Low-fat sprat. As their prey becomes leaner, North Sea guillemots may go hungry.

MARINE MAMMALS

Does 'Junk Food' Threaten Marine Predators in Northern Seas?

Some fish-eating birds and mammals have full bellies but poor diets, say biologists puzzling over declines among these high-latitude marine predators

In 2004, ecologist Sarah Wanless was observing a colony of guillemots on the Isle of May off the coast of southeast Scotland. These diving seabirds were having a terrible breeding season in the United Kingdom, and some colonies hatched no chicks at all. But Wanless could see that parent birds were catching as many fish as ever, if not more. "We couldn't work out what was going wrong," she said. The light dawned when she and her colleagues measured the fat and protein in the fish being caught, mostly sprat, a member of the herring family. Compared with previous years, the amount of energy a hungry guillemot received from a 10-centimeter sprat plunged in 2004, dropping from 55 kilojoules to 12 kilojoules. "They were largely water," Wanless says.

Wanless concludes that the guillemots (*Uria aalge*) were suffering from a diet of what some ecologists have called marine "junk food." They hypothesize that in some cases, marine predators' prey is being replaced by less nutritious species or, like the sprat, becoming leaner. Human junk food is fatty fare, but for these high-latitude birds and mammals it is the opposite—food without enough fat and energy to sustain them.

The highest-profile possible victim of marine junk food is the endangered Steller sea lion, which has seen a massive decline in its Alaskan population. But some researchers say the sea lion data point to suspects such as overfishing rather than junk food (*Science*, 4 April, p. 44). Among northern seabirds, however, researchers are finding multiple examples of struggling populations eating low-quality diets. The details vary among species, but a growing consensus holds that this is one result of climate-driven changes to food webs, which are disrupted as northern seas warm. "Until recently, we were preoccupied with how much food there was, and where. But what the food is can also be crucial," says Wanless, who works at the Centre for Ecology and Hydrology in Edinburgh, U.K.

Birth of an idea

The junk-food hypothesis, as it's become known to the chagrin of some of the researchers working on it, was born in the early 1990s. John Piatt, a seabird ecologist at the U.S. Geological Survey Alaska Science Center in Anchorage, noticed that some colonies of common murres—the American name for guillemots—in the Gulf of Alaska had not recovered as expected from the 1989 *Exxon Valdez* oil spill. Piatt knew that murres and other seabirds were eating mainly juvenile walleye pollock. But gut content data from the early 1970s showed that they had been eating mostly capelin, an oily fish in the smelt family. A gram of capelin can contain up to twice as many calories as a gram of pollock, a lean white fish related to cod. In experiments using captive chicks of a variety of seabird species, those fed oily fish gained weight much more quickly than those fed pollock. Piatt thought this dietary shift might explain the murre's decline.

But what drove that shift? In the mid-1970s, before the spill, capelin numbers plunged while pollock's surged, as reflected in the catch brought up by research trawlers and the growth of the pollock fishery. This also coincided with a flip in a climate cycle called the Pacific Decadal Oscillation (PDO), which warmed the ocean surface off western Alaska by about 1°C in the space of a few months in late 1976. Except for a cool spell between 1998 and 2002, and another that began in late 2007 and which is as yet too brief to call a reversal, that region of water has been relatively warm ever since. The mid-1970s flip is also around the time when numbers of Steller sea lions in western Alaska began to plummet; in the early 1990s, marine biologist Dayton Alverson of Natural Resources Consultants Inc. in Seattle, Washington, independently wondered whether a switch from eating oily fish to pollock was the cause. In 1991, bird and mammal researchers, including both Alverson and Piatt, met to review seabird declines. At the meeting, seabird ecologist Scott Hatch, also of the Alaska Science Center, says he coined the phrase "junk-food hypothesis."

To test the idea, in 2000, marine-mammal researchers Andrew Trites and David Rosen of the University of British Columbia in Vancouver, Canada, fed captive sea lions either pollock or herring. Adults could survive on pollock, they found, but yearlings could not eat enough to sustain themselves. The animals needed to eat more than 20% of their own body weight in pollock each day, but their stomach capacity only allowed them to consume 17% to 18%. "We gave animals as much pollock as they would eat, and they were losing weight," Trites says. The fact that the Steller sea lion population has actually

Down, down, down. In Scotland, the total abundance of 13 species of breeding seabirds has been dropping since the 1980s.

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increased in southeast Alaska, where the PDO shows the opposite pattern, also tends to confirm the junk-food/climate hypothesis.

But some sea lion experts aren't convinced. "Lab work suggests the juveniles are most vulnerable to low-quality prey," says Lowell Fritz of the National Marine Fisheries Service in Seattle. "But we're not seeing that result currently in the field. We should have seen starving animals, but we didn't—we just saw them not there." Fritz thinks the sea lions were more likely hammered by deliberate shooting and by-catch in fisheries. He also thinks the PDO's effects on fish have been overstated. "I'm not convinced you can see any links [to ocean conditions] beyond the phytoplankton. I'm not seeing a direct link to fish."

Trites says that perhaps juvenile sea lions are scarce because adult females adapted to a low-fat diet by spacing out breeding. Looking at the condition of adult females might settle the question, but those studies haven't been permitted because of animal-welfare concerns. Although they seek to do more studies, Trites and Fritz agree that the cause of the sea lions' original decline may never be known.

At risk. Researchers still debate whether "junk food" led to the decline of the endangered Steller sea lion or whether overfishing is to blame.

CREDIT: A. W. TRITES/UBC MARINE MAMMAL RESEARCH UNIT

The ultimate junk food

As researchers puzzle over Alaska's sea lions, other scientists report that the Baltic Sea has also shifted ecological regimes, at least in part thanks to humans. In the late 1980s, there was a boom in the sprat population, triggered by a combination of warming seas and heavy fishing of the sprat's main predator, cod. This abundance of small, oily fish ought to have been good news for the sea's guillemots, but in fact chick weights dropped through the 1990s, before recovering as cod stocks have regrown, says marine ecologist Henrik Österblom of the Stockholm Resilience Centre. "We thought that because sprat increased, that chick condition would improve. Instead we found the opposite," he says. The North Sea also experienced large ecological changes in the late 1980s, leading to the bad breeding season Wanless observed in 2004, the worst on record, according to the U.K. government's Seabird Monitoring Programme.

The changes to Baltic sprat are some of the best field evidence for the junk-food hypothesis: As the number of sprat went up, the nutritional worth of each fish in the crowded population went down, say Österblom and his colleagues. This matters to guillemots, because they deliver one fish at a time to their chick, "so what that fish contains is incredibly important," says Österblom.

In the past 5 years, the menu for North Sea birds has become even less promising. For reasons that aren't understood, large numbers of snake pipefish, a relative of seahorses, have appeared in these predator's diets. The pipefish have tough skins and are virtually fat-free: "It's the ultimate in junk food," says Wanless. British birders have spotted starving kittiwake chicks—a marine gull that usually eats oily sand eels—surrounded by the corpses of uneaten pipefish.

A junk-food diet can increase mortality in more roundabout ways. In 2004, for the first time, Wanless saw a pair of guillemot parents fishing at the same time, leaving their chick unattended. This atypical behavior has increased year-on-year, and last September, she and her colleagues revealed its consequences in *Biology Letters*: A growing number of chicks are being killed by their adult neighbors in the colony. Malnourishment has more subtle effects, too: A team including Piatt found that kittiwakes reared on low-fat fish in captivity showed higher levels of stress hormone and cognitive deficits. "We measure things that we can, such as growth rate, but hidden behind this could be physiological stresses that put birds at a disadvantage," he says.

In the North Sea, bad breeding seasons for birds are becoming more common (see graph). This summer, the U.K.'s Royal Society for the Protection of Birds reported that "virtually no" chicks fledged from some kittiwake and tern colonies. The main cause is thought to be changes to fish populations due to fishing and the effects of global warming on fishes' planktonic food species, because the North Sea is now 1.5°C warmer than it was 40 years ago. The warming has resulted in a 70% drop in the populations of a tiny crustacean called *Calanus finmarchicus*, thought to be the main food of sprat and sand eels, as well as a rise in the numbers of a warm-water relative, *C. helgolandicus*, which contains much less fat and so is junk food for the fish. So the spread of *C. helgolandicus* makes these fish both fewer in number and leaner.

In another twist, *C. finmarchicus* itself may have become junk food for other seabirds: Its range has shifted north by about 1600 kilometers, and it is now displacing the even larger and fattier *Calanus* species that support vast colonies of little auk, a crustacean-eating relative of the guillemot, in Greenland and Norway. In the long run, little auk numbers might decline and those of fish-eating birds such as guillemot might start to increase in these areas, says seabird ecologist Morten Frederiksen of the University of Aarhus in Denmark. "We might be seeing the whole system shifting north, with junk food–related problems developing at the northern and southern boundaries of the climate zones."

These studies show that "junk food" takes different forms and has different consequences for various species. So does it make sense to group the effects on North Sea guillemots with those on North Pacific sea lions? Seabird ecologist Robert Furness of the University of Glasgow in the U.K. has his doubts. "The junk-food hypothesis is an attractive term but a bit misleading," he says. "Each ecosystem is unique." In his view, simple issues of food quantity—such as the current low sand eel populations in the North Sea—will most often be the critical determinant of predators' health. Frederiksen adds that researchers aren't yet sure how to separate the effects of quantity from those of quality: "Working out how much the problems are a junk-food issue and how much is lack of food is difficult."

But Trites argues that there is an overarching message. "People have to realize that not all fish were created equal," he says. Should that message hit home, the only thing left to fix will be the name. Trites thinks a better analogy for predators' woes is a diet of celery. Piatt agrees: "Junk food is very fatty," he says. For animals, "it's the lean cuisine that's the problem."

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