

# Climate change impact on Italian butterflies

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SUMMARY - Climate change impact on Italian butterflies - The main purpose of this paper is to evaluate the effects of current climatic variations on butterflies. The decline of Lepidoptera is involving the whole of Europe, and is reaching alarming proportions in Germany, Netherland, Belgium and Great Britain. Out of 280 Italian species, 21 are facing extinction. Our data shows that since 1798, at least 277 Italian populations of butterflies and zygenids have become extinct. The extinctions caused by climate change are 32.4% (90 populations) before 1950, rising to 48% in 2000. In addition, 67.6% of butterfly population extinction seems to be attributable to habitat modification. The results show a decrease of hygrophilous species since 1950 due to higher temperatures and lower water contributions. Climate change produced also range expansions at high elevations and latitudes and phenological variations on daily movements. Global warming has also promoted the arrival and expansion of numerous alien species (i.e. *Cacyreus mashalli*, a south African lycaenid, which is now widespread in Italy even at high altitudes).

Key words: biodiversity, extinctions, climate change, conservation, Italy

## 1. A VARIABLE CLIMATE

The climate of the Earth's globe, as any characteristic of the Universe, is in constant evolution.

Already in the 1920, Milutin Milankovitch had demonstrated the existence of long terms climatic variations, of the order of thousands of years, related to changes in the Earth's orbit.

To these factors, others have been added more recently (cf. for example Hays et al. 1976), both of natural and anthropogenic origin, such as variations in the solar constant and in the global oceanic circulation, or as the increase in the concentration of greenhouse gases in the atmosphere.

Each factor has a different periodicity, and the apparent irregularity of the climate derives from the interaction of these periods. Around 1000 AD, when Leif Erikson (perhaps) first reached America, Greenland was very green and the climate overall mild.

Cornwall was the "corn wall" and grapes were grown there. The subsequent cooling led to the so-called "little ice age" which developed in our latitudes from 1300 to 1850. The glaciers of the Alps then reached their maximum historical extension. Today we are observing the progressive warming of the globe. The factors of natural origin, however, do not seem to be sufficient to explain the speed with which the climate is changing. According to the fourth report of the IPCC (International Panel on Climate Change), climate warming is now an unequivocal reality, closely linked to the consumption of large quantities of fossil fuels and large-scale deforestation (IPCC 2007). The direct consequence is a high increase in the concentrations of CO<sub>2</sub>, methane and other greenhouse gases, which will help determine the fastest climate change since the last ice age. Over the past hundred years, the Earth's climate has experienced an average temperature rise of about 0.74 °C. Climate models predict, by 2100, a further increase in average temperatures, between 1 ° and 3.5 °C, together with changes in the distribution and variability of rainfall (IPCC 2007).

## 2. THE DECLINE OF DAYLING LEPIDOPTERS

Insects are characterized by short generational times and a high reproductive rate. Are also organisms generally ectothermic, whose life cycle is whose survival are strongly influenced by temperature.

These characteristics perhaps make them the zoological group on which the effects of short-term environment changes are more easily identifiable.

Butterflies, in particular, being - among the other - conspicuous and well known, are especially suitable for carrying out studies effects of environmental changes and have been shown even better indicators of birds or green plants (Thomas et al. 2004).

The Italian fauna includes 280 species of daytime butterflies.

The data on the Italian distribution of diurnal butterflies are relatively abundant, also thanks to the vast bibliography, which includes over 2000 works. Recently the Ministry of the Environment sponsored the creation of a database that, after many revisions, counts today about 200,000 historical data. Only two versions "in progress" of that databases have been published, the most recent of which dates back to 2006 (Balletto et al. 2006a, 2006b). Mostly the Italian species are well known from a taxonomic, chorological, biological and ecological point of view.

Italian diurnal butterflies inhabit the entire range of terrestrial environments, from sea level to higher altitudes, even if in Italy relatively few of them can reproduce above 2500 m. The species linked to the various vegetational horizons, in fact, are quantitatively very different from each other. Beginning from higher altitudes, 47 species are widespread only, or above all, above the limit of the arboreal vegetation and must, therefore, be considered eu-alpine. Among others, about ninety are linked to the mountain horizon.

Of the latter, about half gravitate mainly on that upper (horizon of beech and fir trees, more rarely at that of Turkey oak), the remaining ones on the lower one (horizon of oaks, or hills).

Few species, such as *Colias hyale*, *Maculinea alcon*, *M. teleius*, *Euphydryas aurinia* (s. Str.), *Coenonympha oedippus*, are lowland and inhabit only the Po Valley.

The exclusive eu-mediterranean entities, exclusive of the coastal strip, are about a dozen.

From a more general point of view, it can be said that diurnal butterflies are very often ecologically ecotonal and only rarely are they related to stable climatic type environments.

In other words, just a little less 10% (25 out of 280) of our species inhabit the horizon alpine or is characteristic of forests; the other 90% live transient environments.

The available data show that diurnal butterflies are in decline everywhere in Europe: as many as 21 species, for example, are extinct in Belgium and 5 have disappeared from Great Britain in historical times. In Italy it could be at least one extinction event has occurred (*Lycaena helle*), but the data is not completely certain.

During a study sponsored by the Ministry of the Environment and entrusted to the Italian Zoological Union, it is estimated that the species threatened with extinction in Italy are 21 (Balletto et al. 2006a).

Species of the alpine horizon and truly forest species are generally the least threatened (Balletto 2005). In fact, an important problem is represented from the species of the meadows, which, once abandoned, quickly turn into woods.

Among the latter, the species at higher short-term risk of extinction are then those strictly plain. The butterflies of the genus *Maculinea*, finally, given their very particular larval biology, not only need good conditions for the adults, larvae and host plants, but also for the ants that host them during the winter period.

The main causes of the threat are identifiable in the removal of habitats and changes in the use of soil and agronomic practices. Such transformations generate fragmentation and isolation, thus increasing the probability that dangerous events may occur.

To these is added the key role of changes in climatic conditions in the decline of butterflies.

The effects of the action of this last factor, however, are sometimes difficult to separate from those of habitat transformation.

The climatic changes have already begun to have repercussions on the flora and fauna of the whole world, as is clearly suggested by many simulations and projections, based on long-term studies (Thuiller et al. 2005, 2006; Kühn et al. 2008). Changes in distribution, in the extension of the areas, in phenology, fitness, population dynamics and in the consequent probability of extinction have already been recorded for plant and animal biodiversity and in different ecosystems.

This will lead, locally, not only to changes in the composition and structure of the biocenosis, but also in the functional balances of ecosystems, determined, as is well known, by the interactions between communities living (biotic factors) and chemical-physical parameters of the environment (abiotic factors).

However, a complete understanding of how climate change affects communities does not yet exist: time series are often scarce, particularly for invertebrates and some ecosystems, including mountain ones. The comparison between recent data and historical data is not always easy: the latter have not always been collected in a rigorous way and are sometimes difficult to interpret.

A favorable climate can determine the growth of a population and its expansion towards other favorable habitats, while harmful climatic events are among the causes of annual fluctuations in Lepidoptera populations (Warren 1992). This can be done by:

- displacements of range (latitudes or higher altitudes);
- changes in phenology.

During the 20th century, 34 relatively mobile species out of 54 analyzed in Great Britain underwent northward displacements at their northern limit (Parmesan et al. 1999).

### 3. THE COMMUNITY OF BUTTERFLIES AND CLIMATE CHANGE

Rocci (1911) was the first author to take over the decline of some species of Italian butterflies. Evidence of this phenomenon in Italy were subsequently accumulated over the years by various authors (from Storace 1952, up to Scalercio et al. 2006). As of 1798 at least 277 populations of diurnal butterflies and zigenids existed extinct.

Although most of the extinction is attributable to changes in land use (67.6% of extinctions), climate change has been directly or indirectly responsible for many extinctions equal to about one third of the total. Most of them occurred between 1901 and 1950.

The most affected by this phenomenon are a large part the population of thermophilic species whose habitat has undergone reforestation or urbanization. Extinctions apparently caused by climate change are 32.4% (90 populations) until 1950, but the extinction rate attributable to this lawsuit is increasing and has reached 48% in 2000. Until 1950 there were no significant ecological differences between the extinct species caused by climate change. Recently we are witnessing a decrease in the quota of hygrophilous species, affected by the heating and lower water intake.

As expected, the effect of climate change was more perceived by populations at the margin of the areas in which their species lives (86% of extinct after 1950) which therefore have a greater number of extinction probability, while extinctions due to habitat changes cannot be correlated with the biogeographical pattern of the species.

The mechanism on the base of the extinction process due to climate changes is still partially unclear. Although the number of extinctions prior to 1900 is low, our data shows that climate change would not be a new and recent cause of decline of daytime butterflies, but that their effect is present long since. The first extinct populations for this cause date back, in fact, to the last century while the peak of extinctions ranks between 1900 and 1950. Also a majority of extinctions caused by climate change concerns thermophilic species. Although it is easy to imagine that extinctions follow the succession of climate change with some delay, and, at least in some cases, it can be inferred that they are

probably related to changes in rainfall regimes, not all of them come fully explained by our simple perception of a Planet that is progressively and rapidly overheating.

### 3.1 SPECIES THAT BENEFIT FROM GLOBAL WARMING

Global climate warming allows for the natural expansion of thermophilic species and the stabilization of alien species, eg. *Danaus chrysippus* and *Cacyraeus marshalli*.

The chances of survival lie in the ability of individual species to adapt to new conditions, varying, for example, the voltinism, the length of the flight period and the distribution (Pollard et al. 1993).

Invasive species have certainly benefited in their expansion from the mitigated climatic conditions. The lycaenid *Cacyraeus marshalli*, native species of southern Africa, has larvae that they feed on cultivated geraniums (*Pelargonium*). Its presence in Europe it was first observed in Mallorca in 1990; subsequently it spread first to mainland Spain, then to France and many other parts of Europe. In Italy was first observed in Rome in 1997.

Its expansion in the Peninsula was quite fast:

it was first observed in Sanremo in 2001, in Milan in 2002. In 2003, perhaps also due to the particularly sultry summer, it had already become the most common butterfly both in Genoa and in Turin. Its spread, now unstoppable, is limited only in part by the low temperatures winter. We recently investigated probabilities both in the laboratory (Quacchia et al. 2008) and in the field that this species can "naturalize" and also live at the expense of native wild geraniums (*Geranium* spp.), common in many hill and mountain habitats.

Our laboratory results show how the species can develop completely at the expense of *Geranium* spp., inviting us to reflect on the potential danger it poses to our biodiversity.

In particular it can represent a risk to the native species of lycaenidae which feeds on *Geranium* spp. such as *Eumedonia eumedon* and *Aricia* spp., species found in many areas in which we have ascertained the presence of *C. marshalli*.

### 3.2 POPULATION FACING LOCAL EXTINCTION

The influences of climate change can be observed also at the level of single populations.

Since 1997 we have been engaged in the study of biology and in the conservation of two populations of *Maculinea* (*M. alcon* and *M. teleius*). In particular, we evaluate the extent and the state of health by monitoring with the method of capture-marking-recapture (Nowicki et al. 2005), oviposition behavior (Bonelli et al. 2005) and relationships with the host ant (Barbero et al. 2002). Comparing the average temperatures recorded during the flight period (year  $t$ ) with the number of individuals captured the following year (year  $t + 1$ ) we observed how particularly sultry years (1997, 2003) lead to a net decline in the population the following year (1998, 2004), while temperate summers (2001-2002) favor its recovery (2002-2003). In fact, in extremely hot summer seasons (e.g. 2003) an asynchrony between the flight period of adults and the maturation of plants nurturers, such as to cause the death of many pregnant females with consequent decrease of offspring and therefore of adults in the following year. We also found a strong influence of high temperatures on the activity of flight with a shift and a substantial reduction of the same. This phase shift could compromise the matings and modify the relationship with the parasitoids, with consequences not yet assessable.

These observations are in agreement with what found in other geographic areas, where some species of Lepidoptera have been affected by the consequences of events of extreme climatic conditions (Parmesan et al. 2000). The frequency of such events seem to have increased in the last few decades and we can suppose a further intensification (IPCC 2007).

If hot summers occur for several consecutive years and as dry as those observed in 1997 and 2003, the two species of lycaenids (*M. alcon* and *M. teleius*) could not being able to survive since, as noted in other Lepidoptera that require specific habitats for their survival and are not very mobile (Woiwod 1997), a shift towards more latitudes or altitudes elevated would not be possible. It should be emphasized that for the *M. alcon* and for *M. teleius*, the Italy represents the limit southern area of the Europe.

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