Occurrence and experimental introduction of *Capricornia boisduvaliana* (Duponchel, 1836) (Lepidoptera: Tortricidae) in Finland

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Välimäki, P. & Itämies, J. 2002: Occurrence and experimental introduction of *Capricornia boisduvaliana* (Duponchel, 1836) (Lepidoptera: Tortricidae) in Finland. — Entomol. Fennica 13: 89–97.

The rapid decline of *Capricornia boisduvaliana* in Finland during the past two decades is summarised. The only known occupied meadow is located in northern Finland, in the vicinity of Rovaniemi. The distribution of the species in two provinces (*Oba* and *Obb*) was surveyed in 1998 by searching through 95 sites. No other occupied sites were found. The biology of the species was also studied. Larvae overwinter as half-grown and feed on *Trifolium pratense* L. close to the ground, where they spin silken webs around the base of the food plant and among protective litter. In Finland, the species is currently critically threatened, and restoration of habitat and experimental introductions were, therefore, started in the summer 1999 in Rovaniemen mlk. close to the known occupied site. The eggs produced by 15 females were divided into three groups and transported onto three restored meadows. Habitat restoration at three other sites was also started in the same summer. The next summer, reinforcement + introductions were carried out. After the first two years, both larvae and adults were observed at two introduction sites. Restoration of habitats continued in 2001.

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Received 30 April 2001, accepted 21 November 2001

1. Introduction

Due to the fast reduction and fragmentation of natural habitats and decreasing local abundance, many lepidopteran species have been included in local and regional red books in Europe (Heath 1981, Rassi & Väisänen 1987, Rassi *et al.* 2001). The decreasing trend, attributed to the deteriorating habitat quality, is often shown to be due to various human activities (Thomas 1983, Thomas *et al.* 1986, Warren 1987). This has stimulated research efforts in conservation biology (Caughley 1994).

Given the current rate of habitat fragmentation, introductions of lepidopteran species have become current issues in species conservation in Finland and in other countries (Somerma 1997). Without exact knowledge about the biology of species, conservation efforts may fail. The biology of many butterfly species (Rhopalocera) has been studied in detail, which has made precise conservation plans possible (e.g. Kuussaari *et al.* 1998, Thomas 1984, Wahlberg 1998). In contrast, few detailed studies have concentrated on the biology of microlepidopteran species in Finland. In

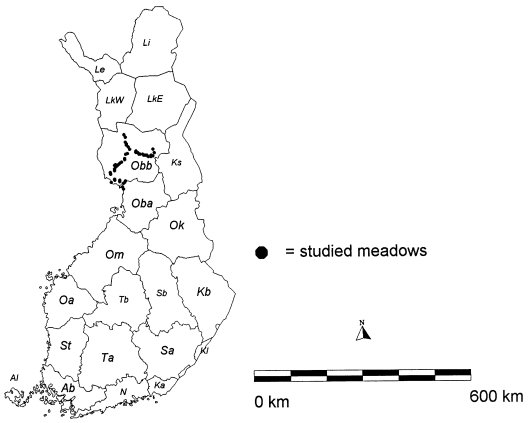

Fig. 1. The study area.

general, many microlepidopteran species are even more committed to certain habitats than macrolepidopteran species, which emphasizes their importance in conservation biology in the future. Despite careful planning, the success of introduction is not always ensured (see review in Pöyry *et al*. 2001). Successful introductions have, in general, been accomplished on networks of vacant patches, suggesting that introductions should be planned and executed in a metapopulation context rather than at the scale of single habitat patches and single local populations (Thomas 1992).

The tortricoid moth, *Capricornia boisduvaliana* (Duponchel, 1836), has recently been declining rapidly, possibly due to the radical changes in agriculture, followed by the overgrowth and decline of suitable habitats. In the 1960's, the moth was still relatively common in agricultural surroundings. In Europe, it has been found in several countries, e.g. from Sweden to Bulgaria (Karsholt & Razowski 1996). In Finland, its distribution formerly covered the area from southern Finland to *Ostrobothnia Borealis* (Kyrki 1978). The only biogeographical provinces where it has not been reported are *Satakunta*, *Nylandia*, *Karelia Australis* and the four northernmost provinces (Kerppola *et al*. 1995). It was classified as extinct in Finland until it was found again in 1995 at one of its old northernmost sites (Mutanen *et al*. 1998). It is currently classified as critically endangered in Finland (Rassi *et al*. 2001). Only fragmentary information about the ecology of *C. boisduvaliana* has been available. Old lepidopterologists have known how and where to search for it, but exact literature has been missing. Hannemann (1961) presumes it to live on Norwegian spruce (*Picea abies* (L.) Karsten). This may be based on Schütze (1931), who cited it from Sorhagen (1886). Kennel (1921) assumes the species to feed on *Pinus abies*. Ryrholm & Ohlsson (1999), on the other hand, suppose its larvae to live on Alpine bistort (*Polygonum viviparum* L.).

We had three aims: firstly, to map the distribution of *Capricornia boisduvaliana* in Finland before the 1990's and to search for it around the currently occupied meadow. Secondly, we studied the biology of the species. Thirdly, we made habitat restoration plans and carried out an introduction experiment to ensure the long-term survival of the species.

2. Material and methods

The mapping of the former distribution of *C. boisduvaliana* was made by checking specimens from zoological museums and some private collections.

The field study was done within the biogeographical provinces *Oba* and *Obb* while searching for suitable meadows along the line Kuivaniemi–Kemijärvi following the coastline of the Bothnian Bay and the river Kemijoki, and along the line Rovaniemi–Meltaus following the river Ounasjoki (Fig. 1). The mapping was carried out in June and July 1998. It was divided into four phases: (1) description of the known site and breeding experiments with the larvae discovered, (2) mapping of similar biotopes, (3) netting of imagos, and (4) egg laying experiment with females. The search for larvae was started on 8 June. The search was concentrated on the ground layer, because T. Mutanen had collected microlepidopterous larvae from higher levels in the previous autumn, but had not found *C. boisduvaliana*. The netting of imagos was started on 6 July, when the first adult was observed. The netting time varied from one to two hours per site. We had 27 potentially good sites and 68 less promising ones. The different meadows were visited one to five times, depending on their probable suitability and similarity to the "hot spot", i.e. the only known occupied meadow. In rainy weather, no adults were netted. The work was done between 06:00 and 24:00 hours.

While netting adults, we also tried to estimate the population size subjectively, but no mark-recapture study was carried out. The male population size was calculated from the number of observed specimens at the peak flight time with the following formula: males observed $\times 3 \times 6$. The numerical values in the formula are based on the following assumptions. Firstly, one-third of all individuals is flying during the peak flight time. This has been confirmed for several species (Nieminen 1996, see also Warren 1987). Secondly, one-sixth of the individuals could

be observed, which is based on our experience of the probability of capturing microlepidopteran species. The estimate of the total population size was obtained by multiplying the estimated number of males by two. This is based on the assumption that the sex ratio is 1:1 in nature, which is a reasonable assumption in view of the larval breeding experiments.

The studied meadows were grouped into three categories according to their similarity to the known occupied site. (1) Meadows closely resembling the known site, where one could expect *C. boisduvaliana* to live (5 meadows). (2) Sites that were more grassy, but otherwise quite similar to the original spot (17 meadows). (3) Other meadows where the food plant *Trifolium pratense* L. was abundant. The meadows included in the group 3 were mostly either already overgrown or very dry. These sites, with a few exceptions, were visited once.

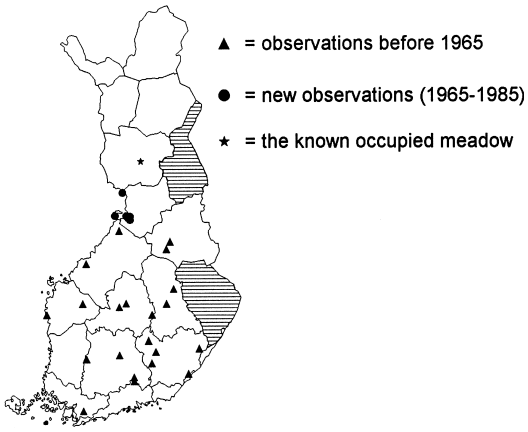

Fig. 2. Past and present occurrence of *Capricornia boisduvaliana* (Lepidoptera: Tortricidae) in Finland. Shaded provinces = exact place not known.

3. Results

3.1. The decline of *Capricornia boisduvaliana* in Finland

Capricornia boisduvaliana has previously been distributed almost throughout the country, but a few decades ago the occurrence of the species began to decline rapidly (Fig. 2). The last specimens from southern Finland were observed in the 1960's (Table 1). However, the species was still found in a few places in *Oba* and *Obb* in the 1970's and early 1980's. It was recorded in Kempele, Kuivaniemi, Oulu and Rovaniemen mlk. at that time. At the end of the 1980's, even those populations seem to have gone extinct and no other occupied sites, except the small meadow at Sierilä (see below), are currently known.

3.2. Description of the occupied patch

The known site is located at Rovaniemen maalaiskunta, Sierilä (Uniform grid 7369:463). It is a southwest-facing slope bordered on the northern side by very dry pine heath forest, on the eastern side by Norwegian spruce (*Picea abies*) forest. The meadow is bordered on the southern and mostly on the western side by the river Kemijoki. It is well sheltered from wind, and also well exposed to sunshine. The total area of the meadow is 0.7 ha, of which only 0.3 ha seem to be suitable for *Capricornia boisduvaliana*. We divided the meadow into three zones based on humidity and vegetation (Fig. 3).

At the highest elevation, close to the border of the pine heath, there is a very dry meadow zone. Sparse and very low vegetation characterise this zone, where the typical plants are e.g. *Achillea millefolium* L., *Botrychium lunaria* (L.) Swartz, *Trifolium repens* L., *T. pratense* and *Maianthemum bifolium* (L.) F. W. Schmidt.

Towards the river, the vegetation becomes more luxuriant and thicker. This zone is characterised by *Geranium sylvaticum* L., *T. pratense*, *Botrychium boreale* Milde and some Poaceae species.

The lowest zone of the meadow is heavily influenced by floods. The vegetation in this zone is even more luxuriant and higher. It is characterised by *Filipendula ulmaria* (L.) Maxim., *Trollius europaeus* L. and grasses (Poaceae). In this zone, *T. pratense* is not as abundant as in the other two zones.

When the two upper zones are compared to the other meadows in the study area, there are striking differences in the abundance of grasses and in the average height of vegetation, especially in July. In the two uppermost zones, both the height of vegetation and the abundance of grasses are generally much lower than at the other studied meadows. Also, mosses seem to be scantier in the ground layer.

3.3. Biology of larvae

At first, we searched for larvae quite randomly near the places where most of the imagos had been collected in previous years. Small larvae were found within silken webbing around *Trifolium pratense*. Because the larvae looked like typical tortricoid larvae, the search was concentrated mostly around *T. pratense*. The first attempt produced eight larvae, and some more were found later. The larvae were then brought into a laboratory and kept in jars with fresh *T. pratense*. After a couple of weeks, when the first adult emerged, it was ensured that they represented *C. boisduvaliana*.

The larvae spin a silken tube and webbing around the lower parts of *Trifolium pratense*, lying close to ground among the litter. The tube is about 2 cm long and rather weak at first, i.e. if handled roughly, it could easily break. When disturbed, the larva crawls quickly backwards and escapes from the tube among the litter. The larvae feed on lower leaves and probably also other green parts of *T. pratense*. In the final phase the webbing covers almost the whole base of the food plant. The larvae usually occurred solely on plants growing singly in open or semiopen areas (zones 1–2 in Fig. 3). This points out the necessity of dry and open meadows for the survival of this species. Pupation takes place in the tube. The larva is dark grey with a black head capsule.

3.4. Occurrence of the species in *Oba* and *Obb*

In spite of the extensive search, no *Capricornia boisduvaliana* moths were found except at the hot spot. Even there, the numbers observed were quite low compared to the previous years. *C. boisduvaliana* is typical midsummer moth, whose adult phase is on the wings from the end of June till the

Table 1. Summary of the checked material on the decline of *Capricornia boisduvaliana* in Finland.

Province	Location	Last observation	Observer
Ab	Karislojo		E. Reuter
Ta	Pirkkala		Grönblom
Ta	Nastola	19 June 1920	Löfqvist
Ta	Vierumäki		Fabritius
Ta	Kuhmois		K. Ehnberg
Tb	Saarijärvi		coll. Hackman
Tb	Pyhähäkki	26–29 June 1947	W. Hackman
Sa	Imatra		Nybom
Sa	Mäntyharju	1966	O. Peltonen
Sa	Mikkeli		Brandt
Sa	Punkasalmi		Lindeberg
Sa	Punkaharju	29 June 1950	O. Peltonen
Sa	Kangasniemi		Sundman
Sb	Kuopio		Aro
Sb	Haminanlahti	4 July 1907	Fabritius
Oa	Lapua	6 July 1918	A. Ulvinen
Oa	Närpes	4 July 1950	Nordström
Oa	Nilsiä		Hellén
Ok	Kajana		J. E. Aro
Ok	Paltamo	4 July 1934	Winter
Om	Ruukki	14 July 1924	Löfqvist
Om	Gamla Karleby		Hellström
Oba	Uleåborg	1970's	coll. Nylander
Oba	Oulu	30 June 1971	J. Kyrki
Oba	Kempele	6 July 1974	J. Kyrki
Oba	Kuivaniemi	1 July 1979	J. Karvonen
Oba	Hailuoto	10 July 1966	O. Peltonen
Obb	Rovaniemen mlk.	23 June 1980	H. Saarenmaa

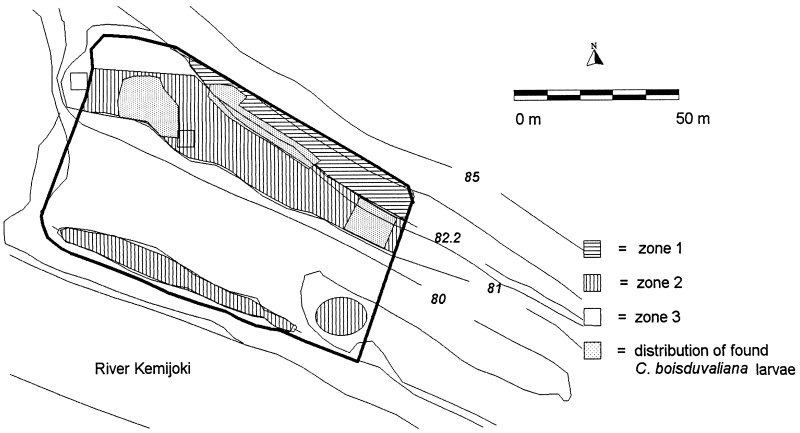

Fig. 3. A schematic map of the known occupied meadow of *Capricornia boisduvaliana* in Rovaniemen mlk. (For explanations of zones, see text).

end of July in Finland. The summer of 1998 was a late one, compared to the average. Adults were observed between 6 and 24 July (Table 2). Altogether 48 specimens were seen, while during the two previous years, such numbers had been observed within a single day (T. Mutanen pers. comm.). The capture rate of females was much lower than that of males. Males were actively flying early in the morning between 08:00 and 11:00 hours and again in the afternoon between 15:00 and 17:00 hours, while females were mostly sitting among the vegetation. In egg-laying experiments, however, females seemed to have similar activity pattern as males had. In a terrarium, we found out that males show definite phototaxis, which might give a possibility to collect them even with light traps. In contrast, females showed no phototaxis. Females lay their eggs on the lower leaves of *T. pratense* or on the litter near the host plant. Usually, only one or two eggs were laid on each leaf. The eggs are white in colour and almost invisible because of their small size (diameter < 0.5 mm).

A rough population size estimate was 300 individuals. As stated earlier, the population obviously reached the bottom of its fluctuation curve in 1998. This is more likely to be due to the natural variation in population size than due to any other factors, such as collecting during the previous years.

4. Restoration of habitats and introduction of *C. boisduvaliana*

The observed numbers of *C. boisduvaliana* individuals have been so low for the past few years that the known population is likely to become extinct in the near future. The area is also influenced by the plans to build a hydropower plant, which makes the need for habitat restoration even more urgent. In this case, three alternative restoration efforts could be carried out: (1) transplantation of the whole meadow, (2) building a barrier to hold back the rising water level, or (3) introduction of specimens to new places. To our knowledge, transplantation of whole habitats and insect communities has not yet been accomplished anywhere. So far, however, the idea has not yet been totally rejected either. This could possibly be accomplished most successfully during the winter, when the ground is frozen and moths are hibernating as small larvae. The building of a protective bank probably does not give enough shelter to ensure long-term survival of the species, because the humidity conditions and the vegeta-

Table 2. Dates and observed numbers of *Capricornia boisduvaliana* individuals in 1998 in the occupied meadow.

Date	Females	Males	Σ, individuals
6 July	–	1	1
7 July	–	3	3
13 July	2	6	8
16 July	3	7	10
20 July	4	9	13
21 July	3	3	6
22 July	4	2	6
24 July	1	–	1
Σ	17	31	48

tion will surely change anyway after building the power plant. Introduction of the moth seemed to be the most reasonable way to protect the species at the time.

In the summer of 1999, two places (Vanttauskoski and Pirttikoski) were selected as targets of the restoration management plans and experimental introduction. In both places three meadows were restored. The most important criteria in selecting the meadows were (1) the maximal similarity to the hot spot, (2) the abundance of the food plant *Trifolium pratense*, and (3) the land ownership and land use. In addition to the fulfilment of the above-mentioned criteria, the moth communities were also found to be very similar to the occupied meadow in Sierilä (Table 3). The similarity of communities might be a useful criterion for selecting the sites of introduction in the future. Five out of six selected meadows needed restorative management. The growth of bushes and small trees (*Salix* spp., *Populus tremula* L. and *Betula pubescens* Ehrh.) is the biggest threat, as overgrowth changes the humidity and vegetation of the ground layer, causing *T. pratense* to die away. The removal of bushes was the first task to accomplish. The bushes were pulled away with their roots. At two meadows, the ground layer was partly ploughed, in order to allow meadow plants to invade into these spots. Some bigger trees were also removed to enlarge the suitable open habitat for *C. boisduvaliana*. In 2001, three more meadows were managed in the vicinity of previously restored meadows in Pirttikoski in order to create a network of suitable patches for the moth (Fig. 4).

Females were captured during two periods (2–5 and 10–14 July 1999). A total of 15 females was captured for the introduction. These moths were released into three restored patches. On each of the three restored meadows, two breeding cages were placed on *T. pratense* for oviposition. One male was released into each cage to ensure fertilisation of the female, although the captured females were assumed to have already mated. The primary significance of the cages was to prevent the females from escaping before oviposition. The apparent tendency of individuals to leave a patch with a low population density has been observed with some other species, and it should be taken into consideration on the introduction of species to empty habitat patches (e.g. Kuussaari *et al.* 1996). Secondly, it is easier to observe the overwintering success if the sites of oviposition are precisely known. Some of the females were also allowed to lay eggs *in vitro*, and the eggs were introduced. Part of the eggs were placed in the cages, while the rest were left without any shelter in the vicinity of *T. pratense* shoots. In addition, one female was also released freely on each meadow. At the end of July, the cages were removed, except from one site.

Due to the fact that the population size seemed to continue to be very small at the original site, no moths were released onto the other managed meadows. In the year 2000, four and five females were released onto the two meadows where overwintering seemed to have been successful

Table 3. Occurrence of lepidopteran species feeding on *Trifolium pratense* in Sierilä and in the three restored meadows in Pirttikoski (P1, P2, P3).

Species	Sierilä	P1	P2	P3
Coleophora deauratella Lienig & Zeller	+		+	+
Syncopacma cinctella (Clerck)	+	+	+	+
Celypha cespitana (Hübner)	+	+	+	+
Capricornia boisduvaliana (Duponchel)	+			
Ancylis badiana (Dennis & Schiffermüller)	+		+	+
Cydia compositella (Fabricius)	+		+	
Cyaniris semiargus (Rottemburg)	+	+	+	+
Polyommatus icarus (Rottemburg)	+			+
Scopula immorata (L.)	+	+	+	+
Scotopteryx chenopodiata (L.)	+	+	+	+
Callistege mi (Clerck)	+			+
Euclidia glyphica (L.)	+	+	+	+

(patches 2 and 4 in Fig. 4). So far, a small-scale network of six patches has been created in Pirttikoski area. The total areas and mean distances to the other patches are presented in Table 4.

The sites to which *C. boisduvaliana* had been introduced were inspected in the spring and summer of 2000 and 2001. When estimating the success of introductions, patches were classified as occupied or vacant. In the spring of 2000, we observed typical silken webbings around *T. pratense* in two meadows (patches 2 and 3 in Fig. 4). In July, adults were also seen on flight at those two sites. The second overwintering was also successful in these two patches. Hence, two of the new closely situated patches seem to be suitable to ensure at least short-term survival of *C. boisduvaliana* populations. In the third introduction site there was no signs of the moth during 2000–2001, which implies that the introduction has failed there.

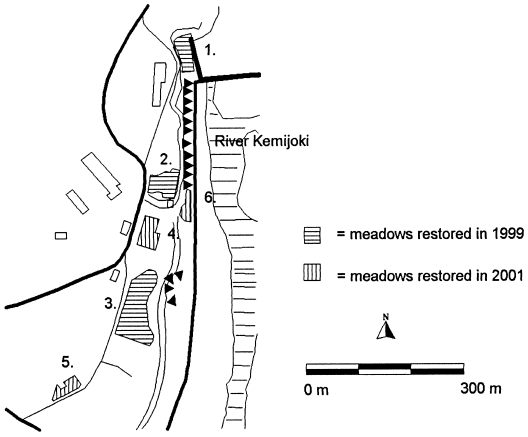

Fig. 4. The network of the six restored meadows in Pirttikoski.

5. Discussion

There is hardly any unambiguous explanation for the decline of *C. boisduvaliana*, but the reduction in the total area and the increasing fragmentation of suitable habitat patches, due to the changes in the methods and structure of agriculture, have surely had a great influence upon it. The changes in agricultural practices have been especially remarkable in northern Finland (Pitkänen & Tiainen 2000), although many changes have also been reported from southern Finland. For example, cattle are not kept outdoors as much as earlier, which leads to the decrease of open meadows and increasing fragmentation of such habitats. Detailed investigations have revealed that the declining trends of many other lepidopteran species can also be attributed to deteriorating habitat quality, often due to various human activities (Thomas 1983, Warren 1987). *Trifolium pratense* is still quite common and abundant throughout the country, so the distribution of the larval food plant does not explain the decline of the species. The occupancy of patches is more likely to be affected by other characteristics affecting habitat quality, such as openness, humidity and vegetation height. The overgrowth of open meadows is clearly the greatest single threat for the species, as it is to many other species living in similar habitats.

The biology of the species was studied in detail, which made precise restoration and introduction plans possible. Even when the management planning is carried out carefully, the long-term persistence of the species in the new environment cannot be ensured, as has been seen in the intro-

Table 4. Properties of the six restored meadows in Pirttikoski (see Fig. 4). Distance = mean distance to the centre points of the other patches.

Patch	Restored in	Area (m^2)	Distance (m)	Introduction in	Adults 2000 (+/–)	Adults 2001 (+/–)
1	1999	1713	408	1999	–	–
2	1999	2192	214	1999, 2000	+	+
3	1999	6355	252	1999, 2000	+	+
4	2001	1805	200		–	–
5	2001	1062	402		–	–
6	2001	842	210		–	–

duction experiment of the endangered Baton blue butterfly (*Pseudophilotes baton* (Bergsträsser)). In that case, the introduction at first appeared to be successful (Marttila *et al*. 1997), but the species disappeared five years later, probably due to the unfavourable weather conditions during the flight season in one summer, which decreased the population size to a very low level (Marttila *et al*. 1999). Similar results have also been reported in some other introduction studies (Pöyry *et al*. 2001). As stated earlier, successful introductions have generally been accomplished on networks of vacant patches, suggesting that introductions should be planned and executed in a metapopulation context rather than at the scale of single habitat patches and single local populations (Thomas 1992). In the present case, the beginning also seems promising. However, although the experiment has been successful in some patches, the long-term survival of the species is not ensured. Though *C. boisduvaliana* overwintered successfully in two patches, reproduction may not have succeeded, as population sizes may have been too small and densities too low, which could lead to e.g. difficulties in finding mates. This so-called Allee effect refers to a decrease in population growth rate at low population densities (Sæther *et al*. 1996). Low population density also increases emigration rate in certain patches (Kuussaari *et al*. 1998), which also has remarkable effects on population dynamics (e.g. Hanski *et al*. 1994). Reproduction in restored patches has not been confirmed yet, because already fertilised females have been introduced from Sierilä in both years. In addition, reason for failure in the third introduction meadow has not been discovered yet, which makes future of this project even more uncertain.

There is not much time left for restoration attempts of *C. boisduvaliana*. Even large single populations are at great risk of extinction, which is why a large-scale network of meadows suitable for *C. boisduvaliana* should be set up within the next few years, if we intend to retain the species in the Finnish fauna. Hanski *et al*. (1996) suggest that, for metapopulations living in networks of small habitat patches, the minimum viable metapopulation size is about 10 extant populations, and the number of suitable patches in the network should exceed 20 for the long-term persistence. The number of patches is not the only important factor, but the distance between the patches is also crucial. According to our observations on the behaviour of *C. boisduvaliana* females, the colonisation distances of vacant patches must, on average, be very short and the patch density in the networks should, therefore, be high. The restoration of 20 suitable patches should not be an overwhelming problem, because many old meadows and farmlands could still be managed quite easily. In addition to this, most of the possible restoration sites are owned by Kemijoki Oy, which has already shown a positive attitude towards the protection of this moth species. In the future, much planning and work should also be done to keep the restored meadows suitable and to prevent overgrowing due to the natural succession.

Acknowledgements. The project was funded by the Kemijoki Oy hydropower company, represented by Olli Nenonen, Manager of Environmental Matters. Kemijoki Oy also provided assistance for field work. Tomi Mutanen and Heikki Pöykkö kindly guided us to the hot spot and participated in the field work. The following persons helped us in one way or another: Jari Junnilainen, Kimmo Kaakinen, Jaakko Karvonen, Marko Mutanen, Osmo Peltonen, Kai Saloranta, Reijo Siloaho, Manu Soininmäki, Reijo Teriaho and Kari Vaalamo.

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