Impact of climate change on the insect communities

Paper-Zoology-4024: Insect Ecology

Unit-5

Introduction

The effects of climate change on biodiversity represent one of the most pressing challenges for conservationists in the 21st century. The ability of biodiversity to respond to contemporary climate change is much more of an unknown, given the potentially unprecedented rate and magnitude of projected increases in the earth's surface temperature. The stresses imposed by climate change on habitats, life histories and interactions between species may be such that widespread extinctions are inevitable unless climate change can be arrested or effective conservation measures can be adopted. Global modelling of biogeographic responses to climate change suggests that there will be sweeping changes to local ecosystems and communities.in turn it causes individualistic responses of species distributions to climate change.Biological systems respond to a wide range of environmental drivers, of which climate change is only one. Current declines in the global distributions, population sizes and genetic diversity of species are associated with anthropogenic processes such as habitat loss and fragmentation, pollution, overexploitation of natural resources and the spread of invasive alien species. Meta-analyses of studies conducted for a wide variety of taxa and geographical regions have shown convincing evidence that biological systems are already changing in ways consistent with climate change The two best-documented climate-related biological changes are shifts in species distributions and changes in phenology, with species shifting their ranges to higher latitudes and elevations, and life cycles beginning earlier in spring and continuing later in autumn associated with increasing temperatures.

The following evidences from the different studies will clearly lustrates the climate change effects on shifts in insect species distribution and phenology,

2.1 Shifts in species distributions

The geographical ranges of most species have upper and lower latitudinal limits, and often have lower and upper elevational limits within particular regions .These boundaries to geographic ranges are often set by regional climates that determine both the average availability of temperature, water and suitable conditions for growth and reproduction, and the most extreme conditions to which species and their essential biotic resources are exposed. As small, ectothermic organisms, insects are particularly sensitive to fluctuations in local temperature or moisture levels and, as a result, their distributions and habitat use are often closely related to climate.For example, **the northern range limits of British butterfly species** are closely correlated with summer isotherms, reflecting the availability of warm conditions for development and adult activity at upper latitudinal range margins. In addition, at increasing latitudes, butterflies become progressively more restricted to warm microhabitats, for example, by south-facing slopes, short vegetation and bare ground, emphasizing the temperature limitation of species as they approach their 'cool', upper latitudinal margins . There is also strong evidence that summer heat availability sets upper latitudinal limits to the distributions of many species of **Hemiptera in the Arctic and northern Europe** .In contrast, insect distributions may be limited at their lower latitudinal margins by excessive temperatures or inadequate moisture availability, either directly through limits to their physiological tolerance or indirectly through climate effects on larval host plants in the case of herbivorous insects. Perhaps as a consequence of these two distinct patterns at 'cool' and 'warm' range margins, Species richness is greatest in warm, wet cells in central Europe, and declines both towards cool northern Europe and the hot dry Mediterranean, probably reflecting both declines in plant productivity and direct effects of temperature on insect physiology . climate change is expected to shift the locations of suitable climates for species. Recent climate warming is expected to cause range shifts to higher latitudes and elevations. The first documented example of such a range shift was provided by work on **Edith's checkerspot butterfly Euphydryas editha** ,a non-migratory species that breeds in discrete localities in North America. By the 1990s, populations of E. editha had gone extinct from many locations, even though its larval host plants and apparently suitable habitat remained. Rates of local extinction were greatest at low latitudes and at low elevations, such that the average location of populations increased by 92 km northwards and 124 m upwards. In the same 100-year period mean annual isotherms moved 105 km northwards and 105 m upwards, suggesting a climatic link that is supported by the mechanisms involved in local extinctions in this species.

Temperature and precipitation during spring determine:

(i) whether E. editha adults emerge at a time when conditions are reliable for flight and reproduction

(ii) whether larvae reach diapause before summer host plant senescence. Drier, hotter and more extreme or unpredictable climatic conditions increase extinction risk at low latitudes and elevations,leading to a northward and upward shift in the average latitudes and elevations of populations.

One of the first multispecies studies of range changes associated with climate change also showed a predominant pattern of poleward shifts in butterfly distributions. Species ranges shifted northwards during the 20th century for 22 (63%) of 35 non-migratory European butterflies that had data for both northern and southern margins. Only two of the species showed southward shifts, and regional climate warming is the most likely explanation for the predominant pattern of colonization at upper latitudinal margins and/or extinction at lower latitudinal margins. For the species whose ranges shifted polewards, 21 (96%) showed northern range margin expansions and only 8 (36%) showed southern margin contractions.

Butterflies have been valuable model systems because of a wealth of historical data about their distributions, and because they depend on thermal conditions throughout their life cycles. Insects vary greatly in their habitat use, thermal physiology and dispersal capacity., Many species may be suffering declines at their warm margins that go undetected because their regional populations persist but shift to higher elevations. Two studies have shown recent increases in the average elevations of atlas grid cells occupied by butterfly species. In Britain, four butterfly species at the southern margins of their distributions have gone extinct from low-elevation 10 km grid cells and colonized high-elevation cells, leading to a mean increase in elevation of 41 m between pre-1970 and 1999 (Hill et al., 2002). In the Czech Republic, the average altitude of occupied **atlas grid cells (~11 × 12 km)** increased significantly for 15 butterfly species between 1950 and 2001, with 10 species retracting from low altitudes, 12 expanding at high altitudes and a mean upward shift of 60 m. Actual recent changes in species' elevational ranges may be even greater than recorded in studies based on grid cells, since such cells may include wide altitudinal variation, particularly in mountainous regions. Research on the elevational associations of butterflies in the Sierra de Guadarrama (a mountain range in central Spain) showed that the lower elevational limits of 16 species that were restricted to high altitudes (i.e. species at their warm range margins) rose on average by 212 m (± SE 60), accompanying a 1.3°C rise (equivalent to 225 m) in regional mean annual temperature between 1967–1973 and 2004.

Table 11.1. Examples of evidence for recent climate-related distributional shifts in insect species.

Evidence for climate-related range shift Taxa (Location) References

(a) Multispecies correlational studies in warming climates:

Poleward latitudinal shifts: Example: Butterfl ies (Europe)
expansions at upper margins; Example:Odonata, Orthoptera,
contractions at lower margins; Example: Hemiptera, Lepidoptera,
increase in average latitude. Example:Coleoptera (Britain)

Upward elevational shifts:

colonizations at upper margins; Example: Butterfl ies(Britain,Czech Republic;Spain)
extinctions at lower margins; Example: Odonata, Orthoptera,
increase in average altitude. Example: Hemiptera, Coleoptera(Britain)

(b) Mechanistic studies

(1)Extinctions at low elevations/ latitudes linked to rainfall decline and temperature increase; shift poleward (mean + 92 km) and upward (mean + 124 m). Example: Butterfly Euphydryas editha(Western North America)

(2) Extension of upper latitudinal margin linked to increased overwintering survival at warmer temperatures. Example: Bug Nezara viridula (Japan)

(3)Extension of upper latitudinal margin linked to warmer temperatures and higher humidity, increasing egg hatch and population size.

Example: Bug Philaenus spumarius

(4)Extension of upper latitudinal margin linked to increased overwintering,survival at warmer temperatures; possible role of increased growth rate and voltinism in warmer summers.

Example:Butterfly Atalopedes campestris (Northwest, USA)

(5)Extension of upper latitudinal margin (+87 km) and upper elevational margin (+110–230 m) linked to: (i) increased winter larval survival; and (ii) increased summer adult dispersal at warmer temperatures.

Example: Moth Thaumetopoea pityocampa (France, Italy)

(6)Extension of habitat range linked to microclimate warming, resulting in increased habitat availability and habitat connectivity, permitting range expansion. Example:Butterfly Hesperia comma (Britain).

The close correlation between temperature increase and changes in lower elevational limits, coupled with the fact that the larval host plants of the study species were widespread in the region (and that widespread butterflies which used the same larval host plants showed no elevational range shifts), implied that climate rather than direct habitat change was the most important driver in the system.it appears that climate change and habitat decline have been equally responsible for local extinctions near their range margins.

2.2 Shifts in phenology

In addition to the shift in space of species distributions, recent climate change has led to an ecological shift in time, with **changes to the seasonality of species' life cycles** (phenology). Phenological studies have predominantly shown species becoming active, migrating or reproducing earlier in the year, associated with increases in temperatures that lead directly to increased growth rates or earlier emergence from winter inactivity .Recent reviews of such studies show mean advances in the timing of spring events by 2.3–5.1 days per decade. Increasing temperatures have also allowed a number of species to remain active for a longer period during the year or to increase their annual number of generations. Long-term data from several insect-recording schemes in Europe and North America have provided evidence for advancement in appearance dates of adult insects as annual temperatures have increased **(Table below).** In Britain, the annual first appearance dates from 1976 to 1998 for 28 out of 33 butterfly species were negatively related to temperature for at least 1 month of the year (i.e. earlier appearance at higher temperatures), and an increase in temperature of 1°C led to an average advance in first flight date of 4.5 days. Conditions during early spring seem to be particularly important, with 22 species appearing significantly earlier associated with high February temperatures. The appearance dates of 11 species became significantly earlier in more recent years, even when taking account of monthly temperatures, suggesting either a progressive effect of some additional climatic or host plant effect or an evolutionary change. First appearance by butterflies has also advanced in California (North America) and Catalonia (Spain) associated with higher temperatures and lower rainfall in winter or spring. There is a similar negative relationship between temperature and insect appearance dates in Austria, with three butterfly species, the bee Apis mellifera and the cockchafer Melolonthus melolonthus showing 3- to 5-day advances associated with 1°C warmer February–April temperatures. However, in this case there was no temporal trend for earlier emergence, perhaps because population sizes of the species declined over time, leading to later first observations. Mean flight dates (the estimated date of peak abundance during the adult flight period) for the first annual generations of species have advanced in conjunction with advances in first appearance date. For example, the peak of the first generation of 104 common microlepidopteran species in the Netherlands advanced on average by 11.6 days between 1975 and 1994, accompanying a 0.9°C increase in annual mean temperature. In univoltine species, mean flight date is closely correlated with first appearance date, but multivoltine species may increase their number of generations following early first emergence. **Changes in insect phenology with**

year-to-year changes in temperature are mirrored by geographical relationships between phenology and regional temperature. For example, mean peak flight date for microlepidoptera is 5.1 days later in the north than in the south of the Netherlands, reflecting a 0.9°C difference in mean annual temperature. Insect emergence date also becomes delayed at higher elevations in mountainous regions, potentially restricting species to shorter periods of adult activity .

Table shows the Changes in annual appearance dates of insects associated with climate change.

Taxon	Location	Time period	Temperature increase	Change in appearance date
Butterflies	Britain	1976–1998	1.5°C (Feb–Apr mean) 1°C (May–July mean)	Advance, 26/35 spp. (13 significant, mean 8 days per decade)
Butterfly (Pieris rapae)	NE Spain	1952–2000	1.4°C(annual mean)	Advance, 11.4 days
Butterflies Stefanescu et al. (2003)	NE Spain	1988–2002	1–1.5°C(Feb, Mar, June mean)	Advance, 17/17 spp. (5 significant, mean 4.1 weeks)
Butterflies	California	1972–2002	1.2°C (annual daily max.)	Advance, 16/23 spp. (4 significant, mean 24 days)
Bee(Apis mellifera); Butterflies (*Aglais urticae,* P.*rapae, Gonepteryx rhamni*	Austria	1951–1998	1.3°C (Feb–Apr mean)	Delay, 3–7 days