Meanbh-chuileag - the Highland biting midge

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What is a midge? The Ceratopogonidae are a group of small biting flies ('midges') with a world-wide distribution. Out of 60 genera, *Culicoides* is the most important in terms of its impact on man and livestock. These insects are a severe biting nuisance in many areas of the world and are also of considerable economic importance. There are 37 species in Scotland but one, *Culicoides impunctatus* Goethgebuer, outnumbers all others. This species is present throughout the whole of the summer in Scotland, coinciding with much of the country's outdoor industry, including agriculture, forestry, and tourism. The Ceratopogonidae are closely related to the Chironomidae, or non-biting midges, but can be distinguished by the presence of female biting mouthparts, short fore legs and characteristic dark markings on the membranous wings (see Figure 1), which are folded, scissor-like at rest or when feeding (see Figure 2). They are most commonly known as 'biting midges' but can also be called 'sandflies', 'punkies', 'no-see-ums', no-nos', 'moose-flies' or 'biting gnats', depending on geographical location. The Gaelic name for the Highland midge is *Meanbh-chuileag* (tiny fly) emphasising its diminutive, 1.4 mm wingspan.

The females of most species of biting midge have specialised mouthparts that pierce the hosts skin with finely-toothed mandibles and maxillae. These work in a scissor-like fashion to create a pool of blood, from which the insect feeds. Saliva, containing an anticoagulant to maintain the flow of blood, is pumped into the wound. The host's body responds to the midge's saliva by releasing histamine at the site of the wound,

Figure 2 *C. impunctatus* feeding on a human. *C. impunctatus* feeds by biting and feeding from a pool of blood and not sucking as a mosquito does. The insect in the Figure is engorged with blood and the abdomen is bloated. The blood-meal provides additional nutrients and blood-fed females can lay more eggs.

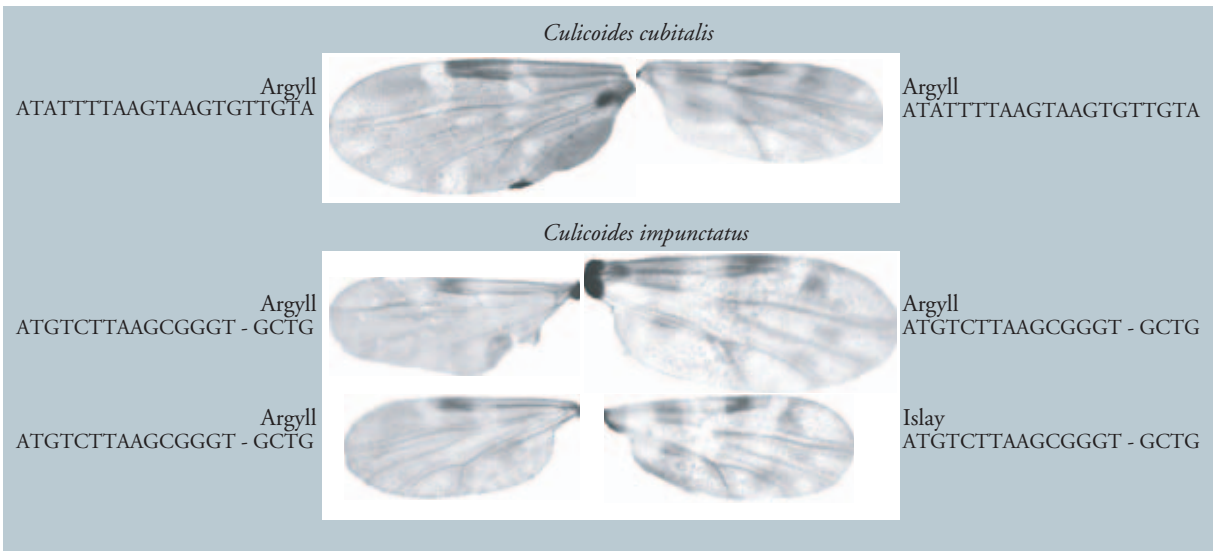

Figure 1 The Figure shows the wing patterns from a number of individuals from two *Culicoides* species: *C. cubitalis* in the top panel and *C. impunctatus* in the bottom. These patterns are one of the most important taxonomic features. Both species show a range of overlapping characters (size, venation, coloration) that makes accurate identification difficult. However, the rDNA sequences of the two species exhibit clear differences (inset panels).

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resulting in the characteristic itching and swelling of the midge bite. Left undisturbed, a female midge will feed for 3-4 min, taking an average of 2 µl blood (see Figure 2).

Ceratopogonid midges have a world-wide distribution, with the exception of the Arctic and Antarctic. There are approximately 5000 species in 60 genera. Members of four genera feed on the blood of vertebrates, with the most important genus being *Culicoides*. The remaining genera feed on the tissue fluids of other insects. There are more than 1400 named species of *Culicoides*, 50 of which have been implicated in vectoring various pathogens and parasites to man and other animals. These small flies are quite distinct from the longer and slender mosquitoes that have specialised mouth parts for piercing and sucking from blood vessels.

Midges in Scotland There are 37 known *Culicoides* spp. in Scotland. About 20 of these are mammalophilic with five regularly attacking man, including *C. impunctatus* (the 'Highland biting midge'), which is responsible for 70-95% of the biting attacks on humans. *C. impunctatus* probably occurs throughout the UK, breeding in acidic, boggy ground, although it is in Scotland that by far the largest numbers are found. Whether or not different races are present in the UK is unknown. Each species has specific requirements in terms of breeding ground, bloodmeal host etc., resulting in a characteristic distribution. For example, *C. obsoletus* Meigen (which will also bite man), is perhaps the most abundant *Culicoides* spp. in the UK, concentrated around domestic gardens, although it is outnumbered by *C. impunctatus* in western Scotland. Other species concentrate around farmland, breeding in animal manure (e.g. *C. nubeculosus* (Meigen)), whereas others are found around salt marshes and coastal regions (e.g. *C. maritimus* Kieffer and *C. halophilus* Kieffer). In addition to spatial separation, the *Culicoides* species in Scotland are also separated on a temporal basis. For example, whilst most species are crepuscular, with peaks of activity at dawn and dusk, *C. heliophilus* Edwards is most active during the daytime. Also, amongst the eight members of the '*pulicaris*' group of midges, the largest *C. delta* Edwards appears in May, *C. pulicaris* (Linnæus) and *C. punctatus* (Meigen) occur in late spring-summer, *C. lupicaris* Downes & Kettle and *C. grisescens* Edwards appear in late July/August and *C. impunctatus* can be found for the duration of the summer, appearing first in late May. *C. impunctatus* remains dominant in upland areas of Scotland and creates the greatest havoc with regard to agriculture, tourism and other outdoor industry during the summer months.

Midges are not a new phenomenon in Scotland. Midges have been found in 75 million-year old amber and their more recent history in Scotland has been eloquently described by Hendry[1], including Bonnie Prince Charlie's encounters with the 'mitches' whilst hiding in the hills after Culloden. Scotland's midge fauna was first described at the beginning of the twentieth century but it wasn't until the middle of the century when the Scottish midge problem was investigated more fully, with the University of Edinburgh's 'Midge Control Unit', established in 1952. This era produced some basic knowledge on the biology of midges in Scotland, particularly of *C. impunctatus*. More recently, after a lapse in research of more than 30 years, modern approaches to the midge problem have produced a wealth of information on their population dynamics and mating activity etc. These studies have highlighted a number of key areas in the midge's life cycle and aspects of its behaviour to which control measures could be addressed, allowing the formulation of a series of potential 'solutions' to the midge problem in Scotland (with possible extrapolation to elsewhere in the world).

***C. impunctatus* Biology** *Life cycle and population dynamics* The life cycle of *C. impunctatus* is the key to

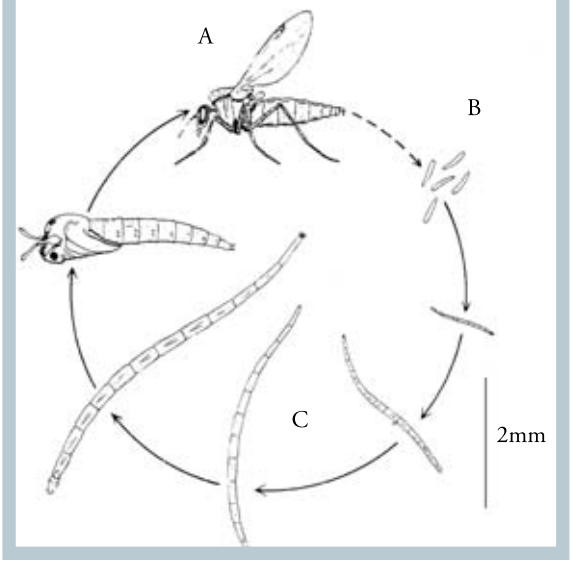

Figure 3 Life cycle of *C. impunctatus*. A: Adult female *C. impunctatus*.; B: batch of eggs (65-80 µm in breadth); C: 4 larval instars; D: pupa.

its success. Midges lay 30 - 100 eggs in the summer months on the surface of damp soil/vegetation. Egg hatch is rapid (< 24 h) and is followed by 4 larval stages which live as omnivores/detritivores in the water films of the surface layers of the soil. The final, fourth larva acts as the overwintering stage, followed by a short (1-2 d) pupal period in May/June (probably triggered by increasing day-length and temperature) and adult emergence (Fig. 3).

Studies have revealed that *C. impunctatus* lay their first (and largest) egg batch *without* taking a bloodmeal, instead using fat and protein reserves built up during the larval stages). This might be a key factor in the survival and success of *C. impunctatus* in what is often an extremely inhospitable climate, with few readily available bloodmeals. Both protandry (males emerging a few days before females) and bivoltinism (i.e. 2 generations per season) have been recognised for *C. impunctatus*, with a generation period of six weeks.

Genetic identity of *C. impunctatus* populations Several *Culicoides* species have been investigated for genetic differentiation. This has resulted in the identification of a number of morphologically similar, sibling species among vector midge populations that varied significantly in their levels of vector competence. These species include the *C. imicola* complex and *C. variipennis*. Figure 1 illustrates the difficulty of accurately identifying closely related *Culicoides* species. Wing patterns are one of the key features, but they can have a wide range of sizes and patterns. Insect pests of plants have many parallels with animal pests. Like mosquitoes aphids pierce plant tissues to reach nutrient supplies. In the process of doing this they can either acquire or pass on viruses. Eriophyid mites are smaller than midges, but they build up in vast numbers on plants causing crop losses. Eriophyid mites have a very limited range of characters with which they can be distinguished. Sensitive techniques have been developed at SCRI for identifying these cryptic species i.e. morphologically indistinguishable species of plant pest insects and mites and these have helped in the study of midges. These use both DNA analysis and ecology, generically referred to as 'molecular ecology'. The main method of analysis is to obtain DNA sequences from informative genes such as ribosomal DNA. Figure 1 includes DNA sequence from a small section of the ribosomal spacer regions of each midge. This type of information is usually easily interpreted when compared with morphology and the DNA sequences clearly grouped individuals from these populations as either *C. impunctatus* or *C. pulicaris*. The results of the complete analysis have yet to be published, but they indicate that there may indeed be races of *C. impunctatus*.

Economic impact of midges Much of the Highland's outdoor industry cannot be readily carried out in the 'midge season'. These industries include timber felling and tree planting, harvesting, and road construction and repair. Forestry and agriculture are integral parts of Scotland's economy and in addition to the many anecdotal reports of the misery midges can wreak with these activities, there are a small number of official reports. The Forestry Authority have estimated that of the 65 working days each summer, as much as 20% can be lost due to midge attacks preventing men from working. Ironically perhaps, there is far less information available on the effects of midges on the single largest input of income into the Highlands each summer; tourism. Hendry (1996) estimates that 13-14 million tourist trips are made to Scotland each year (mainly in the summer), valued at approximately £2 billion. Many caravan parks, campsites, tourist attractions etc. open only during the 3 months of summer, which thus dominate the local economy. Although again, most reports of midge attacks are anecdotal, it is clear that midges have the ability to restrict and even prevent many tourist activities. Some visitors are undoubtedly driven away, whilst others remain and suffer, being mentally unprepared and provided with no immediate relief other than to apply repellents and avoid the peak midge times. The exact impact of midges in Scotland on 'customer satisfaction' and the loss of income through visitors either leaving, not enjoying their holiday to the full or persuading friends against a visit to the Highlands is undocumented and presently, can only be guessed at.

A press article covering the launch of a 'midge festival' held throughout August 1998 in Argyll wrote of the midge that: "Throughout the 1990s the insect has sustained a highly skilled PR campaign" (Sunday Times, 7/6/98). This period of time has coincided with the introduction of 'midge forecasts' on local radio stations, questions in the House of Lords to the Scottish Secretary concerning Scotland's midge problem, and considerable press coverage (TV, radio and newspaper) of recent research initiatives directed at *C. impunctatus*.

Ecological impact of midges An area worth considering is what would happen to food chains if midges were removed. Midge numbers can be drastically

reduced by both unusually cold winters and very dry summers but what the effects are on the organisms which rely on them for food is unknown. From the existing data on prey-selection by bats and birds the effects, however, are likely to be minimal, perhaps resulting in a small shift in prey selection in areas of significant midge reduction. This would not be unusual, since the commonest species of bat in Scotland (i.e. pipistrelles) are know to feed unselectively on the available insects, as do many species of warbler and other passerines. Concerning the larval stages, biting midge larvae will only constitute a very small proportion of the total soil fauna and their overall input into the system is likely to be relatively small. It is also inconceivable that any midge control programme would completely remove these insects from the food chain.

The future Biting midges have traditionally been difficult to study, both in the field due to the often unpleasant habitats they live in and their biting activity, and in the laboratory, due to difficulties in maintaining them and also, problems with identification. They have also been the poor cousins of mosquitoes and other biting insects regarding research and development funding. In countries where they are primarily a biting nuisance, authorities are often reluctant to admit to their presence for fear of deterring visitors, particularly when there are no successful means of controlling midges. Concerning disease transmission, although vectors of some major livestock pathogens, biting midges are deemed to be relatively unimportant concerning human health. Recent advances in molecular taxonomy and identification (as reported here) and the application of state-of-the-art methods of investigating midge biology (e.g. determining host preferences, identifying novel attractants and repellents and further understanding the influence of climate on midge populations), however, are helping to bring biting midge research into the modern era and midges should be considered alongside other insects of medical and veterinary importance. Areas to concentrate on include the development of effective means of monitoring and control, the identification of taxonomic subpopulations of key species regarding their responses to control measures and their potential to act as disease vectors and also, the influence of climate on midge populations in relation to their changing threat to both human and animal populations.

[1.] Hendry, G. (1996). *Midges in Scotland*. Mercat Press, Edinburgh.