Change in the life history trait? – an alternative overwintering strategy of the *Macaria fusca* (Thunberg, 1792) (Lepidoptera, Geometridae, Ennominae)

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Macaria fusca (Thunberg, 1792) is a small geometer moth species that inhabits mountain heathland just above the timberline and occasionally warm forest openings in the mountains. Existing literature describes the species overwintering as a half-grown larva. However, in our observations, we detected an alternative overwintering strategy of M. fusca as a half-developed egg, contrary to the claims in the literature. Additionally, we briefly describe the rearing methods of the species and document what appears to be the first known outbreak of the species.

Key words: Lepidoptera, Geometridae, Ennominae, Macaria fusca, overwintering strategy, outbreak, Utsjoki, Finland.

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Introduction

All land areas will experience warming due to climate change, but according to various climate change scenarios, global warming will be most pronounced in northern regions (Ruosteenoja et al. 2016). This strong global warming is causing arctic and subarctic habitats to undergo changes and eventually disappear, putting several northern species at risk. For organisms in these habitats, life-cycle adjustments are necessary for survival in a changing environment.

The life cycle properties of moths and butterflies make them highly sensitive to even minor changes in their environments, making them excellent indicators of changes caused by climate change (Erhardt & Thomas 1991). Furthermore, a warming climate may enhance the winter survival of moth species in northern regions. For instance, Jepsen et al. (2008) predicted the northeastward expansion of the outbreak range of the winter moth (*Operophtera brumata*) due to improved egg winter survival in the warming climate. Consequently, milder winters might lead to outbreaks of unforeseen species (e.g., Tenow et al. 1999).

Macaria fusca (Thunberg, 1792) is a small geometer moth species that inhabits dry heaths and warm forest openings in the mountains. The species is Eurasian, found in the Alps, Fennoscandia, the French Pyrenees, Macedonia, the Kola Peninsula, and across Northern Siberia to

Kamchatka (Skou & Sihvonen 2015). In Finland, the species is mainly found in the mountains of Lapland, and adult moths (imago) typically fly in early July (Mikkola et al. 1989).

The larva of the *M. fusca* lives on european blueberry (*Vaccinium myrtillus*), crowberry (*Empetrum nigrum*), and several other shrubs. The larvae are also found on herbaceous plants such as whitlow-grasses (*Draba*) and mountain violet (*Viola calcarata*) (Valle 1946, Mikkola et al. 1989, Silvonen et al. 2014, Skou & Sihvonen 2015). It has been observed that the species overwinters as an immature larva (Valle 1946, Mikkola et al. 1989, Silvonen et al. 2014, Skou & Sihvonen 2015). In this short article, we describe our empirical observation of an alternative overwintering strategy of *M. fusca* during rearing, as a half-developed egg, along with what appears to be the first known outbreak of the species.

Materials and methods

The larvae of the species were observed on 26 June 2022, in Finland, Inari Lapland (InL), Utsjoki, Buollánoaivi (WGS84: 69,84908°- 69,863231°; 27,10485° – 27,14172°). Most of the larvae were in the ultimate instar, and some were in the penultimate instar. The larvae had consumed a large area of dwarf birch (*Betula nana*) shrubs, rendering them leafless, along with the vegetation under them, such as crowberry (*Empetrum nigrum*). The outbreak of *M. fusca* resembled outbreaks of the autumnal moth (*Epirrita autumnata*, (Borkhausen, 1794)) and winter moth (*Operophtera brumata*, (Linnaeus, 1758)), although the food plant was mainly dwarf birch instead of downy birch (*Betula pubescens* subsp. *czerepanovii*) (Tenow 1972; Haukioja et al. 1988).

Because the authors were not aware of any other mentions of *M. fusca* outbreaks in the literature and the Kevo Subarctic Research Station has a long history of researching outbreaking moth species (e.g., Haukioja & Hakala 1975, Ruohomäki et al. 1997, Huttunen et al. 2012), about 50 larvae were collected from the area within a couple of minutes and transported to the Kevo Subarctic Research Station for rearing.

The larvae pupated quickly after collection, and adults emerged approximately after a week and a half. Adults were paired in plastic vials (volume: 1,26 dl, height: 7,26 cm, diameter: 4,6 cm), and copulation was easily obtained in a few minutes.

Macaria fusca eggs were easily acquired in the absence of a food plant and extra nutrition. Females laid multiple eggs on a small piece of plastic netting. Since literature indicates that *M. fusca* overwinters as an immature larva (Valle 1946, Mikkola et al. 1989, Silvonen et al. 2014, Skou & Sihvonen 2015), the eggs were kept in plastic vials (20 vials, volume: 0,13 dl, height: 2,6 cm, diameter: 2,6 cm) outside in the rearing house for hatching.

Results

Eggs began to change color quickly from green to red, indicating successful pairing and fertilization. Subsequently, the eggs started to darken slowly, but development entirely paused in all vials. This stage is the third from the left to the right in the figure (Figure 1). Some of the eggs were brought indoors at the end of autumn for hatching, but the egg development discontinued. Half-developed *M. fusca* eggs were kept overwintering with other reared species in their natural habitat (3 cm below ground level) or in the Kevo Research Station's earth cellar. On 19 May 2023, overwintering was interrupted, and eggs were transferred to room temperature.

Surprisingly, some of the eggs were already black, and the rest started to darken in color. First, the eggs that were kept overwintering in the natural habitat began to change color, and after that, the ones that were kept in earth cellar. The first larva hatched immediately after the transfer, and within a week, almost all eggs had hatched. Rearing continued, and larval development proceeded normally without pauses. The larvae shortened and began pupation on 1 July 2023. Pupation was simultaneous with wild larvae observed in Utsjoki, Buollánoaivi, in June 2023.

FIGURE 1. The development of the *M. fusca* (Thunberg, 1792) egg is illustrated from left to right in the figure.

Discussion

Here, we observed an alternative overwintering strategy of *M. fusca* in rearing as a half-developed egg, contrary to what is claimed in the literature. If there truly is a change in the overwintering strategy (as the strategy is flexible), this illustrates the species' adaptation capabilities to environmental changes, some of which are and will be occurring in the future, especially in northern regions due to climate change.

The outbreak might be one possible explanation for why *M. fusca* changed its overwintering strategy. According to Sillanpaa (2008), autumnal moth's larval development is known to be faster during larval crowding, but usually, larvae pupate at a smaller size, leading to lower fecundity. The study notes that this can be explained by alternative host plants used during the outbreak (low-quality diet), as the main host plant is already defoliated. A lower-quality diet can act as a cue of approaching scarcity and resource shortage (Sillanpaa 2008). *Macaria fusca* females are narrow-winged and fly rarely, only for short distances (Skou & Sihvonen 2015). The aforementioned characteristics render *M. fusca* a species with a predominantly localized distribution. In instances where the entirety of available food plants is depleted from a given habitat during the summer season, a deficiency arises for emerging larvae in the subsequent autumn, especially if the overwintering strategy is in the form of immature larvae which need nutrition before overwintering.

Another possible explanation for this kind of change in the overwintering strategy might be related to constantly changing climatic factors. One might ask, do *M. fusca* eggs withstand the cold better than larvae? Could better cold resistance as eggs in higher elevations during less snowy winters explain life-cycle changes (Jepsen et al. 2008)? The question remains to be answered. Warming temperatures and winters in subarctic regions might disrupt diapause; many insects require a chilling period or some other cue during diapause, after which they can continue development (Lehmann et al. 2017). If this cue is not sensed, emergence might be delayed or not happen at all (Tougeron 2019).

Geographical location and photoperiodism have also been shown to affect the overwintering strategy, and in some cases, it makes the strategy flexible depending on environmental conditions (James 2009). Original information about *M. fusca*'s overwintering stage may have been observed at lower latitudes, meaning it might differ in higher latitudes. Rearing conditions in a shaded rearing house might also explain why hatching did not occur in rearing; in natural mountain habitats, eggs are exposed directly to weather conditions (e.g., sunlight and rain), which did not occur in the rearing house.

However, our preliminary results from further research under different environment/ temperature and light conditions indicate that *M. fusca*'s overwintering strategy in Finnish Lapland does appear to be indeed a half-developed egg. In any case, additional studies on the subject are needed. The authors will continue their research and emphasize the importance of observing regular ecological and phenological changes, especially in northern regions. The authors also wish to underscore that, within taxonomically well-explored groups such as Lepidoptera, opportunities for novel discoveries persist, thus emphasizing the ongoing dynamism inherent in scientific inquiry.

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References

Erhardt, A. & Thomas, J.A. 1991. *Lepidoptera as indicators of change in the semi-natural grasslands of lowland and upland Europe*. Pp. 213– 236 in Collins, N. M. & Thomas, J. A. (Ed.), The conservation of insects and their habitats. Academic Press, London.

Haukioja, E. & Hakala, T. 1975. Herbivore cycles and periodic outbreaks. Formulation of a general hypothesis. *Reports from the Kevo Subarctic Research Statio*n 12, 1–9.

Haukioja, E., Neuvonen, S., Hanhimäki, S. & Niemelä, P. 1988. *The autumnal moth in Fennoscandia*. Pp. 163– 178 in Berryman, A. A. (Ed.), Dynamics of forest insect populations: patterns, causes, and implications. Plenum, New York.

Huttunen, L., Niemelä, P., Ossipov, V., Rousi, M. & Klemola, T. 2012. Do warmer growing seasons ameliorate the recovery of mountain birches after winter moth outbreak? *Trees* 26, 809–819.

James, D.G. 2009. Comparative studies on the immature stages and biology of *Hesperia colorado idaho* and *Hesperia juba* (Hesperiidae). *Journal of the Lepidopterists' Society* 63, 129–136.

Jepsen, J.U., Hagen, S.B., Ims, R.A. & Yoccoz, N.G. 2008. Climate change and outbreaks of the geometrids Operophtera brumata and Epirrita autumnata in subarctic birch forest: evidence of a recent outbreak range expansion. *The Journal of Animal Ecology* 77(2), 257–264.

Lehmann, P., Van Der Bijl, W., Nylin, S., Wheat, C.W. & Gotthard, K. 2017. Timing of diapause termination in relation to variation in winter climate. *Physiological Entomology* 42(3), 232–238.

Mikkola, K., Aalto, A., Jalas, I. & Peltonen, O.K. 1989. *Suomen perhoset*, Mittarit 2. 280 pp. Recallmed, Klaukkala.

Ruohomäki, K., Virtanen, T., Kaitaniemi, P. & Tammaru, T. 1997. Old Mountain Birches at High Altitudes Are Prone to Outbreaks of Epirrita autumnata (Lepidoptera: Geometridae). *Environmental Entomology* 26(5), 1096–1104.

Ruosteenoja, K., Jylhä, K. & Kämäräinen, M. 2016. Climate projections for Finland under the RCP forcing scenarios. *Geophysica* 51(1-2), 17–50.

Sillanpaa, S. 2008. How do food quality and larval crowding affect performance of the autumnal moth, Epirrita autumnata? *Entomologia Experimentalis et Applicata* 129(3), 286–294.

Silvonen, K., Top-Jensen, M. & Fibiger, M. 2014. Suomen päivä- ja yöperhoset: maastokäsikirja [A field guide to the butterflies and moths of Finland]. 820 pp. Bugbook Publishing, Ostermarie.

Skou, P., & Sihvonen, P.M. 2015. *Ennominae I*. Pp. 1– 657 in Hausmann, A. (Ed.), Geometrid Moths of Europe, vol. 5. Brill, Leiden.

Tenow, O. 1972. The outbreaks of Oporinia autumnata Bkh. & Operophthera spp. (Lep., Geometridae) in the Scandinavian mountain chain and northern Finland 1862–1968. *Zoologiska Bidrag från Uppsala*, Supplement 2, 1–107.

Tenow, O., Nilssen, A.C., Holmgren, B. & Elverum, F. 1999. An Insect (Argyresthia retinella, Lep., Yponomeutidae) Outbreak in Northern Birch Forests, Released by Climatic Changes? *The Journal of Applied Ecology* 36(1), 111–122.

Tougeron, K. 2019. Diapause research in insects: historical review and recent work perspectives. *Entomologia Experimentalis et Applicata* 167(1), 27–36.

Valle, K.J. 1946. Suurperhoset Macrolepidoptera IV. Mittarit, Geometrae. *Vanamon julkaisuja*. 370 pp. WSOY, Porvoo-Helsinki.

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