CHAPTER 10
ONLINE CASE
STUDY

Effects of climate change on population dynamics

All species undertake seasonal activities, such as migrating, mating, breeding, and raising young. The study of the timing of such activities is called **phenology**. In recent years, numerous studies have examined the effects of climate change on species phenology. The initial seminal papers in this field (e.g. Beebee (1995) for amphibians; Crick et al. (1997) for birds) simply described long-term phenological changes. More recent studies have linked change not to the year itself, but to long-term environmental changes such as spring temperatures (e.g. Parmesan, 2006) or food supply (e.g. Buse et al., 1999).

Many bird species synchronize their breeding so peak demand for food by their offspring coincides with peak supply of suitable food sources, such as caterpillars. This makes sense given that, for some species such as blue tits *Cyanistes caeruleus*, each chick eats around 100 caterpillars a day, so adults need to find over 1000 for large broods. For similar reasons, moths and butterflies will synchronize laying their eggs so that maximum food demand from caterpillars when they hatch coincides with an abundance of new green leaves. This is vital, since as leaves, particularly tree leaves, age, their tannin content increases dramatically, and tannin is mildly toxic to caterpillars when ingested in large amounts. There is thus a direct feeding (and timing) link between these three trophic levels, as shown in Figure A.

The timing of leaf burst on trees, caterpillar emergence, and bird breeding varies annually. In cold years, leaf burst will be delayed, butterflies and moths that have overwintered as pupae will be delayed in emergence, and birds will delay nest building. In warm years, everything tends to advance. When change occurs at the same rate and at the same magnitude at all trophic levels, there is no issue. This is largely the case for species such as blue tits *Cyanistes caeruleus* in temperate woodland (Goodenough et al., 2010). However, when change occurs at different rates or magnitudes, the linkages between the trophic levels can start to decouple and a **phenological mismatch** occurs.

Phenological mismatches tend to occur because species in the second trophic level are not able to adjust as quickly as those in the first trophic level, and species in the third (and subsequent) trophic levels are less able again to adjust their phenology appropriately. In the case of the simple bird–caterpillar–tree link, leaf burst is directly controlled by temperature and light levels. Caterpillar hatching is controlled by the date on which the eggs are laid (which itself is dependent on the development of the adult inside the pupa), and temperature as eggs develop faster in warmer weather. For birds, the situation is more complex, as females need sufficient resources to form their eggs and then typically lay one egg per day until the clutch is complete, or nearly so, at which point there is around a 14–18-day incubation period depending on species. This means that the ability of birds to respond to changes in the abiotic and biotic environment is reduced.

If birds breed later than the ideal time, there is less food for the young. This means that reproductive success often declines substantially and adults have to work harder, which affects their survival. In severe cases, such as that seen for the pied flycatcher *Ficedula hypoleuca* in the Netherlands, which has declined by 90% largely due to climate change induced phenological mismatches (Both et al. 2006), this can have a substantial effect on population dynamics.

Online Case Study 10 Figure A The trophic level interactions between blue tit *Cyanistes caerileus*, caterpillars such as those of winter moth *Operophtera brumata* and trees including Pedunculate oak *Quercus robur*.

Source: *Cyanistes caerileus* and *Quercus robur* photographs by Anne Goodenough; *Operophtera brumata* caterpillar photograph by Jo Stafford, used with kind permission.

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