UNIVERSITY OF THE ARCTIC

Module 8
Life in the Ocean

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Key Terms and Concepts

- hydrography
- turbidity
- fast ice
- polynyas
- haloclines
- pelagic
- benthic
- epontic
- thermohaline circulation (THC)
- euphotic
- aphotic

Learning Objectives

Upon completion of this module, you should be able to

1. explain the major features that set Arctic seas and ecosystems apart from other marine systems, including those in the Antarctic; and explain the major difference between terrestrial and marine life.

2. explain the importance of light (or lack there of) and sea ice for marine life.

3. describe the global importance of Arctic seas.

4. describe, using examples, the major habitat types and nutritional groups in the marine environment.

5. explain the function of phytoplankton—and that of other primary producers—and its major types; be able to list a few species important in Arctic and Subarctic seas.

6. explain the function of zooplankton (and other grazers), its major types, and be able to list a few species important in Arctic and Subarctic seas.

7. list at least ten Arctic and Subarctic fish species, and explain their importance in the Arctic marine ecosystem.

8. list at least ten major Arctic marine mammals, and briefly describe their distribution and life history.

9. list at least ten Arctic seabirds, and briefly describe their distribution and importance; explain the role of seabirds in linking the marine and terrestrial ecosystems.

Reading Assignment

AMAP (1998), *Assessment Report: Arctic Pollution Issues*: chapters 2.6 (pages 20–23) and 4.6 (pages 128–135).

Overview

This module explores some of the fundamental aspects of marine ecology and biodiversity. It begins with contrasting Arctic seas with temperate and Antarctic waters and explains a few key factors that characterize the physical marine environment. Most of the chapter, however, is devoted to a description of the Arctic marine ecosystem, from primary producers (phytoplankton, macroalgae), through grazers (zooplankton, gastropods, etc.), to fish and top predators (such as marine mammals and seabirds).

Lecture

Introduction

Approximately two-thirds of the Arctic region is ocean. This includes the Arctic Ocean and its adjacent shelf seas, as well as the Nordic Seas—Eastern North Atlantic Sea, including Greenland Sea, Iceland Sea, and Norway Sea)—the Labrador Sea, and the Bering Sea. Not surprisingly, many Arctic life forms are directly or indirectly dependent on the sea or its products.

Several physical factors make Arctic marine ecosystems unique from other oceanic regions. These include the following:

- a very high proportion of continental shelves and shallow water
- a dramatic seasonality in terms of sunlight and corresponding primary production—in fact, primary production ceases completely during winter
- an overall low level of sunlight and, hence, cold sea temperatures
- the presence of extensive permanent and seasonal ice cover, creating very special hydrographic conditions in the upper strata of the water column beneath the ice
- a strong influence from fresh water, coming from rivers and ice melt
- recent periods of glaciation and, therefore, a short geological time frame for species to adapt and evolve into new forms. (In contrast, the Antarctic Ocean is several million years older and contains many more endemic species than do the Arctic seas.)

As a result, Arctic marine ecosystems tend to be relatively simple compared to temperate and tropic systems, with short food chains and low overall species diversity. However, the low overall species diversity—and, hence, low levels of ecological competition—mean that Arctic species are relatively free of competition and can often reach high abundance and biomass.

Although Arctic seas, in general, are not especially productive, subpolar seas, such as the Bering, Barents, and Iceland seas, include some of the most productive patches of ocean in the northern hemisphere. For example, the Barents, Bering, Chukchi, and Iceland seas include nutrient-rich upwelling areas that support large concentrations of migratory seabirds, as well as a diverse community of sea mammals and some of the richest fisheries in the world.

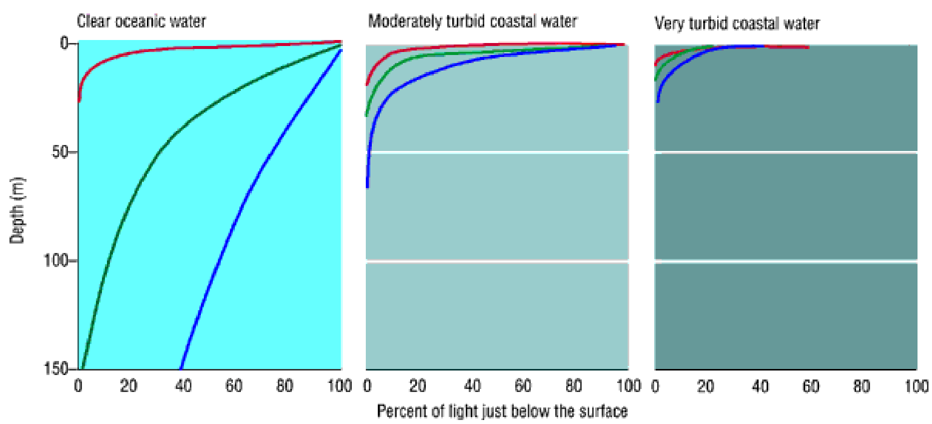
Student Activity

How important is the marine ecosystem, including the sea ice and seashore, for you? That is, what percentage of your food and family income comes from the marine environment?

Some Important Physical Features and Processes

Sunlight

Sunlight is essential for photosynthesis and, thus, for primary production by plants. In clear sea water, there is a close relationship between the altitude of the sun in the sky and the amount of sunlight that is absorbed—versus reflected—by the sea surface. Different wavelengths of the sunlight have different capacities to penetrate the sea water: red wavelengths have the poorest capacity to penetrate and, therefore, are sorted out first; whereas blue wavelengths penetrate deepest into the water. Wind conditions, sea ice, and the turbidity of the sea water itself are also of primary importance in determining how much sunlight actually reaches the upper layers of the ocean. (See fig. 8.1.)

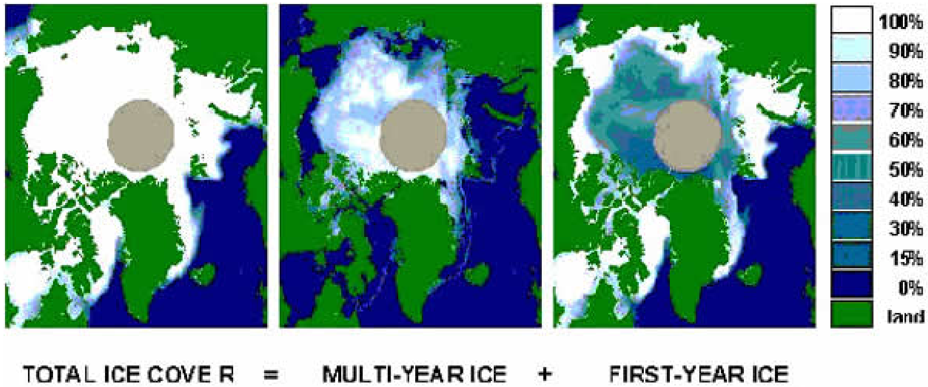


Source: Born and Böcher (2001)

Fig. 8.1 Light at different wavelengths penetrates to various depths of the sea; blue light penetrates deepest. Light penetration also depends on the amount of dissolved matter—or turbidity—of the sea water.

Sea Ice

Sea ice is a characteristic feature of the Arctic marine environment. Its extent in the Arctic has a clear seasonal cycle, with maximum ice extent in March, when it covers the entire Arctic Ocean and large parts of the Bering and Barents Seas and may extend all the way south to Iceland. A minimum of sea ice cover is seen in September, when only the Arctic Basin is covered (see fig. 8.2). However, there is large year-to-year variability both in maximum and minimum coverage.

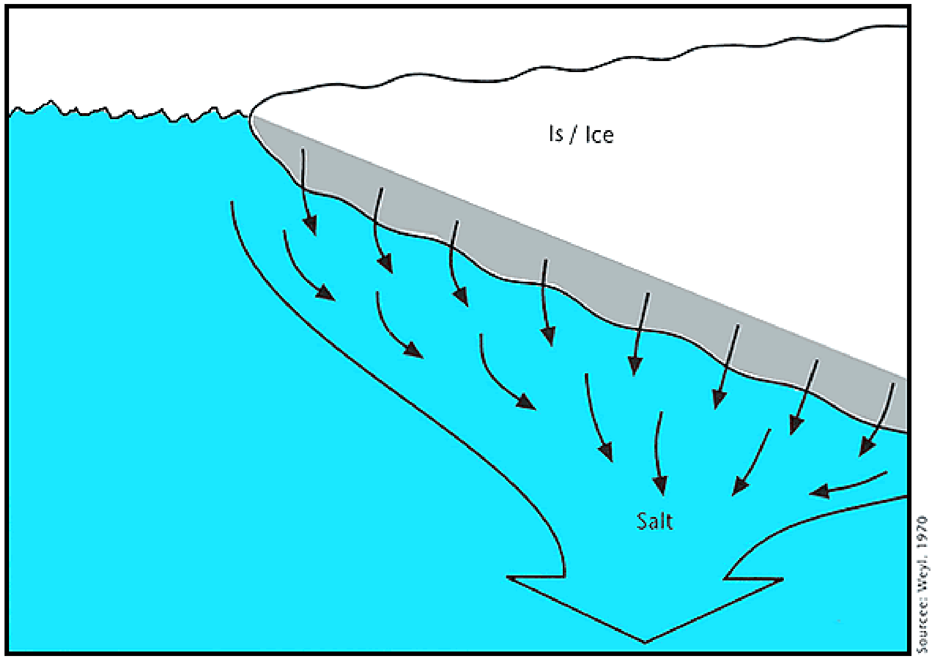


Source: Johannessen and Miles (2000)

Fig. 8.2 Arctic total sea ice cover and its two components—multi-year ice and first-year ice—as derived from satellite data in winter. The multi-year ice also represents the minimum ice extent in summer.

Fast ice grows seawards from a coast and remains in place throughout the winter. Fast ice is found along the whole Siberian coast, the White Sea, north of Greenland, the Arctic Archipelago in Canada, Hudson Bay, and north of Alaska. Within the fast ice, *polynyas*—semi-permanent open water regions—are found ranging in area up to thousands of square kilometres. Polynyas are environmentally important, as they provide areas of high heat loss to the atmosphere, are regions of deep-water formation, and are often a location of intense biological activity, year-round.

Sea ice influences the exchange of heat and other properties between atmosphere and ocean and, together with snow cover, determines the penetration of light into the sea. It is also influential in the thermohaline circulation (see later in this module). This is because when sea water freezes, salt is leached out into the sea below. This is called brine rejection (see fig. 8.3). Sea ice also provides a biological habitat above, beneath, and within the ice, and, when it melts in summer, it results in the stratification of the upper ocean. The marginal ice zone—that is, the ice edge—is important for plankton production and plankton-feeding fish. For some marine mammals, sea ice provides a place for birth and functions as a nursery area.



Source: Born and Böcher (2001)

Fig. 8.3 Brine rejection, or salt leaching, from sea ice

Student Activity

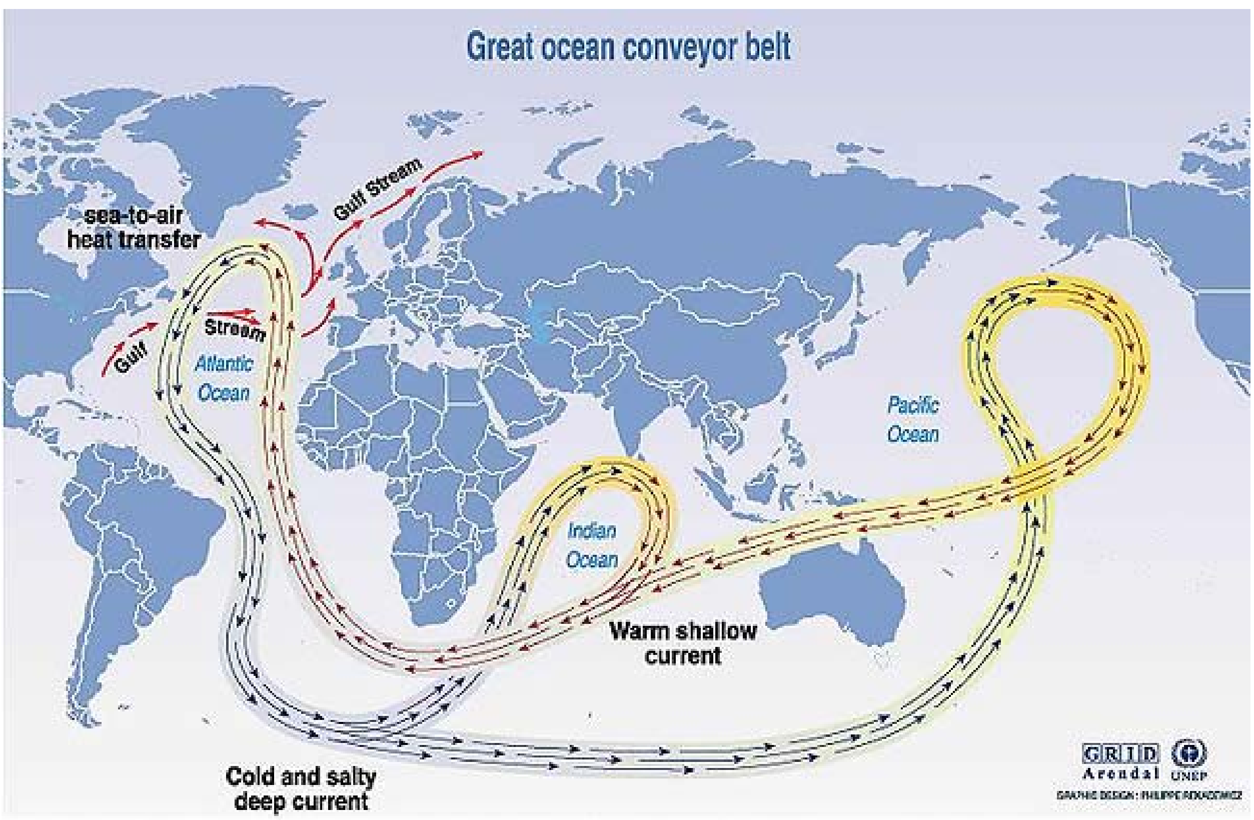
Climate warming is already melting the Arctic sea ice, and some models predict that all summer ice will be gone by the end of this century. What would the consequences, if any, be for you and the life you live?

The Halocline

The freezing and thawing of sea ice, as well as freshwater input through river runoff into the Arctic Basin, has profound effects on the uppermost layer of the water column, 50–200 m, and, thus, on primary production. Fresh water is lighter than the saline sea water and floats on top. Thus, during spring, when snow and sea ice thaw and rivers carry high amount of fresh water from land, a fresh surface layer is formed in the ocean. This layer is lethal to most marine organisms adapted to sea water. The freshwater layer further impedes vertical mixing within the water column. The transitional zone between the fresh surface layer and the saline sea water below is termed the *halocline*. Haloclines are a characteristic of all Arctic seas.

Temperature

Low temperatures are also a characteristic of most Arctic seas. In areas with constant ice cover, temperatures in the upper layer stay below 0°C throughout the year. However, a special feature in the North Atlantic is the heat transported by the currents. The inflow of South Atlantic water to the northern Atlantic region keeps waters—and land—in parts of the area much warmer than they would otherwise be. This inflow of warm southern seas is actually maintained by a special feature: the *thermohaline circulation (THC).* THC is initiated when the cooling and freezing of sea water increases the density of surface waters through brine rejection (see fig. 8.3) to such an extent that surface waters sink and push waters at greater depths to move out of their way. The THC, which is initiated in the northernmost parts of the Atlantic Ocean (Greenland and Labrador seas), is the main driving force behind the "Great Ocean Conveyor Belt," a global system of ocean currents (see fig. 8.4). The marine Arctic is thus a very active player in the global climate system.



Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Source: GRID-Arendal, http://www.grida.no/climate/vital/32.htm

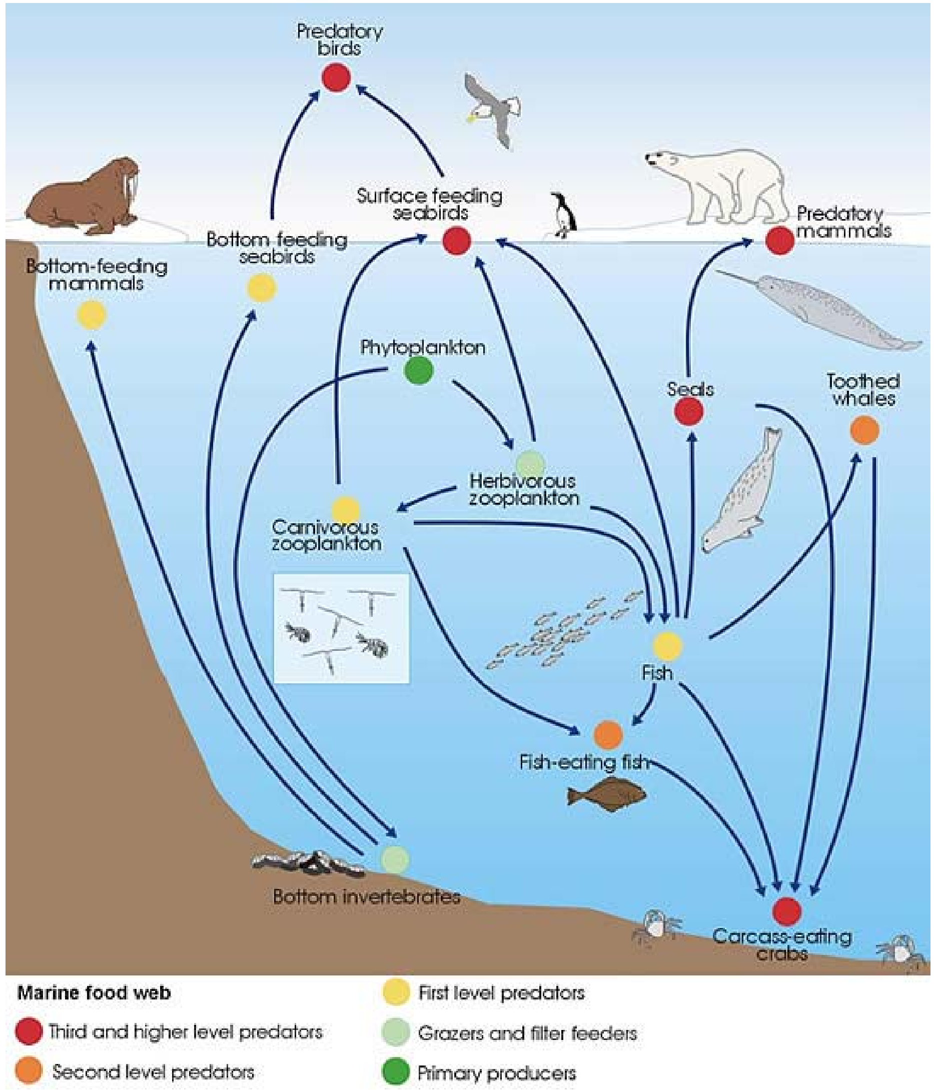
Fig. 8.4 The Great Ocean Conveyor Belt

The Arctic Marine Ecosystem

Definitions

Sea water is a relatively uniform and stable medium compared to both fresh water and air. Except for the extreme upper layer, both temperature and salinity oscillate within a narrow range. In this respect, the sea can be regarded as one large ecosystem.

Arctic marine organisms tend to grow slower and live longer than their temperate and tropical counterparts, and many species have conservative reproductive strategies (e.g., begin laying eggs at a relatively advanced age, lay few eggs, and care for the young for a long time, like most seabirds). However, some groups that live in unstable environments, such as immediately under the sea ice, use an alternative, opposite strategy, as they live short lives and have a high reproductive output. Animal species, such as many whales and seabirds, either migrate into Arctic marine areas during the productive summers or have the ability to cope with periods when food is not readily available. Many full-time Arctic marine residents store large quantities of energy-rich lipids in reserve in their bodies during periods of abundance to deal with seasonal fasting; others overwinter in a dormant form. (See fig. 8.5.)



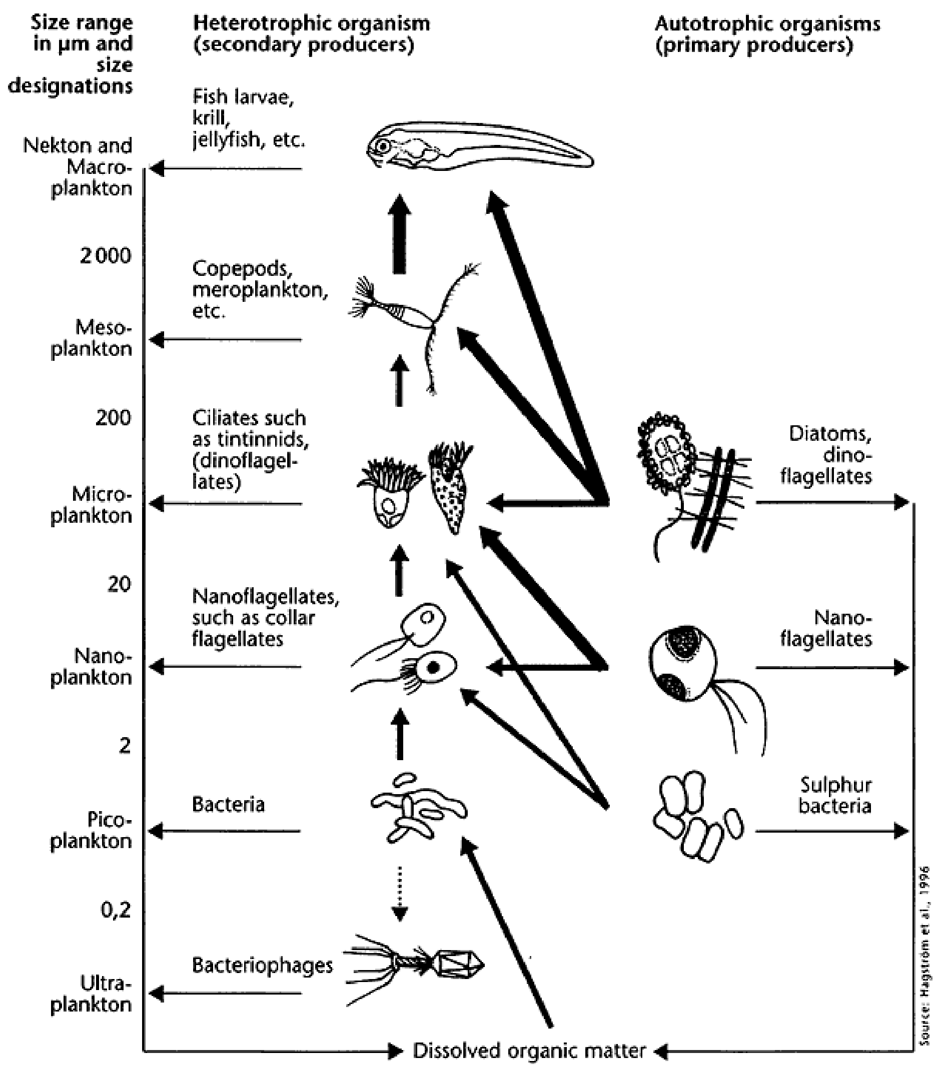
Source: CAFF (2001)

Fig. 8.5 A generalized Arctic marine food web

The Pelagic, Benthic, and Epontic Environments

Apart from seabirds and marine mammals, most marine species live in one of two fundamental ways. Species that live and feed in the water column are called *pelagic.* Those that live and feed in conjunction with the ocean bottom are termed *benthic.* Some species alternate between these two ways of life, depending on their stage of development. For example, many fish or invertebrate larvae start out leading a pelagic life and later become permanently benthic. A special part of the benthic biotope is the *intertidal* or *littoral zone*, which is the part of the coast that lies between the lowest ebb-tide level and the highest high-tide level. The plants and animals of this zone must be able to withstand regular cycles of submergence and exposure. In the Arctic seas, there is an additional way of life called *epontic.* Epontic species are those that live on the underside of the sea ice. The underside of the ice—a kind of "inverted sea bottom"—provides a wide-ranging biotope, which is not found in other seas.

The pelagic environment contains organisms in all sizes from the smallest viruses and bacteria (< 1 µm), to the largest creature on earth, the blue whale (up to 30 m in length). Pelagic organisms that do not have enough muscle energy to swim against the currents, but essentially drift with them, are termed *plankton.* These include the smallest unicellular organisms, up to large jellyfish. *Phytoplankton* are the primary producers or photosynthesizing part of the plankton; and *zooplankton* are the grazers or secondary producers. Figure 8.6 provides an overview of the types and size classes of plankton.



Source: Hagstrom et al. (1996), cited in Born and Böcher (2001)

Fig. 8.6 Major types and size classes of phytoplankton and zooplankton (primary and secondary producers). Arrows show the flow of energy in the microbial food chain.

The benthic environment contains *epiflora* and *epifauna,* that is, plants and animals that live on the sea bottom. The attached photosynthesizing epiflora in the euphotic shallow water and littoral zones consist mostly of macroalgae (algae > 1 mm), including brown, green, and red algae. Mobile unicellular microalgae are also common on or in the bottom substrate. The epifauna consists of a diverse group of mobile and sessile organisms. Another part of the benthos is the *infauna*, that is, organisms that live in the sediments, either largely stationary or mobile. These include a variety of worms, such as the polychaetes, bivalves, crustaceans, and some fish. Some of the infauna forage in the water column—for example, sand eels and shrimp—and then return to their burrow.

Euphotic and Aphotic

Most marine organisms are in one way or another dependent on the primary production that takes place in the upper part of the water column. As we saw before, there are limits to how deep sunlight can penetrate and still supply surplus energy for photosynthesis—as you remember, photosynthesis "creates" energy through converting solar energy into energy-rich compounds, while respiration and waste disposal "use" energy. The uppermost zone in the water column—maximum 100 m—where primary production occurs, is termed *euphotic*; while the zone below, where there is not sufficient light for primary production, is *aphotic.* The width of the euphotic zone depends on the amount of sunlight and the amount of dissolved matter in the water column; the stronger the sunlight and clearer the sea water, the wider is the euphotic zone (see fig. 8.1).

Nutritional Groups

As in any ecosystem, marine organisms can also be classified by their way of obtaining food. Primary producers—the photosynthesizing part of the biota—must spend their lives in or close to the euphotic zone. The same applies for the secondary producers (the herbivores and grazers) that feed on the primary producers (e.g., the planktonic copepods, euphosids, bivalve larvae, and the benthic filters, such as bivalves, barnacles, and tunicates) in the intertidal or shallow-water zones. Other nutritional groups such as carnivores, carrion eaters, omnivores, detrivores, parasites, and commensals are less dependent on a specific biotope.

The Marine Food Chain

Phytoplankton

Primary production of organic matter in the Arctic and Subarctic seas is performed primarily by microscopic unicellular algae, the phytoplankton, in the water column and microalgae associated with ice (ice algae). These algae use light to produce organic matter by photosynthesis, thereby reducing CO_2 while releasing O_2 and producing carbohydrates, which can then be converted into other essential compounds, such as proteins, nucleic acids, and lipids.

The produced organic matter is eaten by herbivorous grazers, mainly zooplankton, which in turn may be eaten by fish, ultimately ending in top carnivores, with a loss of 75–80 % of the organic matter from one trophic level (link in the food chain) to the next. The main losses are associated with the burning of nutrients (respiration) within the organisms themselves and with the microbial degradation of organic matter in the water column, which releases CO_2 and nutrients. However, a fraction of the organic matter sinks to the bottom; the deeper the water column, the smaller the fraction. Primary production mainly takes place in the short summer, which lasts 2–4 months per year in the Arctic Ocean. During parts of the summer season, light availability extends to up to 24 hours per day. In Subarctic fjords, the growth season may last up to eight months.

Student Activity

Search the Internet for different forms of Arctic phytoplankton (e.g., diatoms, prymnesiophytes, dinophytes). Draw them, and try to figure out why they are classified as different groups.

Microscopic *diatoms* are responsible for most primary production in Arctic marine systems, whether in the water column or in the ice, similar to other ocean areas. Diatoms, like all photosynthetic organisms, possess the photosynthetic pigment Chlorophyll *a* and, in addition, Chlorophyll *c* and the golden brown carotenoid pigment fucoxanthin (the pigment that gives colour to kelps). The diatom cell is surrounded by a sculptured siliceous cell wall that consists of a "lid" and a slightly smaller "bottom" half (see fig. 8.7). Diatoms come in all shape and occur, singly or in long chains. About 160 species of diatoms are known from high northern latitudes, which is about half of all known phytoplankton species in these waters. Prymnesiophytes are also important primary producers in the water column, exemplified by the two bloom-forming species: *Phaeocystis* spp. and *Emiliania huxleyi*. The huge, milky white blooms formed by *E. huxleyi* can be observed from space. (See fig. 8.8, and for more images and information, see http://www.soes.soton.ac.uk/staff/tt/eh/satbloompics.html.) In addition to diatoms and prymnesiophytes, dinophytes, chrysophytes, and green flagellates are common in Arctic and Subarctic waters.

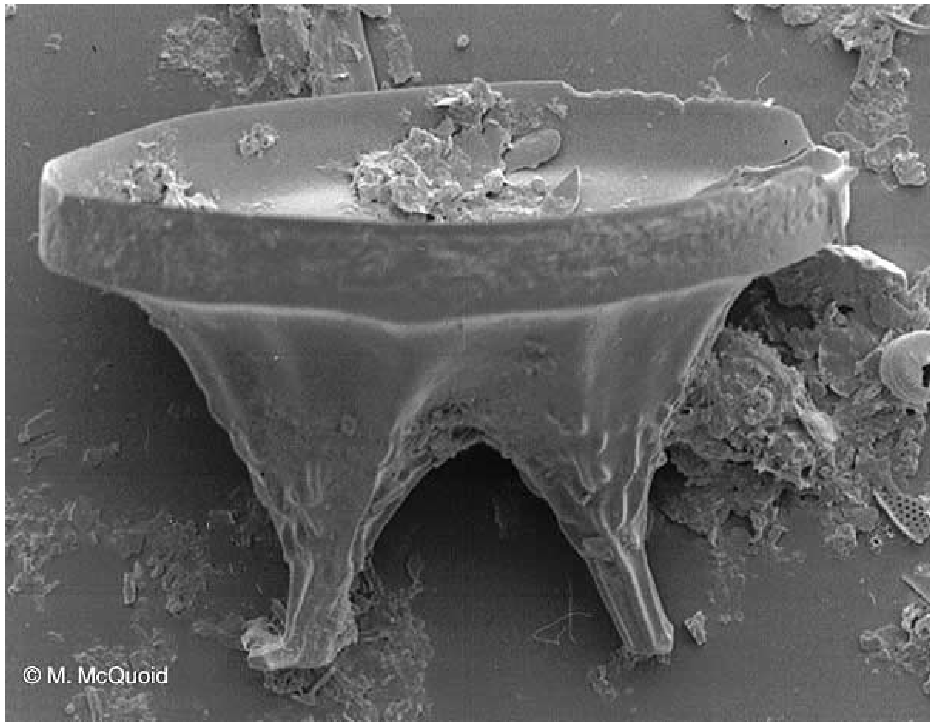
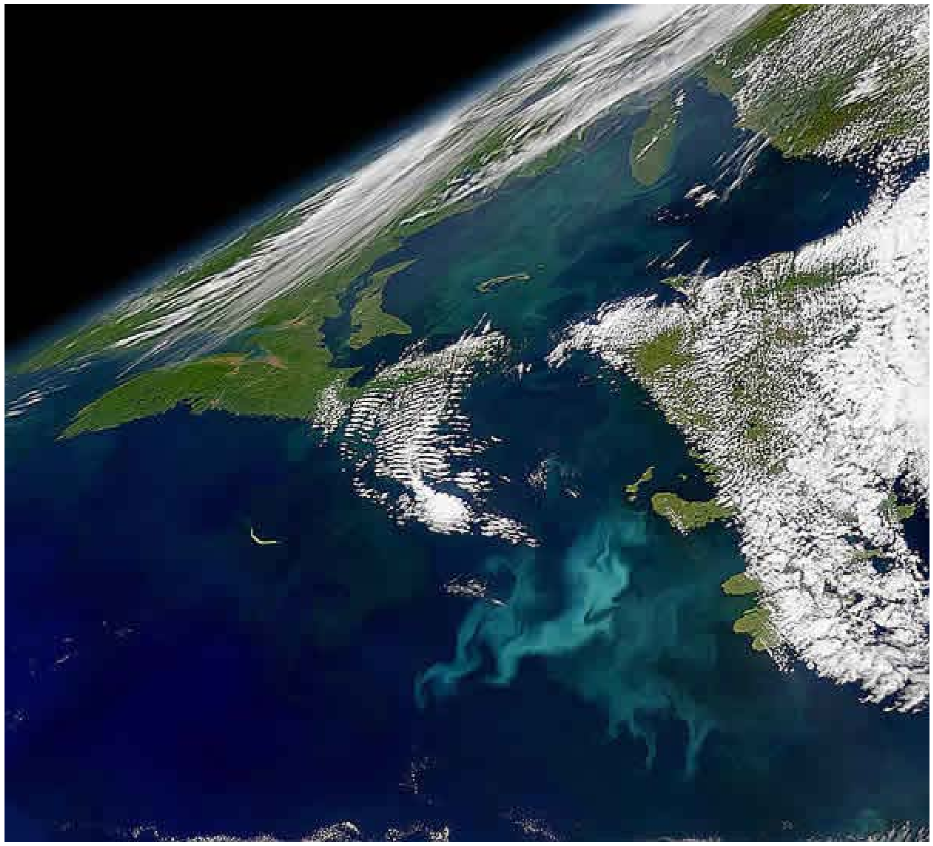


Photo: In McQuoid (2002)

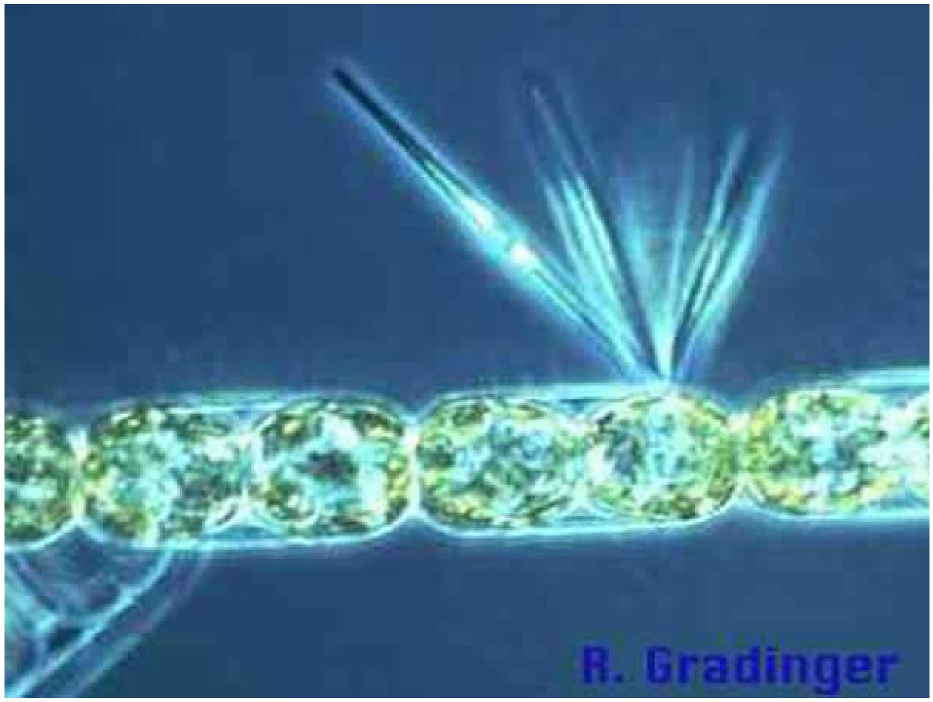
Fig. 8.7 The diatom *Chaetoceros mitra* is common in Arctic waters.



Source: SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE, from University of Southampton, http://www.soes.soton.ac.uk/staff/tt/eh/satbloompics.html

Fig. 8.8 Satellite images of *Emiliania huxleyi* blooms off Newfoundland in the western Atlantic, on July 21, 1999

Ice algae live on, within, and under the sea ice. They can display quite a high level of species diversity in some areas; whereas in other areas, one or two species dominate. Diatoms dominate the underside of the ice. For instance, *Melosira arctica* (see fig. 8.9) can form impressive “mats” on the underside of old pack ice, unique to the Arctic Ocean. Dinophytes are also common. Ice algae can infiltrate the ice to a depth of tens of centimetres, and various flagellated groups can grow profusely in melt ponds on the ice. Ice algae start growing early in the season, as soon as sufficient light penetrates the ice and snow cover.



Source: NOAA,
http://oceanexplorer.noaa.gov/explorations/02arctic/background/sea_ice/media/diatoms.html

Fig. 8.9 The ice algae *Melosira arctica*

The growth season in Arctic marine waters begins with a phytoplankton bloom that feeds on winter nutrients; it is triggered when solar radiation is sufficient to achieve a rate of photosynthesis in the mixed part of the water column that is larger than the total algal mortality. In seasonally ice-covered Arctic waters, phytoplankton blooms arise as the sea ice thins, retreats, and breaks up, permitting solar radiation penetration in the spring. Ice-edge blooms develop rapidly because water from the melting ice establishes a wind-mixed layer of only 15–35 m deep, while at the same time the nutrient-rich waters hidden under the ice become exposed. Phytoplankton and ice algae blooms beneath the pack ice depend on the melting of the snow on top of the sea ice. Thus, the growth season begins late and lasts for only six weeks in extreme cases.

Plants affiliated with bottom substrates are somewhat restricted in Arctic areas because of freezing and ice-scouring from both sea ice and small icebergs. Hard-bottom intertidal substrates can support thick mats of brown algae, for example, knotted and bladder wracks (see fig. 8.10). Brown and red macroalgae are also found in sublittoral zones, down to about 40 m in clear waters, forming kelp forests even in the High Arctic (e.g., *Alaria esculenta* and *Laminaria saccharina*. All macroalgae are important substrates for many forms of epiphytic—that is, that grow on or use other organisms as a substrate—microalgae and various invertebrate fauna.

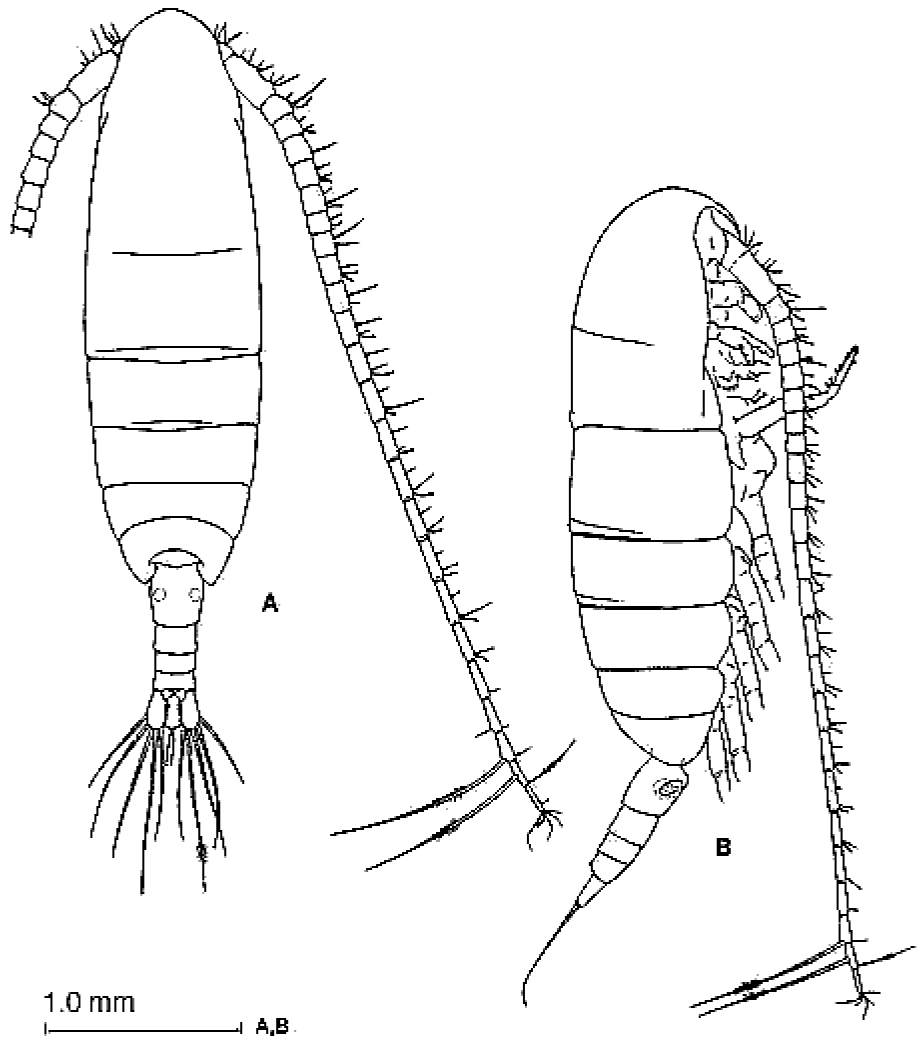
Photo: Sue Scott, in MarLIN,
http://www.marlin.ac.uk/species/species_index.asp?Phy=Chromophycota

Fig. 8.10 The brown algae bladder wrack (*Fucus vesiculosus*), (left) and knotted wrack (*Ascophyllum nodosum*), (right) are common seaweeds in the North Atlantic.

Zooplankton

Mesoplankton (see fig. 8.6) are represented by a total of approximately 260 species in Arctic and Subarctic seas. The geographic species richness, however, varies from less than 40 species in the East Siberian Sea to an excess of 130 species in the Barents Sea.

The most abundant mesozooplankton group in terms of species richness, abundance, and biomass belongs to the family Calanoidae in the crustacean order Copepoda. The most important of them are *Calanus finmarchicus* (see fig. 8.11), *C. hyperboreus*, and *C. glacialis* in Atlantic and Arctic waters, and *C. marshallae*, *Eucalanus bungii*, *Neocalanus* spp., *Metridia longa*, and *M. pacifica* in the North Pacific and the Bering Sea. *C. finmarchicus* dominates in Atlantic water; *C. hyperboreus* is found in both Atlantic and Arctic waters, and *C. glacialis* is found almost exclusively in Arctic water. These copepods are important transfer links between primary production and the upper levels in the food web because they store large amounts of lipid during spring and summer phytoplankton bloom for overwintering and reproductive purposes.



Source: WHOI, http://globec.whoi.edu/images/calanus_Gerber_smaller.html

Fig. 8.11 *Calanus finmarchicus*. Legend: A: dorsal view; B: lateral view.

Krill (euphausids) are swarming, shrimp-like crustaceans that are common in some Arctic waters on the Atlantic side and in the Bering Sea. Some species (e.g., *Thysanoessa inermis*) are herbivores; whereas other species exhibit omnivorous or even carnivorous foraging habits (e.g., *T. raschii*, *T. longipes*, *T. longicauda*, and *Euphausia pacifica*). Krill can constitute up to 45% of mesozooplankton catches by weigh, but are, as a rule, less prominent in the Arctic Ocean than in some areas of the Southern Ocean.

Crustacean amphipods are represented by few species (e.g., *Apherusa glacialis*, *Gammarus wilkitzkii*, and *Themisto libellula*) that are associated with sea ice or ice-influenced waters. *Themisto libellula*, which is important food for the upper trophic levels, is predatory and feeds on herbivorous copepods and other ice-affiliated zooplankton. The largest among the ice amphipods, *G. wilkitzkii*, can reach a length of 3–4 cm.

Although copepods, amphipods, and euphausids are predominant in terms of mesozooplankton biomass in Arctic regions, most major marine zooplankton groups are represented—that is, hydrozoans, ctenophores, polychaetes, decapods, mysids, cumaceans, appendicularians, chaetognaths, and gastropods.

Benthos

Several thousand invertebrate species have been recorded on Arctic and Subarctic seabeds. In the deep Arctic Ocean, however, both the benthic macrofauna diversity and biomass is low, largely because little organic matter reaches the bottom. The shallow Subarctic and Arctic waters have important pelagic and benthic food webs, with the benthos playing a much greater role in system production and turnover than at lower latitudes. The Bering and Chukchi seas contain some of the highest faunal biomass in the Arctic, as well as in the world ocean. Regions of high benthic production in shallow Arctic seas, such as Lancaster Sound and the Bering, Chukchi, and Barents seas support a large component of bottom-feeding fish, whales, seals, walruses, and sea ducks. Benthos in intertidal areas includes barnacles, gastropods, blue mussels, clams, omnivorous and detritivorous amphipods, motile crustaceans, and infauna (burrowing animals), which are dominated by small polychaetes and nematodes.

At mid-water depths, bivalves, polychaetes, and crustaceans exhibit considerable diversity (see fig. 8.12). Some sessile forms are quite abundant on hard-bottom substrates (e.g., sponges, bryozoans, sedentary polychaetes, and molluscs. Motile forms, such as brittle stars, sea urchins, sea stars, and sea cucumbers can be abundant in some areas, as can decapods and isopods. Some crustacean species occur at densities sufficient to be commercially significant. This includes pandalid shrimps (northern shrimp, *Pandalus borealis*; and sidestriped shrimp, *Pandalopsis dispar*) and several crab species (red king crab, *Paralithodes camtschatica*; golden king crab, *Lithodes aequispina*, Tanner and snow crab, *Chionoecetes* spp.; and Dungeness crab, *Cancer magister*). Softer-bottom substrates permit thick-shelled burying molluscs, such as *Mya truncate* and *M. arenaria*, and a number of polychaete species. Commercially important molluscs in the Arctic include blue mussels (*Mettles eludes*), Iceland scallops (*Chlamys islandica*), and clams.

Photo: V. Juterzenka, Piepenburg, Schmid, in NOAA, http://www.oceanexplorer.noaa.gov/explorations/02arctic/background/benthos/media/echinoderms.html

Fig. 8.12 Rich benthic community in the European Arctic. Feather stars, basket stars, the sea cucumber (all in the group of echinoderms) and anemones prefer hard bottom as a substrate.

Fish

Arctic and Subarctic waters are inhabited by roughly 150 species of fishes. Few of them are endemic in the Arctic but are also found in Subarctic and even temperate areas. This is unlike the situation in the Antarctic, where most fish species are endemic. In any given area, Arctic fish communities are generally dominated by only a handful of species. Overall, nine fish species may be considered abundant in Arctic and Subarctic waters and several of them are commercially valuable:

- Greenland halibut (*Reinhardtius hippoglossoides*)
- Polar cod (*Boreogadus saida*)
- Atlantic cod (*Gadus morhua*)
- Greenland cod (*Gadus ogac*)
- Pacific cod (*Gadus macrocephalus*)
- capelin (*Mallotus villosus*)
- long rough dab (or American plaice) (*Hippoglossoides platessoides*)
- Atlantic herring (*Clupea harengus*)

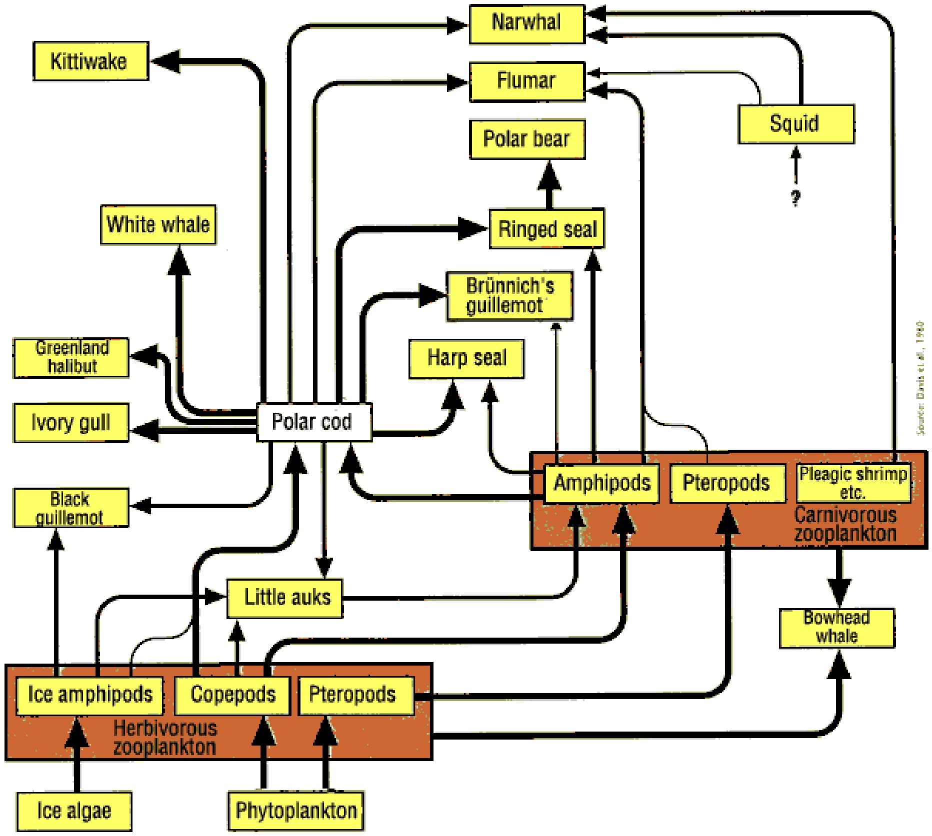
- redfish (*Sebastes* spp.), e.g., *S. mentella* and *S. marinus*

Among these species, Greenland halibut, Polar cod, and capelin are circumpolar in their distribution. Greenland cod is also predominantly Arctic although it has a regionally restricted distribution, near Greenland. All of the other species are caught principally in Subarctic or northern temperate (Boreal) areas.

Capelin is a small, mainly pelagic fish that eats zooplankton—so it is a planktivore. It is a circumpolar species, abundant in some regions within the Arctic, particularly in the North Atlantic and Barents seas, and an important part of the diet of other fishes, marine mammals, and seabirds. Capelin stocks are subject to large fluctuations in distribution and abundance.

Atlantic herring is a Subarctic to Boreal species. It is also a pelagic planktivore and an important food species for seabirds and mammals, as well as for larger fishes, in all areas where it occurs.

Polar cod is a small fish (the adult is 23–27 cm), but a key species in many Arctic food chains (see fig. 8.13) and a major link in the transfer of energy from zooplankton to top carnivores. Polar cod is eaten by a variety of larger fish, as well as by many seabird species and most Arctic marine mammals. This small fish spends much of its time associated with ice and remains in Arctic cold-water masses throughout its life. Its stock sizes seem to have been underestimated.



Source: Born and Böcher (2001)

Fig. 8.13 The Polar cod has a central position in the food web of High Arctic marine ecosystems.

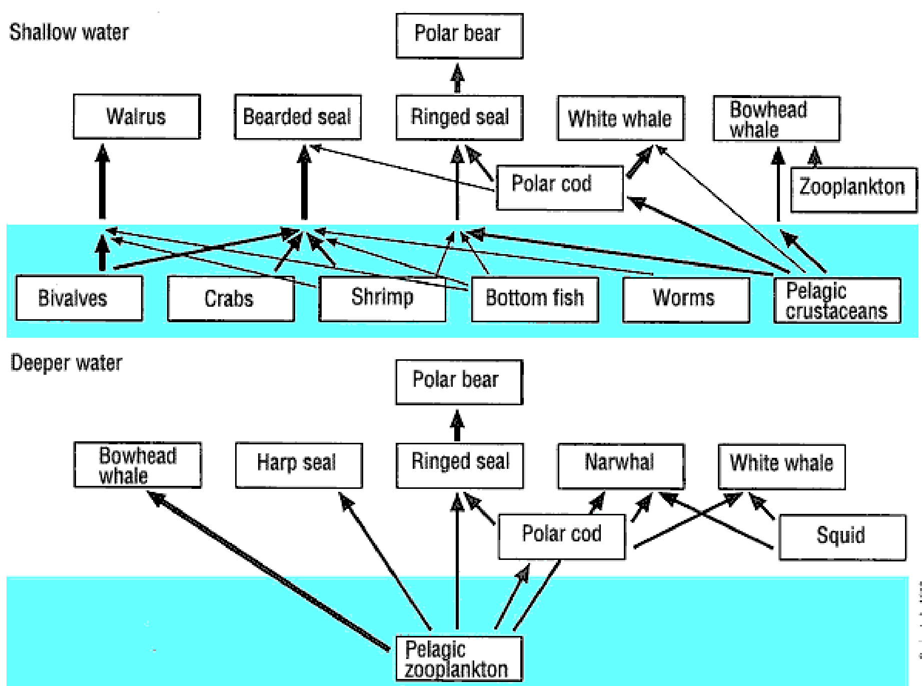
Walleye pollock is the most abundant fish species in the Bering Sea, and it comprises the bulk of the commercial catch. Juvenile pollock are important forage fish for older pollock, other fish species, and marine mammals and birds.

Greenland halibut is a bottom-dwelling flatfish of importance to commercial fisheries in both the North Atlantic and Pacific oceans, as well as to deep-feeding sea mammals, such as narwhal and hooded seals, and benthic-feeding sharks, such as the Greenland shark. During their first few years as immature fish (until age 4–5 in the eastern Bering Sea), they inhabit depths of 200 m. In the Atlantic Ocean, the immature fish occur mainly from 200–400 m. Adults occupy mainly continental slope waters from 200–1000 m or more.

Atlantic cod, by far the most important commercial species in the North Atlantic, is mainly found in Subarctic and Boreal waters. Young cod are an important part of the diet of large cod as well as marine mammals.

Marine Mammals

Marine mammals are a dominant feature of the Arctic marine megafauna, and both resident and migratory species are present. Many marine mammals are top predators in the Arctic (see fig. 8.14). Furthermore, they provide the mainstay of the diet of coastal peoples throughout the region and have been the subject of extreme levels of commercial exploitation originating from more southerly regions.



Source: Born and Böcher (2001)

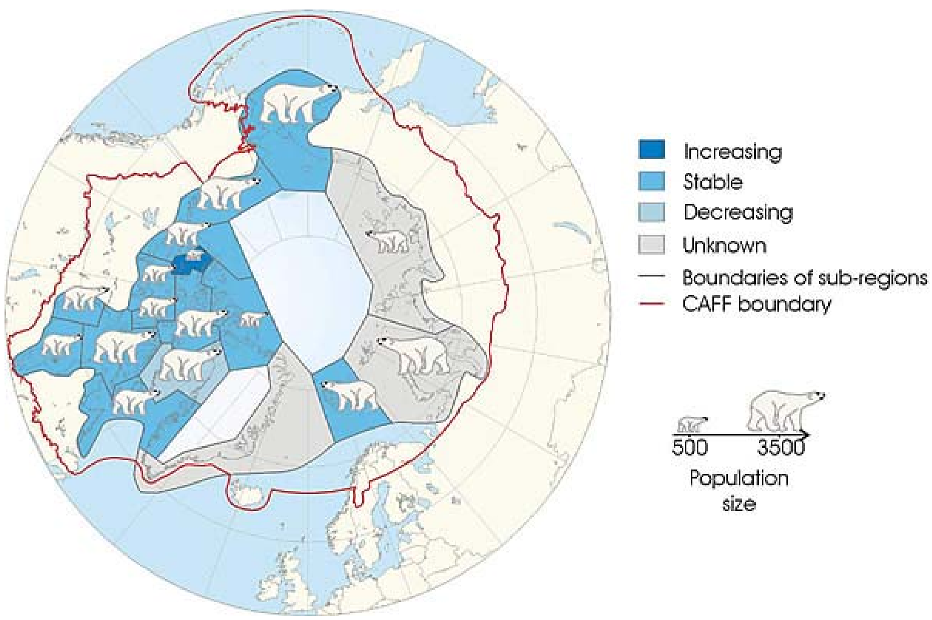
Fig. 8.14 The most important food web relationships of Arctic marine mammals in shallow and deeper waters

Polar Bears

The polar bear (*Ursus maritimus*) is a pinnacle predator and is found throughout the circumpolar Arctic. It depends on sea ice for most components of its life cycle. Polar bears feed almost exclusively on ice-associated seals—mostly ringed seals. From tracking studies, it has been shown that bears can be roughly divided into two groups: those that remain resident in a relatively small area, less than 3000 km^2; and those that follow a quite fixed annual cycle of migration that can take them thousands of kilometres, covering more than 200,000 km^2. However, both groups spend most of the year moving across, and hunting on, sea ice. Adult bears can swim quite long distances, if required, but mothers with cubs must depend on ice corridors to move young cubs from terrestrial denning areas to hunting areas out on the sea ice.

Pregnant females dig snow dens in the early winter and give birth to their cubs several months later. They require a significant depth of snow for this purpose and tend to return year after year to sites that accumulate sufficient snow early in the season. When females emerge from the den with their young, the mother has not eaten for 5–7 months.

The global—circumpolar—population size of polar bears is estimated to be 22,000–27,000 animals (see fig. 8.15). Factors, such as global warming, which influence the distribution, movement, duration, and structure of sea ice can profoundly affect the population ecology and survival of polar bears, in part through the impacts on their principle prey species, the ringed seals.



Source: CAFF (2001)

Fig. 8.15 The polar bear occurs in 16 distinct populations. At present, most of these populations are stable, owing to conservation and management efforts under the International Polar Bear Treaty. However, the population status of polar bears in Siberia is largely unknown.

Student Activity

Why, do you suppose, are the largest creatures on Earth—the great whales—found in the sea, rather than on land?

Seals

Ringed seal (*Phoca hispida*) is a circumpolar species (see fig. 8.16) distributed throughout all Arctic oceans, all the way to the North Pole. The ability of these seals to maintain breathing holes in thick sea ice enables them to occupy areas vast distances from ice edges, which other seal species are unable to reach. Ringed seals use sea ice exclusively as breeding, moulting, and resting (haulout) habitat and rarely, if ever, come onto land. Ringed seals are the most numerous Arctic seal, numbering in the millions. Ice-associated crustaceans and fish constitute much of their diet. As for polar bears, factors, such as global warming, that influence the distribution and duration of sea ice and snow can have profound effects on the population ecology of ringed seals.

Source: CAFF (2001)

Fig. 8.16 The bearded seal (*Erignathus barbatus*) and its distribution

Bearded seals have a patchy circumpolar distribution. They use drifting ice for breeding and other haul-out activities, but occasionally they haul out on land during the summer months. They are for the most part benthic feeders, eating a wide variety of fish, molluscs, and other invertebrates. This dietary preference restricts their functional range to relatively shallow areas. The global population of bearded seals is not known, but probably in the hundreds of thousands in the Arctic alone.

Harbour seals (*Phoca vitulina*) have one of the broadest distributions among all seals, ranging from temperate areas as far south as southern California and north to the Bering Sea in the Pacific Ocean; and from southern Europe to Arctic waters in the North Atlantic Ocean. They are a coastal, non-migratory, species that aggregate in small numbers on rocky outcrops, beaches, and intertidal areas. Harbour seals commonly do not haul out on ice, but they may do so if shore-based sites are inaccessible. Harbour seals are opportunistic feeders that eat a wide variety of fish species and some cephalopods and crustaceans. Currently, harbour seal populations are small and declining within the Arctic region.

Three seal species are distributed mainly in the Atlantic sector of the Arctic: harp seal (*Phoca groenlandica*); hooded seal *Cystophora cristata*; and grey seals *Halichoerus grypus*. Harp seals number approximately 3 million individuals. They are highly gregarious and migratory, follow the pack ice, and feed primarily on small marine fish, such as capelin, herring, and Polar cod. Hooded seal is a large, pack-ice breeding northern species that follows an annual movement cycle that keeps them in close association with drifting pack ice, similar to harp seals. They feed on a variety of deep-water fishes, including Greenland halibut and different redfish species, as well as squid at considerable depths. The global population size of hooded seals is difficult to estimate but is considered to be at least half a million animals. Grey seals were historically abundant in Iceland and along the coastal regions of northern Norway and northeastern Russia. However, they have been depleted through hunting and government culling programs and in some areas have been extirpated. It is estimated that only 4,500 and 5,000 grey seals inhabit the Barents region and Icelandic waters, respectively.

Two ice-breeding seals occur only in the Bering Sea region: the spotted seal (*Phoca largha*) and the ribbon seal (*Phoca fasciata*). The spotted seal inhabits ice-covered areas and eats a wide variety of prey, including fishes, crustaceans, and cephalopods. Their population size is unknown. Ribbon seals are also poorly known, pack-ice breeders; they do not haul out on land. Current data on the population size of the ribbon seal is not available, but 100,000—200,000 animals were counted during the 1970s.

Northern fur seals (*Callorhinus ursinus*), Steller's sea lions *Eumetopias jubatus*, and sea otters (*Enhydra lutris*) all breed terrestrially on the Pribilof, Aleutian, Commander, and Kurile islands. The latter two species breed as far south as the California coast. None of these species are High Arctic inhabitants, but they all live at the fringes of the North Pacific Ocean and are likely to be influenced by changes such as alterations to the southern edges of the seasonal pack ice in Arctic waters.

Walrus

Walruses (*Odobenus rosmarus*) are restricted to the Arctic. Their distribution is circumpolar (see fig. 8.17), but the Atlantic and Pacific populations are somewhat disjointed. Therefore, two subspecies are recognized, the Pacific walrus and the Atlantic walrus. The global population of walruses is estimated to be about 250,000 individuals, of which the great majority belongs to the Pacific subspecies. Walruses haul out on pack ice for most months of the year, using land-based sites only during the summer months, when sufficient ice is unavailable. Walruses have a narrow ecological niche that depends on the availability of large areas of shallow waters (less than 80 m) with suitable bottom substrate that will support productive bivalve communities. They must have access to haul-out areas relatively close to feeding areas, which for some parts of the year means an ice platform near foraging grounds.

Source: CAFF (2001)

Fig. 8.17 A walrus (*Odobenus rosmarus*) colony, Bering Strait, Russia; and the distribution of walrus

Whales

Three whale species are truly Arctic: white whale or beluga (*Delphinapterus leucas)*, narwhal (*Monodon monoceros*), and bowhead whale (*Balaena mysticetus*). These species are commonly found in ice-covered waters, where they use edges, leads, and polynyas to surface and breathe. They travel through areas that satellite images suggest are fully covered by sea ice; but, obviously, they must find, or create, open water in these areas to breathe. Narwhal is only found in the Atlantic sector of the Arctic, whereas the other two species have patchy circumpolar ranges. All three species have seasonal movement patterns, largely determined by north–south movements of annual sea ice. All species depend heavily on small fish in their diet, especially Polar cod, but narwhal also consume significant amounts of cephalopods (i.e., squids). Bowheads consume a greater proportion of planktonic crustaceans than either of the other two High Arctic whales.

Other whale species frequent Arctic waters in summer but remain in relatively ice-free waters and spend most of the year elsewhere. Common baleen whales include the blue whale (*Balaenoptera musculus*), fin whale or finback (*B. physalus*), minke (*B. acutorostrata*), sei (*B. borealis*), and humpback whale (*Megaptera novaeangliae*). Toothed whales include the harbour porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli)*, killer whale (*Orcinus orca*), white-beaked dolphins (*Lagenorhyncus albirostris*), right whale (*Eubalaena glacialis*), and grey whale (*Eschrichtius robustus*).

Most populations of the great whales in Arctic waters were heavily depleted, and some, such as the right and grey whales in the northern parts of the Atlantic Ocean, were more or less extirpated as a result of extensive commercial whaling during the last few centuries. This resulted in a worldwide ban on commercial whaling in 1986. However, subsistence hunting of Arctic whales (mostly bowhead, narwhal, and beluga) is still allowed and ongoing in parts of the Arctic. (See Module 10.)

Seabirds

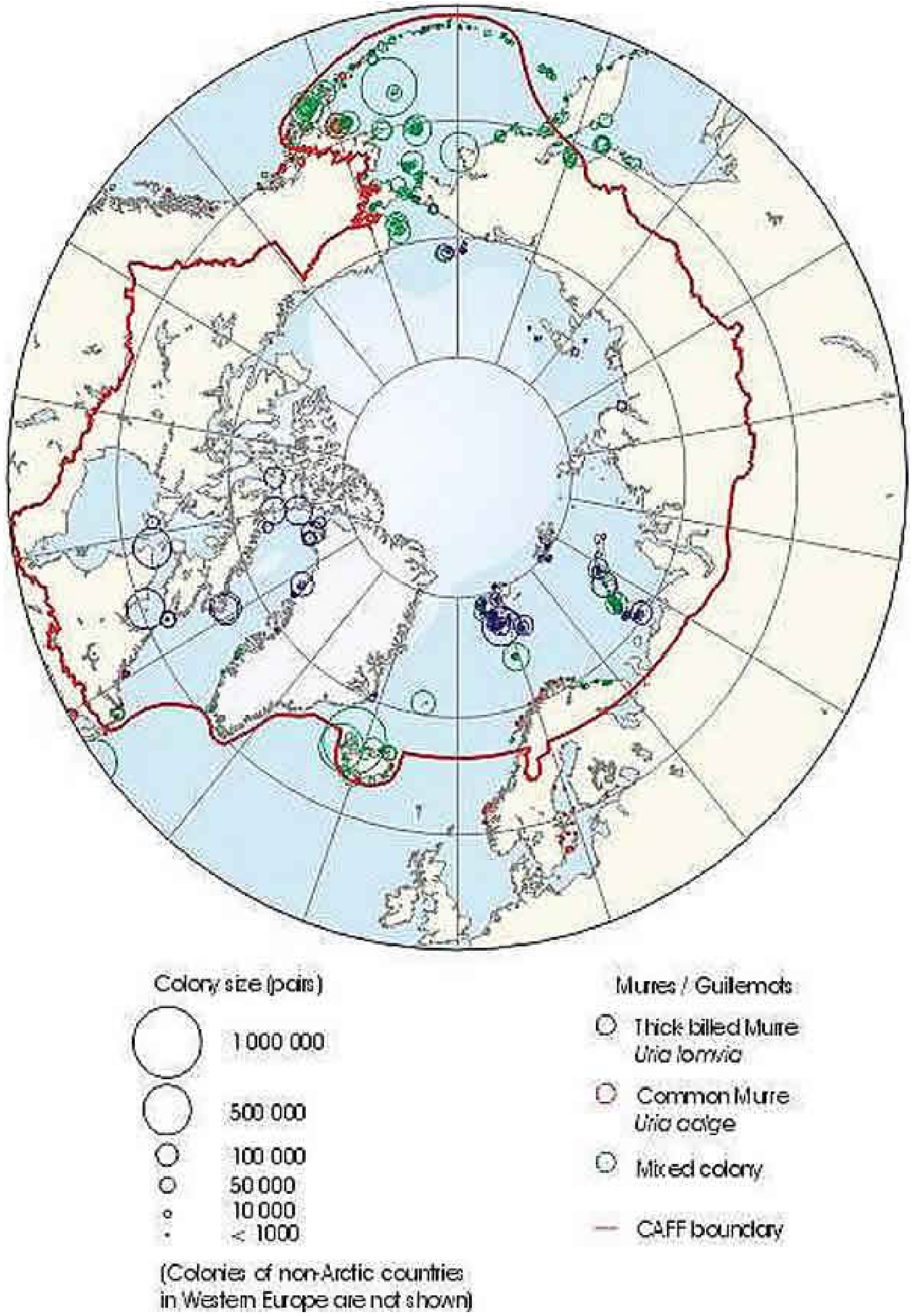
The Arctic is home to some of the largest seabird populations in the world. More than 60 seabird species frequent the Arctic region, and more than 40 species breed there. A few species, such as common eider (*Somateria mollissima*); spectacled eider (*Somateria fischeri*); black guillemot (*Cepphus grylle*); thick-billed murre, or Brunnich's guillemot (*Uria lomvia*); little auk (*Alle alle*); ivory gull (*Pagophila eburnea*); and northern fulmar (*Fulmarus glacialis*) remain in the Arctic year-round, using the southern edges of the sea ice or other open water areas for feeding in the winter. More commonly, seabirds migrate into Arctic areas to take advantage of the productive summers but winter elsewhere. Extreme cases are the Arctic tern (*Sterna paradisaea*), red phalarope (*Phalaropus fulicarius*), and northern phalarope (*P. lobatus*): these summer in the High Arctic but spend the winter in the southern hemisphere. Arctic polynyas are extremely important winter habitats for seabirds that remain in the north year-round; for example, the globally threatened population of spectacled eider that overwinters in a few polynyas in the Bering Sea. In the rare instance when such polynyas freeze for longer than a few days, the mortality rate of birds can be so high as to alter the bird population growth and affect the species for decades.

Most Arctic seabirds nest in large colonies on cliffs, which affords them some protection from terrestrial predators, such as the Arctic fox; others, such as Sabine's gull (*Larus sabini*), nest on the ground on isolated islands; and still others use burrows, either on sloping ground (e.g., little auk), or in rock crevices (e.g., black guillemot). Several auk species are among the most abundant nesting Arctic seabirds. These include the little auk (*Alle alle*); thick-billed murre, or Brunnich's guillemet (*Uria lomvie*); common murre, or common guillemot (*Uria aalge*); and the Atlantic puffin (*Fratercula arctica*). The black-legged kittiwake (*Rissa tridactyla*) is the most numerous Arctic gull, but glaucous gull (*Larus hyperboreus*) is also common. Arctic terns (*Sterna paradisaea*) are abundant in some regions, as are common eiders.

Student Activity

What are the six most common seabird species in your area?

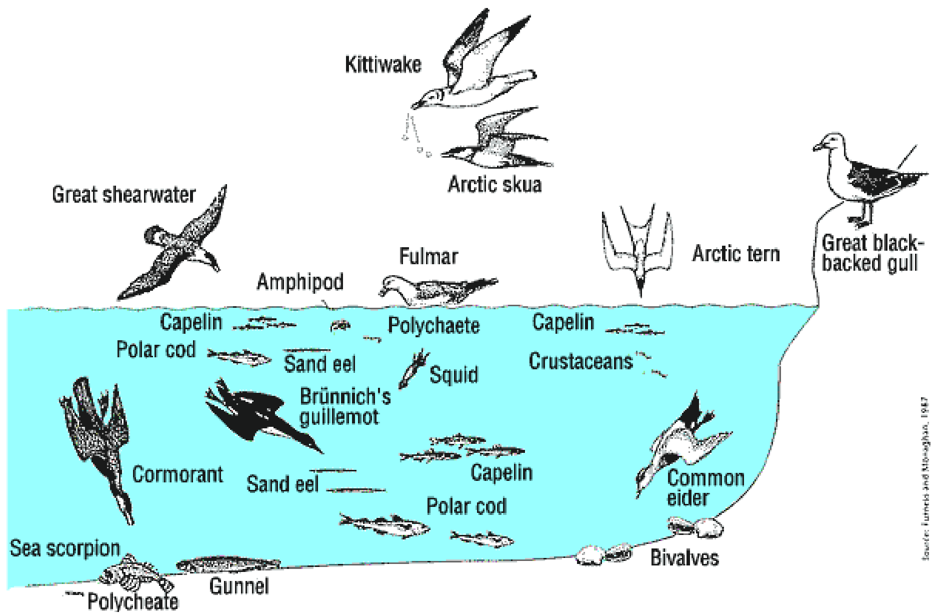
The two murre (guillemot) species are among the most numerous seabirds in the Arctic. The world population of the common murre is estimated to be 12–15 million breeding birds, of which 8–11 million breed in the Arctic. The Arctic is home to the entire population of the thick-billed murre (Brünnich's guillemot), which is currently estimated to be 14 million birds. The largest colony on Novaya Zemlya may once have been the largest colony of seabirds in the northern hemisphere. Researchers estimated that 1.6 million birds were breeding there in the 1930s. Today, there are far fewer birds (see fig. 8.18).



Source: CAFF (2001)

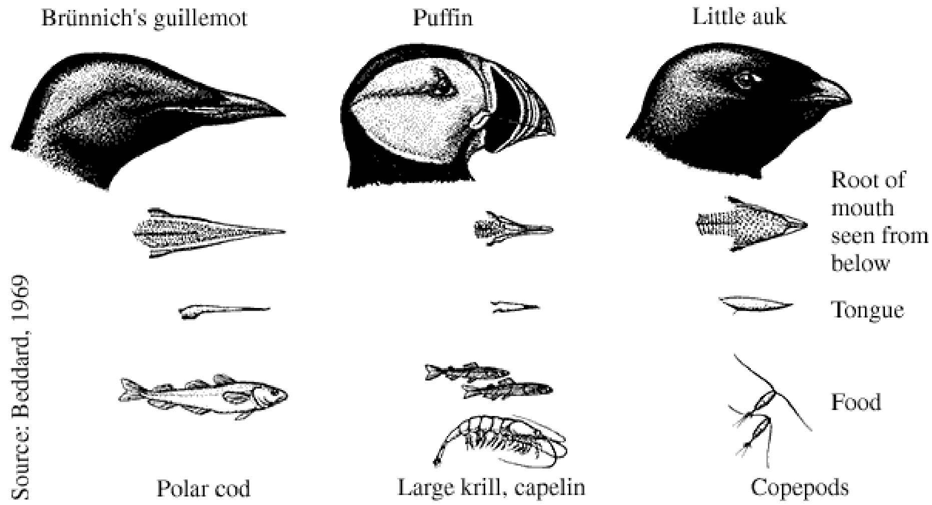
Fig. 8.18 Colonies of common and thick-billed murres in the Arctic

Most Arctic seabirds forage on small fish and large invertebrates (mainly crustaceans), primarily in the upper and mid-water column. Foraging is often concentrated in areas, such as ice edges, where upwelling occurs and marine zooplankton are concentrated. Eiders are an exception in being benthic foragers that feed in shallow water areas, primarily targeting echinoderms (e.g., sea stars, brittle stars, sea urchins) and molluscs. Surface feeders, such as kittiwakes and fulmars, forage on the wing, dipping into the water to capture prey; or they feed while sitting on the surface of the water when prey are dense and available within the top few centimetres. The alcids (i.e., murres and puffins) and their allies “fly” under water to considerable depths given their body sizes in search of prey (see fig. 8.19 and fig. 8.20).



Source: Born and Böcher (2001)

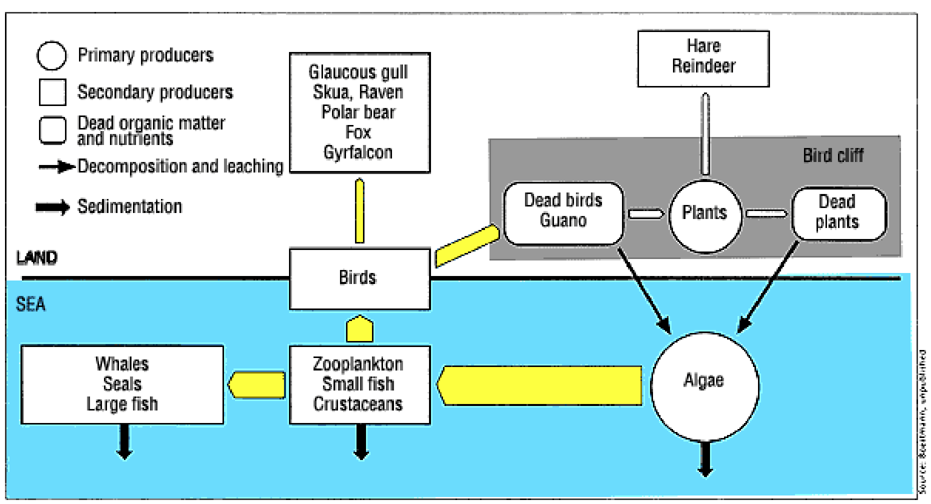
Fig. 8.19 Different feeding strategies of seabirds allow them to occupy different ecological niches.



Source: Born and Böcher (2001)

Fig. 8.20 Related species (here alcids) avoid competition through adopting different foraging strategies, which are reflected in their beaks and mouth parts.

Seabirds provide an important link between the marine and terrestrial ecosystems by moving energy and nutrients from the sea onto land—for example, through being a prey to terrestrial predators, and by providing nutrients (droppings/guano) for terrestrial plants. Conversely, there is a transport of energy from bird cliffs to the sea through dead birds and guano. (See fig. 8.21.)



Source: Born and Böcher (2001)

Fig. 8.21 The transport of matter and energy around a seabird colony. The thickness of the arrows indicates the magnitude of transport.

Summary

The Arctic seas include a significant part of the Arctic region in physical, ecological, and socio-economic terms. The main seas are the Arctic Ocean and its adjacent shelf seas, as well as the Nordic Seas—Eastern North Atlantic Sea, including Greenland Sea, Iceland Sea, and Norway Sea—the Labrador Sea, and the Bering Sea. Marine ecosystems obey the same laws as ecosystems on land, with primary producers (phytoplankton) providing the basic energy on which all other life depends. However, there are significant differences from life on land, mainly owing to differences in the physical properties of the media, salt water versus air. The Arctic seas provide bountiful stocks of plankton, fish, marine mammals, and seabirds, which have sustained Arctic inhabitants for millennia and on which the economies of some of the Arctic nations depend.

Glossary of Terms

benthos	the flora and fauna at the bottom of a sea or lake.
biotope	well-defined geographical area, characterized by specific ecological conditions (soil, climate, etc.), which physically supports the organisms that live there.
commensalism	*Biology* an association between two organisms in which one benefits and the other derives no benefit or harm.
detrivores	a being that feeds on detritus, fine particles of dead organic material.
endemic	(of a plant or animal) native and restricted to a particular region or country.
euphausids	(from the Latin name of the best-known species: *Euphausia superba*) shrimp-like marine invertebrates; important organisms of the plankton (zooplankton). The terms EUPHAUSIDS and KRILL are synonyms.
haul out	*verb* (of seals and walruses) come out of the water to rest on the rocky slopes of the shore.
haulout	*noun* a place along the shore where marine mammals haul out.
hydrography	the science of studying and charting bodies of water.
sessile	(*Botany & Zoology*) **1** (of a flower, leaf, eye, etc.) attached directly by its base without a stalk or peduncle. **2** fixed in one position; immobile.

siliceous	made of silica.
upwelling	**1** a welling upwards, esp. the rising of cold water from the bottom of the sea, often bringing with it a renewed source of nutrients. **2** the water that has risen in this way.

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