SPRING FORWARD

Warmer climates accelerate life cycles of plants, animals

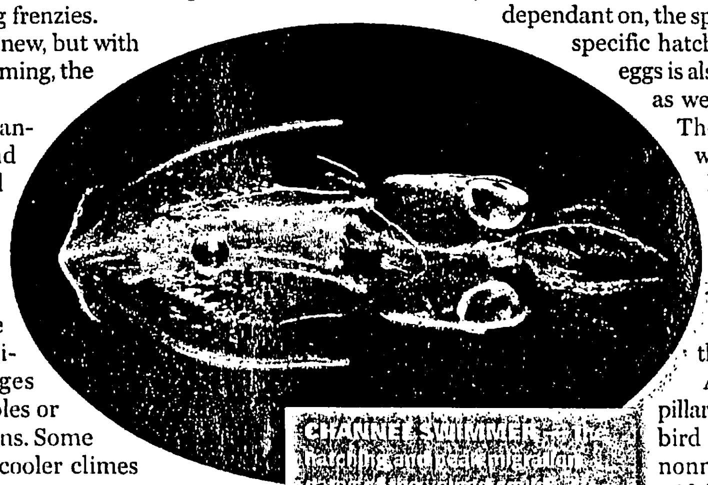
BY SID PERKINS

Ever since the winter solstice last Dec. 22, the days have been getting longer in the Northern Hemisphere and the noonday sun has climbed higher in the sky. These are nature's biggest cues that spring is nigh. As warmth gradually returns to the northern temperate latitudes, so do the birds that migrated south last autumn. Once back, they establish territories, make their nests, breed, and fledge their young. Meanwhile, bulbs and seeds sprout, trees bud, and insects emerge and start consuming the tender foliage. Plankton proliferates in lakes and ocean shallows, whereupon larval fish and seabirds begin their feeding frenzies.

Thus the cycle of life begins anew, but with a recent trend toward global warming, the cycle is changing.

Phenologists, who study organisms' responses to seasonal and climatic changes, have noted that the annual cycles for many creatures are beginning earlier on average, as global temperatures rise. Also, some heat-loving plants and animals have taken advantage of a warmer climate to expand their ranges toward the north and south poles or upslope toward higher elevations. Some organisms that thrive only in cooler climes have retreated from the heat.

On a regional scale—say, a forest—phenological effects on an organism may be masked by factors such as habitat loss, competition from non-native species, short-term variations of climate, or odd circumstances of local geography. On a global scale, however, scientists say the picture is clear: Global warming, regardless of its cause, is having discernable and generally detrimental effects on the planet's ecosystems. In the future, the winter solstice may presage a radically transformed set of biological responses.



CHANNEL SWIMMER — [illegible]

THE HEAT IS ON In the past century, the average global temperature has risen about 0.6°C. That sounds like a small amount, but research on a wide variety of organisms shows that it's enough to drive major biological changes.

If a species responds to warming, it usually does so in one of several ways, says Terry L. Root, an ecologist at Stanford University. The population density of a species may change at locations within its normal range, or that range may shift, she notes. Or the timing of major events in the life cycle of the species—migration, flowering, or egg laying, for example—can accelerate or lag. Other changes, such as in body size or genetic variability within a species, might occur over longer periods, Root notes.

Significant problems can crop up when the intimately connected species in an ecosystem experience life cycle changes at different rates. Consider Europe's winter moth, *Operophtera brumata*, and the oak tree *Quercus robur*, which produces the young leaves that are the caterpillar's predominant food. Thirty years ago, the budding of the oak and the hatching of the caterpillars were synchronous, says Marcel E. Visser, a biologist at the Netherlands Institute of Ecology in Heteren. However, he notes, the past quarter century's trend toward warmer springs in Europe has disrupted that timing.

Precisely when the oak buds open is related to, but not solely dependant on, the spring's rise in temperatures. The specific hatching time of the winter moth's eggs is also related to rising temperatures as well as other factors, says Visser. The recent spate of particularly warm springs in some parts of Europe is causing the caterpillars to hatch 2 to 3 weeks before oak buds open. That's not good for the caterpillars, which typically can survive only 2 or 3 days—and absolutely no more than 10 days—without food.

A dearth of winter-moth caterpillars bodes ill for the small European bird *Parus major*, or great tit. This nonmigratory species—a common, widely studied bird that's similar to North America's chickadees—depends on winter-moth caterpillars to feed its fledglings. A 23-year study of great tits and winter moths at one site in the Netherlands revealed that by 1995, the early caterpillars were hatching about 9 days sooner and developing into moth pupae more quickly than they did in 1973. The birds' egg laying and hatching schedule hadn't changed dramatically, so the fledglings' caterpillar food source was disappearing just when the young birds needed it.

Visser and his colleagues recently conducted a broader analysis of great tits at 23 sites in six European countries. That study showed that some populations have been able to respond to climate change. In Britain, for example, the birds' egg-laying date has shifted earlier, so it now more closely follows the availability of food, Visser and his colleagues report in the Feb. 22 *Proceedings of the Royal Society of London B.*

SEA CHANGES Although ocean temperatures vary less from year to year and from season to season than air temperatures do, seabirds nevertheless can suffer from phenological shifts in the

I. FORSYTHE/CFPHBASE

availability of prey. One spot that's been particularly affected in recent years is Triangle Island, the home of British Columbia's largest colony of seabirds.

From 1971 to 1996, the peak of the spring bloom in marine zooplankton off the coast of British Columbia leapt forward more than 2 months. That acceleration was driven mostly by ocean warming in the area, says Douglas F. Bertram, a conservation biologist with the Canadian Wildlife Service in Delta, British Columbia. The 1990s, in particular, brought warmer-than-normal temperatures to the region's offshore waters, he notes.

One of the plankton species affected by the warming—*Neocalanus cristatus*, an orange crustacean no more than 6 millimeters long—has traditionally spent only about 2 months of its life near the ocean's surface. When sea-surface temperatures are above normal, however, these small animals develop more quickly and spend even less time at the surface, where many of their predators roam.

That can be good news for *N. cristatus*, but it can be exceedingly bad news for *Ptychoramphus aleuticus*, commonly known as Cassin's auklet. This 20-centimeter-long seabird breeds along the North American coast from Alaska's Aleutians to Mexico's Baja California. However, up to half the world's population of the species breeds at Triangle Island, a small outcrop just off the northwestern tip of Vancouver Island. A poor year in this island's rookeries can mean a bad year for the entire species.

OUT OF SYNC — [illegible]

H. LEMME, WWW.FORESTRYIMAGES.ORG; A. MORRIS/VIREO

Even though Triangle Island's auklets in the 1990s were generally breeding earlier in the year than they were in the 1970s and 1980s, phenological disconnects still occurred. In the summer of 1998—in the late stages of the strongest El Niño Pacific-warming phenomenon on record—sea temperatures were much higher than normal. That meant that the zooplankton bloom had largely come and gone by the time the birds hatched. As a result, auklet parents returned to their burrow nests with gullets filled with larval rockfish—"an unappetizing gray mush," Bertram notes—instead of *N. cristatus*, the preferred prey. Accordingly, large numbers of auklet chicks died that year, and those that survived grew more slowly than normal.

In 1999, when zooplankton was available throughout the auklets' breeding season, the chicks survived and grew at normal rates, says Bertram. He and his colleagues reported their 4-year analysis of climatic effect on the Cassin's auklets' breeding success in the March 20, 2002 *Marine Ecology Progress Series*. Even though El Niño causes only short-term variations in ocean temperatures, scientists believe that organisms will respond similarly to long-term temperature changes brought about gradual trends toward global warming.

Nearly half a world away from British Columbia, researchers have linked differences in ocean temperatures to changes in the timing of annual migrations of squid. Each year large numbers of *Loligo forbesi*, the veined squid, hatch in cold waters 75 to 100 meters deep in an area hundreds of kilometers southwest of England, says David W. Sims of the Marine Biological Association in Plymouth, England. Then, the squid move into the English Channel and the North Sea, where they spend the only summer of their yearlong lives.

Sims and his colleagues analyzed squid-migration data garnered by their organization's trawlers between 1953 and 1972, a period before commercial fishermen eagerly sought *L. forbesi*. The researchers found that in years when water temperatures on the sea floor near Plymouth were warmer than normal, the peak of the squid migration occurred earlier in the year. In years when the water was warmest, peak migration occurred between 4 and 5 months earlier than it did in the coolest years, says Sims.

Although Sims and his colleagues are still conducting their summer trawling surveys, they don't collect many squid these days. "Commercial fishing is obscuring our view of what's happening with the squid," Sims notes. "It's hopeless, really."

TIME TO HEAD NORTH Migratory birds are already displaying effects from long-term global warming, as well as responses to year-to-year variations in temperature, that scientists believe indicate how future climate change might permanently affect the animals.

Since 1909, researchers have been trapping birds on the island of Helgoland, which lies about 70 kilometers off the northwestern coast of Germany. This 2-square-kilometer, flat-topped outcrop of sandstone lies on an avian flyway that links Africa and central Europe to Scandinavia, says Kathrin Hüppop, a phenologist at the Institute of Avian Research, an agency of the regional government on the island.

Bird studies on Helgoland were interrupted by two world wars, but data collection has been consistent and uninterrupted since 1960. In that time, researchers have trapped about 12,000 birds of 200 different species, says Hüppop. She and Ommo Hüppop recently analyzed the reams of accumulated data to look for changes in migration dates that could be related to climate changes.

Of the 24 most-frequently trapped species, half were long-distance travelers that typically spend the winter in sub-Saharan Africa, and the other 12 were short- or medium-distance trekkers that winter in Europe or northern Africa. Over the 41-year period, 7 of the long-distance migrants and 11 of the other species generally passed through Helgoland earlier in years when the temperature there was warmer.

The Hüppops found an even stronger correlation between early migration and a regional climate parameter known as the North Atlantic Oscillation (NAO) Index. That number reflects the difference in atmospheric pressure between a long-lived