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Effects of Climate Change on the Biology and Distribution of Insects

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ABSTRACT
This review summarizes the main effects of climate change on insects described by numerous authors. Among the possible effects, the hight associated temperatures stand out, which influence the dynamics of their populations through effects on survival, life span, fecundity and dispersion. Most insects have short cycles, high reproductive capacity and mobility, so their physiological responses at increasing temperatures can produce rapid and large-scale population changes. The response of each species depends on its geographical distribution, trophic level and natural history. Populations in medium to high latitudes benefit more from higher temperatures through faster development and increased survival. Less is known about the effects on tropical species. A small increase in temperature will extend the northern and southern limits of the tropics and temperate regions, and with it the geographical distribution limits of many insects, particularly those vectors of diseases. Mortality can drop with warmer winters, and lead to migration towards the poles. The physiological effects on insects can be indirect, through trophic interactions (i.e. host plants and natural enemies). Insects stand out in documented cases of distribution expansion due to climate change.

KEYWORDS: Insect distribution, acuatic insects, insect vector

EFFECTS ON THE DISTRIBUTION OF INSECT SPECIES

Invertebrates are very sensitive to climate change, as they do not regulate their temperature. Thus, many insects are affected by extreme climates (droughts, heat waves or periods of cold). The tropics harbor the greatest biodiversity, but when warmed by climate change and deforestation they can dry up or fragment, until many insects are not allowed to live (Williams et al., 2003), especially in areas with a high risk of extinction of species, with very close host-plant interactions, or that live in micro-environments (Lewis, 2006).

The distribution of insect species depends on their specialization (range of host plants and habitat), mobility, and other conditioning factors (Régnière 2009).

Bebber et al. (2013) collected information on hundreds of insects and diseases, and estimated an average of 2.7 ± 0.8 km per year of approach to both poles since 1960, although with a lot of variation between groups of spp.

Although butterfly species are declining in the UK, some are increasing (Thomas 2005, Franco et al., 2006). Butterfly species in England decrease faster in the south, while those distributed in the south are expanding to the north (Conrad et al., 2004). According to Thomas (2005), in Great Britain the northern limit of most species of butterflies is a diffuse line between 4 and 8ºC. However, it is the juveniles, not the adults, who define the climatic limits of insects (Dennis 1993, Thomas & Clarke 2004).

Some insects in Canada have displaced their distribution to the north, such as the defoliating caterpillars *Lymantriamonacha* (L.), *L. dispar* (L.) and *Choristoneurafumiferana* Clemens (Vanhanen et al., 2007). The same thing has happened in Europe with the pine processionary, *Thaumetopoeapityocampa* Schiff. (Battisti et al., 2006), the geometrids *Operophterabrumata* (L.) and *Epirritaautumnata* (Borkhausen) in Scandinavia (Jepsen et al., 2008) and the cabbage moth *Plutellaxyllostella* L. (Coulson et al., 2002). In this last moth, the greater movement of masses of warm air to the north has caused its arrival in the Norwegian islands of Svalbard in the Arctic Ocean, more than 800 km from the northern limit of its normal distribution in western Russia.

EFFECTS IN THE DISTRIBUTION OF INSECT VECTORS OF DISEASES

Several spp. of Culicidae that transmit malaria, dengue, Zika virus, chinkunguya, viral encephalitis, filariasis, West Nile disease, etc., have a tropical and subtropical distribution. An increase in temperature will lead to an increase in their adaptation areas and, therefore, to a higher incidence of the diseases that they transmit. Two examples. In 2016, local cases of Zika virus were detected in Florida. In the same year, females of *Aedesaegypti*with eggs were found in northern Chile, where they had been eradicated at the beginning of the 20th century. This greater geographic distribution can also occur in the case of hematophagousredviids that transmit Chagas disease, endemic in many countries of the Americas.

EFFECTS ON THE DIVERSITY OF SPECIES

The richness of insect species is increasing in the cold regions of the globe (Andrew & Hughes 2005). For Parmesan et al. (1999), the geographical distribution of insect species seems to be undergoing two simultaneous modifications: expansion in the extreme north and contraction in the extreme south, in their respective limits of latitude and altitude.

GENETIC ALTERATIONS FOR CLIMATE CHANGE

Climate change is rapidly affecting the genetic structure of insect species. For example, very rapid morphological changes have been seen in short periods (one decade), in flight capacity (Hill et al., 1999, Thomas et al., 2001), cycle variations, induction of diapause (latency) (Burke et al., 2005), physiology of development (Rank and Dahlhoff 2002), and cold tolerance (Calosi et al., 2008).

EFFECTS ON AQUATIC INSECTS

Aquatic invertebrates, which live in relatively narrow ranges of temperature, have been more affected than terrestrial species (Ward and Stanford 1982, Master et al 2000, Woodward et al., 2010), and their richness is an indicator of water quality (Wright 1994).

Climate changes alter the cycles of aquatic insects (Woodward et al., 2010), affecting not only their metabolism, rate of growth and development, but also their ability to survive in habitats where temperature variations exceed their thermal tolerance range.

As the temperature of water varies in depth and in time, the thermal tolerance of aquatic insects determines variations in their distribution (Ward and Stanford 1982, Woodward et al., 2010).

In the Northern Hemisphere, large-scale thermal changes are affecting the phenology, development and activity of aquatic insects (Parmesan 2007, Richter et al., 2008).

ASYNCHRONY BETWEEN PLANTS, HERBÍVOROUS INSECTS AND THEIR NATURAL ENEMIES

Plants serve as food for short seasonal periods, so their phenology, associated with the availability of moisture in Mediterranean and tropical areas, and temperature in temperate/boreal areas, are vital for many insects, especially those univoltine. The synchrony of plants and insects is vital in areas with marked seasonality. When a host plant leaves being available, insects migrate to neighboring plants. In temperate regions, oligophagous and polyphagous insects exploit a seasonal sequence of neighboring host plants. In seasonal environments there are often mechanisms of synchronization such as diapause or photoperiodic development inhibition. Temperature can induce changes in the duration of the cycle (rate of development), voltinism, density, size, genetic composition, intensity of use of the resource and in the geographical and local distribution, and therefore in colonization and extinction (Bale et al. 2002, Stireman et al., 2005, van Ash andVisser 2007).

Phenological changes linked to metabolic processes in aquatic insects could affect the synchrony of key stages in life histories and the availability of food resources or environments, and cause imbalances and possible local extinctions of aquatic insect populations (Menzel et al., 2006, Richter et al., 2008), andchanges in the structure of these communities and in the geographical distribution of some spp. (Winder and Schindler 2004, Ryan and Ryan 2006, Woodward et al., 2010).

THE CASE OF FRUIT FLIES IN CHILE

Fruit flies are quarantine pests for Chile. However, the Mediterranean fruit fly *Ceratitiscapitata*Wiedeman is detected in the central valley almost every year. Its detection with pheromone traps and immediate eradication action have prevented its establishment. The possible establishment of *Anastrephasuspensa*(Loew) and *Bactroceradorsalis* (Hendel) in the country was evaluated with the CLIMEX software (Valenzuela 2011, Araya 2012). This study concluded that both flies could only be established by increasing temperatures due to climate change, so in the meantime, their expensive trapping with sexually attractive pheromones is not justified.

CONCLUSIONS

The increasingly abundant information on the effects of climatic changes on insects in numerous studies leads to the conclusion that these changes affect them, and therefore human beings, and therefore every effort should be made to avoid, or at least minimize, this climate modification.

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