extraordinary seasonal migration routes. Wilson's petrel flies up to 16,000 km (10,000 miles) on its yearly route from its breeding ground in Antarctica along the Gulf Stream to Labrador during the Southern Hemisphere winter. It then returns the 16,000 km back to Antarctica during the Southern Hemisphere summer.
- Penguins (see fig. 17.10a):
    a. Are social birds that live and breed in large flocks.
    b. Their breeding grounds are called rookeries.
    c. They swim in flocks. They use their wings for propulsion and their feet for steering.
    d. They can swim almost 10 mph underwater.
    e. Penguins feed on fish, krill, squid, and shellfish.
    f. With the exception of the Galápagos, all other species live in the Southern Hemisphere. The emperor and the Adelie penguins inhabit Antarctica.
- Pelican (fig. 17.10b) and cormorants:
    a. Are large fishing birds with big beaks.
    b. Are generally found in coastal areas but can venture farther out to sea.
    c. The pouch on the beak of pelicans is used in catching fish.
    d. The North American white pelican fishes in groups.
    e. The Pacific's brown pelican dives from heights as great as 10 m (33 ft) to catch fish.
    f. Cormorants are black, slender birds. They have snake-like necks and hooked bills at the tip.
    g. Cormorants float on the surface and dive from the surface to catch fish. They swim with their feet.
    h. Cormorants must return to land periodically to dry out because they do not have water-repellant feathers.
- Terns (fig. 17.10c) and gulls:
    a. Are found all over the world, with the exception of the South Pacific between South America and Australia.
    b. Gulls are very strong fliers and will eat anything. They search for food over the beach and open water.
    c. Terns are smaller than gulls. They have a slender bill and forked tails.
    d. The Arctic tern breeds in the Arctic. In the winter it migrates south of the Antarctic Circle, a round-trip of 35,000 km (20,000 mi).
- Puffins, murres, and auks:
    a. Are heavy-bodied, short-winged, short-legged diving birds.
    b. Their food consists of fish, crustaceans, squid, and some krill.
    c. They all are limited to the North Atlantic, North Pacific, and Arctic areas.
- Shorebirds:
    a. Most shorebirds are migratory.
    b. Different species of shorebirds arrive in areas at different times of the year and search out different kinds of shoreline so there is no great competition among them for food.
    c. They feed on worms, shrimp and other crustaceans, snails, clams and other bivalves, and other

organisms that live in the mud and sand.
    d. The specific food source for each species depends on the bird's physical characteristics such as the length and shape of their beak and neck.
- As humans and their cultural effects occupy more and more of coastal habitats, or alter coastal environments for recreational and development uses, the effects on marine birds due to interference and habitat reduction can be devastating.

Major Concept (XIII) *Relatively few reptiles are true marine creatures. The reptilian nekton that do exist include lizards, snakes, and turtles.*

Related or supporting concepts:
- The lizards include the marine iguana of the Galápagos Islands and the gavial and false gavial, which are saltwater crocodiles that live primarily around Indonesia and northern Australia. The iguana is an herbivore, feeding on algae, while the crocodiles are decidedly carnivorous.
- The iguana has a flattened tail to aid in swimming, large claws for climbing back out of water, and regulates its buoyancy by expelling air to remain submerged.
- There are about fifty different kinds of sea snakes found in the tropical waters of the Pacific and Indian oceans. They are not found in the Atlantic Ocean.
- Some species leave the water to lay eggs on land while others give birth to live young in the water.
- Sea snakes can expel nitrogen to the water through their skins, thus allowing them to dive to depths as great as 100 m (330 ft), remain submerged for up to two hours, and surface rapidly without any adverse effects.
- Sea snakes are poisonous and eat fish. They give birth to live young.
- There are eight species of marine turtles (all considered endangered or threateded); green, hawksbill, leatherback, loggerhead, Kemp's ridley, black, Australian flatback, and the olive ridley.
- The olive ridley is thought to be the most abundant and the Kemp's ridley the least abundant.
- All of the marine turtles live in warm, tropical, and temperate waters. The differ from land turtles by having limbs modified as flippers and shells that are typically smooth and light to increase buoyancy and streamline the body for swimming.
- The largest turtles are the green, hawksbill, leatherback, and loggerhead.
    a. Green turtles are herbivores, eating grasses and algae, and weigh 140 kg (300 lb) or more.
    b. The hawksbill feeds primarily on sponges and inhabits reef environments.
    c. Loggerhead turtles weigh between 70 and 180 kg (150 and 400 lb) and are also found around reefs and wrecks on the bottom. They are carnivorous and feed on crabs, mollusks, and sponges.
    d. The giant leatherback is the largest marine reptile and may weigh as much as 900 kg (2000 lb). It dives as deep as 1000 m (3300 ft) to feed on jellyfish.
- Turtles often make long migratory journeys from their feeding grounds to nesting sites where they return to land to lay their eggs. The leatherback travels 5000 km (3100 mi) while the green turtle migrates 2250 km (1400 mi).
- The greatest threat to the survival of these creatures is humankind. Sea turtles are aggressively hunted for their:
    a. eggs for food,
    b. shells for tortoiseshell products,
    c. skins for leather, and
    d. fats and oils for the cosmetics industry.

  In addition, significant numbers of turtles are killed as newly hatched young by predators, and as adults, die after ingesting plastic waste or suffocating in shrimp nets.
- There is a vast international illegal trade in turtle products that is equivalent to the illegal ivory trade in dollar value.
- The U.S. and 115 other nations have banned import or export of sea turtle products.
- Roughly 80% of all sea turtles in U.S. waters nest in Florida.
- Special devices called turtle excluding devices or TEDs, have been designed for shrimp nets that will allow turtles to escape the nets while the shrimp remain trapped. The National Marine Fisheries

Service required all shrimpers to install TEDs in 1994.

Major Concept (XIV) *Another important group of nekton are the squid (see fig. 17.12).*

Related or supporting concepts:

- There is a large world fishery for squid and the related cuttlefish and octopus. The 1998 world harvest was 3.6 million metric tons.
- Squid travel in large schools in deeper water during the day and migrate upwards at night.
- These animals can move very rapidly by ejecting jets of water from a tube like structure known as the funnel.
- Squid can float with neutral buoyancy. They sometimes rest on the bottom.
- They have a wide range of bioluminescence and coloration and can disappear rapidly.
- They have eight short arms and two long tentacles with suckers at their ends.
- Some species have bioluminescent lures to attract prey.
- Squid possess highly developed eyes and brains in comparison with other invertebrates.
- Some species are only a few centimeters in length but the giant squid *Architeuthus* may grow to more than 20 m (65ft) in length (little is known about them because no giant squid has been captured alive).

Major Concept (XV) *Fish are the third most abundant group of animals in the sea with about 12,000 different species.*

Related or supporting concepts:

- The fish are a very diverse group of creatures with a wide variety of shapes and sizes to adapt to their environment (see fig. 17.13). There are streamlined fish for rapid movement, flat fish that live on and near the bottom, and slender elongate fish that live in the soft sediment or in narrow openings between rocks or coral.
- While fish populate the entire pelagic environment, they are found in the highest concentrations where there are dense populations of plankton in zones of upwelling, shallow coastal regions, and estuaries.
- Fish are equipped with fins that are used for locomotion, to change direction, balance, brake, and in some instances, to glide just above the water's surface or “walk” on soft muds.
- Some species travel alone while others (herring, mackerel, menhaden) prefer to move in schools consisting of a few to thousands of individuals.
- Herring in the North Sea have been seen in schools 15 km long by 5 km wide (9x3 mi).
- Schools usually consist of individuals of a common size (age) from a single species. Schools have no definite leaders.
- Schooling fish have wide-angle eyes and the ability to sense small changes in water displacement that allow them to maintain their position in the school.
- Ocean fish are divided into two groups:
    a. fish with skeletons of cartilage such as sharks and rays, and
    b. fish with skeletons of bones.

Major Concept (XVI) *The cartilaginous fish are generally considered the more primitive group. Two members of this group we will discuss are the sharks and rays.*

Related or supporting concepts:

- In a sense, the shark is a living fossil. It first appeared in the oceans 450 million years ago, before the mammals appeared. It is distinct from other fish, both by its cartilaginous skeleton and by its tooth-like scales that have a hard dentine covering similar to our teeth.
- The shark's teeth occur in a number of overlapping rows and are rapidly replaced when lost.
- Sharks are remarkably well adapted to their environment by having:
    a. good eyesight,
    b. an excellent sense of smell that is particularly sensitive to chemicals associated with feeding

and can detect chemical concentrations as low as 1 part per billion,
    c. good hearing,
    d. a well-developed sensitivity to vibrations, currents, and pressure changes in the water, and
    e. an ability to detect weak electrical fields in the water created by some prey as well as by its own movement through the earth's magnetic field, thus providing it with a natural compass.
- There are more than 350 species of sharks.
- Some sharks feed on plankton. These include the largest fish in the oceans, the whale shark that may exceed 15 m (50 ft) in length, the basking shark that attains lengths of 5–12 m (15–40 ft), and the megamouth, 4 m (14 ft) long and weighing 680 kg (1500 lb), which is known from two specimens.
- Many sharks are very skilled predators and can attack large prey. They often act as the scavengers of the seas, killing the weak and old animals.
- Sharks will occasionally attack humans. Recent increases in reported shark attacks along the northern coast of California have been attributed to the increased population of the shark's natural prey, seals and sea lions, after the establishment of the Marine Mammal Protection Act.
- Shark meat is enjoyed as a table food in many regions of the world.
- There are roughly 450–550 species of skates and rays.
- Skates and rays:
    a. are shark-like fish that are flattened and live along the bottom,
    b. swim by undulating their large side fins,
    c. typically have thin whip-like tails that may be barbed and poisonous,
    d. may feed on plankton but are generally carnivorous, eating crustaceans, mollusks, other benthic organisms, and sometimes fish, and
    e. occasionally can produce electrical shocks of up to 200 volts for defensive purposes,
    f. most rays bear their young live while skates enclose the young in a leathery capsule called a sea purse or mermaid’s purse from which they emerge in a few months.
- Rays bear their young live while skates produce eggs that are contained in flexible capsules.

Major Concept (XVII) *Most food fish are bony fish that live in the epipelagic zone, or at depths less than about 200 m (660 ft).*

Related or supporting concepts:

- Commercial species of fish often have very sleek shapes and are capable of traveling long distances at relatively fast speeds. These are typically predatory fish.
- Among the most important of the commercial fish are the small sardines, anchovy, menhaden, and herring. These fish travel in schools feeding on plankton.
- Larger fish that swim freely in the open sea and are commercially harvested include mackerel, pompano, swordfish, and tuna.
- There are also a group of bottom-dwelling or demersal fish, including the flounder, halibut, turbot, and sole.
- Finally, there are the rockfish that live near the bottom, in and around rocks. Examples include perch and snapper.

Major Concept (XVIII) *The fish of the deep sea are not well known because of the difficulty and expense of probing the depths and few have been exploited commercially (see fig. 17.16).*

Related or supporting concepts:

- In the dim, transitional mesopelagic layer from 200 to 1000 m (660–3300 ft) there are vast numbers of fish, many of them relatively small and luminous.
- The genus *Cyclothone* is thought to be the most abundant fish in the oceans. There are many species of *Cyclothone*, each living at a relatively fixed depth.
- The coloring of these fish is related to the depth at which they swim, dark colors at greater depths and lighter silvery colors in shallower water to blend with the dim light.
- The lantern fish has a worldwide distribution. There are roughly 200 species of lantern fish. They can

be identified by the pattern of photophores along their bodies.
- Squid, porpoises, and tuna feed on lantern fish.
- Sablefish are caught commercially in waters off Alaska, British Columbia, and Washington State. It is also found off southern California at depths of 800 to 1500 m (2640–4950 ft).
- Often the geographical location of these fish is related to the temperature of the water. Deep-sea fish at low latitudes can be found at shallower depths in high latitudes.
- There is some suggestion that denser populations of very deep-dwelling fish exist under surface waters of low productivity where food can sink to great depth rather than being rapidly consumed in shallower water.
- In the bathypelagic zone where it is always dark, predatory fish have evolved in a variety of interesting ways that increase their ability to catch prey. These include:
    a. the presence of light-producing organs to lure prey,
    b. large teeth that sometimes fold backward towards the interior of their mouths to prevent the escape of prey, and
    c. over-sized mouths that can be unhinged to swallow particularly large prey.
- Most of these deep-sea fish are small, between 2 and 10 cm (1–5 in), and they often have low metabolic rates because of long periods of time between feeding. They typically have no spines or scales, are mostly black in color and have small eyes, huge mouths, and expandable stomachs.

Major Concept (XIX) *The nekton, all members of the* Kingdom Animalia*, can be classified into two Phyla and six classes as described in section 17.6 in the text.*

Major Concept (XX) *The world marine fish catch has continued to grow in the past few decades as human population has increased.*

Related or supporting concepts:
- The total marine fish catch continued to increase from 21 million metric tons in 1950 to 86 million metric tons in 1989.
- The world harvest declined for the first time in forty years in 1990. From 1990 to 1993 it varied between 70 and 80 million metric tons.
- In 1996 and 1997 the world harvest had again increased to 87 million metric tons.
- In 1998 the world harvest dropped to 79 million metric tons due to the 1997–98 El Niño event.
- Catches returned to between 85 and 86 million metric tons in 1999 and 2000.
- Over the years the use of the fish catch has changed. In 1950, 90% of the catch was used as food for people with the remaining 10% used for fish meal to feed poultry and livestock in the more developed nations. Today, roughly two-thirds of the world catch is used to feed people and one-third is used as food for domestic animals and fish farms.
- The use of fish meal to feed livestock and poultry is only about 20% efficient. For every ton of fish meal eaten, only 0.2 ton of additional animal protein is produced.
- A variety of new fisheries have opened up as demand for seafood has increased. At the same time, some old, established fisheries are in decline as catches diminish and costs rise.
- The fastest growing product in the U.S. seafood market is a highly refined fish protein called surimi that can be flavored to form artificial crab, shrimp, and scallops.
- In 2003 the Pew Oceans Commission released a highly critical report on U.S. ocean and fisheries policy.
- The Pew Commission called for:
    a. the principal object of U.S. fisheries policy to be the protection of marine ecosystems,
    b. the creation of an independent government agency to manage the ocean around the U.S.,
    c. doubling ocean research spending over five years, and
    d. establishing a network of national marine reserves or protected areas.

Major Concept (XXI) *The anchovy fishery off the coast of Peru has produced the world's greatest fish*

catches for any single species.

Related or supporting concepts:

- The anchovy is a small fish that feeds on phytoplankton found in the large region of upwelling along the Peruvian coast.
- They travel in dense schools that makes it easy to harvest large numbers.
- The fish in this industry are all processed into fish meal and exported as food for domestic animals.
- The fishery began in 1950 with a harvest of 7000 metric tons. By 1962 it had grown to an annual harvest of 6.5 million metric tons.
- The harvest increased rapidly in size until its peak year in 1970 when 12.3 million metric tons were taken. After 1970, the size of the fish began to decline and it was necessary to take more individuals to make up a ton of fish.
- From 1950 to 1972 there were three instances of El Niño along the Peruvian coast that brought warm, nutrient-poor water to the region that had a tremendous adverse effect on the anchovy fishery. The 1973 catch was down to only 2 million metric tons.
- After 1973, government quotas were placed into effect to try to save the fishery. While it began to come back, El Niño struck two more times in the following decade.
- From 1983 to 1985 the catches were limited to 150,000 metric tons but in 1988 it was back up to 3.6 million metric tons and seemed to stabilize for a few years.
- In 1994 the fishery reached a peak of 12.5 million metric tons.
- Catches in 1995–97 held steady between 8.6 and 7.6 million metric tons.
- The 1997–98 El Niño caused a dramatic drop in the harvest to only 1.7 million metric tons in 1998.
- By 1999 the catch had increased to 8.7 million metric tons and by 2000 to 11.3 million metric tons.
- The history of the anchovy catch is shown in figure 17.18 in your text.

Major Concept (XXII) *The tuna fishery is a very important one but it is under intense scrutiny because of the large numbers of porpoise that are killed.*

Related or supporting concepts:

- The world tuna catch from 1988 to 2000 grew from 4.0 million metric tons to 5.7 million metric tons.
- The U.S. harvests about 50% of the world's tuna catch. The U.S. fleet of tuna boats operates out of southern California.
- Massive seine nets, 1100 m (3600 ft) long and 180 m (595 ft) deep, are used to capture schools of tuna, yielding as much as 150 tons of tuna at a time.
- Unfortunately, tuna are often accompanied by porpoise that swim above the tuna and are caught in the nets as well, where they can drown.
- It is estimated that as many as 500,000 porpoises were killed in 1970. This number has dropped since the passage of the Marine Mammal Protection Act in 1972.
- Various efforts to minimize the incidental catch of porpoise have reduced the number killed to about 20,000 from more than 150,000.

Major Concept (XXIII) *Another regulated fishery in the United States is the salmon fishery.*

Related or supporting concepts:

- The salmon industry is centered along the Pacific Northwest and Alaska. The fish spawn in fresh waters and remain there as juveniles for up to a year before migrating to the sea to spend from one to four years as adults.
- Fully mature adults return to the same fresh waters where they hatched to spawn. As they return they are fished commercially and for sport.
- The dangers to these fish come from over harvesting and the pollution of the freshwater streams and rivers where they spawn.
- Salmon require high-quality, pollution-free water and clean, gravel-bottomed, shady, cool streams for spawning.

- Federal, state, and privately owned hatcheries harvest eggs from mature fish. They raise the juveniles and return them to the sea when they are ready.

Major Concept (XXIV) *For nearly 400 years the Atlantic cod have been harvested in the waters off Newfoundland.*

Related or supporting concepts:

- Fishing for Atlantic cod has changed over the past 400 years.
    a. For nearly 400 years they were caught on hand lines.
    b. This practice changed with the introduction of longlines with hundreds of hooks and net traps in the 19th century.
    c. Trawl nets 45 to 60 m (150–200 ft) long were used as early as 1895.
    d. In the 1950s huge factory ships dominated the cod fishery.
- The size of the harvest of Atlantic cod has changed significantly over the years as well.
    a. One hundred years ago 50,000 metric tons were taken by hand fishing.
    b. In 1968 the harvest reached a high of 810,000 metric tons, nearly three times the amount caught in a single year before 1954.
    c. By the 1970s the catch had dropped to less than 200,000 metric tons.
    d. Canada and the United States extended their territorial limits to 200 miles off shore to exclude foreign vessels from the fishing grounds. Unfortunately, recommended cuts in harvest quotas were not made.
    e. Between 1968 and 1992 there was a 69% decrease in the catch.
    f. Between 1993 and 1996 there was another drop of the same magnitude.
    g. In 1999 the catch was 9700 metric tons and the 2000 catch was 11,400 metric tons (still significantly below the 43,700 metric tons caught in 1990).
- The fishery remains tightly controlled with fishing confined to certain areas and a limit of 10,000 metric tons.
- In 2002, European scientists advised the European Union to ban cod fishing in the North Sea, where cod spawning schools have dropped to 15% of 1970 catches. North Sea cod catch quotas were reduced 45% in 2003.

Major Concept (XXV) *With increased pressure on traditional commercial fish species there is more activity fishing other species such as shark.*

Related or supporting concepts:

- U.S. commercial shark fishing began in the late 1970s when 21 metric tons of thresher sharks were brought to port in California.
- By 1982 the thresher shark harvest had increased to 1100 metric tons but in 1989 it fell to 300 metric tons and the thresher fishery collapsed.
- Shark population are declining all over the world.
- Shark catches have been increasing steadily since the 1940s.
    a. The 1990 world catch was 690,000 metric tons.
    b. The catches of 1996–2000 have exceeded 800,000 metric tons.
- Estimates are that all shark species populations have dropped 50% in the last 8–15 years.
- The diminishing population of sharks is further exacerbated by their low reproductive rate, slow growth, and slow maturation.
- The Asian demand for shark-fin soup has supported a shark fishery that removed the fins and discards the carcass at sea. This practice is known as “finning.”
- In 1992–93 the National Marine Fishery Service (NMFS) established quotas on commercial shark fishing in the Atlantic, Gulf of Mexico, and Caribbean. Recreational fishing has been restricted and finning is banned.
- In 2002, the United Nations Convention on the International Trade in Endangered Species placed basking and whale sharks, the world's largest fish, on its list of fish that can only be hunted and traded

within strict limits.

Major Concept (XXVI) *One promising way to increase the world fish harvest without endangering fisheries is to increase fish farming practices.*

Related or supporting concepts:

- Fish farming is known as mariculture or aquaculture.
- Mariculture has a long history, it began in China roughly 4000 years ago.
- Fish may be raised one species at a time in a process called monoculture or a number of different species may be raised simultaneously in a single pond in polyculture.
- While mariculture is popular in China, Southeast Asia, Japan, and Israel, it is not as popular in the United States.
- Fish farming in the U.S. provides only 2% of our fishery products, but it accounts for 50% of the catfish consumed and nearly all of the trout.
- Successful mariculture requires:
    a. a market for the product, and
    b. a carefully chosen species that:
        1. reproduces in captivity,
        2. have hardy juveniles,
        3. gain weight rapidly,
        4. consume cheap and readily available food, and
        5. have a high market price.
- While commercial fishing has declined, aquaculture of marine species has nearly tripled in the last decade (4 million metric tons of fish and shellfish in 1987 and 14 million metric tons in 2000).
- Sixty percent of the salmon eaten worldwide is raised in pens.
- Populations of parasitic sea lice can increase dramatically in salmon pens.
- Farming large numbers of fish requires the use of antibiotics and produces significant quantities of fish waste and uneaten food that deplete the amount of oxygen in the water.
- A typical fish farm may raise 400,000 to 1 million fish.

Matching Key Terms with Major Concepts

At the end of the chapter in the textbook is a list of key terms. You should to be able to match each of these with one of the previously listed major concepts. To test your ability, try to match the following key terms with the number (I–XXVI) of the appropriate major concept identified in this section:

mammal	polyculture	surimi
cetaceans	echolocation	sea ranching
mariculture	dugong	sirenia
pinniped	baleen	incidental catch
sea cow	demersal fish	monoculture
cartilage		

Test Your Recall

Answer the following questions to test your understanding

FILL IN THE BLANK

1. The free swimmers of the oceans are called the _____.
2. Mammals are _____ blooded.
3. The young of mammals are born _____.

4. Whales often _____ long distances between feeding and birthing grounds.
5. Dolphins and porpoises are small _____ whales.
6. Dolphin and porpoise populations are endangered by the _____ fishery.
7. The _____ whale communicates with "songs" that may be up to 30 minutes in length.
8. True seals lack external _____.
9. Pinniped means _____ _____.
10. Walrus have large canine teeth called _____.
11. Baby seals are called _____.
12. IWC stands for the _____ _____ _____.
13. Sea otters must rely on their _____ for warmth.
14. Manatees belong to a group of organisms called _____.
15. MMPA stands for the _____ _____ _____ _____.
16. Under the MMPA, mammals can be taken for scientific _____ and for public _____.
17. Sea snake's skin is impermeable to salts but permeable to _____.
18. The rarest and most endangered sea turtle is the _____ _____.
19. Fish either have skeletons of _____ or of bone.
20. The world's largest fish is the _____ _____.
21. About 3% of the _____ species of birds are marine.
22. To conserve _____ birds reduce and concentrate their urine, forming uric acid.

TRUE - FALSE

1. The squid is a relative of the clam and oyster.
2. Whales are cetaceans.
3. Toothed whales have baleen.
4. The International Whaling Commission has the power to arrest violators of whaling quotas.
5. Porpoises can swim at speeds in excess of 30 knots.
6. Walruses use their tusks primarily to dig clams from the seafloor.
7. Sea otters have a layer of insulating blubber to keep them warm.
8. Sea otters feed on shellfish in shallow coastal waters.
9. Sea cows and dugongs belong to the same group of nekton.
10. It is currently unlawful to import sea turtle shells.
11. Marine iguanas feed on small fish and crustaceans.
12. There are about 30 species of sea snakes in the Atlantic Ocean.
13. The incidental catch of sea turtles in the shrimp fishery has been a factor in their decline in some regions.
14. Squid populate deeper water and migrate to the surface at night.
15. The dominant group of organisms in the nekton is the fish.
16. Sharks first appeared on earth about 120 million years ago.
17. There are more than 350 species of sharks.

18. Most food fish live at relatively shallow depths.
19. Very deep-dwelling fish are often equipped with light-producing organs.
20. Mariculture is a major source of halibut in the U.S.
21. The eyesight of marine birds is poorly developed, as they can feel their prey underwater.
22. The wandering albatross has a wingspan of up to 3.5 feet.
23. Cormorants must return to land to dry out and warm up.
24. Coastal habitat destruction has dramatic and negative effects on marine bird populations.

MULTIPLE CHOICE

1. Marine mammals
    a. breathe air.
    b. bear live young.
    c. nurse their young.
    d. are warm-blooded.
    e. all of the above.
2. Whales are
    a. pinnipeds.
    b. cetaceans.
    c. crustaceans.
    d. sirenia.
    e. fish.
3. Which of the following is not a species of whale?
    a. bowhead
    b. sei
    c. dolphin
    d. dugong
    e. right
4. The earliest known European whaling occurred
    a. between A.D. 800–1000.
    b. between A.D. 1500–1550.
    c. between A.D. 1300–1320.
    d. between 700–500 B.C.
    e. between 800–1000 B.C.
5. Porpoises
    a. are small toothed whales.
    b. are usually found traveling alone.
    c. are able to swim very fast.
    d. a and c above.
    e. all of the above.
6. Porpoises can swim at speeds in excess of _____ knots.
    a. 10
    b. 20
    c. 30
    d. 40
    e. 50
7. Seals
    a. are pinnipeds.
    b. often make long migrations.
    c. spend a lot of time out of water.
    d. have four characteristic swimming flippers.
    e. all of the above.
8. Which of the following is known for its ivory tusks?
    a. sea lions
    b. walrus
    c. seals

d. manatees
e. sea cows

9. Sea cows belong to the same group as
   a. sea otters.
   b. holsteins.
   c. dugongs.
   d. iguanas.
   e. guernseys.
10. Manatees are found
   a. along the Florida coast.
   b. in the Bering Sea.
   c. along the California coast.
   d. in the Indian Ocean.
   e. none of the above.
11. Sea snakes
   a. are not found in the Atlantic Ocean.
   b. are very poisonous.
   c. breathe air.
   d. all of the above.
   e. b and c above.
12. The largest sea turtles can weigh as much as _____ pounds.
   a. 500
   b. 150
   c. 300
   d. 1000
   e. 2000
13. Sea turtles
   a. lay eggs on land.
   b. may make long migrations.
   c. are herbivorous.
   d. all of the above.
   e. a and b above.
14. The squid
   a. are restricted to shallow water.
   b. are pinnipeds.
   c. are solitary creatures.
   d. spend daylight hours in the photic zone.
   e. none of the above.
15. An example of a cartilaginous fish is the
   a. herring.
   b. menhaden.
   c. shark.
   d. tuna.
   e. halibut.
16. A fish that lives near the sea floor is the
   a. sardine.
   b. sole.
   c. redfish.
   d. salmon.
   e. mackerel.
17. Sharks have receptors on their skin sensitive to
   a. touch.
   b. pressure.
   c. sound.
   d. vibration.

e. all of the above.

18. Most food fish are found in the _____ zone.
    a. mesopelagic
    b. bathypelagic
    c. abyssopelagic
    d. epipelagic
    e. none of the above
19. Fish that live on or near the bottom are known as
    a. demersal.
    b. ventral.
    c. dorsal.
    d. scavengers.
    e. surimi.
20. The anchovy fishery
    a. is concentrated in zones of upwelling.
    b. is located along the coast of Peru.
    c. has suffered during El Niño.
    d. is carefully regulated.
    e. all of the above.
21. Seabirds swim using their
    a. feet.
    b. wings.
    c. tails.
    d. beaks.
    e. wings and feet.
22. Nesting shorebirds, even when present in great numbers of different species appear to compete very little with one another because
    a. they feed on different prey, and at different times.
    b. they are in a strict bird union.
    c. they eat the same food, but there is always enough.
    d. scientists just haven't studied them close enough to tell.
    e. none of the above.

Visual Aids: Test Your Understanding of the Figures

1. Figure 17.5 presents illustrations of a representative sample of different types of marine mammals. In looking at this figure, try to compare and contrast some physical characteristics of these animals and consider what advantages they derive from these characteristics. For example, which mammals have smooth skin, fur, or apparently large amounts of fat deposits and what advantages do these differences give?
2. Look at figures 17.13 and 17.14 illustrating examples of cartilaginous and bony fish. What basic differences do you see in their forms? Take a look at their gills and fins in particular.
3. What common characteristics do deep-sea fish have that are illustrated in figure 17.16? If you were shown one of these fish at an aquarium would you be able to tell that it was from the deep sea from its physical appearance and why would you come to that conclusion?

Study Problems

1. If a whale moves day and night at an average speed of 5 knots, how many days will it take for it to travel an annual 18,000 km migratory journey linking feeding and birthing areas?
2. From figure 17.4 calculate a rough estimate of the rate of increase in the number of baleen whales caught per year from 1910 to 1970. Ignore the years during the World Wars when whaling was sharply curtailed.

Answer Key for Key Terms and Test Your Recall

KEY TERMS

mammal (II)
cetaceans (IV)
mariculture (XXVI)
pinniped (VII)
sea cow (IX)
cartilage (XIV)
polyculture (XXVI)
echolocation (III)
dugong (IX)
baleen (IV)
demersal fish (XVII)
surimi (XX)
sea ranching (XXVI)
sirenia (IX)
incidental catch (XXV)
monoculture (XXVI)

FILL IN THE BLANK

1. nekton
2. warm
3. live
4. migrate
5. toothed
6. tuna
7. humpback
8. ears
9. feather-footed
10. tusks
11. pups
12. International Whaling Commission
13. fur
14. sirenia
15. Marine Mammal Protection Act
16. research, display
17. gases
18. Kemp's ridley
19. cartilage
20. whale shark
21. 8600
22. water

TRUE - FALSE

1.T 2.T 3.F 4.F 5.T 6.F 7.F 8.T 9.T 10.T 11.F 12.F 13.T 14.T 15.T 16.F 17.T 18.T 19.T 20.F 21.F 22.F 23.T 24.T

MULTIPLE CHOICE

1.e 2.b 3.d 4.a 5.d 6.c 7.e 8.b 9.c 10.a 11.d 12.e 13.e 14.e 15.c 16.b 17.e 18.d 19.a 20.e 21.e 22.a

STUDY PROBLEMS

1. 81 days
2. roughly 900–1000 per year