

## Phenology Trends Observed in Selected Species

Location	Period	Indicator	Observed Change
<b>MAMMALS</b>			
Arctic regions	1993-2006	Caribou and wild reindeer ( <i>Rangifer tarandus</i> ) calving; plant growing season	Caribou spring migration is cued by day length, and typically matches up with the emergence of nutritious plants important for birthing and nursing mothers; however, with warming of 4.6 degrees Celsius, the growing season in Greenland has advanced in recent years by 2 weeks while caribou births have not changed timing. The mismatch of peak nutritious food and calving has been associated with declining offspring production and early deaths of calves.
Scotland - Outer Hebrides Islands	1986-2006	Soay sheep body size; plant growing season	Milder winters and longer growing seasons have made it possible for smaller sheep, which would otherwise succumb to harsher conditions, to survive, decreasing average body size in the overall population by about 5 percent over the two decades.
Canada - Yukon	1989-1998	North American red squirrel ( <i>Tamiasciurus hudsonicus</i> ) births; white spruce ( <i>Picea glauca</i> ) cone abundance	As average spring temperature increased by 2 degrees Celsius and precipitation decreased since 1975, red squirrels have advanced the date they gave birth by an average of 18 days, a change of 6 days per generation. Their primary food source, white spruce cones, has become more abundant over the same period. Early breeders had increased fitness, suspected to be related to higher food availability.
United States - Colorado Rocky Mountains	1975-2009	Yellow-bellied marmot ( <i>Marmota flaviventris</i> ) emergence from hibernation	As temperature has risen, marmots have moved their emergence from hibernation up by more than a month. In years when snowmelt comes later, there is a long lag time before the marmots can easily access food, which compromises litter size and frequency of reproduction.
<b>BIRDS</b>			
Europe	1947-2007	Migration synchrony of cuckoo birds ( <i>Cuculus canorus</i> ) and other migrants	The cuckoo bird is a parasite that lays its egg in other birds' nests; when the cuckoo chick hatches, it pushes the host bird's eggs out of the nest. Cuckoos now arrive at their European breeding grounds 5 days earlier than they did 40 years ago, close to the average advancement for other migrants flying in from sub-Saharan Africa. However, shorter distance migrants arrive more than 14 days earlier, making it easier for them to escape cuckoo bird parasitism while the pressure mounts on the long-distance flyers.
Denmark	1971-2005	Barn swallow ( <i>Hirundo rustica</i> ) breeding	With mean April temperature up 2.2 degrees Celsius, barn swallows have been able to lay their first group of eggs earlier, giving them a longer interval before their second laying of the season. Longer intervals between layings were associated with increased reproductive success.
Netherlands	1985-2005 (caterpillars and birds), 1988-2005 (trees)	Spring timing across 4 levels in a food chain: oaks, caterpillars, small passerine birds (tits and pied flycatchers), and predatory raptors (sparrowhawks)	Oak tree budburst hardly advanced, but the caterpillars that eat the emergent leaves are hatching two weeks earlier. The small birds (tits and flycatchers) that eat the caterpillars also advanced their hatching, but only about half as much. For flycatchers, this mismatch has been associated with population declines. At the top of the food chain, sparrowhawks that prey on the small bird fledglings did not hatch any earlier, though they are the least timing-dependent species in the food chain because they have a diverse diet.
Northern Canada - Hudson Bay	1988-2007	Egg-laying date for Arctic seabird, Thick-billed Murres ( <i>Uria lomvia</i> )	Sea ice break up advanced by 17 days, as did the peak bird population, indicative of peak food supplies. Yet median egg-laying date only advanced by 5 days, creating a gap between when eggs hatch and when the maximum number of adult birds are present. This gap is correlated with a reduction in nestling growth.

<b>MARINE</b>			
North Sea	1958-2002	Phenological changes at different trophic levels in marine pelagic communities	Timing of blooms and peak abundance at various levels of the food chain have shifted at different rates with warming. These timing mismatches among plankton, diatoms, and fish larvae are an additional source of pressure on cod fish populations declining from overfishing.
<b>AMPHIBIANS</b>			
United Kingdom - England	1978-2006	Common frog ( <i>Rana temporaria</i> ) and water frog ( <i>Rana lessonae/esculenta</i> ) spawning; newt ( <i>Triturus</i> spp.) arrival	Common frogs exhibited no change in breeding timing over the thirty years, while water frogs advanced by nearly 3 weeks between 1978-1990 and 1991-2006. Newts advanced their arrival time to the studied ponds by a month or more. Newts will eat frog eggs, but not enough data is available to tell if the timing changes affected predation.
North America - United States and Canada	early 1980s-late 1990s	Spawning of western toads ( <i>Bufo boreas</i> ), Cascades frogs ( <i>Rana cascadae</i> ), spring peepers ( <i>Pseudacris crucifer</i> ), and Fowler's toad ( <i>Bufo fowleri</i> )	Western toads at one Oregon site bred earlier, though not significantly; at the other sites they did not. None of the other three species of frogs and toads exhibited a significant trend toward earlier breeding. If the amphibians rely on insects that have adjusted timing with warming, there could be a potential mismatch.
<b>INSECTS</b>			
Japan - Nagano	1953-2002	Flowering of four cherry and apricot tree species ( <i>Prunus</i> spp.) and appearance of butterfly ( <i>Pieris rapae</i> )	Flowering advanced over the last three decades while butterfly appearance was delayed. Temperature increases varied at different times of the year: during the time when plants got their flowering cues, temperatures increased sharply, whereas when the butterflies were cued, temperatures did not change significantly. This could portend a possible disruption in pollination.
Finland	1993-2002	Parasitoid wasp ( <i>Cotesia melitaearum</i> ) and butterfly host ( <i>Melitaea cinxia</i> ) timing	Warmer temperatures in springtime led to earlier emergence of adult parasitoid wasps, putting them more in synch with their host butterfly, allowing for higher rates of parasitic colonization. Because most butterfly males pupate earlier than the females, a change in timing of the parasitoid could influence butterfly sex ratios.
<b>PLANTS</b>			
Germany	1961-2005	Fruit tree blossoming	Fruit trees advanced their blossoming by the following number of days: apricot - 17.2, peach - 15.7, plum - 14.1, pear - 13.7, apple - 12.5, sweet cherry - 9.6, sour cherry - 9.6. Earlier flowering puts trees at higher risk of damage from late frosts.
Italy - Western Liguria	1981-2007	Pollen season	With warming temperatures, pollen season for common allergenic plants has started significantly earlier: by 83 days for <i>Parietaria</i> plants, 46 for olive, 27 for birch, 26 for grass, and 9 for cypress. Total pollen counts increased for all but grass. At the same time the share of people sensitized (often correlated with allergy symptoms) to all pollen types except for grass also increased, while sensitization to dust mites did not change.
United States - Washington, DC metro area	1970-1999	Flowering dates of 100 plant species	In 89 of 100 species, average blossoming advanced by 4.5 days. Significant correlations were found between earlier blooming and changes in temperature, with nighttime temperatures increasing by 0.2-1.2 degrees Celsius. Only 11 species were flowering later. Plants advancing included false strawberry weed (unpopular with gardeners) by 46 days, and cherry trees (popular with tourists attending the annual festival) by 6-7 days.
United States - New England	1963-2003	Maple syrup season	Syruping season has shifted to start 8 days earlier and end 11 days earlier, resulting in shortening by 10 percent. Cold temperatures allow sap to form and warm temperatures allow it to flow; when nights warm earlier, trees begin to bud and sap is no longer usable for syrup.
<b>Source:</b> Table compiled by Janet Larsen, Earth Policy Institute, March 2010. For more information see <a href="http://www.earthpolicy.org">www.earthpolicy.org</a>			