NATIONAL GEOGRAPHIC

A Changing Pacific Coast

From Mexico to Alaska, one of the planet's most productive marine systems is sustained by movement. Currents, tides, and winds help produce food. Migrations, both horizontal and vertical, transport energy as food, adding to the region's diversity of life. But warming waters and other changes are transforming this ecosystem.

Food Web

Energy moves through oceans in a complex web as animals eat algae, bacteria, and other animals. Relationships between predators and prey are in flux. Some animals change diets during their life stages, as the seasons shift, as they migrate, or as the ocean cycles between warm and cool periods.

PRIMARY PRODUCERS AND CONSUMERS

Producers such as giant kelp and phytoplankton make their own food through photosynthesis or, in the deep sea, through chemosynthesis. Primary consumers feed on producers.

26% Primary consumers
58% Primary producers
Total marine biomass*

SECONDARY CONSUMERS

These animals—which include small fish, baleen whales, squid, and whale sharks—eat primary consumers, such as zooplankton, shellfish, and jellyfish.

16%

TERTIARY CONSUMERS

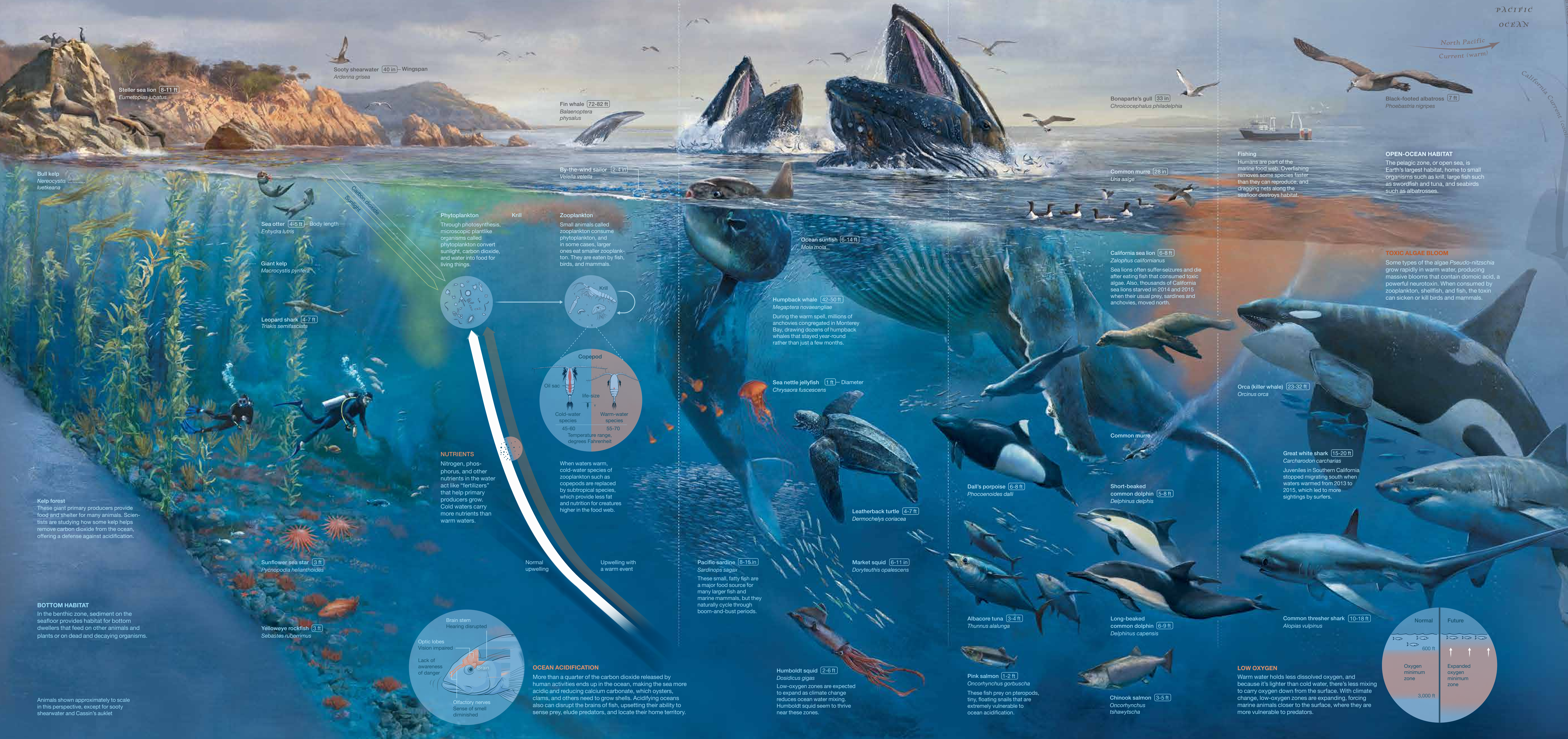
Dolphins, sea lions, and large fish such as tuna typically eat secondary consumers, although some also prey on primary consumers. Most seabirds are tertiary consumers.

<1%

APEX PREDATORS

Orcas, great white sharks, and other top predators eat secondary and tertiary consumers. They have few natural predators and promote biodiversity by limiting populations of other species.

<1%



Cassin's auklet 13-15 in
Ptychoramphus aleuticus
Sooty shearwater 40 in — Wingspan
Ardenna grisea
Steller sea lion 8-11 ft
Eumetopias jubatus
Fin whale 72-82 ft
Balaenoptera physalus
Bonaparte's gull 33 in
Chroicocephalus philadelphia
Black-footed albatross 7 ft
Phoebastria nigripes
Bull kelp
Nereocystis luetkeana
Carbon dioxide
Sunlight
Sea otter 4-5 ft — Body length
Enhydra lutris
Giant kelp
Macrocystis pyrifera
Leopard shark 4-7 ft
Triakis semifasciata
Kelp forest
These giant primary producers provide food and shelter for many animals. Scientists are studying how some kelp helps remove carbon dioxide from the ocean, offering a defense against acidification.
Sunflower sea star 3 ft
Pycnopodia helianthoides
BOTTOM HABITAT
In the benthic zone, sediment on the seafloor provides habitat for bottom dwellers that feed on other animals and plants or on dead and decaying organisms.
Yelloweye rockfish 3 ft
Sebastes ruberrimus
Animals shown approximately to scale in this perspective, except for sooty shearwater and Cassin's auklet
By-the-wind sailor 2-4 in
Velella velella
Phytoplankton
Through photosynthesis, microscopic plantlike organisms called phytoplankton convert sunlight, carbon dioxide, and water into food for living things.
Krill
Zooplankton
Small animals called zooplankton consume phytoplankton, and in some cases, larger ones eat smaller zooplankton. They are eaten by fish, birds, and mammals.
Copepod
Oil sac
life-size
Cold-water species
Warm-water species
45-60
55-70
Temperature range, degrees Fahrenheit
When waters warm, cold-water species of zooplankton such as copepods are replaced by subtropical species, which provide less fat and nutrition for creatures higher in the food web.
NUTRIENTS
Nitrogen, phosphorus, and other nutrients in the water act like "fertilizers" that help primary producers grow. Cold waters carry more nutrients than warm waters.
Normal upwelling
Upwelling with a warm event
Brain stem
Hearing disrupted
Optic lobes
Vision impaired
Lack of awareness of danger
Brain
Olfactory nerves
Sense of smell diminished
OCEAN ACIDIFICATION
More than a quarter of the carbon dioxide released by human activities ends up in the ocean, making the sea more acidic and reducing calcium carbonate, which oysters, clams, and others need to grow shells. Acidifying oceans also can disrupt the brains of fish, upsetting their ability to sense prey, elude predators, and locate their home territory.
Ocean sunfish 6-14 ft
Mola mola
Humpback whale 42-50 ft
Megaptera novaeangliae
During the warm spell, millions of anchovies congregated in Monterey Bay, drawing dozens of humpback whales that stayed year-round rather than just a few months.
Sea nettle jellyfish 1 ft — Diameter
Chrysaora fuscescens
Leatherback turtle 4-7 ft
Dermochelys coriacea
Pacific sardine 8-15 in
Sardinops sagax
These small, fatty fish are a major food source for many larger fish and marine mammals, but they naturally cycle through boom-and-bust periods.
Market squid 6-11 in
Doryteuthis opalescens
Humboldt squid 2-6 ft
Dosidicus gigas
Low-oxygen zones are expected to expand as climate change reduces ocean water mixing. Humboldt squid seem to thrive near these zones.
Common murre 28 in
Uria aalge
California sea lion 6-8 ft
Zalophus californianus
Sea lions often suffer seizures and die after eating fish that consumed toxic algae. Also, thousands of California sea lions starved in 2014 and 2015 when their usual prey, sardines and anchovies, moved north.
Common murre
Dall's porpoise 6-8 ft
Phocoenoides dalli
Short-beaked common dolphin 5-8 ft
Delphinus delphis
Albacore tuna 3-4 ft
Thunnus alalunga
Long-beaked common dolphin 6-9 ft
Delphinus capensis
Pink salmon 1-2 ft
Oncorhynchus gorbuscha
These fish prey on pteropods, tiny, floating snails that are extremely vulnerable to ocean acidification.
Chinook salmon 3-5 ft
Oncorhynchus tshawytscha
Fishing
Humans are part of the marine food web. Overfishing removes some species faster than they can reproduce, and dragging nets along the seafloor destroys habitat.
OPEN-OCEAN HABITAT
The pelagic zone, or open sea, is Earth's largest habitat, home to small organisms such as krill, large fish such as swordfish and tuna, and seabirds such as albatrosses.
TOXIC ALGAE BLOOM
Some types of the algae Pseudo-nitzschia grow rapidly in warm water, producing massive blooms that contain domoic acid, a powerful neurotoxin. When consumed by zooplankton, shellfish, and fish, the toxin can sicken or kill birds and mammals.
Orca (killer whale) 23-32 ft
Orcinus orca
Great white shark 15-20 ft
Carcharodon carcharias
Juveniles in Southern California stopped migrating south when waters warmed from 2013 to 2015, which led to more sightings by surfers.
Common thresher shark 10-18 ft
Alopias vulpinus
Normal
Future
600 ft
Oxygen minimum zone
Expanded oxygen minimum zone
3,000 ft
LOW OXYGEN
Warm water holds less dissolved oxygen, and because it's lighter than cold water, there's less mixing to carry oxygen down from the surface. With climate change, low-oxygen zones are expanding, forcing marine animals closer to the surface, where they are more vulnerable to predators.

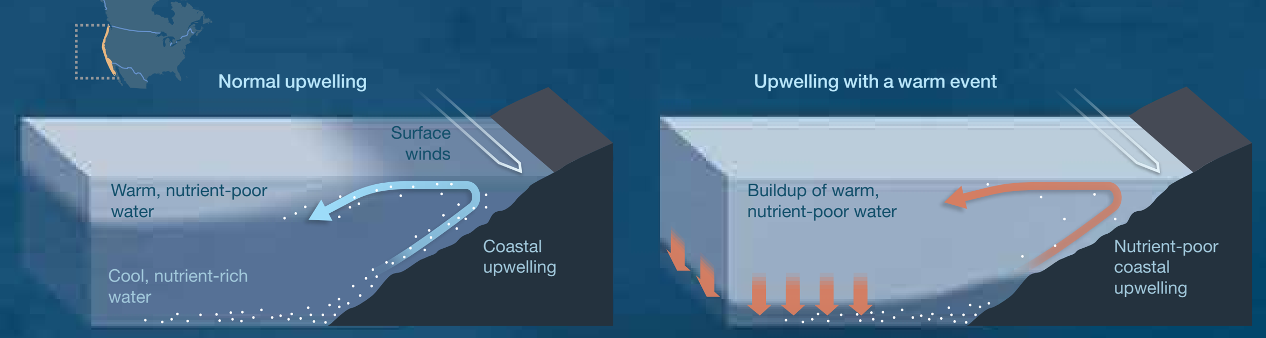
Gulf of Alaska
Prince William Sound
YUKON
PACIFIC OCEAN
North Pacific Current (warm)
California Current (cool)
Summer feeding range
Haida Gwaii (Queen Charlotte Is.)
Vancouver Island
Beaching range
BRITISH COLUMBIA
Vancouver
CANADA
UNITED STATES
Seattle
WASHINGTON
OREGON
Eureka
CALIFORNIA
San Francisco
Santa Cruz
Monterey Bay
Los Angeles
COURSE CORRECTION
Climatic shifts and periodic anomalies—such as El Niño, the Pacific Decadal Oscillation, and the unprecedented warm-water "blob" that began in late 2013—can rearrange food webs, alter marine habitats, and change the geographic distributions of birds, fish, marine mammals, and sea turtles.
Ocean sunfish and common thresher shark
Rarely found north of Vancouver Island, these fish were seen in Alaska.
Humpback whale
These whales feed across the North Pacific coast in summer. A group stayed in Monterey Bay to feed instead of migrating to Mexico.
Cassin's auklet
Tens to hundreds of times the normal numbers were found dead on beaches during the winter of 2014-2015.
Sardine
Egg production moved north.
California sea lion
Mothers that normally prey on small fish such as sardines abandoned their pups to expand their search for food.

*PERCENTAGES DO NOT ADD UP TO 100 BECAUSE OF ROUNDING.

A Shifting Balance

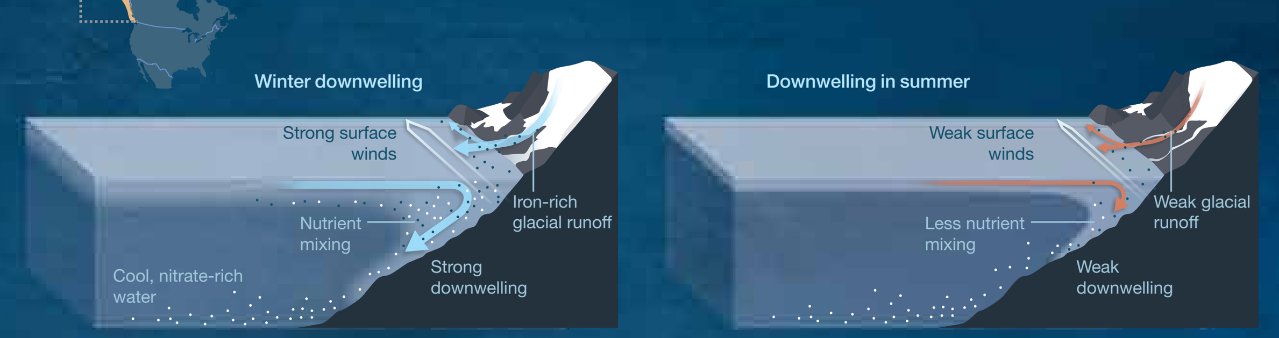
CALIFORNIA UPWELLING

In spring and summer along the West Coast, winds push surface water offshore, drawing cold water up from the deep. Upwelling of these nutrient-rich seas feeds phytoplankton, supporting abundant marine life. In El Niño years, the warm-water layer is thicker, so upwelling draws from less productive seas, reducing the food available in the upper ocean.



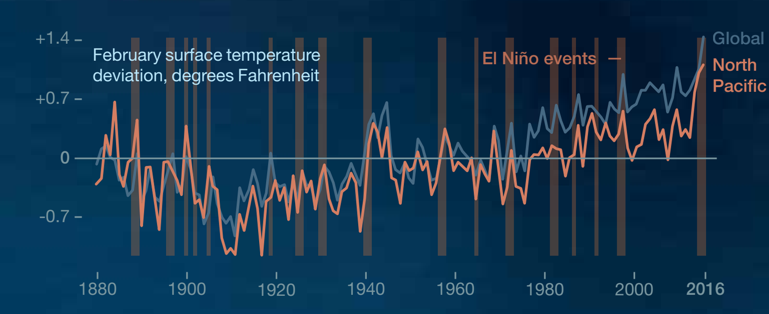
ALASKA DOWNWELLING

Nitrate-rich seas flow north from British Columbia into the Gulf of Alaska, mixing with iron-rich water from streams and glacial runoff, a combination that helps drive productivity. Strong winds near the shore push surface waters down as the current circles counterclockwise along the Aleutian Islands. When winds are weak or runoff tapers, downwelling can stagnate.



WARMER TEMPERATURES

Oceans stabilize climate by capturing and releasing heat. El Niño produces short-term temperature spikes in the North Pacific. But human-induced climate change also warms the ocean, with global average sea-surface temperatures steadily rising and setting new record highs. The North Pacific warmed gradually until an extreme event took place from 2013 to 2015.



THE BLOB

In the winter of 2013-2014, a high-pressure ridge blocked storms that normally cool the Gulf of Alaska. This created a pool of unusually warm water that spread farther and deeper than any other on record. The heat altered food webs, shifted migrations, and fueled toxic algae blooms, offering a glimpse of how future warming may change the eastern Pacific.