Oecologia Montana 1993, **2**, 19 - 22

Fluctuations in catches of *Epirrita autumnata*, (*Lepidoptera, Geometridae*) in eastern Finnish Forest Lapland.

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Abstract. Eleven light traps with a 500 W mixed light lamps were installed in virgin habitats in the Värriötunturi fell area, NE Finnish Forest Lapland (67°44'N, 29°37'E). The traps were operated daily in the years 1978-1992. The total catch of the autumnal moth *Epirrita autumnata* was 134,787 individuals, of which males amounted to 89,006 individuals. One large peak period fell into the years 1983-86, which made up 57.7 % of the total catch, and another seemed to be starting in 1992. No serious attack on the birches of the area occurred during this 15-year-period.The proportion of females stayed below or around 20 % in the low catches, but increased to almost 50 % during the mass occurrences. The synchrony of moth emergence with biotic and environmental factors is assessed.

Key-words: *Epirrita autumnata, Lepidoptera*, light traps, sex variable

Introduction

The autumnal moth *Epirrita autumnata* (Bkh.) is known to cause serious damage to birch trees, especially in the mountain birch forest zone of Lapland. Its caterpillars kill the birches over large areas of northern Fennoscandia at intervals of approximately 9 or 10 years, but the damage is not so serious at more southerly latitudes (Tenow 1972, Haukioja *et al* 1988, Tenow and Bylund 1989). In the area of eastern Itäkaira, eastern Finnish Lapland, the last serious catastrophe to be recorded in which its larvae defoliated the birches was in 1965-66 (Pulliainen 1976).

The fluctuation pattern of the species has been explained in terms of the defensive mechanism of its main food item *Betula pubescens* ssp. *tortuosa* (Neuvonen 1987, Haukioja 1990, Ruohomäki 1991 (and references cited), against parasites (Jussila and Nuorteva 1968, Nuorteva and Jussila 1969, Tenow 1972, Ruohomäki 1991) and against diseases (Tenow 1972). The previous winter temperature also seems to have had an influence on the following summer's catch, especially if there were heavy frosts (Tenow 1972).

The aim of this paper is to provide records of *E. autumnata* population fluctuations at one site in E. Finnish Forest Lapland over a 15-year period.

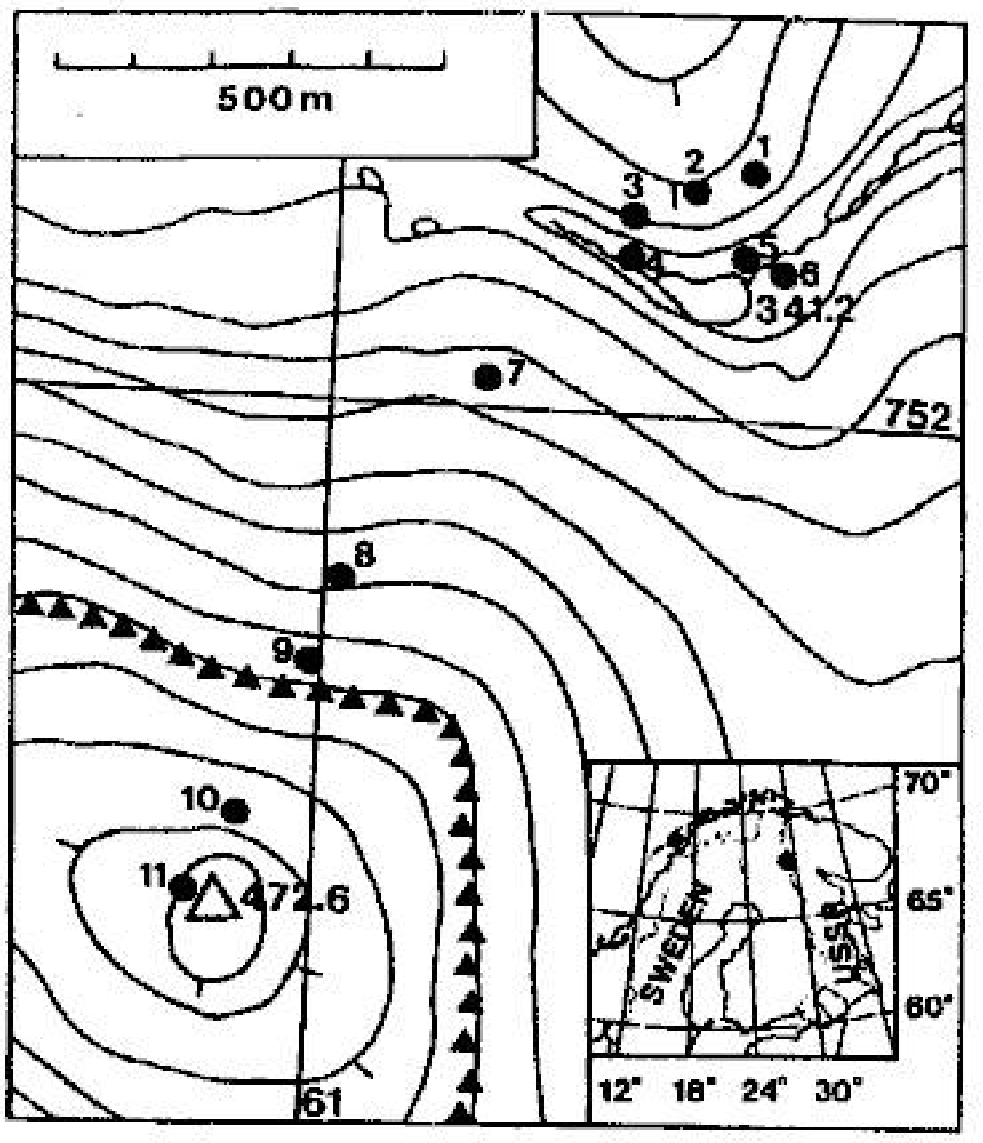

Fig. 1. Location of the study area in E Finnish Forest Lapland and sites of the light traps (1-11) in the Värriötunturi fell area. Coordinates = Grid 27°E and height above sea level.

Material and methods

Eleven light traps (Jalas 1970) with 500 W mixed light lamps were installed in the following virgin habitats in the Värriötunturi fell area, E. Finnish Forest Lapland (67°44'N, 29°37'E; Grid 27°E 751:60, 61; 752:61): (1) Three traps (Nos. 1-3 in Fig. 1) in a dry heath forest of old Scots pines *(Pinus sylvestris)*; (2) Three traps (Nos. 4-6) in a ravine covered by a spruce-dominated mixed forest *(Picea abies)*; (3) Three traps (Nos. 7-9) in a mountain birch forest *(Betula pubescens* ssp. *tortuosa)* on the northern slope of Värriötunturi; (4) Two traps (Nos. 10-11) on the treeless summit of Värriötunturi.

The lights (500 W blended light lamps) were switched on for the period 2000-0800 each night from mid-May to mid-October, and the catches were collected each morning, sorted and the moths stored in a freezer. The moths were later picked out, identified and sexed.

The period of continuous daylight in the Värriötunturi fell area lasts from 30 May to 14 July. The area is snow-free from approximately the end of May to mid-October.

The data was tested against temperature by Spearman rank correlation coefficient using a statistical package (Systat 5.01, Systat Inc., Evanston, IL, USA).

Results

Altogether 134,787 specimens of *Epirrita autumnata* were caught, comprising 89,006 males and 45,781 females. The largest single year's catch was that of 1992, 26,559 individuals, and the smallest that of 1979, only 715 (Fig. 2).

One "full" peak was recorded during this 15-year-period, 1983-86, representing 57.7 % of the total catch, with smaller highs in 1980 and 1990-92. The proportion of females remained at 20 % or even lower during the lows, but seemed to increase to close to 50% during the peaks (Fig. 2).

The catch was tested against the effective temperature sums (ETS) for the same year and the previous year, the frost sum for the previous winter and the frost sum and number of days below -20°C in the previous winter. The data for males and females were tested both separately and combined. The frost sum was tested on the basis of both mean and minimum daily temperatures.

Only two significant correlations were found. Females were correlated with the frost sum of days with minimum temperatures below -20°C during the previous winter ($r=0.518^{**}$;$N=15$) and with the number of days with minimum temperatures below -20°C ($r=0.538^{**}$;$N=15$).

Discussion

Two interesting phenomena came out from our trapping: the steep and sudden rise of population and the change in the proportion of females.

The sudden increase in the autumnal moth population in 1983 was striking - in fact it seemed to take place during the course of a decrease. A rather similar process was recorded at the commencement of the second peak in 1992. The numbers in our area increased tenfold from 1982 to 1983 (for similar phenomenon, see also Linnaluoto and Koponen 1980), the weather conditions in the latter year being close to average as far as the ETS was concerned, while the previous year had been so miserable that conditions could hardly be said to have been favourable for the development of an abundant *E. autumnata* population. The food situation in particular had been poor, the birch leaves still being only one centimetre in length on 2nd July, i.e. about three weeks behind the average schedule (unpubl. material; see also Nuorteva 1966).

One possible explanation could, of course, be that a certain proportion of the pupae had hibernated after an unfavourable summer. This pattern would fit in particular well with the first peak in our material, as summer 1982 was a bad one. So far we do not have any proof of that, but do extra individuals perhaps migrate elsewhere? Tenow (1972) describes how a mass occurrence can sometimes proceed like a wave, a certain area recieving extra individuals from a neighbouring area. Bruun (1992) described how storms carried great numbers of *E. autumnata* to the island of Houtskär in the SW Finnish archipelago, the source area obviously being the Scandinavian Mountain Range. These possibly migrated individuals can, however, hardly increase the numbers so drastically as it seems to happen, but the moths seem to have a huge potential to increase when everything is in synchrony.

A noteworthy feature during the mass feeding phase seems to be an increase in the proportion of females to close to 50 % of the total catch. Does this really mean a change in the sex ratio, or do females move about more in crowded situations for some reason? It is possible that some variation may occur in the sex ratio of the autumnal moth population. It has been noted that a real variation in sex ratio between peaks and lows occurs in small rodents, especially the wood lemming, *Myopus schisticolor* (Kalela and Oksala 1966), and this has been shown to be genetically controlled (Fredga *et al.* 1977) and to be connected with inbreeding (Stenseth 1978). Crowded conditions in particular may reflect in the sex ratio (Charnov 1982).

A further limiting factor may be the larval and/or pupal period, if one or both of these is forced to be too long or the summer is too short. The developmental times of larvae and pupae (Haukioja and Neuvonen 1985, Haukioja *et al.* 1988) suggest that they are from 30 to 40 days for larvae and from 50 to 80 days for pupae. The pupal period also differed between crowded and solitary larvae (Neuvonen 1987, Haukioja *et al.* 1988). The average summer is just long enough for the development of the autumnal moth in this area, but summers with bad weather may not be good enough. The larval periods of *E. autumnata* lasted slightly longer on defoliated than on control trees (Neuvonen 1987), but the pupal weights were lower (Haukioja and Niemelä 1976). Could this explain the decrease in females in the Värriötunturi fell area in 1986?

The curious feature in the present data of a sudden drop in the proportion of females in 1986 might also be connected with this, especially with the Delayed Induced Response (DIR). Female larvae are heavier and they grow longer than males, but the population density may also influence their size (Haukioja *et al.* 1988, Ruohomäki 1991). If their growth is further delayed by DIR, they will not have enough time to develop. The temperature sum for 1986 was close to the long-term average, which thus does not support the idea of an inadequate growing period. However, the female larvae may suffer more than the males from the defensive mechanisms of the birches due to their longer growing period.

An important role lies in supressing a new increase in declining populations where parasitism rate tends generally to be high (Ruohomäki 1991). If female larvae are, more heavily parasitized than male larvae, due to their longer development time, this might reduce their proportion during heavy parasitism phases. The reduction in the rate of growth of *E.*

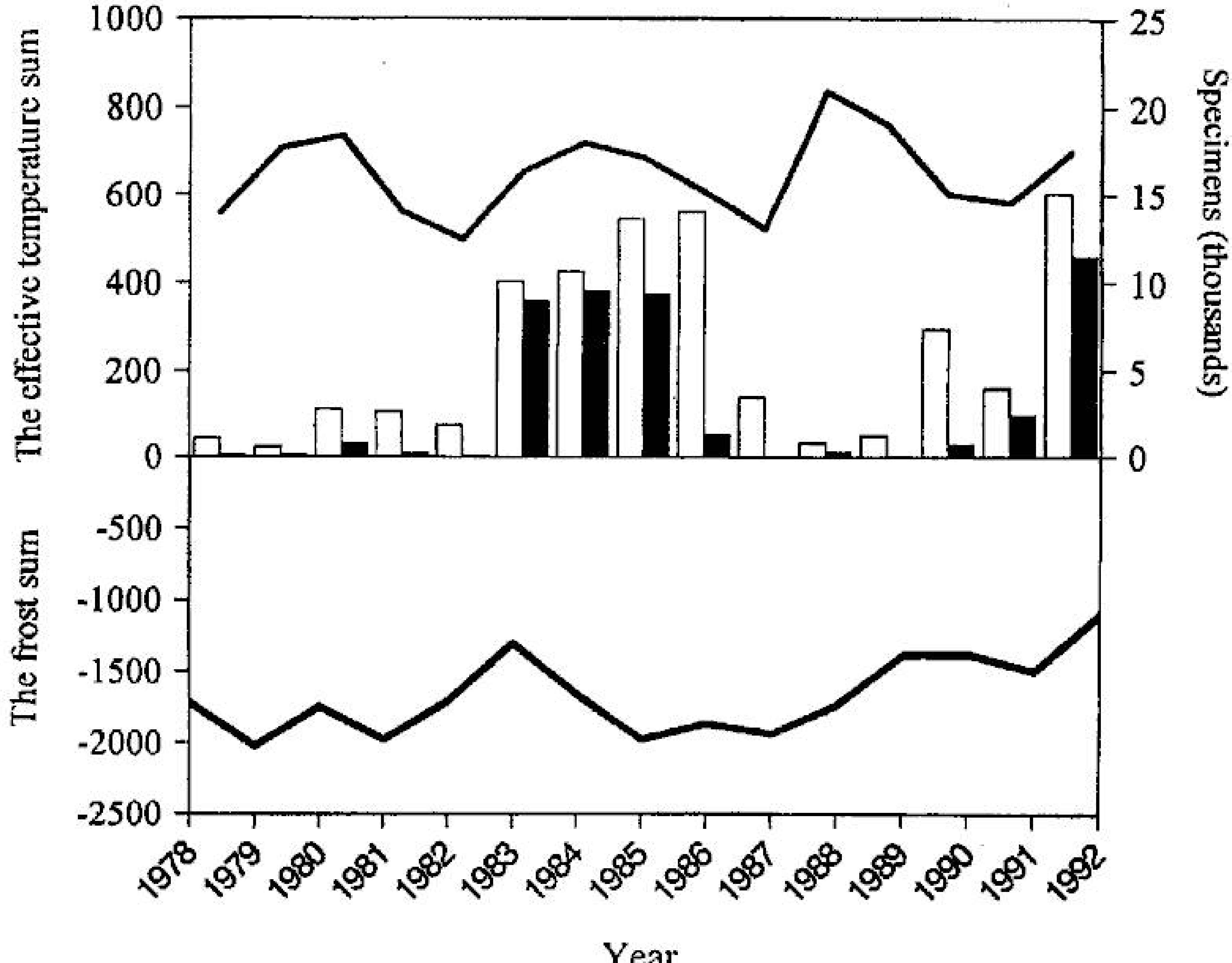

Fig. 2. Yearly catch of *Epirrita autumnata* (Lepidoptera, Geometridae) in light traps in Värriötunturi fell area, E Finnish Forest Lapland. Key to symbols: white column = males; black column = females.

autumnata population due to DIR elevates the ratio of parasites to host population growth rates, and cause higher degrees of parasitism (Neuvonen 1987).

It is known that extremely low temperatures in winter (below -39°C) are fatal for the wintering eggs (Tenow 1972). One rather confusing observation was that the numbers of autumnal moths did not correlate with the frost sum in either the same or the previous year. Niemelä (1980) has found, however, that the peaks most often fall in periods of cold weather, although he could not confirm this statistically. This may be connected with the lower phenol production of birches during cold weather (Haukioja *et al.* 1978). A similar trend concerning the starts of the peaks is to be seen in our results.

Altogether the fluctuation of the autumnal moth seems to be ruled by many factors. It appears there may be some kind of universal factor affecting vast areas. This possibly constitutes the coincidence of the disappearance of limiting factors such as stressed birches with decreasing defence mechanisms.

Acknowledgements

We wish to thank most warmly the staff of the Värriö Station, who have operated the light traps from year to year in all kinds of weather.

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Received 6. March 1994; revised 4 May 1994; accepted 17 May 1993