The Big Trek Northwards: Recent Changes in the European Dragonfly Fauna

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Figure I. Broad Scarlet or Scarlet Darter (*Crocothemis erythraea*, male) – maybe the best studied dragonfly species showing range expansion as a result of climatic changes. Photo: J. Ott.

Dragonflies are one of the best invertebrate groups to document the effects of climatic changes: they are mobile, depend on terrestrial and aquatic biotopes and so give a good picture of biotope and landscape changes, their biology and ecology is well known, they are attractive animals and easy to determine and finally their expansion is studied already for a long time (Ott 2001, submitted, Hickling et al. 2005).

Since the first observation of climate change effects on the range expansion of *Crocothemis erythraea* and some other species (Ott 2001) mean-



Figure 2. Range expansion of Mediterranean and African Odonata in Europe - some examples.

while many more examples could be added. Here some very obvious examples are shown, which were compiled and analysed for the ALARM-project.

Crocothemis erythraea – the first tip of the (melting) ice berg

The first species showing very well the effects of climate change induced range expansion was already in the mid eighties and thereafter the Mediterranean species Broad Scarlet (*Crocothemis erythraea*, Figure 1). After becoming autochthonous first in different parts of southern Germany in the late seventies and early eighties it meanwhile populated all German federal states from south to north and in 2008 it arrived at the northern border to Denmark (Ott 2001, 2007, submitted).

The same process of northward expansion could be shown for all neighbouring countries, such as The Netherlands in the west or Poland in the east, it also arrived the United Kingdom crossing the Channel (Ott submitted). In addition, the species populated biotopes in higher elevations and also other biotope types, even mooreland waters are now settled. All these expansions are related with the increase of higher temperatures, no other reasons could be identified for these changes.

Other dragonfly species of Mediterranean origin expanding their range to the north

Beside *Crocothemis erythraea* a lot of other species with Mediterranean origin expanded their range in the recent years to the north which is shown in the following and in Table **I** and Figure **2**. For this analysis the distribution maps of the species published in Askew (1988) were compared with the actual situation (see Ott submitted) and maps published in Dijkstra & Lewington (2006), Boudot in Trockur et al. (in print), Boudot et al. (2009) and the websites of the French and Finish odonatological societies or organisations (www.libellules.org, www.sudenkorento.fi).

In this group there are damselflies (Zygoptera, 4 species), as well as dragonflies (Anisoptera, 9 species, plus 2): in total about 15 species from nearly all taxonomic families show a clear range expansion in the last two decades; some more may be included, when more data will be available in the future as a consequence of different ongoing dragonfly atlas projects in Europe.

The Africans are coming ...

Very recently a new process seems to have started: after the Mediterranean species populated more and more the central – and partly even the northern – parts of Europe, presently southern Europe is invaded by species formerly typical for Africa.

The Violet Dropwing (Trithemis annulata), a typical species all over Africa and the Middle East, formerly occurred only up to southern Spain and central Italy. But now it can be found even in southern France, having crossed entire Spain and also the Pyrenees, in Italy it now arrived in the area of Ferrara (Boudot et al. 2009). Another Trithemis species - the afrotropical Orang-winged Dropwing (Trithemis kirbyi) (Figure 3) - was not known for Europe at all, but then was discovered for the first time in the isle of Sardinia in 2003 by O. Holusa. After being discovered in 2007 also in southern Spain near Malaga by D. Chelmick, in 2008 for the first time larvae of this species were found proving its first autochthony in Europe (Cano-Villegas & Conesa-Garcia 2009).

The third example of an African resp. Asian species expanding its range to the north is the Black Pennant (*Selysiothemis nigra*), which is actually found up to the area of Trieste/Venice (Boudot et al. 2009) in the eastern part and up to Parma (M. Salvarani pers. comm. 2009) in the western part of northern Italy (Figure **4**).

Conclusion: Risks for the indigenous dragonfly fauna?

All these examples show a clear range expansion to the north: Mediterranean species to middle and northern

Table 1. Damselfly and dragonfly species of Mediterranean origin showing clear northern range expansions in Europe compared to Askew (1988).

Species name	Range expansion in
Coenagrion scitulum	France, Germany, Belgium, Luxemburg, also in the East, e.g. in the Czech Republic, new in the Netherlands
Erythromma lindeni	North-eastern France, parts of Belgium, northern and eastern Germany, new to Poland
Erythromma viridulum	North-eastern France and Netherlands, northern Germany, new to Sweden and the UK
Lestes barbarus	Central parts of Europe, becoming more abundant, new to the UK
Aeshna affinis	Northern France and Germany, Netherlands, new to the UK and Finland
Aeshna mixta	UK up to the central parts, new to Ireland, Sweden and Finland
Anax imperator	UK up to the central parts and new to Scotland, also new to Ireland, Denmark and Sweden
Anax parthenope	Northern France, Belgium, Netherlands, northern Germany and Poland, new to UK and Ireland
Boyeria irene	North-eastern parts of France, new to Germany
Gomphus pulchellus	Northern and eastern parts of Germany, also to Austria
Oxygastra curtisii	Rediscovered in Germany after more than 50 years
Crocothemis erythraea	All central Europe, new for the UK
Sympetrum meridionale	All central Europe, up to northern Germany and Poland
Species name	Increasing tendency of migrations/invasions, e.g. observed in
Anax ephippiger	Germany, also reproducing, and other central European countries
Sympetrum fonscolombii	UK, Ireland, northern France, Belgium, Netherlands, Germany, Poland, partly indigenous populations (second generation)



Figure 3. Orang-winged Dropwing (*Trithemis kirbyi*, male): new to the European fauna since 2003 and expanding in Andalucia, where it is indigenous. Photo: J. Ott.

Europe during the last two decades, and very recently also African species to southern Europe. This phenomenon only could be explained by the increasing temperatures, even if it is still unclear which are the main factors responsible for these changes (mean annual or summer temperature, increased sunshine, less severe winters etc.) – probably it is a combination of all these factors. Other factors, e.g. like the installation of new waters like gravel pits, only play a minor role and interestingly barriers, like east-west orientated mountain chains (e.g., Alps, Pyrenees), do not show an effect. Beside these range expansions dragonflies also show clear reactions in their biology: trends to a faster development of the larvae, trends to more generations and longer flight periods, as well as general changes in the phenology are reported for a high number of species (Ott 2001, 2008, submitted, Hassel et al. 2007).

On the contrary, no species until now was reported expanding its range into the south as a result of climatic changes. But there are some first indications that several so called Eurosiberian species show range contractions or local and regional popu-

lations are extinct (Coenagrion hastulatum, Aeshna juncea, Somatochlora arctica & Leucorhinia dubia - see Ott submitted). These species, being specialists of moorland biotopes, are negatively affected by altered abiotic conditions in their biotopes: changing water tables, drying out of the waters, increase of water temperature etc. are strong negative impacts on their biotopes (Figure 5). In addition, there are also changes in the coenosis. For example, new predators are now present in the waters - such as the aggressive larvae of the invading Anax imperator – and can hinder the resettlement of the former mooreland coenosis

In the Mediterranean until now no replacement of indigenous species by African species is reported, but here the lack of precipitation – in particular in the future, see the ALARM-scenarios – will have severe effects on all kind of waters (Figure $\boldsymbol{6}$). This means a higher risk for more or less all



Figure 4. Black Pennant (Selysiothemis nigra, male), now also found indigenous in northern Italy. Photo: J.-P. Boudot.

dragonfly species, as their live cycle depends on the waters.

Another – actually strongly increasing, but until present only poorly studied – risk for dragonflies are Alien Invasive Species (AIS). In particular invasive crayfish (e.g., *Orconectes immunis*, *Pacifastacus leniusculus*) do have without any doubt a negative affect on populations of autochthonous dragonflies, as most of the crayfish are omnivorous and/or carnivorous and also feed on dragonfly larvae.

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Figure 5. A water in the Palatinate in summer 2006, before drying out several mooreland species, like *C. hastulatum* and *L. dubia*, were present with big populations. Photo: J. Ott.



Figure 6. A small river (Vezzola) in Abruzzi Mountains (Italy) in fall 2007, dried out for a long time. Photo: J. Ott.