A new efficient bait-trap model for Lepidoptera surveys – the "Oulu" model

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To get reliable estimates of biodiversity or relative population sizes, it is important to develop and properly test new survey tools in comparison with previous methods. Here, we introduce a new, effective bait-trap model, viz. the "Oulu" model, for Lepidoptera surveys and monitoring schemes. An extensive field experiment showed that the new bait-trap model captures more individuals and more species than the widely-used "Jalas" model, while the species richness and species composition of the total catches did not differ between the trap models. The differences between the trap models were consistent over time and habitats. We suggest that the "Oulu" model yields high catches because few individuals can escape from the trap. It is thus an effective tool to be used in Lepidoptera surveys and studies.

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1. Introduction

The number of species and relative abundances of the species are the most common indices of biodiversity because they are measurable quantities and linked to other measures of diversity (Gaston 1996). Because it is not feasible to identify all possible species of an area, researchers often need to survey the diversity of certain taxa that are considered reliable indicators of the environment and reliably estimable with given resources (Caro & O'Doherty 1999). Lepidoptera species, moths and butterflies, are considered suitable indicators for biodiversity because they are well known and they interact closely with their environment (Thomas & Mallorie 1985, Launer & Murphy 1994, Sparrow *et al.* 1994, Nieminen 1996a).

Surveys on Lepidoptera diversity have mainly concentrated on butterflies instead of moths, although the latter group is more speciose and the numbers of individuals are often higher (Vane-Wright & Ackery 1984, Karsholt & Razowski 1996). One reason for this bias is that moths are difficult to observe in the field, and the line transect method (commonly used in butterfly surveys) is not suitable for moth surveys. Therefore, moths are usually surveyed using light-traps, a method based on the tendency of many moth species to fly towards light (Jalas 1960, Muirhead-Thomson 1991). There are, however, some limitations in using only light-traps in moth surveys. First, there is wide variation among species in their tendency to fly towards light, and some species are not attracted to light at all (Chernyshev 1961, Taylor & Carter 1961, Blomberg *et al.* 1976, Baker & Sadovy 1978). Second, the efficiency of the method depends on the prevailing light conditions. Moths are attracted to the artificial light only when it is dark, and thus the method is not efficient in, for example, northern areas where nights are very light during the summer. The natural light conditions also vary over the course of the summer, which makes within-season comparisons difficult. Third, a practical limitation of light-trap surveys is the need for electricity.

Lepidoptera can also be attracted to baits that mimic their food sources. Effective baits are e.g. rotting fruits, red wine, and beer with sugar (Daily & Ehrlich 1995, Nieminen & Hanski 1998, Leinonen & Itämies 2000). Bait trapping has been commonly used to survey butterflies in the tropics (Austin & Riley 1995, Daily & Ehrlich 1995, Shuey 1997). Baits have the advantage that they attract species throughout the day and summer also in northern areas. Baits also attract males and females more evenly than light does (Süssenbach & Fiedler 1999, Mönkkönen & Mutanen 2003). Baits may not attract all the species, but they do attract many species that are not attracted to light (Somerma & Väisänen 1990, Süssenbach & Fiedler 1999). Therefore, bait-trapping side by side with light-trapping can make a powerful tool for a survey on Lepidopteran diversity. However, traps designed for butterflies are not suitable for surveying moths (in particular Noctuidae) that are the commonest taxa observed on baits in northern areas. This is because butterfly-traps are usually open from below and their capture efficiency relies on butterflies attempting to move upwards (Austin & Riley 1995, Daily & Ehrlich 1995, Sourakov & Emmel 1995, Shuey 1997). Moths, on the other hand, tend to drop themselves to the ground when threatened; therefore, their capture requires specifically designed traps. Moths are commonly attracted to baits, and bait-trapping may therefore give reliable estimates of moth diversity (see Süssenbach & Fiedler 1999). However, so far only a few passive bait-trap models have been developed for moths. Moreover, there is only limited knowledge about the impact of the bait-trap model on the efficiency of surveys.

To get reliable estimates of biodiversity, it is important that new survey tools are developed and properly tested in comparison with other available methods. Here, we introduce a new bait-trap model for Lepidoptera surveys, hereafter referred to as the "Oulu" model. We experimentally compare the number of species and individuals caught using this trap to those caught using another bait-trap, the "Jalas" model, that has been commonly used in monitoring studies especially in Finland (e.g. Kozlov *et al.* 1996, Leinonen & Itämies 2000).

2. Material and methods

2.1. The bait-trap models

The new "Oulu" model and the traditional "Jalas" model are illustrated in Fig. 1. The call for the novel bait-trap type was raised when the author PV and Manu Soininmäki observed a rare moth species that they coveted escaping from "Jalas" trap. The main aim was to produce a trap with high catch efficiency and low insecticide consumption by constructing more closed trap without significantly decreasing the luring efficiency. The outline of the "Oulu" trap is a 20 l plastic bucket (mouth diameter 28 cm, depth 38 cm) that has three or four evenly-distributed round entrances (diameter 7.5 cm) with transparent inward entrance tubes (length 5 cm). In the experiment, we used traps with four entrances. A removable collecting funnel (diameter of the lower end 4 cm) bisects interior space into upper and lower compartments.

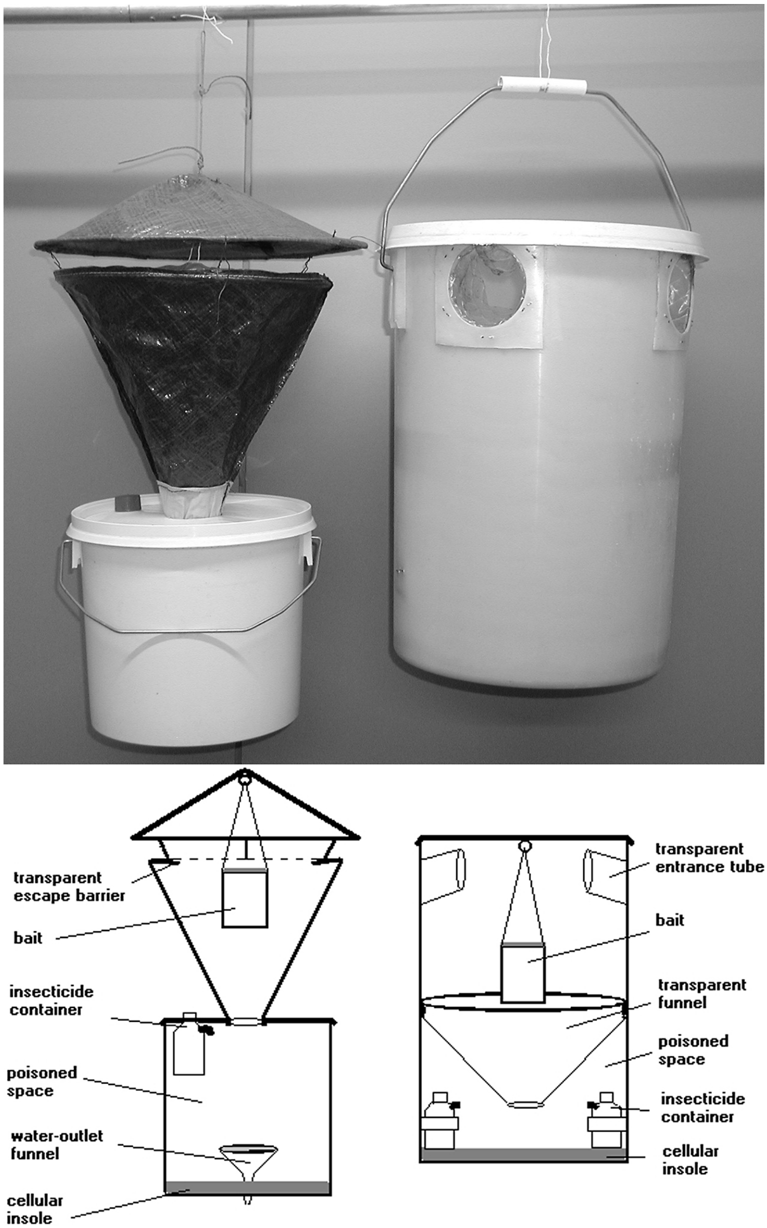

Fig. 1. Bait-trap models of the study. The “Jalas” model on the left, and the “Oulu” model on the right.

The latter compartment comprises an insecticide container and poisoned air. It thus functionally corresponds with the collecting jar of the “Jalas” model, but the “Oulu” model lacks the water-outlet funnel, which results in low outflow of fumigated air. The upper compartment consists of a bait container(s) and transparent entrance tubes that not only prevent insects from escaping once they have entered, but also prevents rain water from getting into the trap.

2.2. The bait

The quality of a bait can affect both numbers of individuals and species caught (Utrio & Eriksson 1977, Sourakov & Emmel 1995, Süssenbach & Fiedler 1999). We used typical beer-based bait that contained 4.5 l beer, 1 kg molasses, 230 g honey, 500 g brown sugar, 1 kg white sugar, 1 apple and 3 g yeast. The bait was allowed to ferment for one week.

2.3. The experiment

The experiment with the two bait-trap models was conducted in Laitila, SW Finland (ca. 61° N, 22° E) in the summer of 1999. The study area belongs to the hemi-boreal zone at the interface of central-European temperate deciduous and boreal coniferous forests. The area is typically a mosaic of temperate deciduous and coniferous forests, agricultural land, meadows and bogs.

Eight pairs of traps, each with one "Oulu" and one "Jalas" model trap, were used. The eight pairs of traps were set up in different locations with at least 150 m between the pairs. In each location the two traps were erected singly on artificial stands 20 m apart, with similar distances to trees, bushes or habitat edges. The traps were hanging from the stand at 170 cm height (from the ground to the entrance of the trap), and the stand structure allowed free flow of air from all directions.

Each pair of traps was set up in different habitats. These habitats were agricultural lay land, cultivated field, garden, bog, aspen forest, mixed forest, coniferous forest and birch forest. Different habitats were used to exclude possible varying effects of habitat on the capture efficiency of the trap types. In particular, four of the habitats were chosen so as to represent open environment and four so as to represent closed forest environment, because there could have been differences in the spread of the bait odour depending on the closedness of the environment and/or trap model. To control for this possible source of variation, also wind measurements were taken at each location (see below).

The trapping was conducted in six periods, four of which lasted 8 days and two 12 days (3.–10.V., 28.VI.–5.VII., 20.–27.VII., 29.VII.–9.VIII., 11.–18.VIII. and 21.VIII.–1.IX.) However, the weather during the first period was exceptionally cold for the study area at that time of the year; temperatures fell below freezing point each night, resulting in zero catches. Therefore, this eight-day period was excluded from subsequent analyses. The emphasis of the remaining periods was in late summer, the time at which moths are most numerous in Finland (Mikkola & Jalas 1976, 1979). The catches were collected each day during the eight-day periods and every third day during the twelve-day periods. The collection was done early in the morning, beginning at 06:00 AM. The positions of the traps within each pair were switched at each visit to minimize the possible effects of microhabitat structure between the stands at each location. Wind speed was measured using a Wallac thermoanemometer beginning at 11:00 PM every night during the eight-day periods, measured for two minutes in the vicinity of each trap at the height of the trap entrance; the mean value of the range where the values stayed for more than half of the time was used as the value for wind speed. Temperatures and other weather conditions were also recorded during the study.

2.4. Statistical analyses

Trap-specific catch efficiency was described by calculating the number of species and the number of individuals caught during each period, and by dividing these values with the number of trapping days. Catch values were always compared within a trap pair, and thus eight pairs of catch values were derived for each period. The comparisons of catch-values between the trap models were performed with repeated-measures analysis of variance that allowed testing for interactions between trap models, trapping periods and open vs. forested environments (Gurevitsch & Chester 1986). In the analysis, the catch value for the number of species or individuals was the dependent variable, the trap model and the period were within-subject factors, and the trap-pair was a between-subject factor. Mauchly's test of sphericity was used to test for the homogeneity of the covariances (Potvin & Lechowich 1990). The normality of the data were tested using Kolmogorov-Smirnov tests and homogeneity of the sample variances using Levene's tests. These analyses were performed with SPSS 8.0 software.

Complete counts of the number of species in a moth community are practically impossible, and any sampling method will thus only give a subsample of the true species richness (total number of species). Different sample sizes may become a problem when the species richness estimates of two methods are compared, because the larger the sample (number of individuals), the

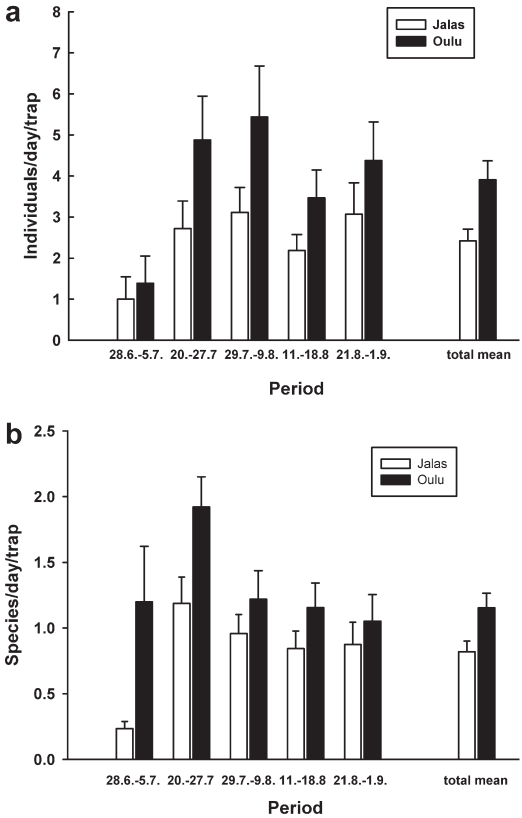

Fig. 2. Mean (± S. E.) catch-values of individuals (a) and species (b) in all periods for the "Jalas" and "Oulu" bait-trap models. Mean (± S. E.) values over all periods are given behind the broken line.

greater the expected number of species captured. This problem may be solved by standardizing both samples from different trap types to a common sample size of the same number of individuals using rarefaction that allows comparisons of the species richness regardless of sample size. The larger sample is rarefied to the smallest sample size, and the expected species number is then calculated for that smaller (sub-)sample. With numerous iterations, a 95% confidence interval for species richness can be generated. If the observed species richness of the smaller sample falls outside this interval, the hypothesis that samples do not differ in species richness can be rejected at $\alpha = 0.05$. The analysis does not, however, take into account whether the species in the samples are the same (Heck *et al.* 1975, Raup 1975, Krebs 1999).

To compare the species composition captured using the two trap models, we first calculated Bray-Curtis similarity indices between all possible combinations of two traps from all traps that were used in the experiment. The Bray-Curtis indices were then subjected to a Mantel test, in which one data matrix presented the indices and the other presented the similarity of the trap models (0 = same, 1 = different). The test permutates the columns and rows of the matrices and estimates the correlation between the matrices (Ranta *et al.* 1997). These tests were done using R software.

3. Results

The "Oulu" model captured significantly more individuals than the "Jalas" model ($F_{1,7} = 12.76$, $p = 0.009$; Fig. 2). On average the "Oulu" model and the "Jalas" model captured 3.91 and 2.42 individuals per day, respectively. The "Oulu" model captured on average also more species than the "Jalas" model (1.15 vs. 0.82 species per day, $F_{1,7} = 8.47$, $p = 0.023$; Fig. 2). Both the number of individuals and the number of species differed among periods (Fig. 2).

The interaction between the trap model and sampling period on the number of individuals was not significant (trap model * period: $F_{4,28} = 0.81$, $p = 0.527$), but it was significant for the number of species ($F_{4,28} = 5.97$, $p = 0.001$). The "Oulu" model captured on average more species in each period, but the magnitude of the differences varied enough to give a significant interaction. The capture efficiency of the trap models was not different between environment types (trap model * environment type: $F_{1,6} = 0.55$, $p = 0.49$ for the number of individuals and $F_{1,6} = 0.45$, $p = 0.53$ for species richness). The "Oulu" model captured on average more individuals and more species in all habitats except in the bog (Fig. 3). This is, however, only a qualitative result, as there were no replicates within the habitat types.

Altogether the "Oulu" model captured 100 species and "Jalas" model 81 species during the experiment. However, the species richness of the total samples did not vary between the trap types, and the higher number of species caught using the "Oulu" model is apparently due to the larger number of individuals captured (1567 vs. 982; Fig. 4). Also the species composition between the

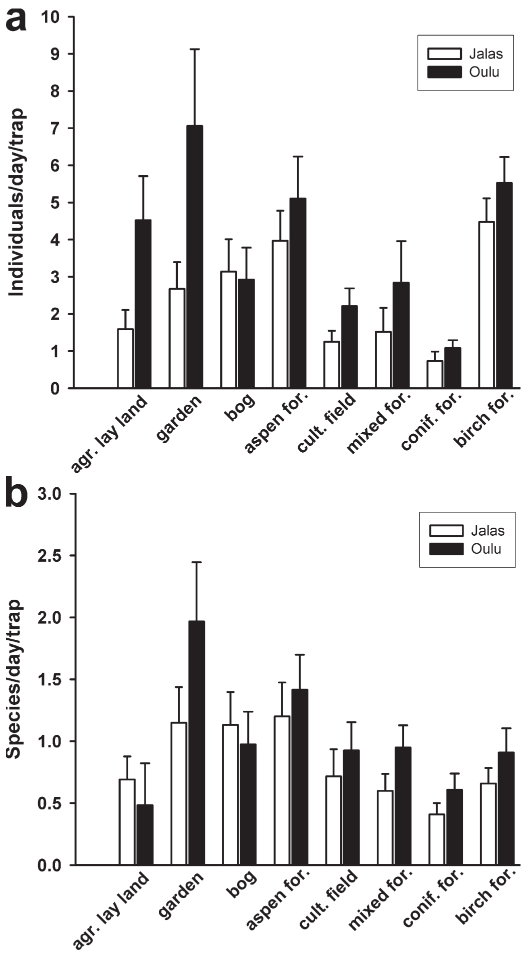

Fig. 3. Mean (± S. E.) catch values of individuals (a) and species (b) for the “Jalas” and “Oulu” bait-trap models in different habitats.

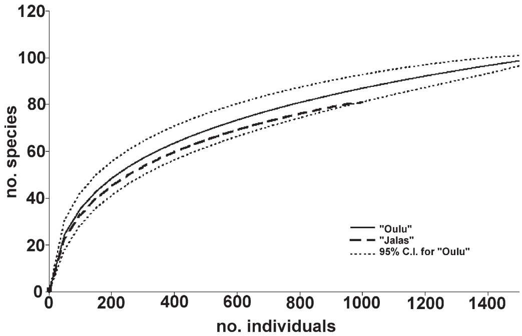

Fig. 4. Rarefied number of species trapped with the “Oulu” model compared with number of species caught using the “Jalas” model, plotted against sample size.

trap models correlated significantly (Mantel test with 1,000 permutations, $r = 0.92$, $p < 0.001$), indicating that the species composition captured did not differ between the trap-models.

The nights were unusually cold and there was detectable wind only in 3 out of 24 nights; in all the other nights, wind speed was less than 0.5 m/s.

4. Discussion

One benefit in using Lepidoptera species as bioindicators is that their diversity and abundance can be surveyed and analysed quantitatively. Here, we have presented a new effective tool, the “Oulu” model bait-trap, to be used in Lepidoptera surveys and monitoring schemes. Cost-efficient passive traps that do not require the presence of the researcher allow comprehensive surveys that continue throughout the flight season. This is important, because surveys conducted over a short period can be misleading due to e.g. unfavourable weather conditions (Fisher *et al.* 1943, Sundell *et al.* 2002). In our experiment, the “Oulu” model bait-trap captured more species and individuals per unit of time than the traditional “Jalas” model, while neither the species richness nor the species composition of the total catches differed between the trap models. The difference between the models was consistent over time and habitats. In addition, the consumption of insecticide and bait seemed to be lower while using the “Oulu” model, thus allowing longer survey periods with more reasonable costs (JL and PV, pers. obs.).

Two mechanisms can explain the higher catch of the “Oulu” model: it can be more effective in luring the moths and/or it can be more effective in capturing them; we suggest that the reason is the higher capture rate. The “Jalas” model is more open and therefore up to 90% of all individuals visiting the trap may not get caught (Keinänen 2003). The “Oulu” model, on the other hand, is more closed and hence probably more difficult for the moths to escape from there. One factor that may differently affect the efficiency of the two trap models is the spread of the bait odour with wind. In this study the nights were calm, as there was detectable wind only during 3 out of the 24 nights. Therefore, the effects of wind conditions could not be well evaluated, and it is possible that the results might be different in windy conditions. The "Oulu" model probably suffers more in terms of luring efficiency from calmness than the "Jalas" model simply due to its closed structure. We suggest that in windy conditions the difference between the two trap types can be even more pronounced than reported here.

Bait-trapping, when used properly, can be an efficient tool, for example, in biodiversity monitoring (Mikkola 1975, Kozlov *et al.* 1996, Nieminen 1996b, Leinonen *et al.* 2003, Mönkkönen & Mutanen 2003). The fact that the two bait trap models differed in terms of catches indicates that those long-term monitoring schemes that aim at e.g. estimating relative population sizes should carefully consider the pros and cons before switching trap models. The "Oulu" model appears to be more efficient in catching individuals than the widely-used "Jalas" model and thus yields a higher number of species as well. However, both models captured similar compositions of moth communities, which makes the faunistic surveys possible to compare. Moreover, the species compositions of the catches differ between bait-traps and light-traps (Nieminen 1996c, Süssenbach & Fiedler 1999); we therefore recommend that in comprehensive surveys these two methods should be used to complement each other.

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