

Life cycle and phenology of *Carabus problematicus* Herbst, 1786 in Denmark (Coleoptera: Carabidae)

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The life cycle and the phenology of *Carabus problematicus* Herbst were studied in a Danish oak wood, Hald Ege, in central Jutland, by means of pitfall trapping and examination of ovaries.

Adult beetles were active from May to October, predominantly in May-June and August-September. The activity in spring was caused by beetles which had hibernated, and which had probably reproduced during the previous year. Newly emerged adults occurred from late July to early August; they reproduced in the autumn, mainly in late August and the first half of September. Consequently, in Denmark *C. problematicus* appears to be an autumn breeder with larval hibernation.

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Introduction

Life cycles of carabid beetles are often described on the basis of seasonal activity variations of the adults. According to Larsson (1939) carabids are either »spring breeders« or »autumn breeders« with adults or larvae hibernating, respectively. The annual activity pattern and the time of breeding, however, are influenced by climate and may accordingly vary in time and space. In *Patrobus atrorufus* (Ström), Refseth (1980) found that the breeding period shifted from autumn to spring with increasing altitude, and in certain species which normally have an annual life cycle, development may last two years in northern and alpine climates (Forsskåhl 1972, De Zordo 1979, Refseth 1984), as well as in temperate lowland habitats in years with unfavourable weather (Jørum 1980).

Carabus problematicus Herbst is an autumn breeder with overwintering larvae in western and central Europe (e.g. Drift 1959, Greenslade 1965, Hurka 1973). For Denmark and Fennoscandia. Larsson (1939) and Lindroth (1945) consider the species to be a spring breeder having summer larvae and hibernating as adults. A biennial life cycle, on the contrary, is described for a subarctic

climate in northern England (Houston 1981).

The discrepancies between these reports might be due to variation in life cycle and phenology with climate. It is possible, however, that the conclusions reached by Larsson (1939) and Lindroth (1945) were incorrect, the more so as they were based chiefly on inspection of museum collections of imagines and larvae, and not on examination of the breeding condition of the beetles. Thus, further studies of the life history pattern of *C. problematicus* in Scandinavia seem to be required. The present account describes the phenology and life cycle of the species in a Danish oak wood habitat.

Distribution and choice of habitat

C. problematicus primarily occurs in western Europe. In Denmark it is widely distributed in Jutland, less so in the easternmost parts. Except for Læsø it is absent from the isles (Bangsholt 1983).

According to Lindroth (1945) the species is decidedly xerophilous in Fennoscandia, occurring on heaths with *Calluna*, *Empetrum*, etc., sometimes also with sparse pine growth.

In Britain (Greenslade 1965) and in cen-

tral Europe (Gries et al. 1973) it is a eurytopic woodland species living on different kinds of soil and under highly varying humidity conditions (Drift 1959, Lauterbach 1964, Löser 1972); rarely does it occur on open heathland, where populations are probably maintained only by migration from adjacent forest habitats (Boer 1970).

In Denmark *C. problematicus* is confined to more or less dry, sandy soil; it occurs in open country as well as in woodland (Hansen 1968).

Study area and method

The investigation took place in 1979 and 1980 in Hald Ege, central Jutland (UTM reference: 32VNH25), an oak wood on poor, rather dry, sandy soil. Most parts of the wood have a layer of raw humus; only minor areas have mull soil. Oaks (*Quercus robur* L., *Q. petraea* Liebl. and *Q. robur* x *Q. petraea*) are the dominating trees, in some places growing in rather open, tall stands, but also forming low, dense, scrublike stands. The underwood is especially rich in juniper (*Juniperus communis* L.), but also honeysuckle (*Loricera periclymenum* L.) and alder buckthorn (*Frangula alnus* Mill.) are common. The most predominant plants in the field layer are bilberry (*Vaccinium myrtillus* L.), wavy hair-grass (*Deschampsia flexuosa* (L.) Trin.), May lily (*Maianthemum bifolium* (L.) Schm.), common cow-wheat (*Melampyrum pratense* L.) and hairy wood-rush (*Luzula pilosa* (L.) Willd.).

Beetles were sampled in pitfall traps, jars 7.5 cm in diameter and 12 cm deep, containing a 4% formaldehyde solution. The samples were taken on 4 study plots with different vegetation; at each site 3-4 traps were used, placed about 20 m apart. The traps were emptied at irregular intervals, usually two or three times a month during the summer. The trapping periods were April-December 1979 and April-October 1980.

Females were dissected in order to determine their breeding condition (Schjötz-Christensen 1961). Individuals with mature eggs were easily recognized; many specimens were in a poor state of preservation, probably because of too long sampling intervals, which made it impossible to decide

whether they were immature or old females which already had laid eggs.

Results

The activity pattern of *C. problematicus* in Hald Ege is shown in Fig. 1. The results are given as number of specimens caught per 100 traps per day (activity density; cf. Thiele 1977). Catches of newly emerged beetles and of females with mature eggs are indicated.

Beetles were active from May to October. Two peaks of activity were recorded, one in May-June and one in August-September. The spring peak was due to old beetles which had hibernated and which had most probably reproduced the previous year. A number of females caught during this period contained conspicuous corpora lutea; but, as stated above others were badly preserved and their state of gonad development could not be determined. In 1979 spring activity was high, starting about mid-May and lasting until the beginning of July. In spring 1980, however, only a few specimens were trapped.

After a summer period with low catches an increase in activity was recorded in late July and early August when newly emerged beetles occurred. The autumn peak of activity coincided with reproduction. Females containing eggs were most predominant in the last half of August and in the first half of September, which, accordingly, was the main breeding period. Some mature females could still be found in October.

Larvae showed little above-ground activity. Only two third instar larvae were trapped, both during 20 May-3 June 1979.

Discussion

The present investigation shows that *C. problematicus* has autumn propagation and larval hibernation in Hald Ege. This result does not correspond with information hitherto given on the life cycle in southern Scandinavia (Larsson 1939, Lindroth 1945), but it agrees well with findings from other parts of Europe.

A detailed account of the life cycle in Holland was given by Rijnsdorp (1980): Newly emerged beetles occur in July and in the beginning of August. Larvae occur from

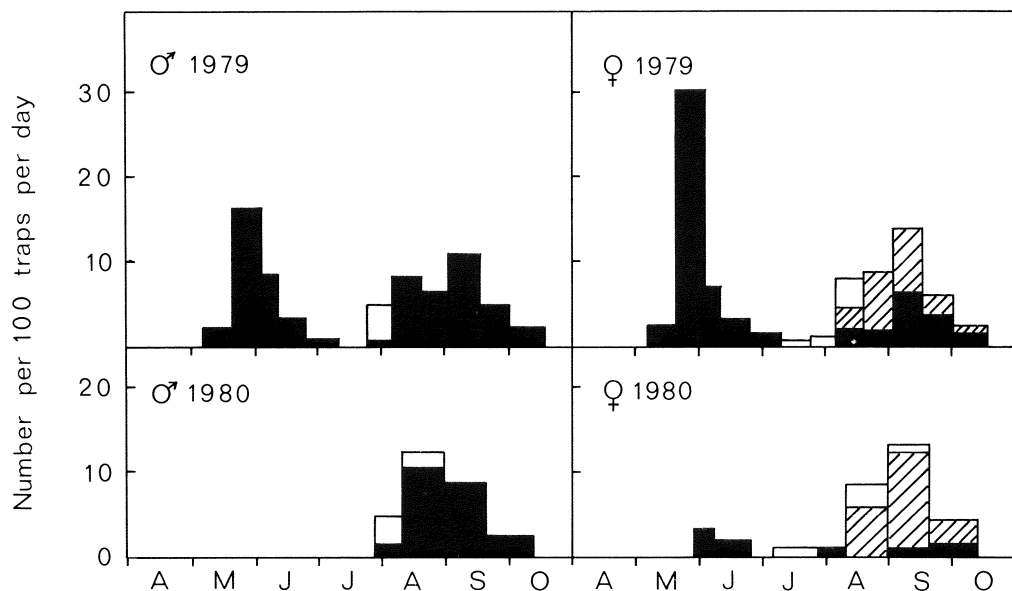


Fig. 1. Activity density (beetles caught per 100 traps per day) of *Carabus problematicus* Herbst in 1979 and 1980. The total number of beetles caught was 246 in 1979 and 72 in 1980.

Signatures

Black area: For males, all except newly hatched beetles. For females, immature as well as post-reproductive animals.

White area: Newly hatched beetles.

Hatched area: Females with ripe eggs.

Fig. 1. Aktivitetstæthed (biller fanget pr. 100 fælder pr. dag af *Carabus problematicus* Herbst i 1979 og 1980. Det totale antal fangne biller var 246 i 1979 og 72 i 1980.

Signaturer

Sorte arealer: For hanner, alle undtagen nyligt klækkede biller.

For hunner, umodne samt post-reproduktive dyr.

Hvide arealer: Nyligt klækkede biller.

Skraverede arealer: Hunner med modne æg.

the end of October to the beginning of June. Besides larvae, a number of old adults hibernate and resume activity in the following spring. Some of these beetles reproduce for a second time in the autumn. The results concerning the life cycle of *C. problematicus* in Hald Ege are in good accordance with those reported from Holland by Rijnsdorp. They also agree with data obtained from southern England by Greenslade (1965) and from central Europe by e.g. Kolbe (1968), Hurka (1973) and Krause (1974).

On the basis of the present study, and considering the fact that previously obtained results from Scandinavia were not based on inspection of gonads, it appears that in Denmark *C. problematicus* is an autumn breeder with larval hibernation.

Acknowledgment

I wish to thank Viborg Statsskovdistrikt for permission to work in Hald Ege.

Sammendrag

Livscyklus og fænologi hos *Carabus problematicus* Herbst, 1786 i Danmark (Coleoptera: Carabidae)

Løbebilleren *Carabus problematicus* Herbst er i Mellemeuropa en efterårsforplanter med overvintring på larvestadiet. Derimod er den hidtil blevet anset for at have forårsforplantning i Danmark og Fennoskandien, en formodning som har været baseret på registrering af imagines og larver i museumssamlinger, men derimod ikke på undersøgelser af gonadetilstanden hos imagines.

I årene 1979 og 1980 har jeg undersøgt artens livscyklus i Hald Ege (EJ; NH25). Indsamlingerne foregik ved hjælp af faldgrubefælder med formalin; fælderne blev tømt ca. 2-3 gange pr. måned. Hunnerne blev dissekeret, hvorved tidspunktet for æglægning kunne fastlægges.

Imago var aktiv fra maj til oktober, især forår (maj-juni) og efterår (august-september), Fig. 1.

Forårsaktiviteten, som var langt større i 1979 end i 1980, skyldtes gamle, overvintrede biller, der formentlig havde forplantet sig det foregående år. Højsommeren var præget af særdeles ringe lokomotorisk aktivitet. Den nye generation fremkom hovedsagelig i slutningen af juli og i begyndelsen af august. Den høje aktivitet i efterårsmånederne faldt sammen med tidspunktet for forplantningen; andelen af hunner med modne æg i ovarierne var størst i sidste halvdel af august og i første halvdel af september.

Larvernes aktivitet på skovbunden var yderst beskedne. Kun to 3.stadie-larver forekom i fælde-materialet, begge i perioden 20.5.-3.6.1979.

Undersøgelsen var vist, at *C. problematicus* i Hald Ege er efterårsforplanter med samme livscyklus som i Mellemeuropa. Denne livscyklus formodes at være den for arten normale i Danmark.

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