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Pettersson, Lars; Franzén, Markus

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LARS B. PETTERSSON & MARKUS FRANZÉN

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Bait traps for moth trapping are increasing in use but little is known about the relative performance of different baits. Here we describe recipes for two of the most commonly used bait types, a wine-based bait and a beer-based bait and evaluate them in a field experiment on Gotland in 2007. Jalas traps (commercially available in Finland) were used and ten traps, five with beer bait and five with wine bait were placed out in a pairwise design and retrieved after 48 hours. Both baits performed well and a total of 365 individuals from 35 different moth species were caught. There were no statistically significant differences in performance between the two baits, neither in terms of number of species caught, nor in terms of total number of individuals. We conclude that both bait types are well suited for moth trapping and that the choice of either is primarily a matter of taste, cost, and availability of ingredients.

Lars B. Pettersson & Markus Franzén, Department of Animal Ecology, Lund University, Ecology Building, SE-223 62 Lund, Sweden, e-mail: lars.pettersson@zooekol.lu.se, markus.franzen@zooekol.lu.se.

Butterflies and larger moth species are considered to be suitable indicators for biodiversity and environmental qualities because they are generally well known taxonomically and respond fast to changes in e.g. habitat availability and regional climate (Conrad *et al*. 2004, Summerville *et al*. 2004). While surveys on Lepidopteran diversity have mainly concentrated on butterflies (Asher *et al*. 2001), moths has recently been highlighted as a less studied group of insects which appears to be severely declining (Conrad *et al*. 2006, Fox *et al*. 2006). In addition, larger moths have recently emerged as an increasingly popular target group for amateur entomologists and could possibly contribute with important information about climate change, population trends, distribution patterns etc (Huldén *et al*. 2000, Mattila *et al*. 2006, Franzén & Johannesson 2007).

Moths can easily be trapped using either UV light or baits. Light is the most used method and attracts most species but requires specialised, often heavy, equipment, careful monitoring, and is dependent on electricity (Leinonen *et al*. 1998). Bait trapping is relatively less labour intensive, can run for several days, and can be used to survey large areas. Another advantage at high latitudes, such as in the northern parts of Scandinavia, is that bait trapping works even during bright summer nights when light traps are of little use. Bait trapping has therefore surfaced as an attractive complement to light traps. The method is today widely used in Finland and is also becoming more popular in Sweden and Denmark. Typically, bait trapping involves using pieces of textile saturated with bait or specialised moth traps, either commercially available or home-made. The relative performance of different baits is however rarely evaluated. Some investigators prefer baits based on beer whereas others prefer ones based on wine. As pointed out by Laaksonen *et al*.

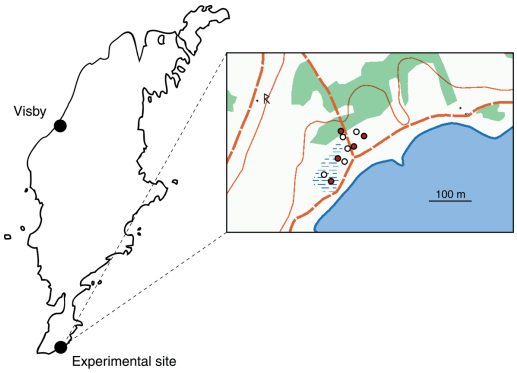

Figure 1. The experimental site near Kvännmyr, Sundre Parish on the island of Gotland. Red circles show positions of traps with wine-based bait while white circles show positions of traps with beer-based bait.

Försökslokalen nära Kvännmyr, Sundre socken, Gotland. Röda cirklar visar placeringen av fällor med vinbaserat bete medan vita cirklar visar placeringen av fällor med öl-baserat bete.

(2006), it is important to have knowledge about how different trap designs and different baits influence the catch. In the present experiment we have therefore attempted to evaluate the relative performance of red-wine based and beer-based moth baits under field conditions. We also provide bait recipes and some recommendations for moth investigations using scented baits.

Methods

Our study area was located near Kvännmyr, Sundre Parish, Gotland (Swedish Grid [Rikets Nät]: 631315 164796), a site with considerable moth diversity which had been surveyed by the authors in August 2006 using UV lamps. Trap positions were distributed over an area of 1.3 hectares (Fig. 1). Following a standard bait-trapping protocol (Söderman 1994), we placed out five pairs of Jalas moth traps (Jalas 1960; Fig. 2, commercially available from Viestipaino Oy, Tampere, Finland <http://www.viestipaino.fi/rysa.html >). In Jalas traps, attracted insects fall into a box where they remain until the trap is checked (Fig. 2, Söderman 1994). All traps were hung at approximately 2 m above ground at representative spots, as similar as possible within each pair, and were secured against wind using nylon cords. The mean distance between trap pairs was significantly greater that the mean distance between traps within pairs (Fig. 1; 33 ± 6 m vs. 15 ± 5 m; Wilcoxon exact test, P=0.016). Within each pair, one trap was randomly assigned the wine-bait treatment and the other was assigned the beer-bait. Baits had been prepared approximately one week before the experiment to allow fermentation and cue saturation (cf. Laaksonen *et al*. 2006). The wine-based bait contained red wine and white sugar (Table 1) and the beer-based bait contained beer, molasses, honey, brown sugar, white sugar, apple and yeast (Table 1, following Laaksonen *et al*. 2006). Traps were filled with bait at noon on August 17, 2007 and collected 48 hours later. Weather conditions were cloudy with sunny intervals throughout the experiment and there was no rainfall. Maximum temperature was 19 °C and minimum temperature 13 °C. The wind was southwesterly at 10 m s^{-1} when traps were placed out but then gradually turned to the south and decreased to 4 m s^{-1} by the end of the experi-

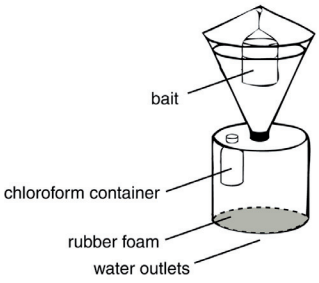

Figure 2. A Jalas moth trap. The bait container was filled with wine-based or beer-based bait. Attracted insects fall into the lower compartment where they remain until the trap is checked..

En Jalas-fälla för betesfångst. Betesbehållaren fylls med vin-baserat eller öl-baserat bete. Insekter som lockas till fällan faller ned i den nedre behållaren där de sedan blir kvar tills fällan vittjas. Foto:Ulrika Samnegård.

Table 1. Baits used in the experiment. The wine-based bait is a typical sugar-saturated red wine bait and the beer-based bait follows Laaksonen et al. (2006). Baits were allowed to settle/ferment for a week before use.

Beten som använts i försöket. Det vinbaserade betet är ett traditionell sockermättat rödvinsbete och det ölbaserade betet är enligt Laaksonen et al. (2006). Betena stod till sig i en vecka före användning.

Ingredient **[Ingrediens]**	Amount **[Mängd]**
Wine-based bait	
Red wine **[Rödvin]**	4.5 litres
White sugar **[Strösocker]**	to satiation **[till mättnad]**
Beer-based bait	
Beer **[Starköl]**	4.5 litres
Molasses **[Melass]**	1 kg
Honey **[Honung]**	230 g
Brown sugar **[Farinsocker]**	500 g
White sugar **[Strösocker]**	1 kg
Apple **[Äpple]**	1 grated **[rivet]**
Yeast **[Jäst]**	3 g

ment. All moths were counted and identified to species by the authors. The nomenclature follows Karsholt & Razowski (1996).

Results

Both baits performed well and caught a considerable number of species and individuals despite the short time that the traps were out (Table 2). The average number of species per trap was 10.2 ± 0.7 (mean ± SE) in the wine-based bait and 9.6 ± 2.2 in the beer-based bait. The number of individuals was 36 ± 4 in the wine-based bait and 37 ± 19 in the beer-based bait. A pairwise comparison of the two bait categories showed no overall differences in bait performance (Fig. 3, Wilcoxon signed rank test, $P>0.05$ for both species numbers and number of individuals). There were tendencies that wine-based baits might collect more *Noctua pronuba* (15 vs. 5 individuals) and beer-based bait more *Agrotis segetum* (68 vs. 41 individuals) but the differences were not larger than could be expected by chance effects.

Table 2. Recorded moth species from the field trial near Kvännmyr, Sundre Parish, Gotland. Numbers indicate total capture per trap category (n=5 traps of each). Species are sorted in systematic order and # indicates species number in Karsholt & Razowski (1996).

Funna nattfjärilsarter under fältförsöket nära Kvännmyr, Sundre socken, Gotland. Antal anger totalfångsten per fällkategori (n=5 fällor av varje). Arterna är sorterade i systematisk ordning och # anger artnummer i Karsholt & Razowski (1996).

#	Name	Wine-based bait	Beer-based bait
8338	*Ecliptopera silaceata*		1
8583	*Eupithecia pusillata*	4	1
8787	*Acronicta rumicis*		1
8789	*Craniophora ligustri*	1	
8873	*Catocala fraxini*	1	
8874	*Catocala nupta*	1	
9496	*Thalpophila matura*	2	2
9505	*Phlogophora meticulosa*	34	29
9748	*Apamea monoglypha*	1	
9766	*Apamea remissa*	1	1
9786	*Mesoligia furuncula*		1
9789	*Mesapamea secalis*		1
9857	*Celaena leucostigma*	1	
9895	*Discestra trifolii*	1	
9917	*Lacanobia oleracea*		1
9987	*Mamestra brassicae*		1
10006	*Mythimna impura*	1	
10007	*Mythimna pallens*	1	
10096	*Noctua pronuba*	15	5
10097	*Noctua orbona*	1	5
10099	*Noctua comes*	24	24
10100	*Noctua fimbriata*	2	1
10199	*Xestia c-nigrum*	13	11
10204	*Xestia baja*	8	6
10206	*Xestia rhomboidea*		1
10212	*Xestia xanthographa*	19	20
10254	*Euxoa recussa*		2
10275	*Euxoa nigricans*	1	
10279	*Euxoa tritici*	2	
10282	*Euxoa obelisca*	1	
10346	*Agrotis ipsilon*	1	2
10351	*Agrotis segetum*	41	68
10356	*Agrotis vestigialis*	1	1
10487	*Eilema depressa*		1
10490	*Eilema complana*		1
Total number of individuals:		178	187
Total number of species:		25	24

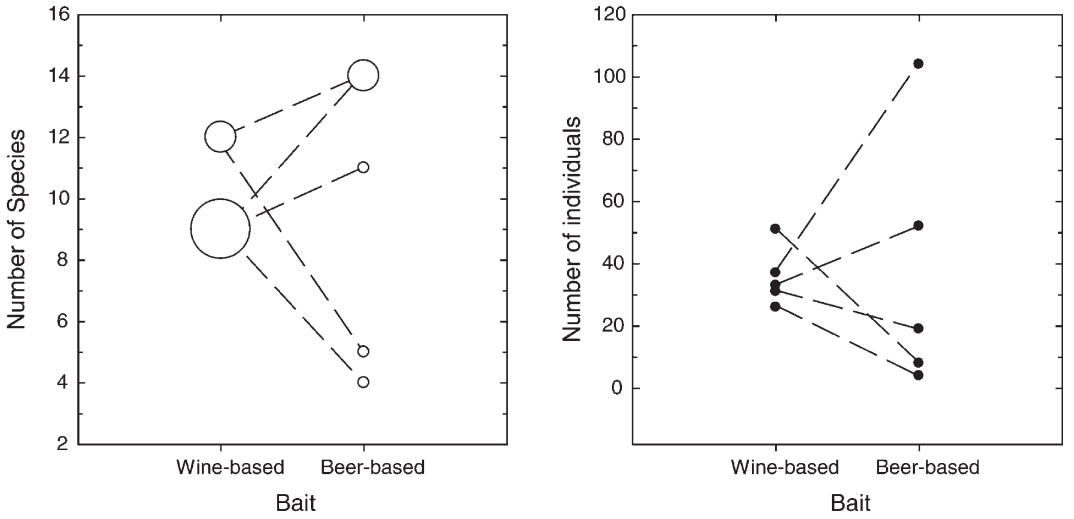

Figure 3. Number of species (left) and number of individuals (right) in the Jalas traps. Trap pairs (one with wine-based bait and one with beer-based bait) are connected with dashed lines. Circle diameters in the left graph denote the number of traps with a given number of species. Large circles indicate three traps, medium sized circles indicate two traps, and small circles indicate one trap.

Antal arter (vänster) och antal individer (höger) i betesfällorna. Varje fällpar (en fälla med vinbaserat bete och en med ölbaserat bete) sammanbinds med streckad linje i figuren. Cirkeldiametrarna i den vänstra figuren visar antalet fällor som fångat samma antal arter. Stora cirklar betyder tre fällor, medelstora cirklar två fällor, och små cirklar en fälla.

Discussion

We chose to run our investigation over a short interval to mimic a typical sampling situation for many surveys. Would baits work during this limited period and would they perform equally well? Our results suggest that they do. Species richness and species composition of the total catches were similar between the two baits, indicating that wine-based and beer-based baits can be successfully used for short-term surveys and as well as for moth monitoring. However, while the two bait types work well in the context where we tested them, there may still be circumstances where they differ in performance. Bait efficiency can potentially differ between species and over the season. Moths with early flight periods such as *Orthosia* are not necessarily attracted by the same cues as species peaking in mid season such as *Noctua* and others. Further, it is quite likely that ambient temperature affects chemical cues differently depending on their relative volatility (*e.g.*,Vallat *et al.* 2005). To find out how bait efficiency interacts with these factors, a long-term approach will be needed (*cf.* Süssenbach & Fiedler 1999, 2000). Interestingly, when noctuid moth trappings over 6 months were combined, Süssenbach & Fiedler (1999) detected differences between a banana-based bait and a wine-based bait. Fewer moth individuals and species were caught in the more exotic banana bait. Nevertheless, when catches were used to predict total moth diversity per site, diversity estimates were similar for the two bait types (Süssenbach & Fiedler 1999). The degree to which bait performance over the season depends on food preferences or temporal patterns of cue effectiveness seems to be a challenging but promising topic for future investigations.

Together with the growing literature on bait-trapping (Söderman 1994, Süssenbach & Fiedler 1999, Laaksonen *et al.* 2006), our evaluation of baits for moth trapping shows that bait trapping

has evolved into an excellent tool for large-scale field surveys of moth diversity as well as for backyard trapping. Using the bait-trapping methodology successfully developed in Finland over the last decades (Söderman 1994) it is now possible to quantify the composition and abundance of moth communities in great detail. Bait traps are both cost- and time-efficient as they do not require the presence of a person, and allow comprehensive surveys that continue throughout the flight season. They also work well in considerable wind as during rainfall (Süssenbach & Fiedler 1999, Pettersson & Franzén unpublished results). Results are probably easiest to standardise when using equipment such as commercial Jalas traps (Söderman 1994), but other ways of bait presentation also work (Süssenbach & Fiedler 1999, see below).

In our study, we caught only few geometrid moths. This is a general experience in bait-trapping studies although the reasons for it remain unclear. In many cases, geometrids are much more abundant at light traps than at bait-trap at the same site (Pettersson & Franzén unpublished results). However, it could also be that Jalas traps and other relatively open designs allow geometrids to escape. Some evidence from this comes from recent findings by Finnish scientists who have used modified trap designs (the new "Oulu" trap) and succeeded in trapping considerable numbers of geometrids (Mönkkönen & Mutanen 2003, Laaksonen *et al*. 2006).

Catches in some of our traps were considerably larger than others (Fig. 3a-b, Table 2) indicating that factors other than bait composition can play important roles too. For instance, the intensity and range of olfactory cues from the bait might depend on the position and immediate surroundings. Further, microclimatic conditions at the trap location, weather conditions, and especially wind exposure might be important for the catch in a single trap. We also noticed that some species were abundant in some traps indicating that species-specific cues can influence catches. This can be females attracting males close to the trap or other species-specific communications that aggregate some species in specific traps. Overall, despite choosing a pairwise design to compensate for differences between trap sites, there were still considerable differences between individual trap catches. To understand how local conditions and moth behaviour interact in influencing trap catches will require further studies with more traps and over longer time-periods.

How should one then choose baits and trapping strategy? Both wine-based and beer-based baits work well, but differ slightly in terms of availability and cost of ingredients. In our study, we used ordinary beer, although other studies have used light beer and then allowed the bait mixture to ferment (e.g., Mönkkönen & Mutanen 2003). A conservative cost estimate based on current Swedish prices and the recipes in Table 1 ends up with the wine-based bait being about 1.7 times more expensive than the beer-based bait (240 vs 140 SEK). Then again, some ingredients of the beer-based bait are more difficult to get hold of, molasses in particular, and you might have to buy much more than what you use. Preparing the wine-based bait is also considerably quicker and simpler. The choice of trapping methodology also offers some different alternatives. The new Oulu trap appears not to be commercially available yet, but there is a detailed description how to build one in Laaksonen *et al*. (2006). Current prices for Jalas traps are 400 SEK per trap, excluding delivery costs. A low-cost alternative is to use cotton strings or cotton fabric soaked in the bait and place them out at suitable trapping spots. Baits are then visited regularly during the night and moths counted or collected. Süssenbach & Fiedler (1999) recommends placing such baits openly, for instance by tightening a rope between two trees and then suspending bait-soaked strings or pieces of fabrics from it. This caught twice as many noctuid moths as when baits were placed directly on tree trunks. Furthermore, placing baits 2 m above the ground was about five times as effective as placing them 0.5 m above ground level. The key to success appears to be good cue dispersal around baits.

Very little is known about how far away that baits are attracting moths. Likewise, little is known about how baits perform over the season and in different habitats. Investigating questions like these are just some of the many exciting

possibilities that can now be addressed by entomologists using bait traps. Both bait types are well suited for moth trapping and that the choice of either is primarily a matter of taste, cost, and availability of ingredients.

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Sammanfattning
Betesfällor för nattfjärilsfångst används mer och mer men ännu är relativt lite känt om hur bra olika typer av beten fångar. I detta arbete ger vi recept på två av de vanligaste betestyperna: ett vinbaserat bete och ett ölbaserat bete. De två betestyperna testades i ett fältförsök på Gotland sommaren 2007. Finsktillverkade sk Jalas-fällor användes för försöket och vi placerade ut tio fällor, fem med ölbete och fem med vinbete, i en parvis jämförelse. Fångsten samlades in efter 48 timmar. Båda betena fungerade bra och sammanlagt lockades 365 individer av 35 olika nattfjärilsarter till fällorna. De två betena skilde sig inte signifikant åt i hur bra de fångade, varken i fråga om totalantal fångade arter eller i fråga om totalantal individer. Vi konstaterar att båda betestyperna passar bra för nattfjärilsfångst och att valet av den ena typen före den andra i första hand är en fråga om smak, kostnad samt tillgänglighet till ingredienser.