Climate Change and Marine Food Webs

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Marine food webs are changing, and for the birds, marine mammals and fish that depend on them, not for the better. Climate changes are altering patterns of nutrient upwellings, timing of fish spawning, and generally upsetting the food web, forcing more of the seabirds and marine mammals to travel longer distances to find food or to rely on suboptimal prey that offer less caloric reward for the effort expended in capturing them.

An albatross. Photo: NOAA

Marine life is an intricate web of interactions between water currents that bring nutrient-rich waters to the surface, feeding an explosion of single-celled plants called phytoplankton, the tiny animals called zooplankton that feed on them, and larger fish that feed on the zooplankton. Many of these fish are unfamiliar to most people because they never show up on our dining tables – sandeels, sprat, menhaden, Arctic cod, and sand lance. All these species are all fatty, oily fish that provide a dense wallop of nutrition each time one is caught.

The North Sea

The Orkney and Shetland Islands off the coast of Scotland are home to enormous colonies of breeding seabirds—common guillemots, black-legged kittiwakes, Arctic terns and skuas, to name a few. In 2004, these birds suffered "catastrophic" breeding failure: on some islands, not a single chick survived to leave the nest, and nearly all seabirds in the area suffered their worst breeding season on record[1]. The Shetland Islands colony numbered 172,000 breeding pairs of guillemots, but they produced almost no young. 6,800 pairs of great skuas produced perhaps fewer than 10 young, and the 1,120 pairs of arctic skuas, 24,000 pairs of arctic terns, and the 16,700 pairs of Shetland kittiwakes failed to produce any surviving young.

An Arctic tern. Photo: Public Domain

[1] Mavor, R.A., Parsons, M., Heubeck, M. and Schmitt, S. 2005. Seabird numbers and breeding success in Britain and Ireland, 2004. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 29.) Available at: http://www.jncc.gov.uk/PDF/pub05_seabirdnos_2004.pdf

The bird species that fared the worst that season shared an important dietary feature: they depend on a small, fatty fish called a sandeel. Scientists observing the colony noticed that in 2004, sandeels were virtually absent from the area and hardly any were seen being fed to young. In other areas, where birds were less dependent on sandeels because other species of high-energy fish were available, breeding birds fared better, though even their chicks were in poorer condition than normal, and parents spent more time foraging and left their young unattended and vulnerable to predation for longer periods of time[2].

Harbor porpoise. Photo: NOAA

Other species also felt the impacts of the loss of sandeels in the North Sea. Harbor porpoises, the smallest of Europe's porpoises, depend on the fish, particularly during spring when young are being weaned and foraging on their own for the first time. When fewer sandeels are available, harbor porpoises are much more likely to starve to death, indicating that they have few other prey choices available, or at least few that provide a suitably calorie-rich alternative[3].

What was behind the loss of sandeels in the North Sea? Fishing does not seem to be the culprit. Sandeels traditionally faced heavy commercial fishing pressure, for their value in the fish oil and fertilizer industries, but for the past decade quotas have been imposed to help preserve sea bird populations, and these quotas were particularly strict in the Shetlands. Many indications are pointing to climate change. Warmer sea surface temperatures are associated with poor survival of young sandeels, particularly in the area of the Shetland and Orkney Islands, which is the southern portion of the fish's range[3]. Sea surface temperatures have been rising since the 1970s, and in 2004 reached a peak of 2.5°C above the long-term average. This rise in sea temperatures has been linked to changes in the zooplankton community, the sandeel's main food source, with the effects rippled up the food chain to threaten the animals at the top[4].

Walrus on Bering Sea ice. Photo: NOAA

Alaska

Food web changes are taking place throughout the marine ecosystems of Alaska. In northern Alaska, the marine food web is intricately tied to the annual cycles of sea ice expansion and retreat, so the

[2] Wanless, S., M.P. Harris, P. Redman, and J.R. Speakman. 2005. Low energy values of fish as a probable cause of major seabird breeding failure in the North Sea. Marine Ecology Progress Series 294:1-8. http://www.int-res.com/articles/feature/m294p001.pdf

[3] Arnott, S.A. and G.D. Ruxton. 2002. Sandeel recruitment in the North Sea: Demographic, climatic and trophic effects. Marine Ecology Progress Series 238:199-210.

[4] Frederiksen, M., M. Edwards, A.J. Richardson, N.C. Halliday and S. Wanless. 2006. From plankton to top predators: bottom-up control of a marine food web across four trophic levels. Journal of Animal Ecology 75:1259-1268.

accelerating retreat of Arctic sea ice has repercussions for many species. Each spring, sea ice sustains an explosive bloom of marine plants. Algae start to grow when snow at the ice surface melts. More algae sprout from the underside of the ice in long, trailing strands, and in the nearby open water. The algae feeds small animals called zooplankton (single-celled animals, tiny crustaceans called krill, and immature invertebrates of many varieties), which are in turn food for the Pacific's most important oily, fatty fish, the Arctic cod, which provides high-quality food for marine mammals and seabirds at the top of the chain[5]. Loss of sea ice to climate change means less Arctic cod, leaving a dietary void for the many species that depend on them-- ringed seals, spotted seals, and a host of other mammals, birds, and larger fish[6,7].

The ice on the surface is important to the animals at the bottom of the ocean as well. Dislodged algae and bits of food rain down through the water column to the sea floor, nourishing vast communities of clams, marine worms and other invertebrates that live on the ocean floor in the shallow waters of the continental shelf. Climate change is causing rapid retreat of sea ice away from the shores, taking the nutrient "rain" of algae out into deep, frigid, lightless waters where there are few bottom-dwelling animals to make use of these nutrients. The food web changes have been particularly detrimental to walruses, because they rely both on a sea-floor bounty of invertebrates fed by the ice edge, and also the ice itself for resting and keeping their young safe from predators[8].

Polar bear with cub. Photo: Scott Schliebe, U.S. FWS

California Coast

Twenty-five miles off the coast of San Francisco lay the Farallon Islands. Craggy, isolated and virtually inaccessible due to tides and shoals, the small archipelago is one of the nation's most important sea bird colonies. The Farallones are ideally situated at a spot where the prevailing winds and a cold-water current moving down the Pacific coast create a nutrient-rich upwelling that forms the basis of an incredibly productive food chain. The isolation and the steady food source make it an ideal home for sea birds: thirteen species have breeding colonies here, and the islands are also home to five species of seals, several types of whales and dolphins, and even great white sharks. However, startling changes are taking place in this important wildlife refuge. Cassin's auklet, a robin-sized seabird that feeds on small ocean crustaceans called krill, suffered near total breeding failure in 2005.

At the same time, hundreds of Cassin's and rhinoceros auklets, murres and tufted puffins began

[5] Gradinger, R.., R.R. Hopcroft and B. Bluhm. 2004. Arctic Census of Marine Life Program Proposal. Available at http://www.arcodiv.org/files/Arctic_CoML_for%20web.pdf. Accessed 5 Jan 2010.

[6] Finley, K.J., M.S.W. Bradstreet, and G.W. Miller. 1990. Summer feeding ecology of harp seals in relation to Arctic cod in the Canadian High Arctic. Polar Biology 10:609-618.

[7] Gaston, A.J., K. Woo, and J.M. Hipfner. 2003. Trends in forage fish populations in northern Hudson Bay since 1981, as determined from the diet of thick-billed murres. Arctic 56:227-233.

[8] Cooper, L.W., C.J. Ashjian, S.L. Smith, L.A. Codispoti, J.M. Grebmeier, R.G. Campbell and E.B. Sherr. 2006. Rapid seasonal sea-ice retreat in the Arctic could be affecting Pacific walrus (*Odobenus rosmarus divergens*) recruitment. Aquatic Mammals 32(1):98-102.

washing up dead, apparently of starvation, on the coasts of California and Oregon.

The culprit seems to have been a "switching-off" of the critically important currents that fertilize the phytoplankton at the bottom of the food chain. The cold water current arrived two months after the auklets' breeding season, leaving nesting birds with no nearby source of food for their chicks[9]. This was not the first time this had happened; similar conditions are seen during El Niño events, a periodic ocean disruption that stems from weakening of westerly winds and thus weakening of upwellings off the North American West Coast. El Niño events have been noted to correlate with reduced food supply and sharp declines in populations[10], and long-term population declines have been tied to warming ocean temperatures[11]. In general, after El Niño years, the upwellings returned, and successful breeding resumed.

2005 however, proved to be the start of a three-year run of breeding failures. Evidence suggests, therefore, that the failure of the current is linked to long term climate changes, and this may spell doom for many of the birds that call the Farallon Islands home.

[9] Jahnke, J., B.L. Saenz, C.L. Abraham, C. Rintoul, R.W. Bradley, and W.J. Sydeman. 2008. Ecosystem responses to short-term climate variability in the Gulf of the Farallones, California. Progress in Oceanography 77(2-3):182-193.

[10] Ainsely, D.G., L.B. Spear, and S.G. Allen. 1996. Variation in the diet of Cassin's auklet reveals spatial, seasonal and decadal occurrence patterns of euphausiids of California, USA. Marine Ecology Progress Series 137: 1-10.

[11] Veit, R.R., P. Pyle, and J.A. McGowan. 1996. Ocean warming and long-term change in pelagic bird abundance within the California current system. Marine Ecology Progress Series 139:11-18.