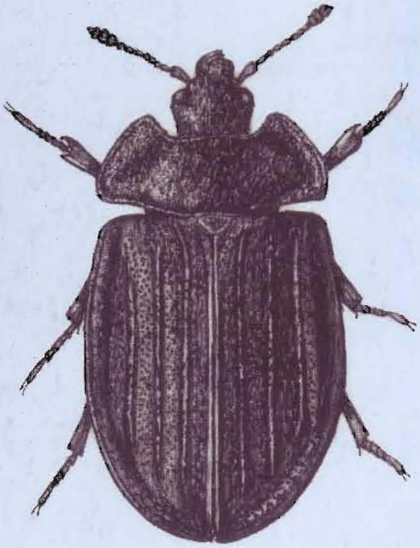
Norwegian Journal of Entomology

Volume 48 No. 1 • 2001

XXV Nordic-Baltic Congress of Entomology

Melsomvik, Norway

27 June – 2 July 2000



Published by the Norwegian Entomological Society
Oslo and Stavanger

NORWEGIAN JOURNAL OF ENTOMOLOGY

A continuation of *Fauna Norvegica Serie B* (1979–1998), *Norwegian Journal of Entomology* (1975–1978) and *Norsk Entomologisk Tidsskrift* (1921–1974). Published by The Norwegian Entomological Society (Norsk entomologisk forening).

Norwegian Journal of Entomology publishes original papers and reviews on taxonomy, faunistics, zoogeography, general and applied ecology of insects and related terrestrial arthropods. Short communications, e.g. less than two printed pages, are also considered. Manuscripts should be sent to the editor.

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Front cover: *Peltis grossa* (Linnaeus, 1758) (Coleoptera, Trogossitidae). Artist: Karl Erik Zachariassen.

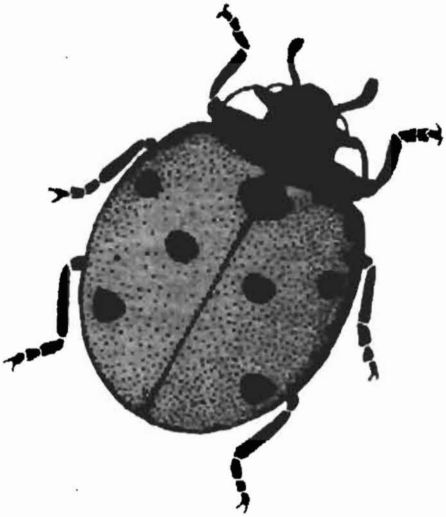
Printed by: Reprografisk Industri AS, Oslo.

ISSN 1501-8415.

Proceedings of the XXV Nordic-Baltic Congress of Entomology Melsomvik, Norway

27 June – 2 July 2000

Lauritz Sømme, Lars Ove Hansen
& Geir E. E. Söli
Editors



Published by the Norwegian Entomological Society
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May 2001

The XXV Nordic-Baltic Congress of Entomology

Jan Emil Raastad

Since 1923 it has been a tradition to arrange the Nordic Meeting of Entomology every third year (with some exceptions) in one of the Nordic countries. In 1997, however, the 24th Congress was held in Tartu, Estonia. The inclusion of the Baltic entomologists was a refreshing input that gave the meeting an optimistic uplift. It was decided to use the name the Nordic-Baltic Congress of Entomology for the future. It was also decided that the next meeting should be held in Norway.

Because arrangements in Norway involves high economical cost, the organizing committee decided to hold the arrangement outside the urban areas. The choice of localization was therefore of quite another character than the beautiful old city of Tartu in Estonia. However, the Melsom School of Agriculture proved to be a good choice. Facilities and food could be offered at a high standard and at reasonable prices. The organizing committee is most grateful to the Melsom School and its staff for friendly and excellent service.

The scenic surroundings offered a lot of possibilities for entomological activities. As you will see from an accompanying paper by Arvids Barševskis, beetle collecting in Melsomvik was most successful, especially with regard to number of species.

The organization of the 25th Nordic-Baltic Congress of Entomology has been a co-operative effort of the Norwegian Entomological Society and the Zoological Museum, University of Oslo. The committees, hereby listed by members, have done the organization work.

The Organizing Committee: Jan Emil Raastad (chairman), University of Oslo, Zoological Museum; Alf Bakke, Norwegian Forest Research Institute; Morten Falck, Norwegian Entomological Society; Lars Ove Hansen, Norwegian Entomological Society/University of Oslo; Sigmund Hågvar, Agricultural University of Norway; Nina Svae Johansen, The Norwegian Crop Research Institute; Preben Ottesen, Norwegian Entomological Society/National Institute of Public Health; Lauritz Sømme, Biological Institute, University of Oslo.

The Advisory Committee: Antti Pekkarinen, University of Helsinki (Dept. of Ecology and Systematics), Finland; Mati Martin, University of Tartu (Inst. of Zoology and Hydrobiology), Estonia; Bengt Ehnström, Swedish University of Agricultural Sciences (ArtDatabanken), Uppsala, Sweden; Eduardas Budrys, University of Vilnius (Institute of Ecology), Lithuania; Voldemars Spungis, University of Riga (Dept. of Zoology and Genetics), Latvia; Lauritz Sømme, University of Oslo (Biological Institute), Norway.

The congress was supported by the Norwegian Academy of Science and Letters, Oslo and Letterstedtska föreningen, Stockholm. In addition, support to strengthen the forest entomology of the congress was given by Samnordisk skogforskning (SNS), Sweden. The contribution of these supporters, as well as the work of many private persons, to secure a successful meeting is most sincerely acknowledged. A special «thanks» to the programme committee.

The participants convened during afternoon Tuesday June 27. The meeting was opened the following morning. The opening address of the congress was given by the chairman of the organizing committee, Jan Emil Raastad, and by the now re-elected congress president, Bengt Ehnström. There were greetings to the congress from representatives of entomologists from Nordic and Baltic countries represented by Mati Martin (Estonia), Antti Pekkarinen (Finland), Edda Oddsdóttir (Iceland), Voldemars Spungis (Latvia), Eduardas Budrys (Lithuania), Preben Ottesen (Norway), and Markus Forslund (Sweden). Greetings were also received from Per-Eivind Johansen, Mayor of Stokke Municipality, and from Karl Hagelund, County Governor, Department of Environmental affairs of Vestfold. The greetings from Hagelund is cited below (abbreviated with permission):

«Dear members of the 25th Nordic-Baltic Congress of Entomology! On behalf of the County

governor of Vestfold, Mona Røkke, and her department of environmental affairs, I have the great honour and pleasure to greet all of you and express my very best wishes for this congress, both for the entomology as profession, and for the building of a scientific network and friendship through such an arrangement.

We are proud that you have chosen our county for this congress. But we are not surprised by your choice, when Norway was going be the host of such a congress.

With a little more than 2200 km² of land and freshwater, Vestfold is the smallest county in Norway, but an important part of our country. We live in a pressure area with respect to further development of our cities and villages, and with big infrastructure projects going on, such as the E-18 highway, modernising our railway and an airport with increasing traffic. Vestfold is a very popular place to live. 80 % of our 210 000 inhabitants are settled within an area 10 km from the coastline. In addition, we have about 15 000 summer cabins, of which more than 90 % are located along the coast. Furthermore, several thousand camping tourists visit Vestfold during summertime.

In Vestfold we have the highest percentage of farmland; 20 % compared to an average of 3 % in Norway as whole. We have a strong practice to protect this farmland against other use because of its high production potential for food like fresh vegetables, fruit and berries and grains. All this makes a strong pressure on the remaining forestland and other not arable land that is our nature environment.

Vestfold and the other counties in the Oslofjord area have the highest biological diversity in Norway. The reason for this is both the mild climate and the geology that varies from rich and soft limestone to very poor and hard granites. Good soils from former sea bottoms, a high percentage of cultivated land and the high variation in the landscape over short distances makes Vestfold a very good basis for many species to live right here.

Earlier we thought of biological diversity as the numbers of trees, flowers, birds and mammals, when land use was on agenda. In the last years people in the nature management administration, have learned that the biggest biological diversity is found in other groups of species, such as lichens, fungi and mosses, as well as invertebrate animals. And among the animals, the insects are the biggest group with an enormous diversity and many species not yet known or scientifically described.

We are told that most of the biological diversity is found in tropical forests and other places far away. But we have to recognise that there is still much to be found even in our own countries. We are responsible to take care of our own biological diversity, although we do not know all the details. I believe that as entomologists you have a very important job to do. We do not know all about how to take care of the biological diversity, but we ought to use our current knowledge. Your knowledge about the various species, and how they may be used as indicators, can help us to point out the right places to take care of areas with special rich and/or vulnerable types of diversity, or to take care of representative localities.

When I read your congress program, I found that the four sections are very suitable to this point of view. You have included important items such as forest entomology, threatened species and conservation strategies in addition to more basic items as general entomology, systematic and faunistic entomology.

I hope that entomologists and conservationists in the administration for nature management in the future can co-operate even better. You have the competence to give the bureaucracy the right arguments in the continuous struggle to take even better care of the richness in our common nature. We are responsible to our children and grandchildren and the generations after them, so they can enjoy the beauty of a butterfly on a good warm day in the summer or wonder about how a crawling beetle on the ground can live down there.

Finally, I wish you all a successful congress and hope that you also will take time to enjoy the diversity of Stokke and Vestfold, not only the insects, but other sides of our environment as well.»

A total of 96 persons were registered as participants of the congress. Naturally, the entomologists from Scandinavia and the Baltic countries were in majority. But we were also pleased to have participants from Russia, Germany and France. Summing up, 1 of the participants were from Denmark, 19 from Estonia, 10 from Finland, 2 from France, 1 from Iceland, 8 from Latvia, 5 from Lithuania, 29 from Norway, 5 from Russia, and 16 from Sweden.

The lectures and posters presented in the respectively sessions were as follows (those marked with an asterix are published in the present issue):

Plenary session

Huldén, L. & Mikkola, K. The climate change divided into seasons; how is the northern insect fauna affected?

Spungis, V. Insects in sandy coastal habitats.

***Ekbom, B.** How to choose a sampling method and what will be wrong with it.

Budrys, E. Phylogeny of the digger wasps of the subfamily Pemphredoninae (Hymenoptera, Sphecidae).

Nordic-Baltic entomology (general)

Chairmen: L.S. Sømme and A. Pekkarinen

***Pekkarinen, A.** Views on late Weichsellan and early Holocene dispersal of insects in NW Europe (Key lecture).

***Hågvar, S.** Ecological studies of the winter active insect *Boreus* sp. (Mecoptera); occurrence and migration on snow, and phenology of egg-laying.

***Skartveit, J.** Aspects of the adult biology of *Bibio johannis* (L.) (Diptera, Bibionidae).

Goodpasture, C. How to photograph insects - a flash approach to insect photography.

Tuubel, E., Toom, T. & Luik, A. Influence of agrotechnology on carabid occurrence.

***Dapkus, D.** Butterflies and moths of Lithuanian peat bogs.

***Koponen, S., Relys, V. & Dapkus, D.** Changes in structure of ground-living spider communities on peat bogs along transection from Lithuania to Lapland.

***Bagge, P.** Water mite fauna of northern streams (River Teno and River Kemi).

***Sømme, L.** Do we need national entomological journals?

Nordic-Baltic forest entomology

Chairmen: K. Heliövaara and A. Luik

Lindelöw, Å., Schroeder, M.L., Weslien, J. & Lindhe, A. Mechanically created high stumps of Norway spruce; aspects on redlisted Coleoptera and pest insects (Key lecture).

***Salingre, G. & Heliövaara, K.** Invertebrate diversity in mixed Norway spruce (*Picea abies*) stands.

Varama, M. Mass outbreak of *Diprion pini* (Hym., Diprionidae) in Finland in 1997-2000.

Smits, A. & Larsson, S. Pine looper (*Bupalus piniarius* L.) fecundity and larval performance as related to density dependent variation in resource quality.

Cedervind, J., Pettersson, M. & Långström, B. Attack by *Tomicus piniperda* on pine trees defoliated by *Bupalus piniaria.*

Långström, B., Cedervind, J. & Hellqvist, C. Estimation of needle losses following defoliation by *Bupalus piniaria.*

Appelqvist, C. & Långström, B. Effects of BT-spraying against Bupalus pinarius on the Lepidoptera fauna at Hökensås, Sweden.

Andersen, J. & Olberg, S. Saproxylic beetles (Coleoptera) in Dividalen, Troms County.

Pettersson, R.B. Assessment of conservation value in pine stands with tracks from saproxylic insects.

Økland, B. Flight activity of sporocarp-visiting beetles.

Lindelöw, Å. «Skogsskada» - a new internet tool to diagnose and report forest damage.

Nordic-Baltic systematics, faunistics, collection management and use of databases

Chairmen: M. Martin and V. Spungis

Aarvik, L. The Norwegian Lepidoptera database (Key lecture).

***Bakke, A., Aarvik, L. & Berggren, K.** Diversity index of nocturnal Macrolepidoptera applied to vegetation zones in Norway.

***Kruus, M. & Viidalepp, J.** Continuous trapping of nocturnal Macrolepidoptera in Estonia (the Nocturna Project 1995-98); first results.

Talvi, T. Patterns of carabid beetle distribution in the Baltic Sea islands (Coleoptera, Carabidae).

***Voisin, J.-F.** The entomology collections of the Muséum National d'Histoire Naturelle, Paris, France.

***Kuzmina, Y.** Chironomidae (Diptera) of the North of Russia.

Ottesen, P. Urban insects in Norway 1994-1999; database management and results.

***Kurina, O.** The genus *Cordyla* Meigen, 1803 (Diptera, Mycetophilidae) and identification aspects of species.

Rindal, E. & Söli, G. Phylogeny of Mycetophilinae (Diptera).

Greve, L. A preliminary survey of Norwegian Lauxaniidae (Diptera).

Falck, M. Family Bombyliidae (Diptera) in Norway.

Threatened insects and conservation strategies in the Nordic-Baltic countries

Chairman: E. Budrys

Ehnström, B. Swedish threatened species unit; past and present (Key lecture).

Hansen, L.O. Conservation of insect diversity in the Oslofjord area.

Antonsson, K. The hermit beetle (*Osmoderma eremita*) in Europe; a nature conservation project.

Posters

Antonsson, K. The hermit beetle (*Osmoderma eremita*) in Europe; a nature conservation project.

***Barševskis, A.** Phenology and ecology of *Notiophilus germinyi* FV. (Coleoptera, Carabidae) in Baltic countries.

***Bernotiene, R.** Bloodsucking blackflies in Lithuania, problems and solutions.

***Budrys, E.** Some aspects of the ethological evolution of digger wasps and the problem of the origin of bees (Hymenoptera, Apoidea).

***Dapkus, D.** Epidemic spider communities in exploited peat bogs in Lithuania.

Grichanov, I. Ya. Dolichopodidae (Diptera); website in the internet.

***Hagström, T.** The Surinam cockroach (*Pycnoscelus surinamensis*), a new green house pest established in Gothenburg.

Hedgren, P.O. Temporal and spatial distribution of bark beetle attacks close to wind felled trees.

***Hiiesaar, K., Jõudu, J., Kuusik, A., Metspalu, L. & Herman, P.** The influence of low temperatures on the development of the Colorado potato beetle, *Leptinotarsa decemlineata* Say (Coleoptera, Chrysomelidae).

Jankevica, L. & Tenbergs, G. Ecological database of Latvian insect pathogens.

***Jucevica, E.** Collembola from the Baltic Sea coast dunes.

Kobro, S. Database of the thrips (Thysanoptera) collection of the Norwegian Crop Research Institute.

Lauk, Y. & Ratassepp, M. Abundance of carabid beetles (Coleoptera, Carabidae) in wetch mixed crops depending on the use of some herbicides.

***Loskutova, O.A.** Plecoptera in ecosystems of the Pechora tributaries flowing in the Timan Ridge and the Urals.

Luik, A., Eenpuu, R., Nõmmiste, K. & Viidalepp, V. Carabids in differently cultivated barley fields.

Mänd, M., Sepp, K. & Truu, J. Landscape structure and bumblebee communities.

Martin, A.-J. & Sõukand, Ü. Distribution of cadmium in social food chain of red wood ants.

***Martin, M. & Elberg, K.** On the structure of the alvar mesofauna in the Island of Saaremaa.

***Martin, M., Mõttus, E., Liblikas, I., Ojarand, A. & Borg-Karlson, A.-K.** Attractivity of isomers of 11-tetradecenyl acetate mixtures for *Archips podana* Scop. and *Aphelia paleana* (Hbn.) (Lepidoptera, Tortricidae).

Merivee, E., Ploomi, A., Rahi, M., Luik, A. & Sammelselg, V. Antennal sensilla of the ground beetle *Bembidion lampros* Hbst. (Coleoptera, Carabidae).

***Metspalu, L., Kuusik, A., Tartes, U., Hiiesaar & K., Hermann, P.** Discontinuous gas exchange, body movements and heart activity during pupal development of Colorado potato beetle *Leptinotarsa decemlineata* Say.

Ploomi, A., Merivee, E., Rahi, M., Bresciani, J., Ravn, H.P., Luik, A. & Sammelselg, V. Typology and distribution of antennal sensilla of the ground beetle *Bembidion properans* Steph. (Coleoptera, Carabidae).

Raastad, J.E. Update on Fennoscandian blackflies (Diptera, Simuliidae).

***Rogovtsova, E.K.** Water beetles of the Komi Republic.

***Salmane, I.** Fauna of the soil Gamasina mites (Acaria, Mesostigmata) along the Latvian Sea coast and their relation to the respective habitats.

Sibul, I. & Voolma, K. Abundance and sex ratio for pine weevils, *Hylobius abietis* and *H. pinastri,* in pine clear-cuttings of different age.

Solevåg, P.K. Rare insects from a biotope in Tafjord (Møre & Romsdal), Norway.

Telnov, D. Anthicidae of Northern Palaearctic; taxonomic and biogeographical aspects.

Turcinaviciene, J. Studies of three Ribes-inhabiting species of the genus *Aphis* L.

***Turka, I.** Plant bug Heteroptera from the monocultures in Latvia.

Voolma K., Sibul, I. & Süda, I. Forest insects attracted to ground traps baited with turpentine and ethanol on clear-cuttings.

Yakovlev, E. & Polevoi, A. Diptera collected with trunk window traps on bracket fungi.

In addition there was an informative book display stand by Apollo Books.

Closing session

Chairman: Bengt Ehnström

There was a general agreement to the importance and usefulness of a regularity of meetings of this kind, and it was recommended that they should be continued in the future. It was agreed to the suggestion of the chairman that we will continue the use of «Nordic-Baltic Congress of Entomology», possibly with the subtitle «a meeting for entomologists of Northern Europe». The most important question also found an answer as Voldemars Spungis took responsibility to organize the next meeting, which will be held in Latvia in 2003.

It was agreed that contacts for future meetings should be organized through e-mail and the Internet. Kjell Antonsson (Sweden) would like to make a complete database of Nordic-Baltic entomologists. The entomological societies will send list of their members to Kjell Antonsen for his database update (name, address, e-mail, field of interest). Action is taken by Preben Ottesen (Norwegian entomologists), Markus Forslund (Swedish entomologists), Antti Pekkarinen (Finnish entomologists), and Voldemars Spungis (Baltic entomologists). The organizer of the 26th Nordic-Baltic Congress of Entomology will receive a copy of the database.

Finally, the closing session decided to send greetings from this congress, a postcard with photo of the delegates of the 25th Nordic-Baltic Congress of Entomology, to the following persons: Edward

Sylvén (Sweden), Kaupo Elberg (Estonia), Andrejs Grindbergs (Latvia), Kauri Mikkola (Finland), Pekka Nuorteva (Finland), Walter Hackman (Finland), Ragnhild Sundby (Norway), Are Gusik (Estonia), Astrid Løken (Norway), and Arne Semb-Johansson (Norway).

Excursions

We believe that field excursions will stimulate and strengthen continued interest in entomology. Therefore, as a central part of the meeting, we offered a variety of small after-lunch excursions on the third day of the congress. Five alternatives of free choice was organized, each for about 20 persons: Borre Lake area (organizer: L.O. Hansen), Farris Lake area (organizer: T. Kvamme), Sandø Island, Tjøme (organizer: A. Fjellberg), Hvasser Island, Tjøme (organizer: P. Ottesen), and a Cultural excursion to Sandefjord and Tønsberg (organizer: S. Hågvar). Although the weather was not at its best, the entomological, as well as the social outcome of the excursions were very satisfactory. Report from the cultural arrangement was that the Whaling Museum was excellent not at least because of a professional and skilled guide.

The working part of the meeting ended with the Saturday's Congress dinner and farewell party with speeches from the President and several other persons. Sunday morning brought excellent weather and there was a common buss for the whole-day excursion to Lifjell Mountains (organizer: P. Ottesen). Here the congress ended in beautiful surroundings, trustfully with a rich outcome in several ways. Of the record, an extra excursion was added to the day programme for the Estonian and Lithuanian group (guide: J.E. Raastad). They had their private buss for transportation and wanted to experience a little more of Norway before their return. A visit to Gaustadtoppen, the highest mountain in this part of Norway, was much appreciated by the group.

It is our firm impression that the congress and the excursions generally were regarded as successful. The many letters and e-mails received from pleased attendants are acknowledged. Looking forwards to meet again in Latvia in 2003!


INTERNAT-GYMSAL-KANTINE

1. Torkel Hagström
2. Åke Lindelöw
3. Elisabeth Hagström
4. Tore R. Nielsen
5. Thor Jan Olsen
6. Jacob Antonsson
7. Per Kristian Solevåg
8. Kjell Antonsson
9. Teemu Rintala
10. Dalius Dapkus
11. Preben Ottesen
12. Per Olof Hedgren
13. Morten Falck
14. Anne Luik
15. Jussi Päivinen
16. Leif Aarvik
17. Ivar Sibul
18. Ingvar Svensson
19. Arne Heggland
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46. Agnis Smits
47. Marti Martin
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50. Seppo Koponen
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63. Riho Raud
64. Larry Hultén
65. Ana Budriene
66. Anne Lene Aase
67. Angela Ploomi
68. Yana Kuzmina
69. Gulborg Søvik
70. Ants-Johannes Martin
71. Eirik Rindal
72. Rasa Bernotiene
73. Jan Emil Raastad
74. Alf Bakke
75. Bjørn Økland
76. Hans Silfverberg
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78. Külli Hiisaar
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Norw. J. Entomol. 48, 11–17. 2001

Examination of some sampling methods in entomology

Barbara Ekbom

Ekbom, B. 2001. Examination of some sampling methods in entomology. Norw. J. Entomol. 48, 11-17.

The purpose of this paper is to discuss some of the problems encountered in designing sampling programs. One problem of central importance in entomological research is the estimation of abundance. Whether our goal be the monitoring of relatively abundant pest insect species or rare threatened species it is essential to design a sampling plan that allows us to minimize error. Intensive sampling efforts should be carefully considered before implementation, as costs can be prohibitive. In this lecture I will consider the usefulness of presence-absence (or abundance-occupancy) sampling in both conservation and pest management scenarios. Some examples from each discipline will be given and emphasis will be put on estimation of error and interpretation of the data obtained. Another topic will be use of traps, in particular pitfall traps, and the accuracy obtained. Careful consideration of exactly what traps measure, for example activity or abundance, is necessary in choosing a suitable trapping technique. The importance of resource distribution when using relative sampling techniques, such as pitfall and pheromone traps, will also be discussed.

Key words: sample size, presence-absence sampling, trap efficiency, pitfall traps, pheromone traps

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INTRODUCTION

Many of the questions we ask, as entomologists, have to do with «How many?». If we wish to compare two habitats we will count insects in each habitat and statistically test the means to find out if there is a significant difference. If we want to determine whether or not an insect pest population threatens a crop we will count insects and compare our results with an economic threshold. If we are worried about population decline in a red-listed species we may monitor populations from year to year and try to determine if the numbers are actually shrinking. An opposite problem can be the increase of an invasive species, in which case we want to find out how rapidly the species is growing and spreading. We may count numbers present by sampling plants, trees, or other hosts. Alternatively we may use traps to estimate insect numbers.

When trying to answer the question «How many?» we will try to estimate the number of insects present by taking samples, as we obviously cannot count all the insects in a population. We also want to be reasonably sure that our estimate is trustworthy, that is we should be able to have a concise statistical estimate of error. It then becomes necessary to ask the question «How many samples do I need to take?». Unfortunately the answer will inevitably be «It depends». The necessary number of samples will depend on the spatial distribution of the insects, the population mean, and the level of desired accuracy. In other words we seem to need a lot of information before we can actually launch a full scale sampling program.

Sometimes we try to estimate insect numbers by using traps. This technique is not without problems because traps will clearly have their limitations. We need to know the efficiency of a trap, that is how are trap catches translated into population estimates. Two types of widely used traps, pitfall traps and pheromone traps, are considered in this paper. I attempt to point out some of the potential problems with these traps so that users will be aware of the need to study the efficiency of traps. The objective of this paper is not to instruct the reader on statistical or modeling methods, many of the books and articles in the reference list do that well, but rather to increase awareness of potential problems.

COUNTS OF INSECT ABUNDANCE

Spatial distribution

Virtually every book on ecological methods begins with a description of three spatial patterns: uniform, random, and aggregated (Southwood 1978, Ludwig & Reynolds 1988, Krebs 1989, Young & Young 1998). This classification has to do with the relationship between the mean and variance of the population. When the mean is greater than the variance the population is uniformly distributed, when the mean is equal to the variance we have a random distribution, and when the mean is smaller than the variance the distribution is aggregated. Obviously the first step in designing a sampling program is to try to have some preliminary estimates of the population mean and variance.

Most insects either have a random or aggregated distribution. For those species showing an aggregated distribution it is desirable to have some measure of the degree of aggregation. Several methods are used to do this, but the method that is perhaps most widely used is to look at the relationship between the mean and variance over a range of different means. This is called Taylor's power law (Taylor 1961). By performing a linear regression of the natural logarithm of the variance (s^2) on the natural logarithm of the mean ($\bar{x}$) coefficients for the intercept (ln a) and the slope (b) are obtained (Young & Young 1998). The slope (b) is a measure of aggregation, when $b=1$ the distribution is random, $b<1$ uniform, and $b>1$ aggregated. The important thing is that we can use our data to find an estimate of variance given any particular mean ($\text{Variance}=a*\text{Mean}^b$, $s^2=a\bar{x}^b$).

Sample size

We want our estimate of mean abundance to be as precise as possible. For example we would like to know that our estimate is within 20% of the actual mean, and we would like this to be true 95% of the time. Using formulae developed elsewhere (Karandinos 1976) the equation will be:

$$\text{Sample size} = (1.96/0.2)^2\,[\text{Variance}/(\text{Mean})^2]$$

The value 1.96 comes from the standard normal distribution and is the value for a probability of 0.95 (for 0.90 the value is 1.645 and for 0.99 it is 2.58). The denominator 0.2 is simply the expression for 20% precision (likewise if 10% precision is desired 0.1 is used in the denominator). The remaining part of the equation has to do with the relationship between the mean and the variance, which is defined by the spatial distribution as described above. Formulae for sample sizes when the spatial distribution is random or aggregated and can be described by a formal mathematical expression such as Taylor's power law are found in numerous books and publications (Young & Young 1998).

When the mean is small many samples will be needed (Figure 1). However, in some situations such as monitoring pest abundance a precise estimation of a very small mean is not very interesting. On the other hand when monitoring rare species such as red listed species precision for even very small means may be important. One practical method of approaching insect sampling when little or nothing is know about the spatial distribution is to take a number of samples, compute 95% confidence limits from the mean and variance of the sample. If the estimate is reasonable given the objectives of the sampling program sampling can stop. Otherwise more sets of samples can be taken and confidence limits calculated after each set until the desired precision is reached (Krebs 1989).

ABUNDANCE – OCCUPANCY RELATIONSHIPS

In population monitoring, for example sampling for estimates of pest abundance, it is often advantageous to classify samples as to whether insects are present or not instead of counting all individuals in a sample. This method of presence-absence or incidence sampling is often easier and faster than numeration sampling. However this type of sampling can only be used if a relationship between the proportion of samples containing insects and the mean density has been ascertained (Gaston 1999). It has been shown for a number of insects that there is often a positive relationship between mean density and proportion occupied (Figure 2). This relationship can often be expressed by again using natural logarithm transformations and then performing a linear regression (Nachman 1981):

$$\ln(\ln(1/(1-p))) = \ln a + b \ln x$$

An example is shown in Figure 2. Determining the relationship is useful for designing sampling plans for pest management. It can also be of importance to determine the relationship between occupancy and abundance in other situations. If we consider conservation and invasion situations we find ourselves at different ends of the scale. From a conservation point of view this is a worrying situation because increasing numbers of empty habitats means a decrease in density and a growing risk for extinction. Considering invasive species as more habitats are occupied the density is also increasing. Therefore monitoring the establishment of an invasive species probably can usually be accomplished by determining the proportion of habitats where insects are present. If this proportion increases over time the abundance of the species is also increasing.

TRAP EFFICIENCY

Traps are dependent on insect movement patterns. They often give measures that are a combination of both activity and abundance. In order to use traps effectively one should try to estimate the ratio of the actual catch to a potential catch.

Pitfall traps

One example of a widely used trap type is pitfall traps. The principle is simple, a ground-living in-

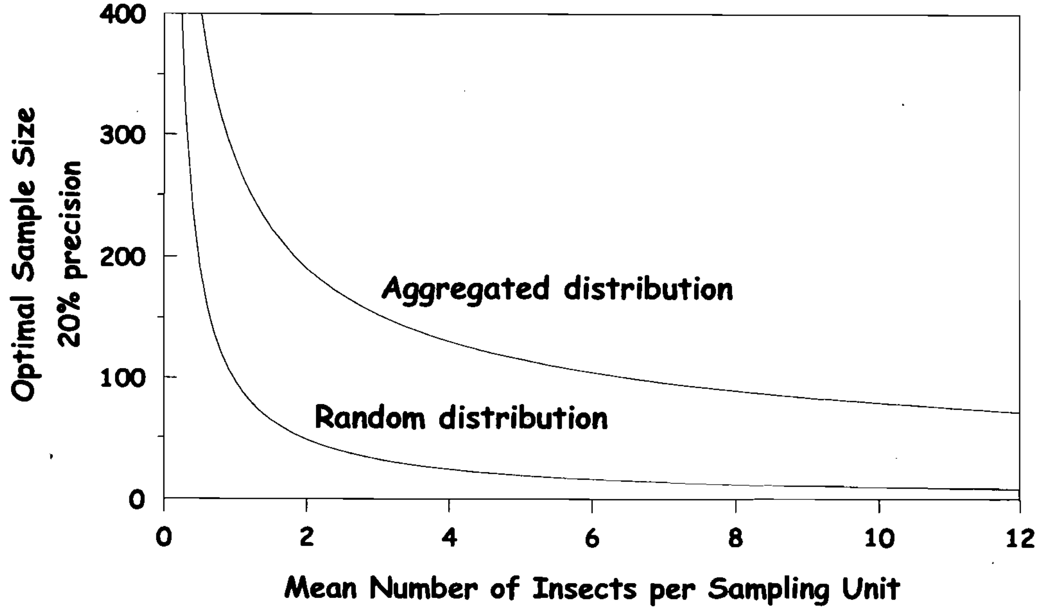

Figure 1. An example of optimal sample sizes for a random and an aggregated distribution. The aggregated distribution is described by Taylor's power law with coefficients a=2.8, and b=1.45 (after Ekbom 1985,1987).

sect running or walking along falls into the trap. However, the key is movement. We have used pitfall traps widely in our work and wished to know something about the capture efficiency.

By using tracking techniques with harmonic radar we estimated parameters of carabid movement in relation to resource availability (Wallin & Ekbom 1994). The resource in this case was the density of aphid prey in cereal fields. We found that several species of carabids responded to high prey density by slowing down. They did not turn more or change direction more often in the presence of high prey density, instead they decreased their speed. Using this data we have written an individual based simulation model that follows predator movement in a field (Firle et al. 1998). This model gives us a tool to study the capture efficiency of pitfalls in relation to both prey and predator density. Details as to the parameters used in the model and the behavior rules are found in Firle et al. (1998).

To estimate trapping efficiency simulations were performed on a lattice representing a 1 ha area. Traps with a diameter of 15.4 cm were placed on a diagonal. Trap densities were 1, 4, or 16. Predators were added at three densities: 1) low, 0.01 per m^2; 2) medium, 0.1 m^2; and 3) high, 1 per m^2. Prey density was scaled from no aphids (0.0, low), through medium densities (0.5, medium), to almost total infestation (0.98, high). Each predator is tracked individually and when a predator is found at the same position as a pitfall trap it is considered captured. The simulations were run for the number of time steps (one time step is 5 minutes) approximating five weeks (2500 time steps). At the end of each simulation the total number of captured predators was recorded. Five simulations for each combination of trap, prey, and predator density (27 combinations) were performed and mean number of captured predators was calculated.

Results of pitfall trap simulations

The number of predators caught per trap during the 5 week period for each of the 27 combinations is shown in Table 1. It is evident that the number of traps is not very important for assessing the magnitude of the catch. The ratio of the number of captured predators to the number of «free» predators was always <0.01 so there should be no depletion effects. We then calculated the average number of insects caught per trap per week. Using these numbers the proportion of predators caught was calculated and related to prey density (Figure 3). Trap efficiency is higher when resource availability is low, that is when predators

Table 1. Number of insects caught per trap. Results of simulations of different predator densities moving on a landscape with different prey densities. The time frame for the simulation was 5 weeks.

		Prey Density No. per m^2		
Predator Density No. per m^2	Number of traps	Low 0	Medium 0.5	High 0.98
Low 0.01	1	0.6	0.4	0.2
	4	0.4	0.2	0.4
	16	0.35	0.3	0.18
Medium 0.1	1	4.25	3.0	2.2
	4	5.9	2.75	1.8
	16	5.4	2.3	1.8
High 1	1	55	25.6	15.4
	4	52.1	26.2	19.8
	16	58.8	25.9	20.7

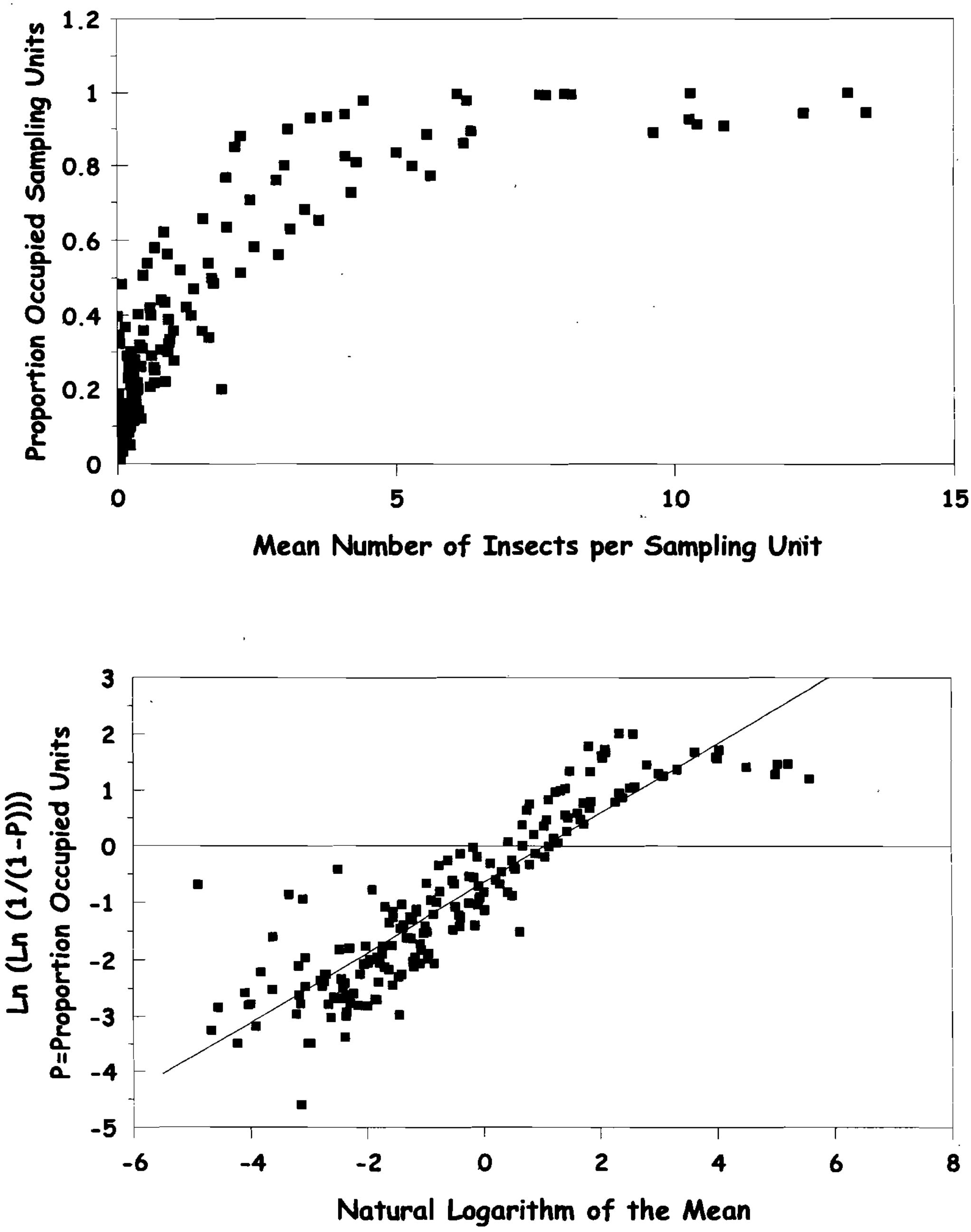

Figure 2. The upper graph is an example of the relationship between means of insect abundance in sampling units and the proportion of sampling units where one or more insects are present. The lower graph shows the values in the previous graph transformed after Nachman (1981), demonstrating a positive relationship between abundance and occupancy. The linear regression is $y = -0.641 + 0.618x$, $r^2 = 0.803$.

are moving at a higher speed and thereby traversing a larger area.

The catches per trap at low prey density were more than two times greater than the catches at high prey density for medium and high predator densities. If we merely look at trap catches we might conclude that there were more predators in areas of low prey density, which is not true because we set the predator densities in the model. However, by measuring the prey density (resource level) as well as the numbers caught in traps we could adjust density estimates from pitfall catches. Some empirical evidence for this phenomenon is provided by a study where catches of a carabid, *Pterostichus melanarius*, were much higher in plots sprayed to kill aphid than in plots left untreated (Chiverton, 1984). The immediate interpretation is that spraying will not affect numbers of predators, but if one takes into consideration that trapping efficiency is changed by prey density the interpretation may be different. Other factors that may influence ground living insect movement are vegetation density and temperature. When designing comparative studies using pitfall traps it would be prudent to try to estimate trapping efficiency in the different habitats investigated.

Pheromone traps

This type of trap actively attracts insects. Use of pheromone traps is popular because they can be used to sample low populations and they attract only insects of one (or a few closely related) species. It is often desirable to estimate population densities by using pheromone trap catches and in order to accomplish this the trap's effective sampling area (ESA, Turchin 1998) needs to be estimated. If we assume that a trap will capture some number of insects, C, and this number is proportional to the population density, m, then C=am. If

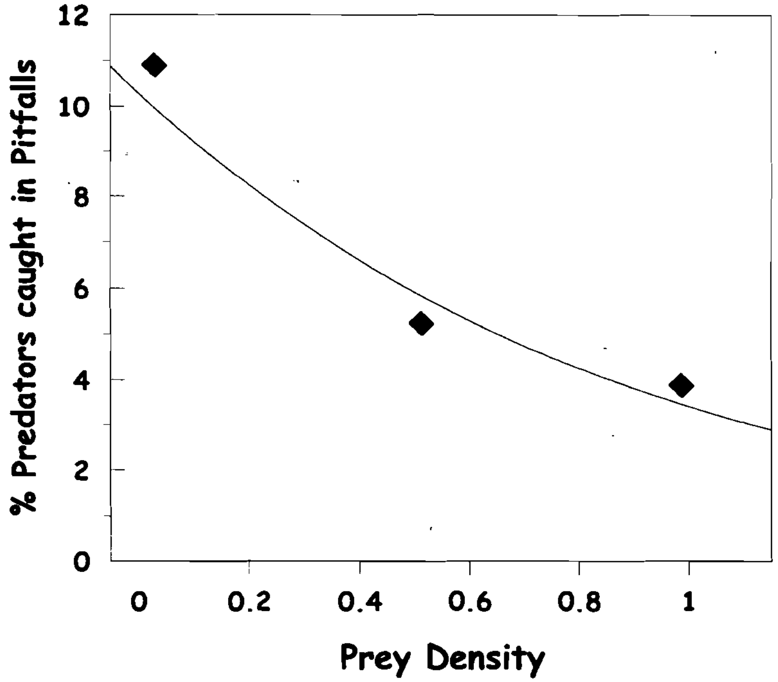

Figure 3. The relationship between prey density and the percentage of predators caught in pitfall traps from a simulation study. The highest prey density is about 30 aphids per plant. Values are means of the results from all three predator densities (low = 0.01/m^2, medium = 0.1/m^2, high = 1/m^2).The exponential regression is $y = 10.3\ e^{-1.11}$, $r^2 = 0.956$.

we can estimate the proportion a, then the population density m=C/a (Turchin 1998).

One way to address the problem of estimating pheromone trap efficiency is to use mark-recapture studies. By releasing a known number of males (M) within a defined area (A) (for calibrating traps an area without a natural population would be desirable) the population density would then be M/A. ESA is then calculated a=(C/M)A. Elkinton and Cardé (1980) did this for the gypsy moth, their recapture rate was 4% and this translated into a=2.56 ha, which corresponds to a sampling radius of about 90 m. If 100 gypsy moths were caught in a trap, population density would be approximately 40 males per ha. All of this assumes that trap efficiency is not influenced by other factors. It was shown by Taylor et al. (1991) that efficiency actually depends on male density. The aerial density of flying males was determined using a suction trap and compared to pheromone trap densities. Suction traps do not actively attract insects and sample a known volume of air per unit time. If the efficiency of a pheromone trap is not dependent on male density then there should be a linear relationship between suction trap catches and pheromone trap catches. However, this was not true and as density increased pheromone traps caught a smaller proportion of the population than at low density (Taylor et al. 1991). Other factors that might influence pheromone trap efficiency are trap density and form as well as wind speed and direction. Any monitoring program using pheromone traps should include an experimental study that attempts to estimate trap efficiency.

Acknowledgements. Sascha Firle is thanked for help with the pitfall modeling. The Carl Trygger Foundation is thanked for financial support.

REFERENCES

Chiverton, P.A. 1984. Pitfall catches of the carabid beetle *Pterostichus melanarius*, in relation to gut contents and prey densities, in insecticide treated and untreated spring barley. Ent. Exp. Appl. 36, 23-30.

Ekbom, B.S. 1985. Spatial distribution of *Rhopalosiphum padi* (L.) (Homoptera:Aphididae) in spring cereals in Sweden and its importance for sampling. Environ. Ent. 14, 312-316.

Ekbom, B.S. 1987. Incidence counts for estimating densities *of Rhopalosiphum padi* (Homoptera: Aphididae). J. Econ. Ent. 80, 933-935

Elkinton, J.S. & Cardé, R.T. 1980. Distribution, dispersal, and apparent survival of male gypsy moths as determined by capture in pheromone-baited traps. Environ. Ent. 9, 729-737.

Firle, S., Bommarco, R., Ekbom, B. & Natiello, M. 1998. The influence of movement and resting behavior on the range of three carabid beetles. Ecology 79, 2113-2122.

Gaston, K.J. 1999. Implications of interspecific and intraspecific abundance-occupancy relationships. Oikos 86, 195-207.

Karadinos, M.G. 1976. Optimal sample size and comments on some published formulae. Bull. Ent. Soc. Am. 22, 417-421.

Krebs, C.J. 1989. Ecological methodology. Harper & Row, New York.

Ludwig, J.A. & Reynolds, J.F. 1988. Statistical ecology, a primer on methods and computing. John Wiley & Sons, New York.

Nachman, G. 1981. A mathematical model of the functional relationship between density and spatial distribution of a population. J. Anim. Ecol. 50, 453-460.

Southwood, T.R.E. 1978. Ecological methods. Second edition. Methuen, London.

Taylor, L.R. 1961. Aggregation, variance, and the mean. Nature 189, 732-735,

Taylor, R.A.J., McManus, M.L. & Pitts, C.W. 1991. The absolute efficiency of gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), milk-carton pheromone traps. Bull. Ent. Res. 81, 111-118.

Turchin, P. 1998. Quantitative analysis of movement. Measuring and modeling population redistribution in animals and plants. Sinauer Associates, Inc. Sunderland, Massachusetts.

Wallin, H. & Ekbom, B. 1994. Influence of hunger level and prey densities on movement patterns in three species of *Pterostichus* beetles. Environ. Ent. 23, 1171-1181.

Young, L.J. & Young, J.H. 1998. Statistical ecology, a population perspective. Kluwer Academic Publishers, Boston.

Received 27 June 2000,
accepted 17 November 2000

THE INTERNATIONAL SOCIETY OF HYMENOPTERISTS

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5th International Conference of Hymenopterists

The 5th International Conference of Hymenopterists will be held in Beijing, China from July 22-26, 2002. It is timed to complement the IUSSI Congress to be held in Sapporo, Japan July 28-Aug 3, 2002.

Conference Venue

This conference will take place in Friendship Hotel, Beijing, which is very close to Institute of Zoology, Chinese Academy of Sciences. Accommodation will be available in this hotel as well as others in Chinese Academy of Agriculture.

Scientific Program

The conference will consist of :

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- sessions for submitted talks
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- specialist discussion groups
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Norw. J. Entomol. 48, 19–30. 2001

Views on the Late Weichselian and the Early Holocene dispersal of insects and other biota in NW Europe

Antti Pekkarinen

Pekkarinen, A. 2001. Views on the Late Weichselian and the Early Holocene dispersal of insects and other biota in NW Europe. Norw. J. Entomol. 48, 19-30.

The history of the last glaciation is fundamental to the present biota in NW Europe. However, our insight into various periods of the Weichselian as well as the dispersal of biota during the Late Pleistocene and the Early Holocene is still fragmentary in many respects. For instance, new radiocarbon dates from Finnish subfossil mammoths indicate much larger ice-free areas in Fennoscandia during the Middle Weichselian 32 000 to 22 500 yr BP than previously assumed. Large areas of the Kola Peninsula and northern coast of Scandinavia (Finnmark) deglaciated already during the Late Glacial interstadial 13 000 to 11 500 yr BP and the Kanin-Kola dispersal route has been very important for the Fennoscandian arctic and subarctic fauna and flora. After the Late Glacial stadial (the Younger Dryas chronozone) the climate ameliorated rapidly about 10 200 yr BP and arctic and subarctic species dissappeared quite suddenly in southern Fennoscandia and new more thermophilous species colonized the areas. Many species previously suggested to be survivors in glacial refugia in Scandinavia obviously had not colonized Scandinavia prior to the Late Weichselian. Yet, fairly recent fossil records of aquatic insects and other invertebrates during 22 000 to 13 000 yr BP on Andøya in the Atlantic coast of NW Norway indicate the survival of the fauna in ice-free refugia during the Weichselian maximum. Alvar biotopes in the islands of Öland, Gotland and Saaremaa (Ösel) as well as certain shore areas of the Baltic Sea, especially those of the Gulf of Bothnia and even some esker biotopes are edaphic and physiognomic «relict» habitats of the Early Holocene biota. DNA markers provide important tools for further studies of the history of previous biota.

Key words: Dispersal of insects, glacial refugia, Weichselian, Holocene alvar.

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INTRODUCTION

The Pleistocene glaciations have caused dramatic changes in the biota on the earth during the last two million years. Many plant and animal taxa have become extinct in Europe during the various periods of climatic deterioration. For instance, the number of tree genera in NW Europe has gradually decreased from about 50 to 20 genera during the six last Quaternary glaciations (Bradshaw 1999) and impoverishment in many other taxa has probably been of similar magnitude. However, there are many «refuged» Palaearctic animal and plant species which potentially could thrive in NW Europe, but which were not able to disperse there during the short epoch of the Holocene.

Oxygen isotope records from deep sea and ice cores isotopes as well as pollen data from terrestrial sites indicate drastic climatic fluctuations during the Weichselian (e.g. Andersen & Borns 1997) and there are a lot of records of mainly arctic or subarctic biota from the two interstadials of the Early Weichselian in various areas of Fennoscandia (e.g. Lindroth 1948, 1969, Lundqvist 1978, Helle et al. 1981, Garcia Ambrosiani & Robertson 1992, Lemdahl 1997a) (see also Figure 3). Furthermore, recent radiocarbon dates from Finnish mammoth bones suggest that before the

Weichselian maximum, large ice-free areas existed in eastern Fennoscandia during at least 10 000 ra (radiocarbon) years and that the Scandinavian Ice Sheet did not reach ice-free areas of eastern Finland prior to 22 500 ra yr BP (Ukkonen et al. 1999). The Scandinavian Ice Sheet extended 500-600 km eastwards from the present eastern border of Finland up to east of the river Dvina (Larsen et al. 1999). However, recent studies indicate that most of the northern Russia and the Arctic Sea coast east of the Kola Peninsula (including the Kanin Peninsula) were ice-free during the Weichselian maximum about 18 000 ra yr BP (Astachov et. al. 1999, Mangerud et al. 1999, Svendsen et al. 1999).

Tree rings, oxygen isotopes from ice core and lacustrine sediment chronology indicate a great deviation between C14 (radiocarbon) and real calendar years in the early Holocene. The absolute age of the termination the the Younger Dryas has been determined to be 11 570 yr (Friedrich et al. 1999, see also e.g Wohlwarth et al. 1993, Björck et al. 1996, Brauer et al. 1999), while the traditional C14-age is 10 000 yr BP. All dates given in this article are traditional and are based mainly on radiocarbon dates (Table 1).

KANIN-KOLA DISPERSAL ROUTE

After the Weichselian maximum the ice sheets melted fairly quickly. Rapid amelioration of the climate has been documented in NW Europe at the transition of the Middle and Late Weichselian about 13 000 yr BP (Figure 2). The Scandinavian and the Novaya Zemlya Ice Sheets were separated about 12 500 yr PB and large areas of the Kola Peninsula and northernmost Norway (Finnmark) were deglaciated before the Younger Dryas about 11 000 yr BP (e.g. Punkari 1993, Rainio et al. 1995, Andersen et al. 1995). Furthermore, there are several radiocarbon dates falling between 12 700-10 000 yr BP from Finnish Lappland and the area of Kuusamo in northern Finland, but these records are generally regarded as erroneous and too old (e.g. Ignatius et al. 1980, Vasari et al. 1996). Yet, the remains of *Corynogera ambigua* Zetterstedt and some other chironomid midges recorded in the lowest lacustrine sediments from Central Finnish Lappland may originate from the Allerød or early Younger Dryas (Hirvenoja 1998 and references therein). The early deglaciated Kola Peninsula has been an important dispersal route for arctic and subarctic and even boreal species from northern Russia to Fennoscandia. This assumption is supported by e.g.:

Table 1. Chronozones from the Early Weichselian to the Early Holocene in thousands of years (ka).

	ka BP
PLEISTOCENE	
Early Weichselian	117-75
Middle Weichselian	75-13
Weichselian maximum	ca 18
Late Weichselian	13-10
Bølling	13-12
Older Dryas	12-11.8
Allerød	11.8-11
Younger Dryas	11-10
HOLOCENE	
Preboreal	10-9
Boreal	9-8

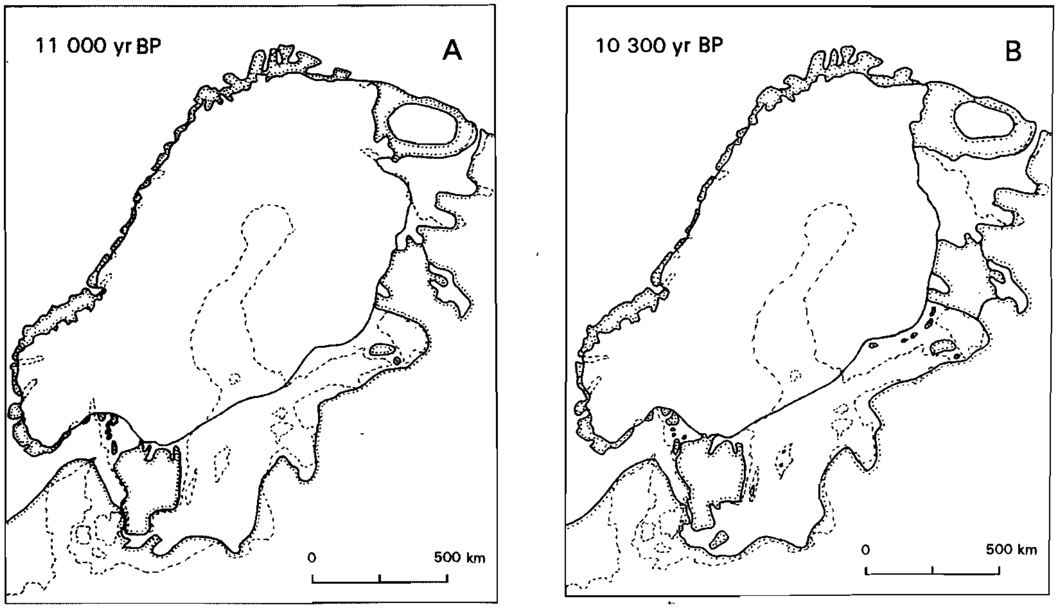
(1) Records of pollen of the Norway spruce *Picea abies* (L.) from the Late Weichselian (12 000 yr BP) in the Komi area and from the Early Holocene (9 500 yr BP) in the Pechora-Kanin area (Lang 1994).

(2) The rich occurrence of vertebrate fossils in northern Pechora area (67°N) between 22 000-10 000 BP (Hufthammer 1998).

(3) Only a narrow outlet of the White Sea separated the Kola Peninsula and the land area lying southwest the Kanin Penisula during 13 000-10 000 yr BP; the water in the southern part of the White Sea basin was fresh and brackish in the northern part (Rainio et al. 1995, see also Sauramo 1958: 432) (Figure 1).

(4) The large occurrence of Ericales pollen in northernmost Norway at the beginning of the Holocene (10 000 yr BP) (Huntley & Birks 1983).

(5) About twenty vascular plant (Hultén 1971) and many insect species including six ground beetles (Lindroth 1949, 1985, 1986) have been recorded in Fennoscandia only or mainly from the Kola Peninsula; Lindroth (1949:730-732) regarded the Kanin-Kola dispersal of «tundra» species as evident (see also Andersen 1983, 1988).



LATE YOUNGER DRYAS AND PREBOREAL BIOTA IN SOUTHERN FINLAND AND KARELIA

During the Younger Dryas most of Finland was covered by ice and southernmost Finland by the Baltic Ice Lake. Only small areas of dry land existed in southern Finland when the Second Salpausselkä marginal moraine was formed and more dry land near the ice margin was in Karelia (Figure 1) (more detailed information in Hyvärinen 1973). Subfossils of beetles and other insects living in arctic-subarctic environments have been found on the Karelian Isthmus (Lindberg 1908, Poppius 1911) and in the Salpausselkä area in Finnish Karelia (Bondestam et al. 1994), e.g. the carabids *Pterostichus vermiculosus* Menetries (Figure 3A), *Bembidion dauricum* (Motschulsky) and the cantharid *Podabrus obscuripes* J. Sahlberg. These remains have been dated to the Late Younger Dryas about 10 000 yr BP and they indicate an arctic or subarctic steppe-tundra environment. Bondestam et al. (1994) demonstrated that arctic and subarctic insect (and plant) species disappeared after about 9500 yr BP and new more thermophilous species dispersed to the area. The change of the fauna was fairly sudden and was caused by a rapid climatic amelioration about 10 150 yr BP. As Lindroth (1949:721) assumed, arctic or subarctic insect species recorded in southern Karelia probably could not reach the fjeld-region of Finland by means of immigration from

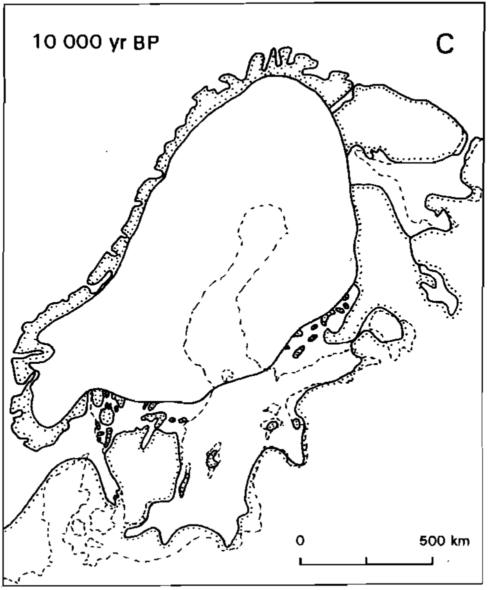


Figure 1. Land contour of NW Europe and the Fennoscandian ice sheet in the Early Younger Dryas (A), in the Late Younger Dryas (B) and at the beginning of the Holocene (C). Mainly according to Rainio et al. (1995) and Björck (1995).

the southeast (see also Kalela 1943). Furthermore, Late Weichselian or Early Holocene subfossils of arctic insect (or plant; e.g. *Dryas*) species have not been recorded in SE Finland north of the marginal morains of the Younger Dryas (the Second Salpausselkä).

ARCTIC AND ALPINE BIOTA IN SCANDINAVIA

A land bridge over the present southern Baltic Sea between southern Sweden and continental Europe (or Själland) existed about 2500 years during the Younger Dryas-Boreal chronozones (the land bridge was broken by the outlet of the Baltic Ice Lake for about 500 years in the Late Younger Dryas) (Björck 1995). The bridge allowed a good dispersal route for arctic/subarctic and later more thermophilous biota from southern refugia to southern Sweden (Figure 1). Beetles recorded by Coope & Böcher (2000) from Late Allerød deposits at Northern Jylland are predominantly northern species and indicate a considerably colder climate than today in Jylland. Younger Dryas insect remains from southern Sweden (Henrikssen 1933, Lemdahl & Gustafsson 1997, Lemdahl 1991, 1997b) indicate arctic conditions and rapid amelioration of the climate at about 10 200 yr BP, which is parallel with that observed by Bondestam et al. (1994) in SE Finland. After the quick amelioration in the transition of the Middle and Late Weichselian, the climate became graduallay colder during the Late Bølling and was cold during most of the Younger Dryas. The amelioration in the end of the Younger Dryas was a very abrupt change in the north Atlantic region (Dansgaard et al. 1989). In England, the mean July temperature has possibly been increased 7-8 °C during some decades, but in Denmark and southern Sweden the amelioration was perhaps a little slower (Walker 1995) (Figure 2).

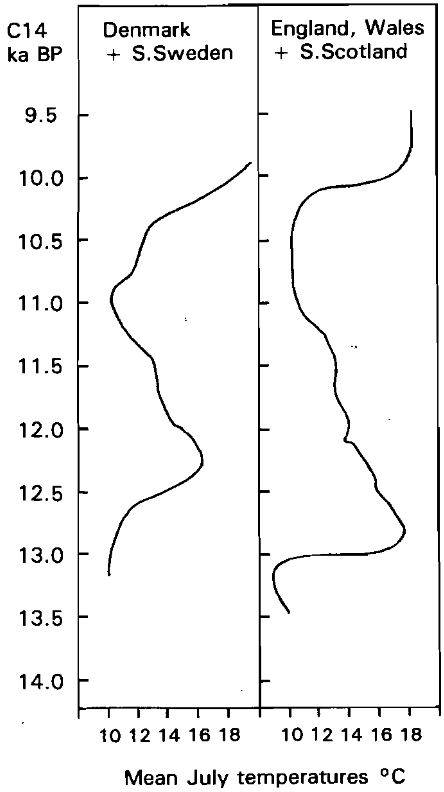


Figure 2. Late Weichselian mean July temperature trends in Denmark and southern Sweden, in England and southern Scotland reconstructed using beetle remains (see e.g. Atkinson et al. 1987). According to Walker (1995); data from Walker et al. (1994) and Berglund et al. (1994).

During the Younger Dryas and Preboreal large areas in southern Scandinavia south of the ice sheet margin were submerged by the North Sea or the Baltic Ice Lake and later the Yoldia See. Impressive Younger Dryas marginal moraines in southern Norway (Rana, Fitjar and Herdla) largely follow the present coastline (e.g. Andersen 1979, Mangerud et al. 1979.). In SW Norway, the level of the seashore was during the Bølling-Younger Dryas 10-40 m above the present shore-line reaching the maximum level during the Younger Dryas transgression; in south Østfold the shore level was about 180 m above the present shore-line at the beginning of the Preboreal (Kryzwinski & Stabell 1984, Anundsen 1985). Consequently, dry land areas in southern and SW Norway were very limited before the retirement of the ice sheet at the end of the Younger Dryas (Figure 1).

There has been much debate about survival of biota in glacial refugia in Scandinavia. In his monumental work of Fennoscandian ground beetles Lindroth (1949) concluded that completely or predominantly short-winged populations of dimorphic carabid species in certain coastal areas of

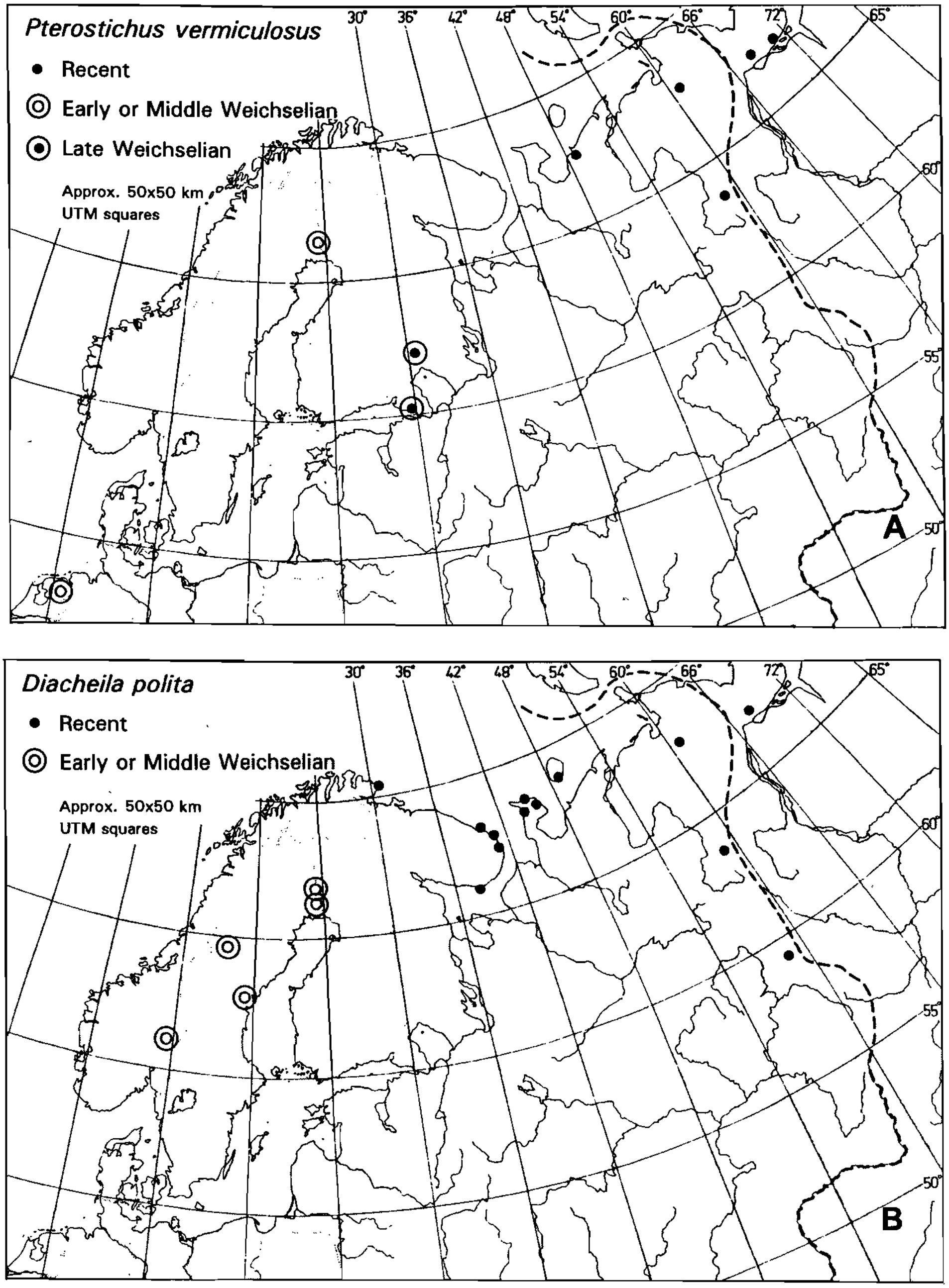


Figure 3. Recent and Weichselian records of arctic ground beetles *Pterostichus vermiculosus* (A) and *Diacheila polita* (B) in Fennoscandia and northern Russia. *P. vermiculosus* occurred during the Younger Dryas in southeastern Finland but could not disperse to the mountain area of Lappland when climate ameliorated quickly at the beginning of the Holocene. *D. polita* has dispersed from northern Russia to the Kola Peninsula perhaps in the Allerød. Records according to Lindberg (1908), Poppius (1910, 1911), Lindroth (1945, 1948), Lundqvist (1978), Coope (1979b), Helle et al. (1981), Korobeijnikov (1991), Carcia Ambrosiana & Robertson (1992), Olshvang (1992), Bondestam et al. (1994), Lemdahl (1997a), Hanssen & Olsvik (1998).

Norway originate from populations which lived there in isolated glacial refugia (see also Lindroth 1969, 1979). Yet, Nilsson et al. (1993) suggested that the brachypterous carabid populations in Scandinavia more reflect recent events than the early postglacial history of the fauna. Geological evidence for ice-free refugia has also been scanty, but the dynamic character of glaciations has been stressed and the fact that refugial areas may have been changing during the course of the Weichselian (e.g. Dahl 1963). Furthermore, new geological arguments have been presented for the existence of many ice-free nunataks in SW Norway (Sollid & Sørbel 1979, Nesje et al. 1987).

Coope (1969, 1979a) suggested that «refugial» populations in western Scandinavia originate from Britain and dispersed in the Late Glacial or Early Holocene via Dogger Land and partially by means of anemo-/hydrocory to the western coast of Norway (see also Brinck 1966a,b). The main arguments by Coope are:

(1) The similarity of the Late Weichselian fauna of Britain with the present fauna in Scandinavia.

(2) There are many fairly thermophilous (forest) species which Lindroth (1949) suggested to have survived in the Norwegian refugia.

(3) Several «high» arctic species known only in the Middle Weichselian deposits in England (or other sites in western Europe or in Fennoscandia) nowadays occur only in northern Russia and Siberia (but not in Scandinavia).

Some of the arctic species recorded in the Middle Weichselian deposits in England like carabids *Diacheila polita* (Faldermann) and *Bembidion crenulatum* F. Sahlberg have later (perhaps in the Allerød) colonized the Kola Peninsula from the east (*D. polita* has recently been recorded even in the Varanger Peninsula in northernmost Norway) (Figure 3B). Recent palynological and subfossil beetle records clearly indicate that arctic and subarctic biota have dispersed also from the southern

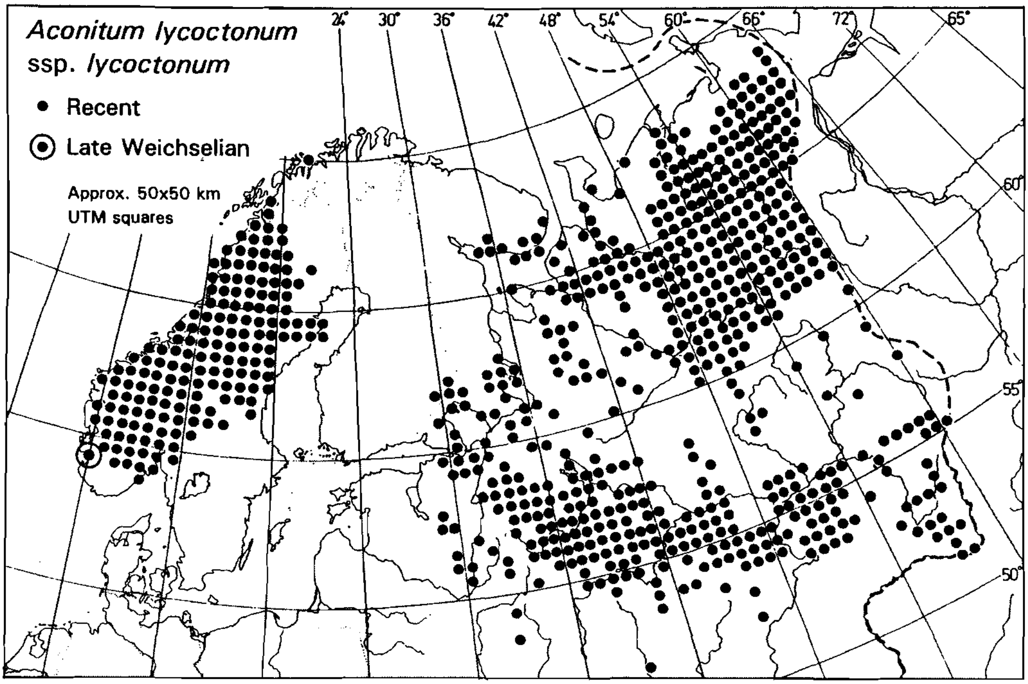


Figure 4. Records of wolfspane *Aconitum lycoctonum* sp. *lycoctonum* in Europe (the records eastwards the Ural excluded) according to Jalas & Suominen (1989) and a subfossil pollen record (in Rogaland) from the Younger Dryas (Paus 1988). Four other closely related species or subspecies occur in central or southern Europe. Published by courtesy of Societas Biologica Fennica Vanamo.

refugia to the Scandinavian mountain area (e.g. Paus 1988, Birks et al. 1993, Lemdahl 1997b). Nilsson et al. (1993) concluded that the Scandinavian arctic-alpine species originate from refugia situated in Central Europe south of the Weichselian ice margin. Consequently, they regarded the colonization from western (British) or eastern (Northern Russian) refugia as unlikely, but they did not take into consider the Kanin-Kola dispersal route.

Opinions expressed about the origin of several disjunct or endemic plant taxa in the Scandinavian mountain area are different (e.g. Fries 1949, Nordal 1987, Borgen 1987, Dahl 1989, Jonssel 1990) and new subfossil records in SW Norway do not support the survival of arctic-alpine plant species on unglaciated areas during the Weichselian (e.g. Paus 1989, Birks 2000). *Aconitum lycoctonum* L. (*septentrionale* Koelle) is an example of a plant species with a disjunct montane range in Scandinavia. The large continuous Eurasiatic distribution of the species extends in the east side of Finland to Russian Karelia and the Kola Peninsula and reaches the arctic zone east of the Kanin area (Figure 4). *Aconitum* is pollinated only by long-tongued bumblebees, especially for *Aconitum* monolectic *Bombus consobrinus* Dahlbom (e.g. Løken 1973, Mjelde 1983). Fries (1949) regarded *A. lycoctonum* as a glacial refuge in Scandinavia and emphasized that *Aconitum* seeds are dispersed mainly by water, which would afford a natural explanation for the postglacial history of the plant in Scandinavia and its absence in southern Finland. Furhermore, the flowers of *Aconitum* from Scandinavia and Finnish Karelia differ morphometrically (Pekkarinen 1979). A pollen record of *Aconitum* from the Younger Dryas in Rogaland in SW Norway (Paus 1988) indicates its late glacial occurrence in Scandinavia. However, a Late Weichselian (Allerød?) colonization of *Aconitum* from the south to Scandinavia cannot been excluded.

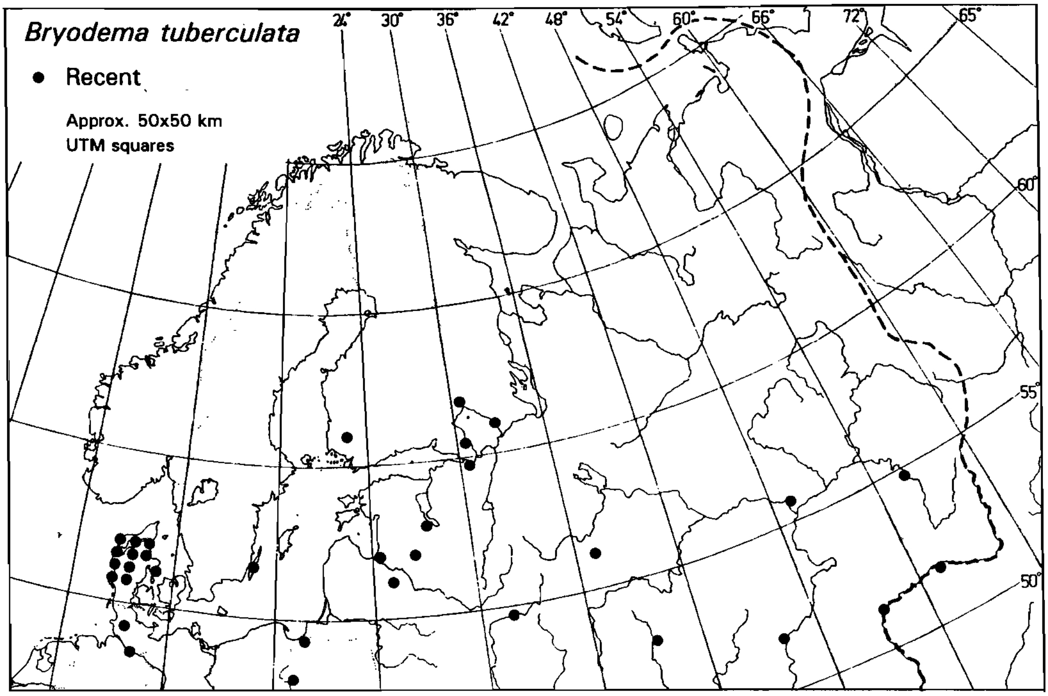


Figure 5. Records of grasshopper *Bryodema tuberculata* in northern Europe according to Zacher (1917), Harz (1957), Albrecht (1963), Holst (1969), Albrecht (1979), Coulianos & Sylvén (1983), Väisänen et al. (1991) and Spuris (1998).

Records of ice-free areas and continuous sediment accumulation before and during the Middle Weichselian on the isle Andøya in NW Norway (e.g. Vorren 1978, Vorren et al. 1988, Alm 1993) are remarkable. Remains of Chironomidae (since 22 000 yr BP), the gastropod *Arianta arbustorum* (19 500-19 000 yr BP), Oribatidae (18 000 yr BP), Trichoptera (13 000 yr BP) and even the weasel *(Mustela erminea* L.) (15 000 yr PB) have been recorded (Fjellberg 1978, Vorren et al. 1988, Solem 1994). These records clearly indicate the survival of refugial biota in Scandinavia during the Weichselian maximum.

The Boreal (8 700-8 000 yr BP) macrofossil findings of *Picea*, *Larix sibirica*, *Alnus glutinosa*, *Corylus*, *Tilia*, *Quercus* and *Ulmus glabra* in the present subalpine zone of Swedish Scandes in Jämtland recorded recently by Kullman (1996, 1998a, b) are surprising. The records clearly indicate that the Early Holocene climate in the Scandes has been at least locally more warm than previously has been assumed on the basis on palynological data. Consequently, the ranges of arctic species in the Scandes were more declined than today during the Boreal temperature optimum.

ALVAR, SEASHORE AND ESKER BIOTOPES

During the Preboreal, arctic-subarctic biota disappeared in southern Fennoscandian lowlands and a new biota, among which were many typical steppe species, colonized the open and largely unsaturated habitats. Iversen (1958) called the Preboreal stage *protocratic* and stressed that it was mainly the rich in light and unleached, often calcarous soil, which favoured steppe species such as a shrub *Ephedra distachya* L. and he regarded the temperature as a less decisive factor.

Alvar limestone formations on the Baltic isles Öland, Gotland and Saaremaa (Ösel) are still existing protoctratic habitats. The Great Alvar in Öland is especially remarkable, since it is situated in the vicinity of the Swedish continent and it has not been submerged during the Ancylus Lake transgression in the Preboreal like perhaps the most alvar areas in Gotland. According to present calculations no land connection has existed southwards to Gotland and, similarly, Öland has also been an island during the entire Holocene (e.g. Svensson 1991, Björck 1995). In the Early Holocene, the summer temperature increased quickly in Gotland reaching the present level in the end of the Preboreal and the Holocene optimum up to the end of the Boreal (Mörner 1980). Probably, the Great Alvar and some other larger alvar areas have earlier been more densely covered by vegetation than nowadays and later human activity, mainly grazing, has diminished vegetation. However, certain alvar habitats in Öland with low-growing vegetation are regarded to have been as fairly stable during the entire Holocene. In their critical study of insect fauna of the Great Alvar, Coulianos & Sylvén (1983) found that unique and most distinctive alvar species live just in these low-growing, especially karst soil habitats. These authors considered three bug species, e.g. *Aradus frigidus* Kiritshenko (oligofag of *Helianthemum*), the moth, *Margaritia manualis* (Greyer), and the dolichopodid fly, *Scellus dolichocerus* Gerstäcker as the most probable relicts from the Preboreal.

The grasshopper *Bryodema tuberculata* (Fabricius) occurs in Scandinavia only in Öland, where it is a characteristic species on low-growing rock alvars (Coulianos & Sylvén 1983). In Jylland, the species had earlier been common in certain heath biotopes, but later it became completely extinct (Holst 1969). It is recorded also from the Baltic countries and the Karelian Isthmus and Ladoga Karelia. Surprisingly, the species was fairly recently found in SW Finland (Väisänen et al. 1991) (Figure 5). The Finnish locality (Säkylänharju) is a glaciofluvial esker biotope 100-145 m above sea level which means that the locality has been dry land since the Preboreal. Marginal moraine and glaciofluvial eskers in Finland are regarded as Early Holocene dispersal routes of several plant species typical to eskers (Jalas 1950). Possibly, *B. tuberculata* has dispersed from southeast to SW Finland along the eskers during the Boreal (see also Väisänen et al. 1991).

Many seashore habitats of the Baltic Sea can also be regarded as protocratic, particularly those of the Gulf of Bothnia with its great land uplift, where an Early Holocone pioneer plant species *Hippophaë rhamnoides* L. is one of the most typical shrubs. Some insect species with predominantly northern distribution in Fennoscandia, but living in a few (isolated) localities in gravelly or stony shores of the Gulf of Bothnia, like carabids *Bembidion virens* Gyllenhal and *B. hastii* Sahlberg (Lindroth 1945, 1985) may be Preboreal relicts. The grasshopper *Sphingonotus caerulens* (L.) recorded in Öland and some isolated shore localities in the Gulf of Finland and the pompilid wasp *Aporinellus sexmaculatus* (Spinola) in the Hanko Peninsula and Gotska Sandön have dispersed northwards after the Preboreal (Krogerus 1932, Ander 1949, Wolf 1967, Coulianos & Sylvén 1983).

PERSPECTIVES

New subfossil data of insects may solve many further open problems of the Pleistocene and Holocene dispersal history of insects in NW Europe like questions concerning various relicts and dispersal routes. Furthermore, DNA markers provide good modern tools for determining phylogeographic relationships between taxa and populations (Avise et al. 1987). Recent studies of mitochondrial DNA variation of insects and other organisms (e.g. Cooper et al. 1995; Jaarola et al. 1999 and references therein) clearly demonstrate that the present patterns of genetic differentation, however, with certain limitations (Taberlet et al. 1998) reflect various origins and colonization histories of populations during the glacial and postglacial time. For instance, genetic studies may solve the disputable origin of arctic-subarcic biota in Scandinavia and possible contact zones with southern and eastern dispersal routes.

Acknowledgements. I am grateful to Sirkka-Liisa Nyéki, Marjatta Rautiala, Pirkko Ukkonen, Eduardas Budrys, Arne Fjellberg, Oddvar Hanssen, Matti Eronen, Seppo Koponen, Torstein Kvamme, Ilpo Mannerkoski, Mati Martin, Hans Silfverberg, Voldemar Spungis, Ilkka Teräs and Risto Väinölä for providing literature or other information. Geoffrey Lemdahl and Lauritz Sømme made useful suggestions and corrections concerning the manuscript.

REFERENCES

Avise, C. A., Arnold, J., Ball, R. M., Bermingham, E., Lamb, T., Neigel, J. E., Reeb, C. A. & Saunders, N. C. 1987. Intraspecific phylogeography: The mitochondrial DNA bridge between population genetics and systematics. Ann. Rev. Ecol. Syst. 18, 489-522.

Albrecht, Z. 1963. Eesti sihktiivalised: Orthoptera s. Saltatoria 147 pp. Eesti NSV Teaduste Akadeemia Zooloogia ja Botaanika Instituut, Tartu.

Albrecht, A. 1979. Utbredningen av rätvingar, kackerlackor och tvestjar i östra Fennoscandien (Orthoptera, Blattodea, Dermaptera). Notulae Entomol. 59, 53-64.

Alm, T. 1993. Øvre Æerasvatn - palynostratigraphy of a 22,000 to 10,000 PB lacustrine record on Andøya, northern Norway. Boreas 22, 171-188.

Ander, K. 1949. *Omocestus haemorrhoidalis* Charp. in Schweden. Opusc. Entomol. 14, 121-149.

Andersen, B. G. 1979. The deglaciation of Norway 15,000-10,000 B.P. Boreas 8, 79-87.

Andersen, B. G., Lundqvist, J. & Saarnisto, M. 1995. The Younger Dryas margin of the Scandinavian Ice Sheet - an introduction. Quatern. Int. 28, 145-146.

Andersen, B. G. & Borns, H. W. Jr. 1997. The Ice Age World. 208 pp. Scandinavian University Press, Oslo.

Andersen, J. 1983. Towards ecologigal explanation of the geographical distribution of riparian beetles in western Europe. J. Biogeogr. 10, 421-435.

Andersen, J. 1988. Postglacial invandring av planter og dyr i norden. Fauna (Oslo) 41, 1-11.

Anundsen, K. 1985. Changes in shore-level and ice-front position in Late Weichsel and Holocene, southern Norway. Norsk Geogr. Tidsskr. 39, 205-225.

Astakhov, V. I., Svendsen, J. I., Matiouchov, A., Mangerud, J., Maslenikova, O. & Tveranger, J. 1999. Marginal formations of the last Kara and Barents ice sheets in northern Russia. Boreas 28, 23-45.

Atkinson, T. C., Briffa, K. R. & Coope, G. R. 1987. Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains. Nature 325, 587-592.

Berglund, B. E., Björck, S., Lemdahl, G., Bergsten, H., Nordberg, K. & Kolstrup, E. 1994. Late Weichselian environmental change in southern Sweden and Denmark. J. Quatern. Sci. 9, 127-132.

Birks, H. J. B. 2000. Floristic and vegetational history of Fennoscandia. Pp. 32-35 in Sandgren, P. (ed.), Environmental changes in Fennoscandia during the Late Quaternary. Lundqua Report 37, Lund University.

Birks, H. B., Paus, A., Svendsen, J. I., Alm, T., Mangerud, J. & Landvik, J. Y. 1994. Late Weichselian environmental change in Norway, including Svalbard. J. Quatern. Sci. 9, 133-145.

Björck, S. 1995. A review of the history of the Baltic Sea, 13.0-8.0 ka BP. Quatern. Internat. 27, 19-40.

Björck, S., Kromer, B. Johnsen, S., Bennike, O., Hammarlund D., Lemdahl, G., Possnert, G., Rasmussen, T. L., Wohlfarth, B., Hammer, C. U. & Spurk, M. 1996. Synchronized terrestrial-atmospheric deglacial records around the North Atlantic. Science 274, 1155-1160.

Bondestam, K., Vasari, A., Vasari, Y., Lemdahl, G. & Eskonen, K. 1994. Younger Dryas and Preboreal in Salpausselkä foreland, Finnish Karelia. Diss. Bot. 234, 161-206.

Borgen, L. 1987. Postglasial evolusjon i Nordens flora - en oppsummering. Blyttia 45, 147-169.

Bradshaw, R. W. 1999. Spatial responses of animals to climate change during the Quaternary. Ecol. Bull. 47, 16-21.

Brauer, A., Endres, C. & Negendag, J. F. W. 1999. Lateglacial calendar year chronology based on annually laminated sediments from Lake Meerfelder Maar, Germany. Quatern. Int. 61, 17-25.

Brinck, P. 1966a. Djurvärlden och det nordiska landskapets utveckling. Norsk Entomol. Tidsskr. 13, 205-244.

Brinck, P. 1966b. Animal invasion of Glacial and Late Glacial terrestrial environments in Scandinavia. Oikos 17, 250-266.

Coope, C. R. 1969. The contribution that the coleoptera of Glacial Britain could have made to the subsequent colonisation of Scandinavia. Opusc. Entomol. 34, 95-108.

Coope, C. R. 1979a. The Carabidae of the glacial refuge in the British Isles and their contribution to the post glacial colonization of Scandinavia and the North Atlantic islands. Pp. 407-424 in Erwin, T. L., Ball, E. G., Whitehead, D. R. & Halpern, A. L. (eds), Carabid beetles their evolution, natural history, and classification. Dr W. Junk, The Hague.

Coope, C. R. 1979b. Late Cenozoic fossil Coleoptera: Evolution, Biogeography, and Ecology. Ann. Rev. Ecol. Syst. 10, 247-267.

Coope, C. R. & Böcher, J. B. 2000. Coleoptera from the Late Weichselian deposits at Nørre Lyngby, Denmark and their bearing in paleoecology, biogeography and paleoclimate. Boreas 29, 26-34.

Cooper, S. J. B., Ibrahim, K. M. & Hewitt, G. M. 1995. Postglacial expansion and genome subdivision in the European grasshopper *Chorthippus parallelus*. Molecular Ecol. 4, 49-60.

Coulianos, C. C. & Sylvén, E. 1983. The distinctive character of the Great Alvar (Öland, Sweden) from an entomological point of view. (In Swedish with English abstract). Entomol. Tidskr. 104, 213-234.

Dahl, E. 1989. Nunatakk-teorien II - endemisproblemet. Blyttia 47, 163-172.

Dahl, R. 1963. Shifting ice culmination, alternating ice covering and ambulant refuge organisms. Geogr. Annaler 45, 122-138.

Dansgaard, W., White, J. W. C. & Johnsen, S. J. 1989. The abrupt termination of the Younger Dryas climate event. Nature 339, 532-533.

Fjellberg, A. 1978. Fragments of Middle Weichselian fauna on Andøya, north Norway. Boreas 7, 39.

Friedrich, M., Kromer, B., Spurk, M., Hofmann, J. & Kaiser, K. F. 1999. Paleo-environment and radiocarbon calibration as derived from Lateglacial/Early Holocene tree-ring chronologies. Quatern. Int. 61, 27-39.

Fries, M. 1949. Den nordiska utbredningen av *Lactuca alpina, Aconitum septentrionale, Ranunculus platanifolius* och *Polygonatum verticillatum*. Acta Phytogeogr. Suecica 24, 1-80.

Garcia Ambrosiani, K. & Robertson, A.-M. 1992. Early Weichselian interstadial sediments at Härnosand, Sweden. Boreas 21, 305-317.

Hanssen, O. & Olsvik, P. 1998. *Diacheila polita* (Faldermann, 1835) (Col., Carabidae) new to Norway. Fauna Norv. Ser. B 45, 116-118.

Harz, K. T. 1957. Die Geradflügler Mitteleuropas. 494 pp. Gustaf Fischer, Jena.

Helle, M., Sønstegaard, E., Coope, G. R. & Rye, N. 1981. Early Weichselian peat at Brumundal, southeastern Norway. Boreas 10, 369-379.

Henriksen, K. L. 1933. Undersøgelser over Danmark-Skånes Kvartære insektfauna. Vidensk. Meddel. Dansk Naturh. Forening 96. Festskrift. II, 1-351, 6 plates.

Hirvenoja, M. 1998. The history of Sompiojärvi and Mustajärvi, *Corynogera ambigua* lakes in northern Finland, in light of the subfossils of Chironomidae (Diptera). Oulanka Reports 18, 7-35.

Holst, K. T. 1969. The distribution of Orthoptera in Denmark, Scania and Schleswig-Holstein. Entomol. Meddr. 37, 413-442.

Hufthammer, A. K. 1998. The middle and late glacial (Weichselian) vertebrates of the Pechora region, north Russia. Preliminary results. In Vuorisalo, T. & Ukkonen, P. (ed.), Tvärvetenskaplig forskning i faunahistoria. Workshop i nordisk faunahistoria 9-11 September 1998 Seili, Åbo, Finland. (Duplicate).

Hultén, E. 1971. Atlas of the distribution of vascular plants in northeastern Europe. 2. revised edition. 531 pp. Generalstabens Litografiska Anstalts Förlag, Stockholm.

Huntley, B. & Birks, H. J. B. 1983. An atlas of past and present pollen maps for Europe: 0-13 000 years ago. 667 pp. Cambridge University Press, Cambridge.

Hyvärinen, H. 1973. The deglaciation history of eastern Fennoscandia - recent data from Finland. Boreas 2, 85-102.

Ignatius, H., Korpela, K. & Kujansuu, R. 1980. The deglaciation of Finland after 10,000 B.P. Boreas 9, 217-228.

Iversen, J. 1958. The bearing of glacial and interglacial epochs on the formation and extinction of plant taxa. Uppsala Universitets Årsskrift 6, 210-215.

Jaarola, M., Tegelström, H. & Fredga, K. 1999. Colonization history in Fennoscandian rodents. Biol. J. Linn. Soc. 68, 113-127.

Jalas, J. 1950. Zur Kausalanalyse der Verbreitung einiger nordischen Os- und Sandpflanzen. Ann. Bot. Soc. Zool. Bot. Fennici Vanamo 24(1), 1-362.

Jalas, J. & Suominen, J. (eds) 1989. Atlas Florae Europaeae. Distribution of vascular plants in Europe. 8. Nymphaceae to Ranunculaceae. 261 pp. Committee Mapping Flora Eur. & Soc. Biol. Fennica Vanamo, Helsinki.

Jonsell, B. 1990. Fjällendemism och annan endemism i Skandinaviens flora. Blyttia 48, 79-81.

Kalela, A. 1943. Die Ostgrenze Fennoskandiens in pflanzengeographischer Beziehung. Veröff. Geobot. Inst. Rübel, Zürich 20, 1-68.

Korobejnikov, Yu. I. 1991: [Ground beetles from the mountain tundra in the Ural]. Pp. 51-60 in Olshvang, V. N. (ed.), [Ecological grouping of ground beetles (Coleoptera, Carabidae) in natural and anthropogenic habitats in the Ural]. Akademiya Nauk SSSR, Sverdlovsk. (In Russian).

Krogerus, R. 1932. Über die Ökologie und Verbreitung der Arthropoden der Triebsandgebiete an den Küsten Finnlands. Acta Zool. Fenn. 12.

Krzywinski, K. & Stabell, B. 1984. Late Weichselian sea level changes at Sotra, Hordaland western Norway. Boreas 13, 159-202.

Kullman, L. 1996. Norway spruce present in the Scandes Mountains, Sweden at 8000 BP: new light on Holocene tree spread. Global. Ecol. Biogeogr. Lett. 5, 94-101.

Kullman, L. 1998a. Palaeoecological, biogeographical and palaeoclimatological implications of early Holocene immigration of *Larix sibirica* Ledeb. into the Scandes Mountains, Sweden. Global Ecol. Biogeogr. Lett. 7, 181-188.

Kullman, L. 1998b. Non-analogous tree flora in the Scandes Mountains, Sweden, during the early Holocene - macrofossil evidence of rapid geographic spread and response to palaeoclimate. Boreas 27, 153-161.

Lang, G. 1994. Quartare Vegetationsgeschichte Europas. Methoden und Ergebnisse. 462 pp. Gustav Fischer Verlag, Jena.

Larsen, E., Lyså, A., Demidov, I., Fundeer, S., Houmark-Nielsen, M., Kjær, K. H. & Murray, A. S. 1999. Age and extent of the Scandinavian ice sheet in northwest Russia. Boreas 28, 115-132.

Lemdahl, G. 1991. A rapid climatic change at the end of the Younger Dryas in south Sweden: Paleoclimatic and paleoenvironmental reconstructions based on fossil insect assemblages. Paleogeogr. Paleoclimatol. Paleoecol. 83, 313-331.

Lemdahl, G. 1997a. Early Weichselian insect faunas from Northern Sweden: climatic and environmental implications. Arctic Alpine Res. 29, 63-74.

Lemdahl, G. 1997b. Late Weichselian and Early Holocene colonisation of beetle faunas in S Sweden. Quaternary Proc. 5, 153-164.

Lemdahl, G. & Gustafsson, G. 1997. Lateglacial and Middle Holocene Coleoptera assemblages from coastal environments in South-Western Sweden. Ent. Tidskr. 118, 177-187.

Lindberg, H. 1908. *Pterostichus vermiculosus* Mén från Dryas-aflagring på Karelska näset. Meddel. Soc. Fauna Flora Fennica 34, 46-47.

Lindroth, C. H. 1945. Die Fennoscandischen Carabidae. Eine tiergeographische Studie. II Die Karten. Göteborgs Kungl. Vet. Vitterh. Samh. Handl., Ser. B 4 (2), 1-277.

Lindroth, C. H. 1948. Interglacial insect remains from Sweden. Sver. Geol. Unders. Årsbok 42, 1-29.

Lindroth, C. H. 1949. Die Fennoscandischen Carabidae. III Allgemeiner Teil. Göteborgs Kungl. Vet. Vitterh. Samh. Handl. Ser. B 4 (3), 1-911.

Lindroth, C. H. 1969. The theory of glacial refugia in Scandinavia. Comments on present opinions. Notulae Entomol. 49, 178-192.

Lindroth, C. H. 1979. The theory of glacial refugia. Pp. 385-394 in Erwin, T. L., Ball, G. E., Whitehead, D. R. & Halpern, A. L. (eds), Carabid beetles: their evolution, natural history, and classification. Dr W. Junk, The Hague.

Lindroth, C. H. 1985-1986. The Carabidae (Coleoptera) of Fennoscandia and Denmark 15, parts 1-2, 1-499. E. J. Brill/Scandinavian Science Press Ltd, Leiden, Copenhagen.

Løken, A. 1973. Studies on Scandinavian bumble bees (Hymenoptera, Apidae). Norsk Entomol. Tidsskr. 20, 1-219.

Lundqvist, J. 1978. New information about Early and Middle Weichselian interstadials in Northern Sweden. Sveriges Geol. Undersökning C 752, 1-31.

Mangerud, J., Larsen, E., Longva, O. & Sønstegaard, E. 1979. Glacial history of western Norway 15,000-10,000 B.P. Boreas 8, 179-187.

Mangerud, J., Svendsen, J. I. & Astakhov, V. 1999. The age and extent of the Barents and Kara Sea ice sheets in Northern Russia. Boreas 28, 46-80.

Mjelde, A. 1983. The foraging strategy of *Bombus consobrinus* (Hymenoptera, Apidae). Acta Entomol. Fennica 42, 51-56.

Mörner, N.-A. 1980. A 10,700 years' paleotemperature record from Gotland and Pleistocene/Holocene boundary events in Sweden. Boreas 9, 283-287.

Nesje, A., Anda, E., Rye, N., Lien, R., Hole P. A. & Blikra, L. H. 1987. The vertical extent of the Late Weichselian ice sheet in the Nordfjord-Møre area, western Norway. Norsk Geol. Tidsskr. 67, 125-141.

Nilsson, A. N., Pettersson, R. B. & Lemdahl, G. 1993. Macroptery in altitudinal specialists *versus* brachyptery in generalists - a paradox of alpine Scandinavian carabid beetles (Coleoptera: Carabidae). J. Biogeogr. 20, 227-234.

Nordal, I. 1987. Tabula rasa after all? Botanical evidence for ice-free refugia in Scandinavia reviewed. J. Biogeor. 14, 377-388.

Olshvang, V. N. 1992. [Structure and dynamics of insect populations in the southern Jamal Peninsula]. 104 pp. Rossijskaya Akademya Nauk, Jekaterenburg. (In Russian).

Paus, A. 1988. Late Weichselian vegetation, climate and floral migration at Sandvikvatn, North Rogaland, southwestern Norway. Boreas 17, 113-139.

Paus, A. 1989. Late Weichselian vegetation, climate, and floral migration at Liastemmen, North Rogaland, south-western Norway. J. Quatern. Sci. 4, 223-242.

Pekkarinen, A. 1979. Morphometric, colour and enzyme variation in bumblebees (Hymenoptera, Apidae, *Bombus*) in Fennoscandia and Denmark. Acta Zool. Fennica 158, 1-60.

Poppius, B. 1910, Die Coleopteren des arktischen Gebietes. Fauna Arctica 5 (1), 291-447. Gustaf Fischer, Jena.

Poppius, B. 1911. Beitrege zur postglazialen Einwanderung der Käfer-Fauna Finnlands. Acta Soc. Fauna Flora Fennica 34 (9), 1-59.

Punkari, M. 1993. Modelling of the dynamics of the Scandinavian ice sheet using remote sensing and GIS methods. Pp. 232-250 in Aber, J.S. (ed.), Glaciotectonics and mapping glacial deposits. Canadian Plains Research Center, University of Regina.

Rainio, H., Saarnisto, M. & Ekman, I. 1995. Younger Dryas end moraines in Finland and NW Russia. Quatern. Int. 28, 179-192.

Sauramo, M. 1958. Die Gesichte der Ostsee. Ann. Acad. Sci. Fenn. A III, Geologica-Geographica 51, 1-522.

Solem, J. O. 1994. Northern immigration of arctic-alpine insects and crustacea in Scandinavia. (In Norwegian with English abstract). Fauna (Oslo) 48, 28-32.

Sollid, J. L. & Sørbel, L. 1979. Deglaciation of western Central Norway. Boreas 8, 233-239.

Spuris, Z. (ed.) 1998. Red data book of Latvia. Rare and threatened species of plants and animals. 388 pp. Instute of Biology, Riga.

Svendsen, J. I., Astakhov, V. I., Bolshiyanov, I. M., Dowdeswell, J. A., Gataullin, V., Hjort, C., Hubberten, H. W., Larsen, E., Mangerud, J., Melles, M., Möller, P., Saarnisto, M. & Siegert, J. M. 1999. Maximum extent of the Eurasian ice sheets in the Barents and Kara Sea region during the Weichselian. Boreas 28, 234-242.

Svensson, N.-O. 1991. Late Weichselian and Early Holocene shore displacement in the central Baltic Sea. Quatern. Int. 9, 7-26.

Ukkonen, P., Lunkka J. P., Jungner, H. & Donner, J. 1999. New radiocarbon dates from Finnish mammoths indicating large ice-free areas in Fennoscandia during the Middle Weichselian. J. Quaternary Sci. 14, 711-714.

Taberlet, P., Fumagalli, L., Wust-Saucy, A. G. & Cosson, J.-F. 1998. Comparative phylogeography and postglacial colonization routes in Europe. Molecular Ecol. 7, 453-464.

Väisänen, R., Somerma, P., Kuussaari, M. & Nieminen, M. 1991. *Bryodema tuberculata* and *Psophus stridulus* in southwestern Finland (Saltatoria, Acrididae). Entomol. Fennica 2, 27-32.

Vasari, Y., Tonkov, S., Vasari, A. & Nikolova, A. 1996. The Late-quaternary history of the vegetation and flora in northeastern Finland in the light of a reinvestigation of Aapalampi in Salla. Aquilo Ser. Bot. 36, 27-41.

Vorren, K.-D. 1978. Late and Middle Weichselian stratigraphy of Andøya, north Norway. Boreas 7, 19-38.

Vorren, K.-D., Alm. T., Gulliksen, S. & Løvlie, R. 1988. The last deglaciation (20,000 to 11,000 B.P.) on Andøya, northern Norway. Boreas 17, 41-77.

Walker, M. J. C. 1995. Climatic changes in Europe during the last glacial/interglacial transition. Quatern. Int. 28, 63-76.

Walker, M. J. C., Bohncke, S. J. P., Coope, G. R., O'Conell, M., Usinger, H. & Verbruggen, C. 1994. The Devensian/Weichselian Late-glacial in northwest Europe (Ireland, Britain, north Belgium, The Netherlands, northwest Germany). J. Quatern. Sci. 9, 109-118.

Wohlfart, B., Björck, S., Possnert, G., Lemdahl, G., Brunnberg, L., Ising, J., Olsson, S. & Svensson, N.-O. 1993. AMS dating Swedish varved clays of the last glacial/interglacial transition and the potential/difficulties of calibrating Late Weichselian «absolute» chronologies. Boreas 22, 113-128.

Wolf, H. 1967. Die Wegwespen Finnlands. Acta Entomol. Fennica 23, 1-46.

Zacher, F. 1917. Die Geradflügler Deutschlands und ihre Verbreitung. 287 pp. Gustaf Fischer, Jena.

Received 1 July 2000,
accepted 10 December 2000.

Norw. J. Entomol. 48, 31–34. 2001

The Entomology Collections of the Muséum national d'Histoire naturelle, Paris (France)

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Voisin, J.-F. 2001. The Entomology collections of the Muséum national d'Histoire naturelle, Paris (France). Norw. J. Entomol. 48, 31-34.

Founded in 1626 as a botanical garden and established in 1793 as a museum, the Muséum national d'Histoire naturelle is one of the oldest research institutions in the world. The staff of the Entomological Laboratory includes 42 persons, 25 being research scientists. Its insect collections are the richest in the world and count 45 550 000 specimens, a little more than three quarters of them being prepared and labelled. The most represented groups are the Coleoptera, Diptera, Lepidoptera and Hemiptera. There are about 270 000 types among them. The laboratory faces serious space problems, and for some groups the upper limit will be reached within a few years.

Key words: France, museum, entomology, collections.

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HISTORY

The Natural History Museum in Paris is one of the oldest scientific research institutions in the world; its origin is linked with the fashion of botanical gardens and curiosities cabinets which started to flourish in the 16th and 17th centuries in towns like Padua, Strasbourg and Montpellier. In Paris at the beginning of the 17th century, there was a tiny «Jardin du Roy» (King's Garden), not at the place where the Museum is to-day, but on the Île de la Cité not far from Notre-Dame.

In 1626 King Louis XIII issued licenses letters founding and organising a «Jardin Royal des Plantes médicinales» (King's Garden of Medicinal Herbs) on a small piece of land which is now part of the Jardin des Plantes, where the Museum is installed. This success crowned the efforts of a scientist of the time, Guy de la Brosse, but, in a typical French way, political considerations were important in the king's decision. The issue at hand was to counterbalance the influence of the absolute power of the conservative Sorbonne and to settle the antagonism between the professors of the School of Medicine and the innovating physicians of the Court, which had grown so virulent that it had become prejudicial to the exercise of medicine (Barthélémy 1979).

During the following one and a half centuries, the King's Garden grew in both diversity and surface until Georges Louis Marie Leclerc de Buffon (1707-1788) organised it as one of the most prominent museums of the time. He also had purchased several pieces of land around the King's Garden, thus giving it a much larger area.

At the beginning of the Revolution's troubled times, the existence of the King's Garden was threatened a few times, because it was a heritage of the monarchy to the revolutionaries' eyes. However, the energetic and obstinate action of a few people turned the events to the advantage of the institution. Among them was Joseph Lakanal, a member of the day's parliament, the Convention Nationale. Things went on in a rather surrealistic way. On 10 June 1793, in the middle of a session devoted to the defence of the country, which was being invaded by the allies and shaken by revolts, Lakanal pleaded the cause of the garden and obtained from the Convention Nationale a decree establishing it as a governmental institution - the Muséum national d'Histoire naturelle. In 1794 the last pieces of land were bought, thus giving the Jardin des Plantes its present boundaries.

Lakanal's project established twelve chairs in the Museum, each one directed by a professor. The Chair of Zoology of Insects, Worms and Microscopic Animals fell to J.B. de Lamarck, who was the first to propose a scientific theory of Evolution. When he died, his chair was split into a chair of Annelids, Molluscs and Zoophytes, which fell to A. de Blainville, and one of Natural History of Crustaceans and Insects, with P.A. Latreille as director. This chair persisted until 1917, at which time the Crustaceans were removed from it, and then became the «Laboratoire d'Entomologie», which has persisted until now either under this name or under that of «Laboratoire d'Entomologie générale et appliquée» (1976-1985). Its last head was the late Professor L. Matile, a Dipterist. A list of all directors of this laboratory until now can be found in Table 1.

Table 1. List of the directors of the Laboratoire d'Entomologie since 1793 (from Barthélémy (1979) and documents from Muséum national d'Histoire naturelle.).

10 June 1793 **Zoologie des Insectes, Vers et Animaux Microscopiques** **J.B. de LAMARCK**
1830 **Histoire naturelle des Annélides Mollusques et Zoophytes** **A. de BLAINVILLE** (and 8 professors after him)
and **Histoire Naturelle des Crustacés et Insectes** **1830: A. LATREILLE** **1833: V. AUDOUIN** **1841: H. MILNE EDWARDS** **1862: E. BLANCHARD** **1895: E.L. BOUVIER**
1917 **Vers et Crustacés** separated from Insects **G. GRAVIER**
Laboratoire d'Entomologie **1931: R. JEANNEL** **1951: L. CHOPARD** **1956: E. SEGUY**
Laboratoire d'Entomologie Générale et Appliquée **1961: A.S. BALACHOWSKY** **1976: J. CARAYON**
Laboratoire d'Entomologie **1987: C. CAUSSANEL** **1998: L. MATILE**

ORGANISATION

To-day the entomology laboratory of the Muséum national d'Histoire naturelle is housed in two adjoining buildings, together covering 6 576 m^2 on a basement and three floors. The first, the old building, dates from 1923 and is in an advanced state of disrepair and faces serious security problems, in particular concerning the electric wiring. The second, the new building, dates from 1968 and is in better condition. The Société Entomologique de France (French Entomological Society) is housed in the new building and owns an extremely rich entomological library. The laboratory also has its own very rich library which is complementary to that of the Entomological Society. The two buildings are no longer adequate to house the huge insect collections, which occupy 3000 m^2. For several groups, the upper limit will be reached within a few years and there are already serious space problems, especially in the Coleoptera and Lepidoptera sections.

Forty-two people work at the entomology laboratory (1999). Twenty-five of them are research scientists - 19 belonging to the Museum staff and

Table 2. The collections of the Laboratoire d'Entomologie of the Muséum national d'Histoire naturelle in 1997.

	NO. OF SPECIMENS	
GROUPS	**DRY**	**IN ALCOHOL**
Prepared specimens		
Orthopteroids	750 000	5 000
Coleoptera	15 000 000	40 000
Lepidoptera	3 000 000	–
Hymenoptera	800 000	600 000
Hemiptera	2 500 000	4 650 000
Diptera	5 000 000	1 000 000
Odonata & small orders	150 000	10 000
Fossils	50 000	–
Collembolla	–	1 000 000
Slides (excl. Hemiptera)	1 000 000	–
Subtotal 1	**28 250 000**	**7 305 000**
Subtotal 2	**35 555 000**	
Unprepared specimens		
Lepidoptera	500 000	
Other groups (low estimation)	10 000 000	
TOTAL COLLECTIONS	**45 555 000**	
Number of species represented	400 000	

six detached from other research institutions, the Centre national de la Recherche scientifique (C.N.R.S.) (4) and the Ecole pratique des hautes Etudes (2). There are also 17 technicians and administrative employees, all belonging to the Museum.

The laboratory is organised according to the major taxonomic units: Coleoptera, Lepidoptera, Diptera, Hymenoptera, Hemiptera, Orthoptera, Collembola, small groups and Odonata. In 1996, another division was superimposed onto this taxonomically based organisation, that of two research teams, each funded independently. One is named «Origin and Structure of Insect Biodiversity», comprising 12 research scientists, and the other is entitled «Systematics, Biodiversity and Evolution of Insects» and comprises 13 scientists. At the present time, the research policy is that of a single laboratory in which several teams or «themes», depending upon whether or not they have been officially recognised, develop more or less independent research. This vertical structure is a consequence of an assigned research organisation, but another structure, a horizontal one based on the major taxonomic groups, is needed in order to promote the development and management of the collections. New regulations are under study in order to clarify this point as well as the administrative organisation of the laboratory.

COLLECTIONS

In 1997, the collections of the Laboratoire d'Entomologie were estimated to contain about 45 550 000 specimens (Table 2). This makes them by far the largest insect collection in the world, before the Smithsonian Institution in Washington (about 37 000 000 specimens) and the Natural History Museum in London (about 27 000 000 specimens). A little more than three fourths of this material, that is, about 35 555 000 specimens, are prepared, pinned and labelled. They consist in about 28 250 000 dry specimens and 7 305 000 in alcohol. About 400 000 species are represented in this material. All these numbers are low estimations.

The most numerous group is Coleoptera, with 15 000 000 specimens. Then come Diptera, Lepidoptera and Hemiptera (Table 2). From a geographic point of view, the best represented regions are of course France, western Europe and the Mediterranean basin, Madagascar, western Africa, New Caledonia and French Guyana.

The laboratory collections are stored in about 140 000 boxes, kept on 8 km of shelves. The standard boxes used in the laboratory for over one hundred years are 39 x 26 x 5.5 cm and made of light wood and cardboard with a glass lid. One of their advantages is to be light, weighing about one kilogram each. Boxes of other types of course may be found in some of the collections which have been donated to the Museum, the most common, after standard boxes, being «half formats», 19 x 26 x 5.5 cm. Important collections which have been donated to the Museum are not merged into the general collection but are kept separately.

The number of insect types found in the Laboratory of Entomology is about 270 000, of which 185 000 are Coleoptera. On the average, 20 000 specimens are sent on loan every year, and a little over 500 visitors come to work on our collections.

In 1996, a profiling system derived from the one used at the Smithsonian Institution was devised by Th. Bourgoin. After a few tests, a matrix tracking for two collection parameters, curation and scientific information level, have been retained. To date, only the Fulgomorpha Hemiptera and the Diptera collections have been profiled.

NATURAL HERITAGE SERVICE

Distributional data of insects are not officially the responsibility of the Laboratory of Entomology. The Museum houses a special service, called *Service du Patrimoine naturel* (Natural Heritage Service) which is responsible for distributional atlases and regional inventories of animals and plants. It relies on an elaborate web of informers, both professionals and amateurs, most often members of natural history societies and, of course, some of them belonging to laboratories of the Museum. The person in charge of each inventory or atlas works in close co-operation with the service, which provides advice, organisation and technical means. Under the direction of the late Dr. Hervé Maurin, The Natural Heritage Service became a very dynamic institution which works in three directions: inventories of species and of noteworthy natural sites as well as bibliographical references. The main entomological inventories underway concern the Orthoptera, Odonata, Rhopalocera, and xylophagous Coleoptera.

Acknowledgements. I thank here my friends the late Professor L. Matile, Drs. Th. Bourgoin, P. Haffner and the late H. Maurin who put at my disposition information and documents about the Laboratoire d'Entomologie and the Service du Patrimoine naturel, as well as Dr. M. Schlee who corrected my English.

REFERENCE

Barthélémy, G. 1979. *Les Jardiniers du Roy*. 296 pp. Le Pélican, Le Vey Clecy.

Received 28 June 2000,
accepted 31 July 2000.

Norw. J. Entomol. 48, 35–39. 2001

Do we need Nordic national entomological journals?

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Sømme, L. 2001. Do we need Nordic national entomological journals? Norw. J. Entomol. 48, 35-39.

Nordic entomologists may publish their papers in international journals issued in the Nordic countries or in the national journals of the different countries. *Entomologica Scandinavica* was started in 1970 as a joint effort to present Nordic entomology. Although originally dominated by Nordic authors, 75 percent of the articles were by non-Nordic authors in 1995-1999. During 1995-1999, the four main Nordic national journals; *Entomologica Fennica, Entomologiske Meddelelser, Entomologisk Tidskrift* and *Norwegian Journal of Entomology* published more than 3700 pages. The topics are mostly faunistics, but include taxonomy and ecology as well. In *Entomologica Fennica* and *Norwegian Journal of Entomology* most papers are in English, while *Entomologiske Meddelelser* and *Entomologisk Tidskrift* publish several papers in Danish and Swedish, respectively, with abstracts in English. National journals are part of the activities of the entomological societies and important to stimulate the interest of their members.

Key words: Entomological journals, national, Nordic, Entomologica Scandinavica

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INTRODUCTION

The answer to the title is of course yes! In this lecture I will try to explain why, and also illustrate what kind of articles are actually published in some of the national journals. I have selected the four main Nordic national journals in entomology, although entomological papers are also found in a number of other publications, e.g. membership newsletters, reports of different kinds and special lepidopterological publications.

I have not included the Baltic countries in this survey. There is no national entomological journal in Lithuania, while the Latvian Entomological Society publish both *Latvijas Entologs* and *Acta Coleopterologica Latvica.* In Estonia the journal *Lepinfo* was originally for lepidopterologists, but publishes articles on other insects as well.

For many authors there is a dilemma whether to publish their papers in international or national journals. International journals are usually considered more prestigious, while national journals have much lower refusal rates.

Many authors think that their papers will be more frequently read and cited in international journals. This is not always true, since important papers are likely to be discovered by the scientific community. As an example, the doctoral thesis of Semb-Johansson (1958) on insects endocrinology, was published in *Nyt Magasin for Zoologien.* Although the journal is not very well known, his paper became a «Citation Classic» according to Science Citation Index.

NORDIC JOURNALS

In 1967, on invitation from the Swedish Research Council, the initiation of a joint Nordic entomological journal was discussed. Representatives from the entomological societies of the different countries met in Stockholm and agreed that this would be a better way to present Nordic entomology for the international community. On this background, the first volume of *Entomologica Scandinavica* appeared in 1970 with Carl Lindroth as editor.

Each country had to decide if their national journals should be continued or not. In Sweden it was agreed that one national journal would be sufficient. For this reason, *Opuscula Entomologica* was discontinued in 1969, while *Entomologisk Tidskrift* was chosen as the national Swedish journal. *Entomologisk Tidskrift* is the oldest of the two, and in fact one of the oldest entomological journals in the world.

In Denmark it was understood that *Entomologiske Meddelelser* should be continued, and in Finland all three national journals were maintained for some time. *Notulae Entomologica* was considerd to be of greatest interest for amateurs. *Annales Entomologici Fennici* was an international journal for Finish entomology, and *Acta Entomologica Fennica* published longer articles. In 1989 it was decided that Finish entomological publications should be joined in one journal. The name of the new journal caused a lot of discussion, but a compromise was made to leave all the old names. The first volume of *Entomologica Fennica* appeared in 1990.

In Norway the publication of the *Norwegian Journal of Entomology* was carried on until 1978, but at this time funding by the Norwegian Research Council discontinued. The idea was to encourage international publishing by supporting international Nordic journals like *Oikos*, *Holarctic Ecology* and *Entomologica Scandinavica*. *Zoologica Scripta*, which is published by the the Academies of Sciences in Sweden and Norway, is a journal that also includes entomological taxonomical papers.

Did *Entomologica Scandinavica* live up to its ambitions? I raise this question because the number of papers published by Nordic authors has decreased sharply since the beginning and up to the latest volumes. The original purpose was to present Nordic entomology to the international scientific community. During the first five years most of the papers in the journal were written by authors from Nordic countries (Table 1), and in particular from Denmark and Sweden. In the early years there were also a few authors from UK and USA as well as some from other countries. In the last five volumes, however, non-Nordic authors are dominating with 103 papers compared to 33 by Nordic authors. One of the reasons for these changes may be that fewer taxonomical studies are made in Nordic countries, but it is also possible that many taxonomical papers are rejected by *Entomologica Scandinavica* and published in national journals instead. At any rate, we have got an international journal of high quality, but the situation for Nordic authors is not very different from 1967. We still need national journals.

In 2000, *Entomologica Scandinavica* changed its name to *Insect Systematics and Evolution*. The editors own statistics (Andersen & Michelsen 2000) also give the frequency of Nordic and non-Nordic authors.

CONTENTS

In spite of all Nordic international journals, there is still a demand for journals that will publish national faunistic papers. It is generally agreed that records on the distribution of terrestrial arthropods have to be published somewhere. This is in particular important with the present interest in the biodivertsity of nature. In Norway, *Norwegian Journal of Entomology* was continued as a purely faunistic journal under the name *Fauna Norvegica Ser. B* (with subtitle *Norwegian Journal of Ento-*

Table 1. No. of articles in *Entomologica Scandinavica* with Nordic authors and with non-Nordic authors during 1970-1975 and 1995-1999.

Country	1970-1975	1995-1999	Country	1970-1975	1995-1999
Finland	6	5	Argentina	0	9
Denmark	30	11	Canada	1	10
Sweden	89	8	Germany	3	11
Norway	9	9	UK	11	11
			USA	9	26
			Other countries	10	36
Total Nordic	134	33	Total non-Nordic	34	103

mology) from 1979-1998. Later, in 1999 we returned to the original name of the journal.

The present survey of the contents of Nordic entomological journals include the five latest volumes (1995-1999) of *Entomologica Fennica, Entomologiske Meddelelser, Entomologisk Tidskrift* and *Norwegian Journal of Entomology* (Table 2). Most of them are issued in four numbers per year, except *Norwegian Journal of Entomology* which issues two. The mean number of pages per volume range from 130 to 240. During the five year period the total number of printed pages ranged from 1200 in *Entomologica Fennica* to 650 in *Norwegian Journal of Entomology*.

The main content of the journals are entomological papers and short communications (Figure 1). *Entomologica Fennica* is entirely English, and published more than 110 papers and 25 short communications during the period. In Finland, entomological papers of more local interest are published in *Sahlbergia*.

Entomologisk Tidskrift has a different profile. Most papers are in Swedish with an English abstract, and a small number of papers are in English only.The journal has a remarkable high number of book reviews, and different kinds of information to members of the society. In my opinion, this gives the journal a friendly appearance, as it contains more material of general interest to the readers.

Entomologiske Meddelelser publishes most papers in Danish, with an English abstract, but also several papers in English only. There are few short communications, but several book reviews.

Norwegian Journal of Entomology published about 60 papers during the period, mainly in English, but some with a summary in Norwegian. There is a remarkable high number of short communications, but very few book reviews. In addition, members of the Norwegian Entomological Societey receive *Insekt-Nytt* which includes more membership information and popular articles.

TOPICS

With regard to the topics, I have made a relatively coarse division in three categories (Table 3). Some papers may contain both taxonomical and faunistic data, and biogeography may be included both in ecological and faunistic papers. In spite of these discrepencies, Table 3 probably gives a relatively realistic picture of the situation.

Typical for all four journals is a high number of faunistic papers, including short communications, which are mainly faunistic. The Norwegian and Danish journals, in particular, have a large proportion of faunistic articles. Looking through the journals, it strikes me that faunistic papers are often strictly restricted to the country in question. In my opinion, more emphasis should be placed on considering the total distribution in Nordic and Fennoscandian countries since we belong a common geographical area.

More ecological papers are included in the Swedish journal. *Entomologisk Tidskrift* also publish a series of review papers in Swedish on different entomological topics. *Entomologica Fennica* includes a higher proportion of taxonomic papers than the other journals. In fact, *Entomologica Fennica* has a more international appearance than the other Nordic journals. The journal includes papers and authors from several countries, in particular from Russia, but also contributions from all over the world, e.g. from China, Iran, Africa and South America.

Table 2. No. of volumes and pages in the four main Nordic national entomological journals during 1995 -1999.

Journal	Volumes	Issues per volume	Mean no. of pages per vol.	Total no of pages
Entomol. Fennica	6-10	4	240	1199
Ent. Meddr.	63-67	4	177	883
Ent. Tidskr.	116-120	4	196	982
Norw. J. Entomol.	42-46	2	130	650

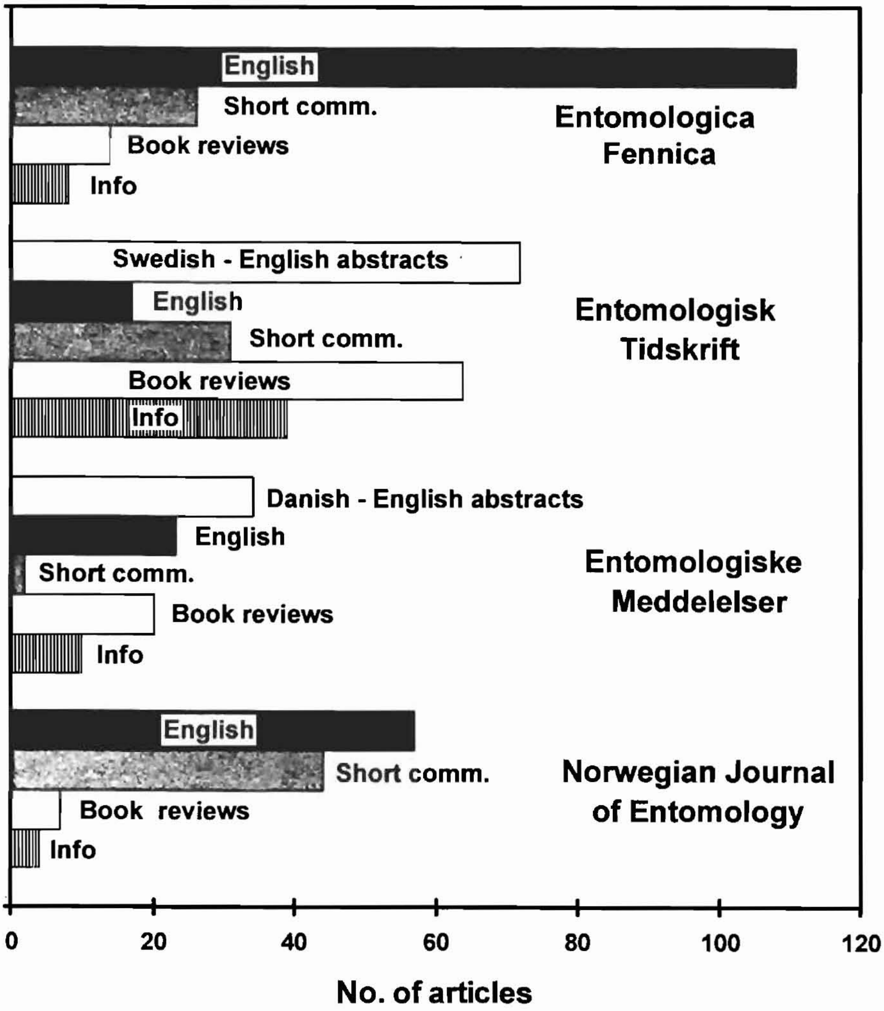


Figure 1. No. of articles, short communications, book reviews and general information in four Nordic national entomological journals during 1995-1999.

Table 3. No. of articles and short communications with main contents of faunistics, taxonomy and ecology in Nordic national entomological journals during 1995-1999.

Journal	Faunistics	Taxonomy	Ecology
Entomol. Fennica	55	49	33
Ent. Meddr.	44	8	8
Ent. Tidskr.	81	4	36
Norw. J. Entomol.	85	3	14

CONCLUSIONS

There is a demand for journals that will publish faunistic data of local or national interest. Eventually, such data form the basis for review papers and books on the distribution and systematics of the insects in question.

In ecology, international journals tend to have high refusal rates. Although not acceptable at a more prestigious level, many ecological studies include valuable data of great general interest. For this reason they should be accepted in national journals.

With regard to taxonomy, the situation is similar. Smaller papers, e.g. description of single new species may not be accepted in international journals, but may find their place in the national ones.

Finally, the national journals publish material of general interest for the readers. In this respect they are an important part of the activities of the respective entomological societies, and a source of information for the members. Members are usually spread all over the country, and for many of them the journal and other membership publications are their only contact with the society. Without the national journals there would probably be less interest in entomology.

REFERENCES

Andersen, N.M. & Michelsen, V. 2000. Message from the editors. Insect Syst. Evol. 31, 1-2.

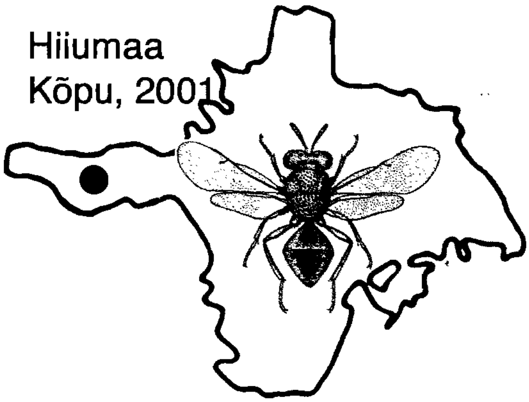
Semb-Johansson, A. 1958. Relation of nutrition to endocrine-reproductive functions in the milkweed bug *Oncopeltus fasciatus* (Dallas) (Heteroptera: Lygaeidae). Nytt Mag. Zool. 7, 1-132.

Received 30 June 2000,
accepted 21 November 2000.

Symposium

Biodiversity of insects and spiders of the islands of the central part of the Baltic Sea

Kõpu, Island of Hiiumaa, Estonia, July 2001



An international symposium on the faunistics, synecology and zoogeography of insects and spiders of the mentioned area will be held at Kõpu on the Island of Hiiumaa, Estonia, from 2 to 8 July 2001.

Presentations about the insects and spiders from the West-Estonian Archipelago, Gotland, Öland, the islands of the Swedish coast from Uppland to Öland and the Ahvenanmaa and Turku Archipelago in Finland are welcome.

Field investigation trips on the island will be arranged in the connection with the symposium. A participating botanist will give information about plant species and communities in Hiiumaa.

The program will also include a report about the Biosphere Reserve of West-Estonian Archipelago.

Number of participants is limited to 35 persons.

The symposium is organized by: the Estonian Naturalists' Society, the Institute of Zoology and Hydrobiology, University of Tartu and the Biosphere Reserve of the West-Estonian Archipelago, Estonian Ministry of the Environment.

For further information please contact the organizing persons:

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Some aspects of mating behaviour of Eumenidae wasps (Hymenoptera)

Anna Budriene

Budriene, A. 2001. Some aspects of mating behaviour of Eumenidae wasps (Hymenoptera). Norw. J. Entomol. 48, 41-44.

The purpose of the present study was to compare the mating behaviour of four eumenid species, *Ancistrocerus antilope* (Panzer), *Symmorphus allobrogus* (Saussure), *Symmorphus murarius* (Linnaeus) and *Discoelius zonalis* (Panzer). The wasps were reared from trap-nests; pairings were observed under bell-glass. In total 312 pairings were observed. Three behavioural categories were scored: duration of the male courtship (including mounting, antennating and copulatory attempts), duration of copulation, and duration of the post-copulatory mate guarding. Statistically significant inter-specific differences of these mating phases were found.

Key words: Eumenidae, *Ancistrocerus*, *Symmorphus*, *Discoelius*, courtship, mating behaviour.

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INTRODUCTION

Among the eumenids (Hymenoptera, Eumenidae), sexual selection has resulted in diversity with regard to behaviour and structures used by males during courtship, the duration of single copulation, repeated copulations by a single pair of wasps, and post-insemination displays (Cowan 1986). Their mating behaviour can be divided into three phases: pre-copulatory period, including premounting phase and courtship, copulatory period and post-copulatory mounting. The purpose of the present study was to compare the mating behaviour of four eumenid species, *Ancistrocerus antilope* (Panzer), *Symmorphus allobrogus* (Saussure), *Symmorphus murarius* (Linnaeus) and *Discoelius zonalis* (Panzer).

METHODS

The wasps were reared from trap-nests, made of fragments of *Phragmites australis* stems. Pairings were observed in an arena with a diameter of 22 cm under a bell-glass of 22 cm height in a thermostat at 26-29°C, exposed to daylight, with additional artificial illumination. One male at the time was placed in the arena with a single virgin female and observed for about 60 minutes. If courtship was elicited, the behaviour was observed until the male dismounted. In total 312 pairings were observed and recorded. Statistical calculations were done using the computer program Statsoft Statistica for Windows, release 4.5. «Courtship» refers to the period starting from the male's mounting until intromitting the female (Cowan 1986).

RESULTS

Pre-copulatory period

There was no significant difference between the studied species in the time until the male discovered the female in the arena (duration of the premounting period - see Table 1; t-test for independent samples resulted in $p > 0.05$ for all pairs of species).

When the male discovered the female, he moved toward her and assumed a horizontal position over the female on her dorsum. When mounted, males of all four species buzzed their wings and held their mouth parts on the female's pronotum or vertex, the area of the cephalic foveae. A mounted male of *S. allobrogus*, *S. murarius* or *D. zonalis* held his forelegs around the sides of female's pronotum, while his mid legs grasped the sides of her propodeum, and his hind legs clung to her petiole. The male of *A. antilope* held his mid legs out to the sides. He lowered his switching or waving antennae forward in front of female's face and then moved the ventrolateral side of the distal part of his hooked antennae along the dorsolateral side of the female's antennae. The male tapped the female's antennae from the distal region of her scape to the tip of her flagellum irregularly and so rapidly that the number of antennal strokings could not be visually established. While antennating the female, the male of *A. antilope* curled his abdomen forward, buzzed his wings, extruded his genitalia, stroked them down the side and underneath to the tip of her metasoma and tried to link genitalia. Then the male raised his antennae straight up, grasping the sides of the female's propodeum with his middle legs in addition to the other pairs. He withdrew his abdomen and stiffened, taking a parallel position over the female dorsum. Males of *A. antilope* repeated this behaviour until linking of genitalia.

Males of *S. allobrogus*, *S. murarius* and *D. zonalis* placed their antennae between those of the females and started to stroke regularly both of the female's antennae from pedicel to flagellum and simply probed with their genitalia from the side toward the tip of female's metasoma. During this stroking, the ventrolateral side of the male's antennae (flagellomeres 8-11) contacted with the dorsolateral side of the female's antennae. As soon as the males mounted, some females of *A. antilope*, *S. allobrogus* and *S. murarius* initiated struggling behaviour consisting of lowering or erecting their antennae, curling their metasomata forward ventrally or sometimes rotating their mesosomata around their longitudinal axis. In the courtship of *D. zonalis*, no apparent struggle was observed. During the courtship males of *S. murarius* stroked the female's antennae 2-37 (8.3±2.7, N=12) times, males of *S. allobrogus* stroked 0-22 (4.4±0.4, N=73) times, while males of *D. zonalis* stroked 0-4 (0.9±0.6, N=8) times.

Duration of courtship of the four studied species is presented in Table 1. Difference of the duration (t-test for independent samples) was significant in pairs of species *S. allobrogus* - *S. murarius* ($p = 0.014$), *S. allobrogus* - *A. antilope* ($p < 0.001$) and *A. antilope* - *D. zonalis* ($p = 0.004$).

Copulation

From the total number of 104 pairings of *A. antilope*, only 8 resulted in copulations. The copulatory period was comparatively long - with a duration of 40-100 minutes (Table 1). Each successful pairing of *A. antilope* included 1-3 (1.50±0.27) copulations. During each copulation, the females of *A. antilope* interspersed quiet behaviour with struggling. Copulation ended with-

Table 1. Duration of phases of mating in Eumenidae wasps in seconds: mean ± standard error of mean (minimum - maximum in brackets)

Species (N - number of successful pairings)		*Discoelius zonalis* (N=8)	*Symmorphus allobrogus* (N=73)	*Symmorphus murarius* (N=12)	*Ancistrocerus antilope* (N=8)
Premounting period		357.0 ± 150.6 (1 - 1341)	729.9 ± 104.5 (3 - 4504)	673.4 ± 126.0 (112 - 1639)	529.8 ± 193.8 (2 - 1760)
Mounting	**Courtship**	26.1 ± 7.6 (7 - 61)	42.5 ± 4.5 (0 - 211)	185.4 ± 142.0 (19 - 1746)	259.1 ± 68.1 (80 - 634)
	Copulation (N - total number of copulations)	154.0 ± 12.1 (106 - 204) (N=8)	82.7 ± 2.1 (39 - 125) (N=74)	456.4 ± 26.1 (333 - 634) (N=12)	3520.3 ± 272.5 (2345 - 5953) (N=12)
	Postcopulating period	19.6 ± 19.6 (0 - 157)	11.7 ± 11.5 (0 - 841)	0	14060.3 ± 7161.5 (113 - 70309)

out an apparent struggling behaviour. In the other species the quiet initial phase of copulation contrasted with struggling near the end of copulation. From 127 pairings of *S. allobrogus*, 73 resulted in copulations. The pairs copulated only briefly (0.65-2.1 minutes - see Table 1). Within 1-113 (48.0±3.1, N=73) seconds after initiation of copulation, the females tried to dislodge the male and exhibited rejection behaviour similar to that during the onset of courtship. From 41 pairings of *S. murarius*, 12 resulted in copulations, which lasted 5.5-10.6 minutes (Table 1). From 40 pairings of *D. zonalis*, 8 resulted in copulations. Copulations lasted 1.8-3.4 minutes (Table 1). Unlike the other species, following the initiation of copulation the males of *D. zonalis* and *S. murarius* usually released their leg-hold within 0-12 (5.8±1.4, N=8) and 1-206 (49.4±17.6, N=12) seconds, respectively. They fell backwards hanging behind their mate by the genitalia. The males dangling by their genitalia remained motionless. Following the initiation of copulation, females of *D. zonalis* and *S. murarius* started kicking the tips of their genitalia and wriggling their abdomens within 1-159 (59.0±25.6) and 182-634 (376.3±34.7) seconds, respectively. The males of *S. murarius* always started to walk immediately after the termination of copulation while the males of *D. zonalis* remained immobile for 0-27 (11.0±4.2) seconds. In one pairing (of 8) of *D. zonalis* and in two pairings (of 12) of *S. murarius* the males did not fall backwards.

Differences in the duration of copulation of the four studied species (t-test for independent samples) were significant ($p < 0.001$) for all pairs of species.

Post-copulatory period

Each pair of *S. allobrogus*, *S. murarius* and *D. zonalis* usually copulated only once and separated immediately after copulation. However, five matings of *S. allobrogus* and one mating of *D. zonalis* made an exception. One pair of *S. allobrogus* copulated twice, the copulations lasted 26 and 91 seconds, with an interval between them of 9 seconds. In four other pairings of *S. allobrogus*, male and female remained together from 2 seconds to 14 minutes after the termination of copulation. In three instances the males simply rode the females, but in one pairing the male initiated courtship behaviour. In one pairing of *D. zonalis* the male simply rode the female before separating. Following termination of copulation, males of *A. antilope* demonstrated behaviour, which was similar to the pre-copulatory courtship and lasted from 1.9 minutes to 19.5 hours. Duration of the post-copulating period is presented in Table 1; the difference of the duration was statistically significant (t-test for independent samples) in the pair of species *S. allobrogus - A. antilope* ($p < 0.001$).

DISCUSSION

The sexual behaviour of *A. antilope* and four other species of eumenid wasps from North America was described in detail by Cowan (1986). The females of *A. antilope* have the longest copulation periods and mate more than once with different males during their reproductive cycle (Cowan & Waldbauer 1984). Mating of the studied European representatives of *A. antilope* is quite similar to that of the North American specimens of this species. However, in our observations the pairs of *A. antilope* copulated even longer and exhibited post-copulating guarding. Several adaptive explanations for lengthy copulations have been suggested (Alcock 1994). Males may form post-insemination associations in order to prevent rival males from mating with the female and the same partner may attempt to remate with the female (multiple copulations per single mounting), thus delivering more sperm. Post-insemination associations may represent a form of mate guarding, in which the male attempts to maximise his fertilization success and induce unreceptivity in the female.

In comparison with *A. antilope*, the females of *D. zonalis*, *S. allobrogus* and *S. murarius* mated quickly. In our observations, once inseminated, females of these species always rejected males that attempted to copulate.

Female's struggling during pre-copulatory or copulatory period may suggest the existence of «cryptic female choice» (Thornhill 1983) with sexual selection acting on male´s behaviours and structures used during this period. The males of all described species used their hooked antennae, or antennae with tyloids on the apical segments during courtship and copulation. Morphological and behavioural studies of male antennal tyloids of the ichneumonid *Pimpla turionella* (L.) (Bin et al. 1999) have revealed that tyloids are release structures of integumentary glands rather than sensory organs. Behavioural observations of mating in *P. turionella* indicate that the intensity of antennal stroking is dependent on female receptiveness. Our observations support the hypothesis, that tyloids of Eumenidae males may have a similar function and serve as source of contact pheromones.

On the other hand, the cephalic foveae on the vertex behind the posterior ocelli of females in many eumenine wasps, indicates that these depressions also represent external openings of paired integumentary glands and probably play a role in mating (Cumming & Leggett 1985). Typically, a mounted male holds his mouth parts on the vertex of the female, and the secretions from these pits may play a role in sexual behaviour (Cowan 1991). Our observations support this hypothesis.

Acknowledgements. The author thanks Dr. E. Budrys for identification of the studied species, preliminary reviewing of the manuscript and meaningful discussions.

REFERENCES

Alcock, J. 1994. Post-insemination associations between male and female insects: the mate guarding hypothesis. Ann. Rev. Entomol. 39, 1-21.

Bin, F., Wäckers, F., Romani, R. & Isidoro, N. 1999. Tyloids in *Pimpla turionella* (L.) are release structures of male antennal glands involved in courtship behaviour (Hymenoptera: Ichneumonidae). Int. J. Insect Morphol. Embryol. 28, 61-68.

Cowan, D.P. 1986. Sexual behaviour of Eumenid wasps (Hymenoptera, Eumenidae). Proc. Entomol. Soc. Wash. 88, 531-541.

Cowan, D.P. 1991. The solitary and presocial Vespidae. Pp. 33-73 in Ross, K.G. & Matthews, R.W. (eds.), The Social Biology of Wasps. Cornell University Press, Ithaca, NY.

Cowan, D.P. & Waldbauer, G.P. 1984. Seasonal occurrence and mating at flowers by *Ancistrocerus antilope* (Hymenopera: Eumenidae). Proc. Entomol. Soc. Wash. 86, 930-934.

Cumming, J.M. & Leggett, F.L. 1985. Cephalic foveae of eumenine wasps (Hymenoptera: Vespidae). J. Nat. Hist. 19, 1197-1207.

Thornhill, R. 1983. Cryptic female choice and its implications in the scorpionfly *Harpobittacus nigriceps*. Amer. Nat. 122, 765-788.

Received 27 July 2000,
accepted 22 December 2000.

Norw. J. Entomol. 48, 45–49. 2001

On the origin of nest building behaviour in digger wasps (Hymenoptera, Apoidea)

Eduardas Budrys

Budrys, E. 2001. On the origin of nest building behaviour in digger wasps (Hymenoptera, Apoidea). Norw. J. Entomol. 48, 45-49.

Comparison of the behaviour of primitive apoid wasps (Ampulicidae, Sphecidae, Crabronidae: Pemphredoninae) reveals xylicolous nesting in a pre-existing cavity to be found among representatives of generalised genera, while advanced taxa are mostly terricolous. This supports the hypothesis that nesting in a pre-existing cavity is a generalised ethological character, while nesting in a female-made burrow in the soil or plant material and a free nest are advanced behaviours. The nest building behaviour could develop from 3 sources: (1) hunting, which may contain digging activities if prey is soil-living; (2) prey transfer, which may include cleansing and deepening of the nest cavity before hiding prey in it, and (3) closing the cavity, which may involve searching for and transferring material and building the nest closure. The analysis of the subsequent steps of evolution from the unicellular wasp nest with a single prey toward the multicellular nest with multiple preys per cell leads to the opinion that nest with communal cells with several larvae per cell, rarely found in digger wasps, is an inevitable intermediate step between the nesting behaviour patterns «multiple cells - one prey per cell» and «multiple prey per cell».

Key words: behaviour, wasp nesting, evolution, Hymenoptera, Apoidea.

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INTRODUCTION

Studies of wasp behaviour have accumulated huge amounts of facts, summarised and evolutionarily analysed in several monographs (Evans 1966, Malyshev 1966, Krombein 1967, Bohart & Menke 1976, Iwata 1976). It is clear that the behaviour of wasps is evolutionarily more flexible than their morphology. Ethological characters are prone to parallelism and homoplasy: similar behavioural patterns occur in different clades of the wasp phylogenetic tree. This is why it is so easy to use the same wasp ethology for opposite evolutionary speculations and so difficult to find common points in different opinions.

This study is a continuation of an earlier effort (Budrys 1990). The objectives of it were (1) formalisation of some behavioural patters, based on the example of Malyshev (1966) and Iwata (1976), and (2) polarisation of some ethological characters for future phylogenetic analysis.

RESULTS AND DISCUSSION

Comparison of the behaviour of generalised apoid wasps from Ampulicidae (nesting biology of Heterogynaidae is unknown), Sceliphrini (Sphecidae), and Pemphredoninae (Crabronidae) reveals that nesting in a pre-existing cavity or that adopted by a female, including the burrow of the prey, is found only among representatives of generalised genera (*Ampulex*, *Chlorion*, *Podium*, *Chalybion*, *Arpactophilus*, *Spilomena*, *Passaloecus*). Representatives of morphologically advanced taxa are mostly terricolous (Prionychina, Ammophilini, *Ammoplanus*, *Diodontus*, *Mimesa*, *Pluto*, *Ammopsen*), while others burrow in plant material (*Pemphredon*) or build free nests (*Trigonopsis*, *Sceliphron*, *Microstigmus*). Accordingly, the hypothesis that nesting using a pre-existing cavity is plesiomorphic to all Apoidea is very credible.

Different species of the generalised genus *Passaloecus* (Pemphredonini) represent three types of nesting: the usage of a pre-existing cavity (e.g. *P. eremita*), burrowing in plant material (*P. singularis*), and nesting in the ground (*P. pictus*). However, the species nesting in twig pith and in the ground use external materials (gum of conifers in *P. pictus*, externally obtained grains of gravel in *P. singularis*) for building the diaphragms between cells, exactly as the users of pre-existing cavities do. In my opinion, the behaviour of different species of *Passaloecus* is a model revealing how burrowing in plant material and in the ground have evolved from the usage of pre-existing cavities. Using of substrate particles for diaphragms and nest closure was an optimisation of behaviour and a further evolutionary step.

Arpactophilus and *Spilomena* (Pemphredoninae: Spilomenina) nest in pre-existing cavities and build the diaphragms between cells of silk. Their closest relative, *Microstigmus*, makes free nests of such silk (Melo 1997), thus demonstrating how the free nest has derived from nesting in pre-existing cavities. The free nest in other sphecids (*Trigonopsis*, *Sceliphron*, *Pisonopsis*, some species of *Isodontia*, *Pison* and *Trypoxylon*) has also derived immediately from the nest in a pre-existing cavity with cell diaphragms, typical of other species of the same or closely related genera (*Podium*, *Chalybion*, the other species of *Isodontia*, *Pison* and *Trypoxylon*). The evolutionary step from using a pre-existing cavity to preparing a burrow or a free nest might be caused by the decreased dependence on the presence and quality of the natural cavity.

In the case of the ancestral type of wasp behaviour the hunting-oviposition cycle (behavioural formula *a* - HPTOC; acronyms of the behavioural elements by Iwata (1976), partly modified) consists of hunting (H), paralysing (P), and sometimes transferring (T) prey into a pre-existing cavity, oviposition (O) and closing the nest cavity (C). It does not contain nest building (N).

The hunting-oviposition cycle of the advanced type of wasp behaviour (HPNTOC or NHPTOC) includes the nest building (N). The set of the nesting behaviour elements of the *i*th hunting-oviposition cycle could be presented in more detail by the formula:

$(N^1N^2N^3\ H^1H^2H^3\ P\ T^1T^2T^3\ O\ C^1C^2C^3)_i$, where

N^1 - searching for the nesting place

N^2 - gathering and transferring the nest material *or* digging and transferring ground particles

N^3 - plastering the free nest *or* dropping out the ground particles ('building' the tumulus)

H^1 - searching for the shelter of prey

H^2 - penetrating into the shelter of prey

H^3 - attacking prey

P - paralysing prey

T^1 - searching for a pre-existing cavity

T^2 - penetrating into the cavity, cleansing

T^3 - transfer of prey to the cavity

O - oviposition

C^1 - searching for material to close the cavity

C^2 - gathering and transferring the material

C^3 - building the cavity closure

The nest building behaviour (N) of the *i*th hunting-oviposition cycle could develop from 3 sources (Figure 1):

1) hunting (H), which could include digging activities in the case of soil-living prey (as, e.g., in *Scolia*), the result would be behavioural formula *b* - $(N(=H)HPTOC)_i$;

2) transfer of the prey (T), which could include cleansing and deepening the pre-existing cavity, the result would be behavioural formula *c* - $(HPN(=T)TOC)_i$; and

3) closing the pre-existing cavity (C), which could consist of searching, transferring the material for the nest plug and building the latter, or even digging a burrow to reach wet soil for the plug, the result would be behavioural formula *g* - $(N(=C_{i-1})HPTOC)_i$. The sequence of the behavioural elements in the hunting-oviposition cycle ***i*** could change, and moving of a particular element to the earlier stage could occur through the loss of the rest of elements of the previous cycle ***i-1*** (Malyshev 1966), thus fusing two cycles (***i-1*** and ***i***) into one, for instance:

$(HPTOC)_{i-1} + (HPTOC)_i = (N(=T_{i-1})HPTOC)_i$ (*d*, *e*), or

$(HPTOC)_{i-1} + (HPTOC)_i = (N(=C_{i-1})HPTOC)_i$ (*g*)

Formulas *a* and *d* (Figure 1) presume the usage of a pre-existing cavity, found correspondingly after and before hunting, formula *c* - a burrowed nest made after hunting.

Formulas *b*, *e*, and *g* reflect the preparation of burrowed nest before hunting, the commonest behaviour in apoid wasps. The nest burrowing behaviour (N) could derive here in three different ways: in case *b* (way 1) from the digging activities while searching for a ground-living prey (former H), or, in case *e* (way 2) from cleansing a pre-existing cavity before transfer and placing prey in it (former T), or, in case *g* (way 3) from digging out a hollow while collecting wet soil for the previous nest plug (former C). I suppose that way 1 is less probable than 2 and 3, because using a ground-living, hidden prey, the search for which includes digging activities, should not induce evolution of the nest building (prey hiding) behaviour.

Formulas *f* and *g* may represent the building of free plastered nest, where the search for nesting place in it (N^1) presumably has derived from the search for the pre-existing cavity (former T^1) in case *f*, or from the search of place with wet soil or other material for the nest plug (former C^1); the transfer of nest material (N^2) and building of the nest (N^3) have derived in both cases from the building of the nest plug (former C^2 and C^3).

Terricolous wasps with nest building types called «rakers» or «pushers» (Evans 1966) might have developed their nesting behaviour from the cleansing of a pre-existing cavity (way 2), while the behaviour of 'pullers' and 'carriers' could have developed from the nest closing activities (way 3). The behaviour of *Ammophila* digging the nest burrow (formula *g*) and the behaviour of *Sceliphron* collecting the mud for a free nest (formula *f*) are externally similar and might have a common origin from the ancestral nesting in a pre-existing cavity (formula *d*). Consequently, an externally similar nest building behaviour of digger wasps might be derived homoplastically. Comparative ethological studies should consider this contingency.

As already mentioned earlier, evolutionary sophistication of wasp behaviour presumably occurred via partial losses in the nesting-hunting-oviposition behavioural cycle (Malyshev 1966). For instance, the multicellular wasp nest with *n* cells (Figure 2, formula *2*) has appeared from the unicellular nest (formula *1*) via the loss of building a new nest tunnel (N) after filling and closing each single cell:

NHPTOC (*1*),

$\mathrm{NHPTOC}_1 + \mathrm{NHPTOC}_2 + \ldots + \mathrm{NHPTOC}_n \rightarrow \mathrm{N(HPTOC)}_n$ (*2*)

The cell with *m* prey specimens has appeared via the omission of oviposition in several hunting-oviposition cycles:

...HPTO... (*3*, *4*)

$\ldots\mathrm{HPTO}\ldots_1 + \ldots\mathrm{HPTO}\ldots_2 + \ldots + \ldots\mathrm{HPTO}\ldots_m \rightarrow \ldots\mathrm{(HPT)}_m\mathrm{O}$ (*5*, *6*)

The subsequent steps of the evolution from the unicellular nest with a single prey to the multicel-

$$\begin{tikzcd}
\mathbf{(HPTOC)}_i\ (a) \arrow[r, "(1)"] \arrow[dr, "(2)"] \arrow[ddr, "(2)"'] \arrow[dddd, "(3)"'] & \mathbf{(N^1(=H^1)N^2(=H^2)H^3PTOC)}_i\ (b) & \\
& \mathbf{(HPN^1(=T^1)N^2(=T^2)T^3OC)}_i\ (c) \arrow[dr] & \\
& \mathbf{(N^1(=T^1_{i-1})HPTOC)}_i\ (d) \arrow[r] \arrow[dr, "(3)"'] & \mathbf{(N^1(=T^1_{i-1})N^2(=T^2_{i-1})HPTOC)}_i\ (e) \\
& & \mathbf{(N^1(=T^1_{i-1})N^2(=C^1_{i-1}+C^2_{i-1})N^3(=C^3_{i-1})HPTOC)}_i\ (f) \\
\mathbf{(N^1(=C^1_{i-1})N^2(=C^2_{i-1})N^3(=C^3_{i-1})HPTOC)}_i\ (g) & &
\end{tikzcd}$$

Figure 1. Three sources (1-3) of the origin of the nesting behaviour (N) of wasps. Other acronyms in behavioural formulas: H - hunting, P - paralysing, T - transferring prey, O - oviposition, C - closing the nest cavity.

lular nest with multiple prey per cell could be expressed in behavioural formulas as follows (Figure 2).

Formulas *1, 2, 5* and *6* reflect the usual solitary wasp behaviours and may be illustrated by numerous examples. Formulas *3, 4, 7* and *8* correspond with building communal cells, with several larvae per single cell, rarely found in solitary wasps (some *Isodontia* and *Pemphredon*) but typical of ants. However, such behaviour (formulas *3* and *4*) seems to be an inevitable intermediate step between the widespread behavioural patterns

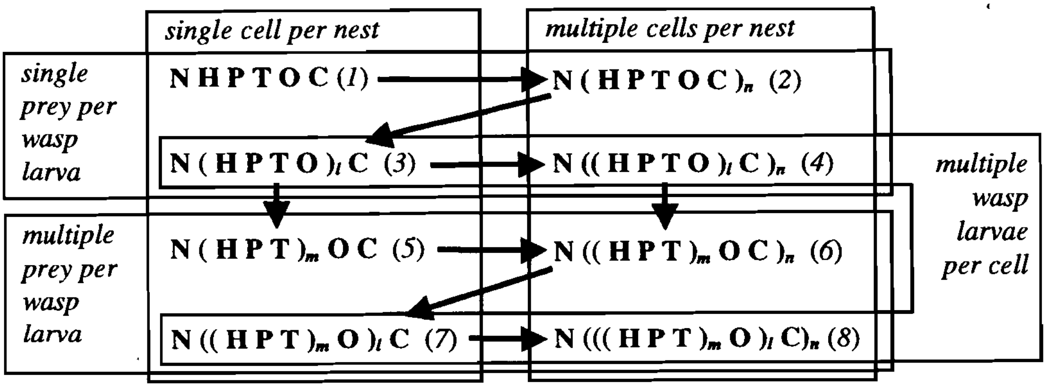

Figure 2. Subsequent stages of the evolution of wasp behaviour related to building the multicellular nest (*l* - larvae per cell, *m* - prey per cell, *n* - cells per nest; other acronyms in behavioural formulas as in Figure 1).

Table 1. Polarisation of some ethological characters of wasps for phylogenetic analysis.

Character	**Plesiomorphic state**	**Apomorphic state(s)**
I. Location of the nest cells (non-additive character)	**0.** in a pre-existing cavity, closed by wasp female (Figure 1, formulas *a* and *d*)	**1.** in a female-made free, plastered nest (Figure 1, formula *f*) **2.** in a female-made burrow in soil derived from digging while hunting (Figure 1, formula *b*) **3.** in a female-made burrow in soil or plant substrate derived from cavity cleansing (Figure 1, formula *e*) **4.** in a female-made burrow in soil, derived from collecting material for the nest plug (Figure 1, formula *g*)
II. Cavity of the nest found or built (inapplicable in case of character I, state 2)	**0.** after hunting (Figure 1, formulas *a* and *c*)	**1.** before hunting (Figure 1, formulas *d, e, f* and *g*)
III. Nest	**0.** with a single prey (Figure 2, formula *1*)	**1.** with multiple prey (Figure 2, formulas *2-8*)
IV. Nest with multiple prey contains(additive character)	**0.** multiple cells with one larva and one prey per cell (Figure 2, formula 2)	**1.** single cell with multiple larvae, single prey per larva (Figure 2, formula *3*) **2.** single cell with one larva (Figure 2, formula *5*) **3.** multiple cells with multiple prey each, one larva per cell (Figure 2, formula *6*) **4.** single cell with multiple prey and several larvae (Figure 2, formula *7*) **5.** multiple cells with multiple prey, several larvae per cell (Figure 2, formula *8*)

«multiple cells - one prey per cell» (*2*) and «multiple preys per cell» (*5* and *6*). Probably this type of behaviour was rarely fixed in the ethological evolution of wasps due to possible cannibalism of larvae and weaker protection against parasitism and predation.

In the case of the two-step way of behavioural evolution from formula *3* to formula *6*, two sequences of the steps may be presumed (formulas *4* and *5*). In other instances of double steps, e. g. from *1* to *3*, or from *5* to *7* (Figure 2), the opposite sequence of step-by-step evolution might be hardly supposed: formulas $(NHPTO)_nC$ (intermediate between *1* and *3*, opposite than *2*), or $(N(HPT)_mO)_nC$ (intermediate between *5* and *7*, opposite than *6*) would represent an unknown in the recent wasps and hardly imaginable behaviour of building several nests with a single closure.

The discussed ethological characters could be polarised for phylogenetic analysis as shown in Table 1.

REFERENCES

Bohart, R.M. & Menke A.S., in collaboration with Court, H.S., Parker, F.D., Grissell, E.E., Levin, D.P. 1976. Sphecid Wasps of the World. A generic revision. 695 pp. Berkeley, Los Angeles, London.

Budrys, E. 1990. Some aspects of behaviour evolution of digger wasps and the problem of the origin of bees (Hymenoptera, Sphecoidea, Apoidea). Pp. 22-24 in V.I.Tobias & A.L.Lvovskij (eds). Advantages of entomology in USSR: insects - Hymenoptera and Lepidoptera. Materials of the 10th meeting of the All-Union Entomological Society 11-15 September 1989. USSR Academy of Sciences, Zoological Institute, All-Union Entomological Society., Leningrad. (in Russian)

Evans, H.E. 1966. The comparative ethology and evolution of the sand wasps. 526 pp. Cambridge.

Iwata, K. 1976. Evolution of instinct. Comparative ethology of Hymenoptera. 535 pp. New Dehli.

Krombein, K.V. 1967. Trap-nesting wasps and bees: life histories, nests and associates. 570 pp. Washington, D.C.

Malyshev, S.I. 1966. Genesis of the Hymenoptera and the phases of their evolution. 329 pp. Moscow. (in Russian; translation to English - 1968, Methuen & Co. London).

Melo, G.A.R. de. 1997. Silk glands in adult sphecid wasps (Hymenoptera, Sphecidae, Pemphredoninae). J. Hymen. Res. 6, 1-9.

Received 8 August 2000,
accepted 1 March 2001.

The Surinam cockroach *Pycnoscelus surinamensis* (L.); a new greenhouse pest established in Göteborg, Sweden

Torkel Hagström

Hagström, T. 2001. The Surinam cockroach *Pycnoscelus surinamensis* (L.); a new greenhouse pest established in Göteborg, Sweden. Norw. J. Entomol 48, 50.

The Surinam cockroach *Pycnoscelus surinamensis* (L.) was first observed in a heated green house at the Botanical Garden of Göteborg, Sweden in 1995. The population is well established today and represents a problem for sensitive plants. The species had previously only been sporadically observed in Sweden.

Key words: *Pycnoscelus surinamensis*, Blattodea, greenhouses

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In the summer of 1995 the so-called Surinam cockroach *Pycnoscelus surinmensis* (L.) was observed in a heated greenhouse at the Botanical Garden of Göteborg (Hagström & Ljungberg 1999). In 1996, the number of those root-eating parthenogenetic cockroaches had increased to such a level that they became a real problem for sensitive plants. The population is well established today. Previously, this species had been recorded only sporadically in Sweden.

The English and Latin names of this cockroach are in fact completely misleading. It originates from SE Asia, but was already established (by synantropic distribution) in the new world in the mid-1700's. Males have (with few exceptions) only been found in Asia. Linnaeus, however, based the description in 1767 on material from Surinam.

In northern Europe, the Surinam cockroach can only survive in heated greenhouses. To switch off the heating system for a week or two in winter would probably kill the whole local population (and a number of sensitive plants). Since this species is subterranean, control by pesticides is rather complicated.

References

Hagström, T. & Ljungberg, H. 1999. Växthuskackerlackan *Pycnoscelus surinamensis* (L.) (Blattodea: Panchloridae) etablerad i Sverige. Ent. Tidskr. 120, 113-115.

Received 27 June 2000,
accepted 21 August 2000.

Norw. J. Entomol. 48, 51–60. 2001

Occurrence and migration on snow, and phenology of egg-laying in the winter-active insect *Boreus* sp. (Mecoptera)

Sigmund Hågvar

Hågvar, S. 2001. Occurrence and migration on snow, and phenology of egg-laying in the winter-active insect *Boreus* sp. (Mecoptera). Norw. J. Entomol. 48, 51-60.

In SE Norway, *Boreus westwoodi* and *B. hyemalis* can be found on the snow surface in coniferous forests throughout the winter, mainly in calm, cloudy weather around or slightly above 0°C. While often at rest or moving slowly around, the insects may show active migration behaviour, especially on warmer, more or less sunny days. During migration, each insect moves in a fixed direction by continuous jumping, covering up to 1.2 m per minute. Different individuals, however, migrate in different directions, both in relation to the cardinal (compass) direction and in relation to the position of the sun. This behaviour, which includes the ability to navigate, is similar to that of four winter-active collembolans, which also use the smooth snow surface for effective winter migration. Dissection of females collected on snow from October to April indicates that *Boreus* lays eggs throughout the winter. When the first batch of about 10-20 eggs have been laid during November, December and January, the ovaries start to produce new eggs and seem to have a continuous egg production until snow melt in April. Earlier studies have shown that eggs are laid among moss in the subnivean air space. Since copulation was very rarely observed on snow, this may occur during autumn before snow fall, or in the subnivean space. Under Norwegian conditions, *Boreus* is mainly a subnivean winter-active insect. However, in mild weather they climb along tree trunks etc. to reach the snow surface, probably for two purposes: to absorb heat for egg development and to migrate (spreading the eggs and perhaps bringing the animals to better feeding places). Sunny, cloudless weather may be risky due to a rapid temperature fall in the evening. It is suggested that continuous jumping as a migration behaviour may be a further evolution of jumping as an escape mechanism away from predators.

Key words: *Boreus*, winter activity, migration, egg-laying.

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INTRODUCTION

The holarctic genus *Boreus* sp. (Mecoptera) (Figure 1), is famous for being winter-active. The flightless imagines hatch from soil in the autumn, and can often be observed on snow at temperatures around 0 °C (Strübing 1950, 1958, Svensson 1966, 1972, Fjellberg & Greve 1968, Sømme & Østbye 1969, Hågvar 1971, Shorthouse 1979). In areas with a permanent snow cover during winter, imagines live most of the time in the subnivean air space where the temperature rarely drops below 0 to -3 °C (Coulianos & Johnels 1962, Shorthouse et al. 1980). On mild winter days, however, they may enter the snow surface, probably through channels created along stems and vegetation penetrating the snow, and they withdraw to the subnivean air space when the temperature drops again (Svensson 1966, Courtin et al. 1984). Both larvae (Withycombe 1922) and adults (Fraser 1943, Strübing 1950, Svensson 1966) eat mosses. No hunting and killing of small invertebrates has been seen in laboratory studies, but Strübing (1950) observed that *B. hyemalis* could suck out the content of dead collemboles. Although *Boreus* is usually considered to be a purely moss feeder, the possible use of animal food remains open.

In this study, the temperature and weather conditions when *Boreus* appears on the snow surface was described more closely, based on observations during many winters. Another aspect was to study the behaviour and movements of *Boreus* on the snow. The smooth snow surface could be used for dispersal, as has been shown for four winter-active Collembola species (Hågvar 1995, 2000). The third purpose was to reveal when egg-laying occurs. Are the eggs laid when the ground is covered by snow, or does *Boreus* delay egg-laying until the snow melts? By dissecting the ovaries of another insect active on snow, *Chionea araneoides* Dalm. (Dipt., Tipulidae), Hågvar (1976) showed that eggs were laid mainly in mid-winter (December and January), and the ovaries were not refilled. By using a similar technique, it should be possible to clarify if also *Boreus* lays eggs in the coldest period of the year.

THE SPECIES STUDIED

Two *Boreus* species occur in Norway: *Boreus hyemalis* (Hag.) in South Norway and *Boreus westwoodi* (L.) in the whole country (Fjellberg & Greve 1968, Greve 1983). Unfortunately, only males can be identified with the present taxonomical knowledge. According to the identified males, most of the present material stems from *B. westwoodi*, but the field observations indicated no differences in ecology between the two species. Both were recorded throughout the snow-covered period, as also found by Fjellberg & Greve (1968) and Svensson (1972). Four males showed an intermediate character concerning the shape of the extension on the third tergite. Also Greve (1983) mentioned intermediate forms and indicated the need of closes taxonomic studies. In the present material, males of *B. hyemalis* usually had darker wings and legs than *B. westwoodi.*

Figure 1. A female *Boreus* on old, coarse snow in mild weather. Photo: S. Hågvar.

MATERIAL AND METHODS

Insects were searched for on snow during many years (1968-2000), mainly on ski. The trips were performed under very different weather and temperature conditions, from -20 to +10 °C. Most temperature measurements during sampling were made with a shaded thermometer at 1.5 m above snow level, supplied with a few measurements 1 cm above the snow surface. A number of extra measurements at various temperature regimes were performed to compare the general temperature differences between the two levels. The snow depth varied greatly, but was usually between 0.5 and 1.5 m.

Most of the material was collected from coniferous forests in the following three localities in SE Norway. I: Østmarka just E of Oslo at 100-200 m above sea level, II: Nordmarka just N of Oslo at 300-600 m above sea level, and III: Vegglifjell W of Veggli in Numedal, at 800-900 m above sea level. In the first two localities, *B. westwoodi* made up around 70 % of the collected males, and 100 % in the third locality.

Altogether 580 females, sampled in alcohol from October to April, were dissected. The number of full size eggs was counted, and it was noted whether further eggs were under development in the ovaries. Most of these females were collected in study areas I and II. Females from locality III, where only *B. westwoodi* occurs, represented 4 % of the dissected females from February, 11 % from March and 46 % from April. The material from all localities was pooled, since egg numbers and the status of the ovaries did not seem to differ between locality III and the two other localities in any month. Because collections were often made selectively on females, relative numbers of males and females will not be discussed.

The speed and mode of movement on the snow surface was observed at different temperature and weather conditions. Especially the ability to move continuously in a fixed direction was studied. Individual migration directions were mapped, both in relation to the cardinal (compass) direction and the position of the sun.

RESULTS

Occurrence and weather conditions

Most observations of *Boreus* on snow were made at temperatures around 0 °C or slightly higher, in cloudy or partly cloudy weather with no wind (Figure 2). Very often, the insects were observed soon after a wet snow fall. However, *Boreus* can also be active in bright sunshine. Temperatures measured at 1.5 m height varied between -3 and 10 °C. At temperatures below -3 °C, animals were never observed on snow, except for a dead female at -5 °C. A few temperature measurements made 1 cm above the snow surface when *Boreus* was active below 0 °C (on dry snow) showed -1.0, -1.3 and -3.3 °C, respectively.

A number of simultaneous measurements at 1 cm and 1.5 m height showed very similar temperatures at the two levels at subzero temperatures (within a few tenths of a degree), while the 1 cm level tended to be about two degrees colder when the 1.5 m level showed 2 to 5 °C. This indicates a span for the air temperature near the snow surface from -3 to 3 °C when *Boreus* is present, if we exclude three exceptional hot days in Figure 2.

Also at the highest densities, according to a subjective scale (shown in black in Figure 2), the weather was most often cloudy and calm, but temperatures were usually above zero. High density was typically observed during two specific conditions: Either in early winter immediately after a wet snow fall of 5-15 cm upon bare ground (typically at 1 to 2 °C), or near the end of the winter on warm, more or less sunny days (up to 5 °C), especially after several preceding days with tempera-

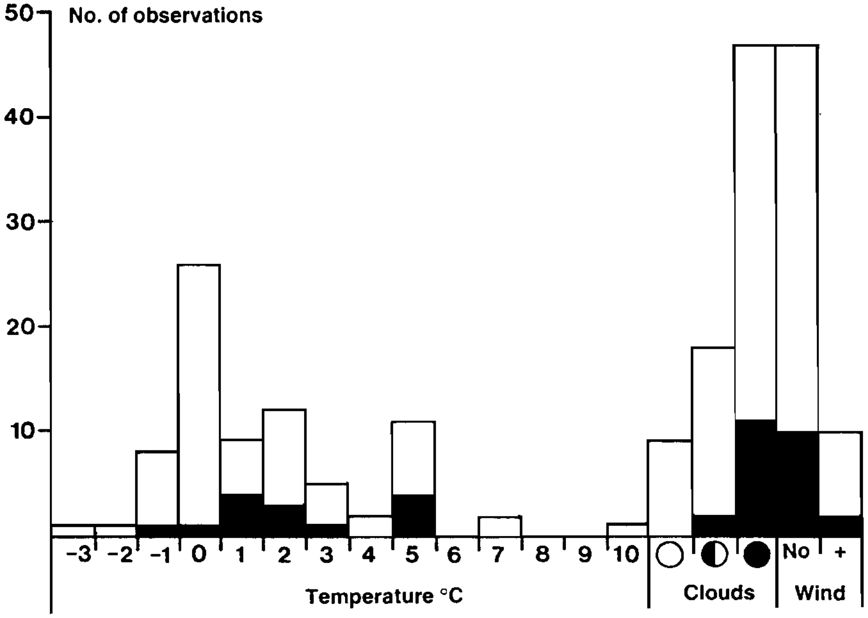

Figure 2. Temperature (to the nearest degree at 1.5 m in shadow), cloud conditions (no clouds, partly cloudy or completely cloudy) and wind conditions (no wind or faint wind), at different cases when *Boreus* sp. was observed on the snow surface. Black bars show conditions during especially high densities of *Boreus*. Compiled observations from many years.

tures above zero. In the last case, snow depth could still be 0.5-2 m, but often with considerable depressions around the stem of large spruce trees.

The two highest densities were observed on 10 cm wet, newly fallen snow upon bare ground, in calm, cloudy weather at 1 °C. One observation was in area II on 1 November while it was still snowing, with about 3-10 m between the insects. The other observation was in area I on 31 January in foggy weather, with about 5-10 m between the individuals, and locally only 1 m or less. Usually, the densities of *Boreus* on snow are much lower. A typical «*Boreus* day» could be to record an individual per 200-500 m along a ski track. However, the occurrence may be patchy, with 10-50 m between each insect locally.

Behaviour on snow

Especially during mild and more or less sunny weather in late winter (March and April), *Boreus* individuals of both sexes may migrate very actively on the snow surface. These observations were made either in area III where only *B. westwoodi* occurs, or in area I in a site where all recorded males were *B. westwoodi.* By repeated jumping in a fixed direction, an individual can move up to one meter per minute. Each jump is typically about 10 cm long. Immediately after landing, the insect rises up again, but after a short jump it may land directly on its feet. Then the insect turns its body in the correct direction and is ready for another

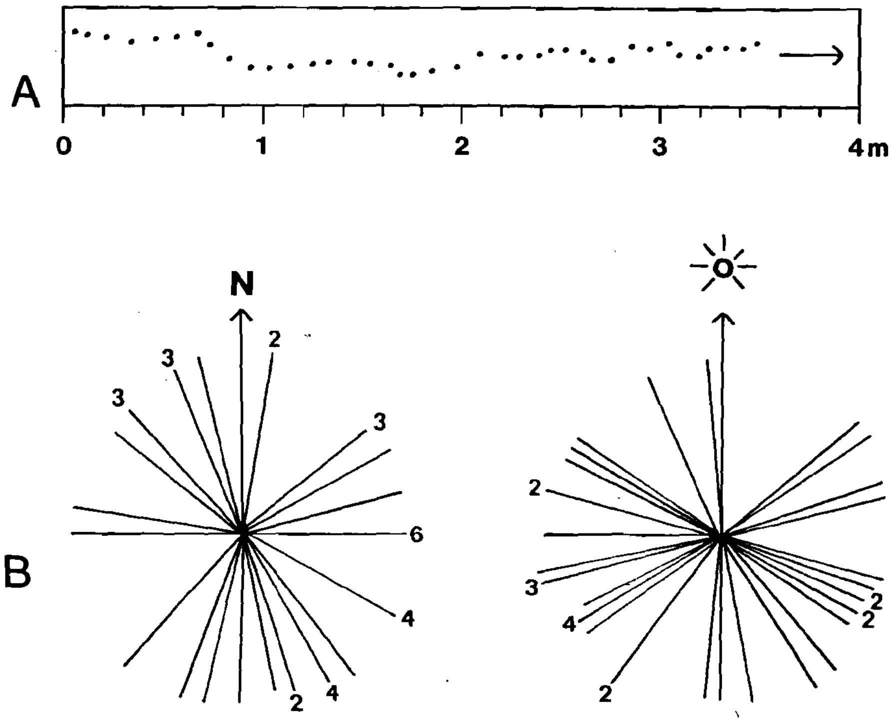

Figure 3. A: Migration route on snow of a female *B. westwoodi* in sunny weather with an air temperature of 10 °C (at 1.5 m height). Each dot represents a starting point for a jump. Deviations from a straight line were sometimes due to the microtopography, as the animal could slide down small hills at landing. The next 3.5 m was passed on flat snow in a very direct line. **B**: Individual migration directions in *Boreus westwoodi,* both relative to the cardinal (compass) direction and to the position of the sun at the actual time. Numbers indicate more than one observation. Both females and males migrated in all possible directions, but each individual was true to a certain chosen direction.

jump. Sometimes, however, it rests a little or walks a few cm in the same direction between the jumps. One migrating route is showh in Figure 3A. Many cases of directional migration were seen, and the longest observed was a male jumping 12.2 m in an almost perfect straight line during 30 min at 5 °C in periodic sunshine. Evidently, navigation is a very easy task.

Although each individual was true to a certain direction, different individuals migrated in different directions. This was the case for both sexes, even at a certain locality at a the same time. Observed migration directions distribute themselves around the whole circle, both in relation to the cardinal (compass) direction and the position of the sun at the actual time (Figure 3B). Even if the insect was disturbed by being picked up and immediately released again, the direction was remembered. However, six individuals, three of each sex, which were kept for three hours in dark boxes in the snow, did not remember their direction. Instead , each of them decided on a new direction which was not related to their former direction or to the current movement of the sun.

Individual migration rates during different weather conditions are shown in Figure 4. The highest rate was 1.2 m/min by a male in partly cloudy weather at 5 °C. In cloudy weather around zero, the mean migration rate was around 0.3 m/min, and the lowest rates were in individuals which mainly walked.

The only three observations of copulation in the present study were on thin snow cover (10-20 cm) in very mild, stable and overcast weather: 11 November (2 pairs, 2 °C), 21 December (5 °C and foggy), and 4 January (3 °C and rain). In fact, no copulating animals were observed at the two highest densities.

Phenology of egg development

Females collected in the second half of October had their abdomen completely filled up with about 10-20 full size eggs, but a looser structure compared to ripe eggs often indicated that they were not yet ready for deposition. As shown in Figure 5, the mean number of full-size eggs per female decreased gradually through the first half of the snow-covered season, from 11.7 in October to 4.9

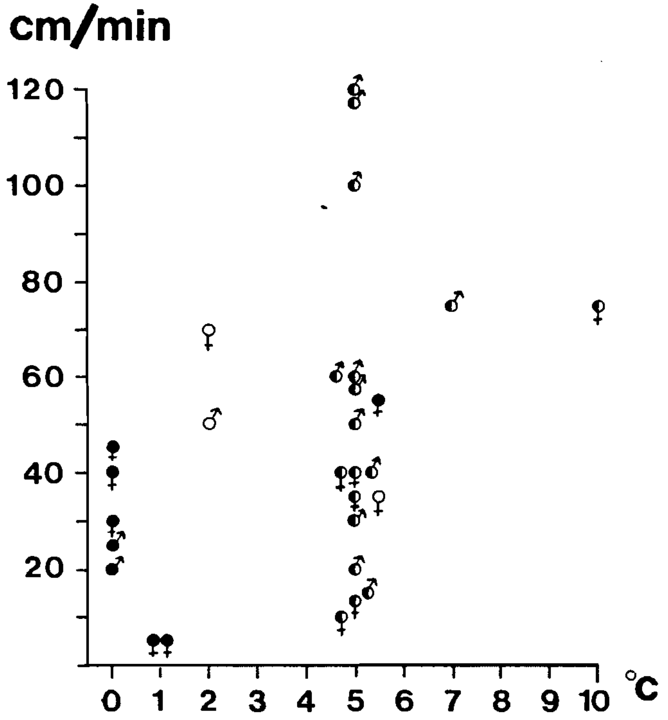

Figure 4. Individual migration rates in *Boreus westwoodi* (males and females) at different temperatures, measured in shadow at 1.5 m height. Open circles: sunny, half black: partly cloudy, and black: cloudy.

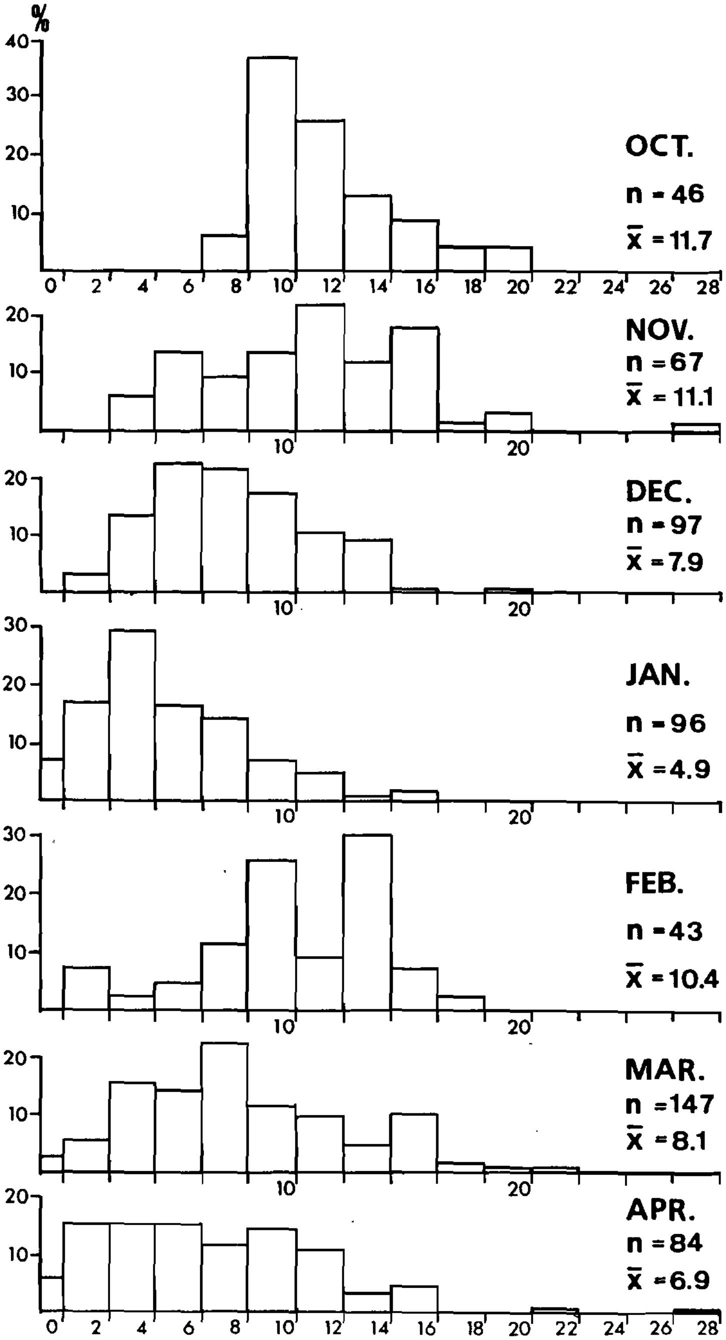

Figure 5. Percentage distribution of the number of full size eggs per female in *Boreus* in different winter months. Each column combines two successive egg numbers. The number of dissected females (n) and the mean number of full size eggs per female are given to the right for each month. All animals were collected on snow.

in January. Except for a few females in January, the ovaries showed no sign of production of new eggs during this period, only a gradual emptying of ripe eggs. However, the abdomen of nearly empty females often contained much of a white, fatlike substance not seen earlier in the winter, indicating that the insects had eaten and were building up resources for further egg production.

In February, the mean number of full-size eggs per female increased again to 10.4 (Figure 5), and was then slightly lowered through March and April. During the whole second half of the snow-covered period (February-April), the ovaries contained eggs in all sizes and stages of development, and the females seemed to be well fed.

DISCUSSION

Occurrence and weather conditions

Already Strübing (1950) and Shorthouse (1979) suggested that these dark insects would be heated by solar radiation. Courtin et al. (1984) managed to demonstrate that the North American species *Boreus brumalis* Fitch absorbed radiation from the sun under clear sky conditions. While the temperature at the snow surface was between 0 and 1 °C, the internal body temperature was raised to 5 to 9 °C. With its relatively long legs, the insect can keep the body some mm above the cold snow surface. According to Herter (1953), the preference temperatures of *B. westwoodi* and *B. hyemalis* are 4 and 10 °C, respectively.

The ability to absorb heat under overcast conditions has not been studied, but it is probably lower. If *Boreus* comes to the snow surface to absorb heat, why does it mainly appear in overcast weather, as also observed by Sømme & Østbye (1969)? In fact, in the present set of observations, it was often snowing (23 %) or foggy (18 %). A possible explanation is that sunny weather is risky for the animals, since a clear sky often implies a rapid temperature fall during the evening or night. Contrary to winter-active Collembola, which are small enough to retreat vertically through the snow layers to escape a sudden cold (Hågvar 1995, 2000), *Boreus* must in due time find a suitable channel down to the subnivean space. Svensson (1966) observed how a *B. westwoodi* male was just able to escape slowly below a spruce tree at -5.5 °C, a temperature which is close to the supercooling point of the two relevant species (Sømme & Østbye 1969). The weather conditions shown in Figure 2 may be a trade-off between the advantage of being heated by solar radiation, and the danger of being frozen to death after sunset. Observations of *Boreus* on snow in sunny weather were mainly on very warm days in late winter, when even clear nights used to be relatively mild.

It is not known how *Boreus* recognizes that favourable weather conditions exist on the snow surface. Zettel (1984) showed that changing barometric pressure lead to increased snow surface activity of the collembolan *Isotoma hiemalis* Schött. As mild weather and snow fall is often combined with a fall in the barometric pressure, this might be a mechanism also for *Boreus*. Maybe *Boreus* stays as near the snow surface as possible, for instance at the base of trees, ready to experience increased temperatures. However, when mild weather appears after a cold period, it often takes two days until *Boreus* appears on the snow. This may be due to cold snow layers, which delay upward migration.

Movements on snow

The ability of directional movements on the smooth snow surface may serve two purposes for this wingless insect. Firstly, as suggested by Solhøy (pers. comm.), it may bring *Boreus* to new food patches. By creeping into the depressions which often exist in the snow around the base of large trees, it may reach moss vegetation on the lower stem or on the ground, where perhaps even animal food like Collembola might be searched for. Secondly, the migration may be a way of distributing the eggs of a given female over a large area, resulting in dispersion. Individuals were several times observed 30-50 m out on the snow surface of lakes and bogs, indicating that these landscape elements could be crossed. Without the ability to navigate and keep a steady course, however, each insect would have jumped randomly around on a limited area. Because different individuals for some reason choose different directions, individuals from a given population become well dispersed.

In North America, Shorthouse (1979) observed migration activity of *Boreus brumalis* on snow. Some individuals were observed hopping a distance of 2 m in 5 minutes, while one was found 70 m from shore on a snow covered lake. Easy migration seems to be a general motive for the occurrence of the genus *Boreus* on snow.

Four species of winter active Collembola also migrate directionally on snow, different individuals choosing diffferent directions (Hågvar 1995, 2000). In both Collembola and *Boreus*, the continuous jumping behaviour during migration on snow might represent a further evolution of an escape behaviour away from predators. After an ordinary escape jump, *Boreus* lays quietly on its side for a while, with retracted legs (Withycombe 1922, Steiner 1937, Strübing 1950, Svensson 1966). However, during migration, both *Boreus* and Collembola immediately rise up after a landing, and prepare for another jump.

Collembola migrating on snow have been shown to use the sun's position as a compass, and it has been suggested that they may even orientate by means of polarized light (Hågvar 1995, 2000). Corresponding experiments with *Boreus* remains to be done. *Boreus* is more difficult to manipulate in the field, since they seem to be disturbed by movements close to the insect.

Predation on *Boreus* on snow was never observed in the present study. The animals may have repellent chemicals: Withycombe (1922) and Svensson (1966) found that they may excrete a strong and characteristic odour when disturbed.

Phenology of egg-laying

In Norway, the strategy of the wingless, winter active Tipulidae *Chionea araneoides* Dalm. is to lay a single, but large batch of eggs (about 100) gradually during the first part of the snow-covered period (i.e. mainly December and January), without refilling the ovaries and presumably without feeding (Hågvar 1976). Because this period is cold, the species has to use the snow surface mainly at subzero temperatures (down to -6 °C), but only in stable, overcast weather (Hågvar 1971). Having larger eggs, and only 10-20 in the primary batch, the strategy of *Boreus* seems to be different. Ovaries which have been emptied for the first ripe eggs, start to refill around midwinter. A refill is indicated both the accumulation of a white, fatty substance that must be due to feeding, the appearance of eggs in all phases of development, and an increase in the number of full-size eggs per female. Therefore, the author suggests that the egg-laying period extends over the whole snow-covered period, which may be up to six months. According to laboratory studies, eggs are laid in moss, 1-2 at a time (Withycombe 1922, Strübing 1950, Svensson 1966, Cooper 1974). However, due to low temperatures in the subnivean space, I suggest that eggs laid during winter may not hatch until after snow melt, which would then synchronize the further development.

Based on laboratory cultures of egg-laying females, collected in different months, also Strübing (1950) assumed that *Boreus hyemalis* lays eggs throughout the winter in the field. It is a remarkable adaptation for a terrestrial insect if it uses the entire snow-covered period for egg-laying and feeding.

Boreus has panoistic ovaries with 7-8 ovarioles (Bilinski & Büning 1998). In the autumn, Steiner (1937) counted about 20 potential eggs in each of 8 ovarioles per ovarium in *B. hyemalis*. This indicates an ability to produce 20 x 8 x 2 = 320 eggs per female, if eggs are not resorbed.

Copulation: When and where?

The very few observations of copulating animals on snow means that copulation is not a main purpose of snow surface activity. The thin snow layer at these observations, the relatively high temperature and the time indicates that copulation may be a typical autumn and early winter activity, perhaps mainly on bare ground. Another early winter observation of copulating *B. hyemalis* was on snow in medio October (Greve 1976). Also Svensson (1966) and Strübing (1958) reported very few observations of copulation on snow from Sweden and Germany, respectively. In Central Europe, where *B. hyemalis* is active in moss throughout winter in snow-free areas, the animals start to copulate shortly after emergence in the autumn (Withycombe 1922, Steiner 1937, Strübing 1950). Observations in culture have shown that copulation in *Boreus* takes a long time: up to two days according to Sauer (1966), often the whole day (Strübing 1958), or a mean of 25 hours (Svensson 1966). Own observations show that copulating animals in the field are so tightly fused that they do not separate even if picked up and put in alcohol. The long duration of copulation may make it difficult for a coupled pair to retract to the subnivean environment fast enough if temperature drops. On the other hand, the presence of well-fed males throughout the winter indicates that they may have a continuous function. Weighing of 167 males (70 % *B. westwoodi* and 30 % *B. hyemalis*) from all winter months showed a stable weight, indicating feeding. Greve (1966) observed copulating pairs of *B. westwoodi* on snow in late winter. Perhaps copulation continues during the entire winter in the subnivean air space.

Conclusions

The main purposes of snow surface activity seems to be heating of the body in order to mature the eggs, and easy migration in order to spread the eggs or to find new feeding patches. Directional movement is possible due to the ability to navigate. Jumping as a migration behaviour could be a further evolution of jumping as an escape behaviour. Sunny weather is probably risky for the animals, because a clear sky often results in a rapid temperature fall in the evening. Ovary studies indicate that eggs are laid throughout the winter.

Acknowledgements. I would like to thank Lita Greve for help with literature, Torstein Solhøy for both literature and valuable comments on the manuscript, and my wife, Eline Hågvar, for being a patient partner during ski trips with many stops during thirty years.

REFERENCES

Bilinski, S. M. & Büning, J. 1998. Structure of ovaries and oogenesis in the snow scorpionfly *Boreus hyemalis* (Linne) (Mecoptera: Boreidae). Int. J. Insect Morphol. & Embryol. 27, 333-340.

Cooper, K. W. 1974. Sexual biology, chromosomes, development, life histories and parasites of *Boreus*, especially *B. notoperates*. A southern California *Boreus* II (Mecoptera, Boreidae). Psyche 81, 84-120.

Coulianos, C.-C. & Johnels, A. G. 1962. Note on the subnivean environment of small mammals. Ark. Zool. Ser. 2, 363-370.

Courtin, G. M., Shorthouse, J. D. & West, R. J. 1984. Energy relations of the snow scorpionfly *Boreus brumalis* (Mecoptera) on the surface of the snow. Oikos 43, 241-245.

Fraser, F. C. 1943. Ecological and biological notes on *Boreus hyemalis* (L.) (Mecopt., Boreidae). J. Soc. Brit. Entomol. 2, 125-129.

Fjellberg, A. & Greve, L. 1968. Notes on the Genus *Boreus* in Norway. Norsk ent. Tidsskr. 15, 33-34.

Greve, L. 1966. Skorpionfluer og snelopper. Naturen 6, 346-354.

Greve, L. 1976. Neuroptera and Mecoptera. Fauna of the Hardangervidda 7, 5-9.

Greve, L. 1983. Norske skorpionfluer - Ordenen Mecoptera. Norske Insekttabeller 3, 10 p. Norsk Entomologisk Forening, Oslo.

Hågvar, S. 1971. Field observations on the ecology of a snow insect, *Chionea araneoides* Dalm. (Dipt., Tipulidae). Norsk ent. Tidsskr. 18, 33-37.

Hågvar, S. 1976. Phenology of egg development and egg-laying in a winter-active insect, *Chionea araneoides* Dalm. (Dipt., Tipulidae). Norw. J. Ent. 23, 193-195.

Hågvar, S. 1995. Long distance, directional migration on snow in a forest collembolan, *Hypogastrura socialis* (Uzel). Acta Zool. Fennica 196, 200-205.

Hågvar, S. 2000. Navigation and behaviour of four Collembola species migrating on the snow surface. Pedobiologia 44, 221-233.

Herter, K. 1953. Der Temperatursinn der Insekten. 378 pp. Duncker & Humblot, Berlin.

Sauer, C.-P. 1966. Ein Eskimo unter den Insekten: Der Winterhaft *Boreus westwoodi*. Mikrokosmos 55, 117-120.

Shorthouse, J. D. 1979. Observations on the snow scorpionfly *Boreus brumalis* Fitch (Boreidae: Mecoptera) in Sudbury, Ontario. Quaest. Ent. 15, 341-344.

Shorthouse, J. D., Zuchlinski, J. A. & Courtin, G. M. 1980. Influence of snow cover on the overwintering of three species of gall forming *Diplolepis* (Hymenoptera: Cynipidae). Can. Ent. 112, 225-229.

Sømme, L. & Østbye, E. 1969. Cold-hardiness in some winter active insects. Norsk ent. Tidsskr. 16, 45-48.

Steiner, P. 1937. Beitrag zur Fortpflanzungsbiologie und Morphologie des Genitalapparates von *Boreus hiemalis* L. Z. Morphol. ökol. Tiere 32, 276-288.

Strübing, H. 1950. Beiträge zur Biologie von *Boreus hiemalis* L. Zool. Beitr. N.F. I, 51-110.
Strübing, H. 1958. Schneeinsekten. Die neue Brehm-Bücherei, Heft 220. 47 pp. A. Ziemsen Verlag, Wittenberg Lutherstadt.
Svensson S. A. 1966. Studier över vissa vinteraktiva insekters biologi. Norsk ent. Tidsskr. 13, 335-338.
Svensson, S. A. 1972. *Boreus* Latreille, 1825 (Mecoptera). A synopsis of described species. Ent. scand. 3, 26-32.
Withycombe, C. L. 1922. On the life-history of *Boreus hyemalis* L. Trans. Ent. Soc. Lond. 1921, 312-319.
Zettel, J. 1984. The significance of temperature and barometric pressure changes for the snow surface activity of *Isotoma hiemalis* (Collembola). Experientia 40, 1369-1372.

Received 27 June 2000,
accepted 12 January 2001

Norw. J. Entomol. 48, 61–70. 2001

Sex ratios, emergence patterns and aspects of swarming and reproductive behaviour of *Bibio johannis* (L.) (Diptera, Bibionidae).

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Skartveit, J. 2001. Sex ratios, emergence patterns and aspects of swarming and reproductive behaviour of *Bibio johannis* (L.) (Diptera, Bibionidae). Norw. J. Entomol. 48, 61-70.

Aspects of swarming and reproductive behaviour of *Bibio johannis* (L.) have been studied in South-West Norway. *B. johannis* is univoltine and the imagines fly in April-May. The sex ratio at eclosion was male-biased, approximately 3:2 males:females. Sex ratios in trap catches were very strongly male-biased. Emergence was slightly but significantly protandrous. Imago lifetime was short, mark-recapture experiments suggested a maximum imago lifespan of approximately three days. Imagines did not feed. The total swarming period lasted about two weeks. Males swarmed a few decimetres above the ground on meadows and fields. Swarming took place mainly between 0900-1300 hours on days with sunny weather. No clear connection between weather variables and swarming intensity was found, but this may be due to unusually warm weather during the study period. No positive evidence for pheromone emittance has been found; visual stimuli seem to be decisive in promoting contact between males and females. Selection for large or small male size was not unequivocally demonstrated.

Key words: Bibionidae, behaviour, sex ratio, swarming

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INTRODUCTION

Bibionid flies sometimes draw attention due to their occasional occurences in very large numbers (Schøyen 1884, Andersson 1944). These insects are short-lived as imagines and frequently form conspicuous swarms consisting of predominantly males (Pecina 1982). However, the swarming behaviour differs considerably between species (Freeman & Lane 1985). Thornhill (1976a,b,c; 1980) has studied aspects of the behaviour of the American bibionid *Plecia nearctica* Hardy, 1940, and the reproductive behaviour of *Dilophus sayi* (Hardy, 1959). Zeil (1983) examined swarming behaviour of *Bibio marci* (L., 1758) and *Dilophus febrilis* (L., 1758). The present paper examines sex ratio, phenology and aspects of reproductive behaviour of *Bibio johannis* (L., 1767). *Bibio johannis* is a small bibionid fly commonly associated with cultivated areas in Europe. It flies in early spring, often in huge numbers, although it is rarely noted due to its small size and early flight period (Skartveit 1995). It has been recorded as damaging crops (Savage 1977), but such damage caused by *B. johannis* seems to be rare.

MATERIAL AND METHODS

The study site was located in Finnøy community, Rogaland county, South-West Norway (approximately 58° 50' N). The site consisted of fields of grass grown for ensilage, harvested in early June and July/August. The dominant grass species was ryegrass (*Lolium perenne*). Cattle manure slurry was applied twice per year (normally April and June/July), inorganic fertilizers occasionally in summer. Edge vegetation consisted of various deciduous trees. Altitude about 30 m a. s. l.

Wind speed and temperature in 1993 were recorded using an Aanderaa datalogger device. A wind sensor model 2740 and a temperature sensor model 2775 were placed 30 cm above ground level at the study site and connected them to a datalogger unit. Data were recorded every 20 minutes.

Population sex ratios were estimated from samples of field-collected pupae (according to Morris 1917), from imagines emerging from samples of field-collected larvae and from imagines collected in yellow water and sticky traps. A sample of field-collected pupae, sorted according to sex, was kept in the laboratory. Emerging males and females were removed and counted several times per day until emergence ceased.

In order to study imago longevity, swarming males were marked with a spot of model airplane paint (Humbrol) on the mesonotum, using a different colour each day. Altogether 122 males were marked on 23-28 April 1993, 397 males and 20 females on 7-11 May 1994 and 532 males and 8 females on 1- 4 May 1995. All observations and trap captures of marked males except those within three hours after marking were noted. Samples of single males and copulating pairs were collected in the field and preserved in alcohol. One such sample was collected each spring in 1992-95. Length of mesonotum was measured using a stereo microscope equipped with a measuring scale.

Swarming activity

Swarming activity was studied using eight yellow water and five sticky traps. Water traps were round washbasins, 32 cm in diameter, filled nearly to the rim with water with a small amount of detergent added. Sticky traps were yellow planks, 15 cm by 2.5 cm by 2 m, placed vertically. Tangle-Trap (R) adhesive was applied to the lower meter of he traps. The sticky traps were placed with 10 m between them, one face facing south. Trapped bibionids were removed and counted once each day in the afternoon after swarming had ceased or the next day before activity was resumed. Flies collected in the sticky traps were grouped according to altitude in six different categories: 0-10, 10-20, 20-30, 30-40, 40-50 and 50-100 cm above ground level.

Diel activity patterns were studied during 30 April and 1 May 1993, by counting specimens caught on the sticky traps and in two yellow water trays at intervals during the day. On 30 April, traps were checked on 0910 and 0940 hours and then approximately every 30 minutes from 1100 hours until 1345 hours. On 1 May, collected specimens were counted every 30 minutes from 0830 until 1330 hours and on 1500 hours.

Attraction stimuli and male selectivity

Possible pheromone effects were tested for using extracts from unmated females, hatched in captivity. The females were killed by freezing and kept frozen. Sigma rubber septa (stopper size 6 mm) were placed in the middle of 30 by 30 cm styrofoam sheets painted green (background colour) to avoid any effects caused by attraction to colour. Each female was soaked and lightly crushed in about 0.5 ml of dichloromethane for 15 min (Solem & Solem 1991). This extract was poured into the rubber septa and the response of swarming males towards it recorded. Two rubber septa were filled with female extract and two (controls) with just dichloromethane in each try. This was tried twice, on 26 and 30 April 1993 from about 1000 hours.

In order to test visual attraction to resting females, females pinned on headless insect pins (15 x 0.25 mm) were placed in the middle of green 30 x 30 cm styrofoam sheets. The females had been dried for at least a week at room temperature before use to try to minimize effects due to volatile pheromones if any were present. Pinned females were also placed in the vegetation above which males were swarming.

In addition, pinned dead females were suspended about 30 cm above ground level by means of 0.30 mm fishing line. During each test, 3 pinned females and 3 pinned males were hung alternatingly with a distance of about 10 cm between each, in an area of large male swarming activity around noon. Contacts between swarming males and the suspended insects were counted for a total of 2 hours 45 min.

RESULTS

Sex ratio

Sex ratios were signficantly male biased both among pupae (Table 1, $\chi^2 = 20.21$ (1993), 46.96 (1994), df= 1), emerging imagines (Table 1, $\chi^2 =$ 16.16 (1993), 25.66 (1994), df= 1) and imagines collected in traps. Male biases were much stronger in trap catches than among pupae and emerging imagines.

Pattern of eclosion

Imagines emerged between 26-30 April 1993. Fraction of females (Table 2) was significantly larger after than before 28 April 0700 hours ($\chi^2 =$ 20.66, d.f. = 3, $p<0.001$, Figure 1) and significantly larger 0900-2400 hours than 2400-0900 hours ($\chi^2 = 11.68$, d.f. = 3, $p<0.01$, Figure 2). Emergence frequencies for males and females were not significantly different (two sample Z-test for proportions, $Z = 1.04$, $p>0.15$).

Flight period and swarming altitude

In 1992, high swarming activity seemingly was restricted to one day, 2 May. In 1993 *B. johannis* was caught in large numbers (> 100 specimens per day on sticky traps) between 28 April and 2 May, followed by a small peak on 5 May as well (Figure 3). In 1994, swarming activity was high on 7-10 May with a distinct peak on 9 May. In 1995, there was moderate activity between 30 April and 10 May, with no definite peak.

High swarming activity lasted no more than three days at any particular trap point (Figure 4). Timing of the swarming activity varied between trap points and was cleary related to the sun-exposure of that swarming point; those from the most sun-exposed areas swarmed first, while those from some areas underneath trees swarmed about ten days later. The highest number of flies were caught on the sticky traps 20 - 30 cm above the ground for males and 30 - 40 cm for females (Figure 5). The density of flies caught (measured per trap area unit) dropped off above 50 cm altitude.

Table 1. Sex-ratios found by different methods

Method	♂♂	%	♀♀	%	♂♂/♀♀
Pupae 1993 (several clutches)	226	62	140	38	1.6
Pupae 1994 (several clutches)	435	63	255	37	1.7
Imagines 1993 (several clutches)	125	64	69	36	1.8
Imagines 1994 (several clutches)	286	62	177	38	1.6
Sticky traps 1993	2547	92	214	8	11.9
Water traps 1992	1638	96	61	4	26.8
Water traps 1993	365	90	41	10	8.9
Water traps 1994	1719	98	37	2	46.5
Water traps 1995	533	95	24	5	22.2
Water traps 1996	388	97	10	3	38.8

Table 2. Eclosion pattern of males and females. Sex ratios among *B. johannis* emerging in various time intervals.

	♂♂	♀♀	♂♂ / ♀♀
Total number of pupae	174	107	1.6
Imagines produced	110	61	1.8
Emergence frequency, %	63	58	
Emerged before 28.IV. 0700 hrs	57	10	5.7
Emerged after 28.IV. 0700 hrs.	53	51	1.0
Emerged 2400-0900 hrs	44	9	4.8
Emerged 0900-2400 hrs	66	49	1.3

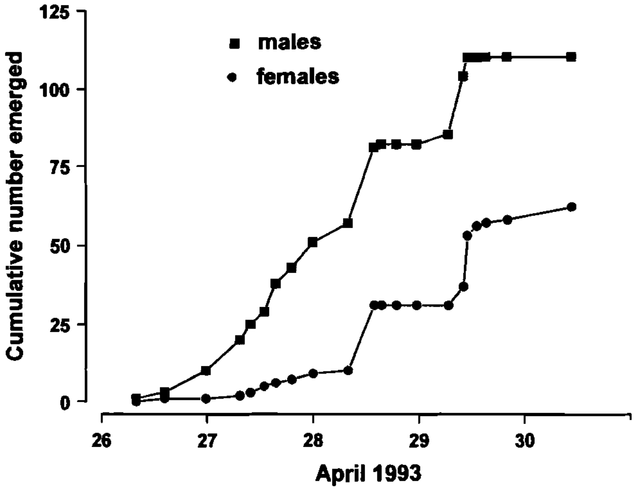

Figure 1. Emergence of male and female *Bibio johannis* in April 1993.

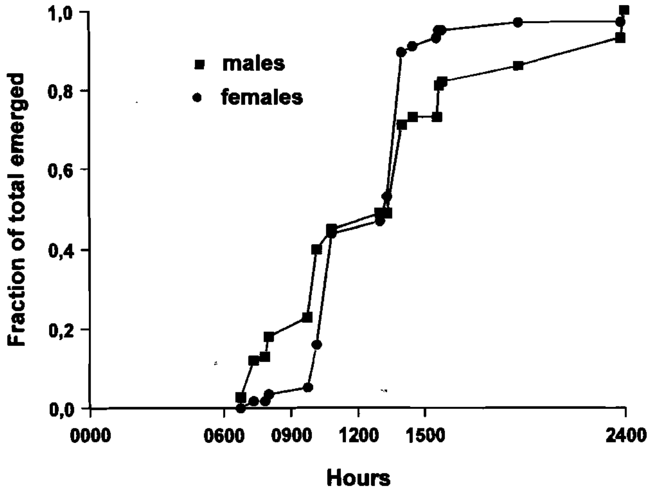

Figure 2. Cumulative percentages of males and females emerged at a given time of the day, several days pooled.

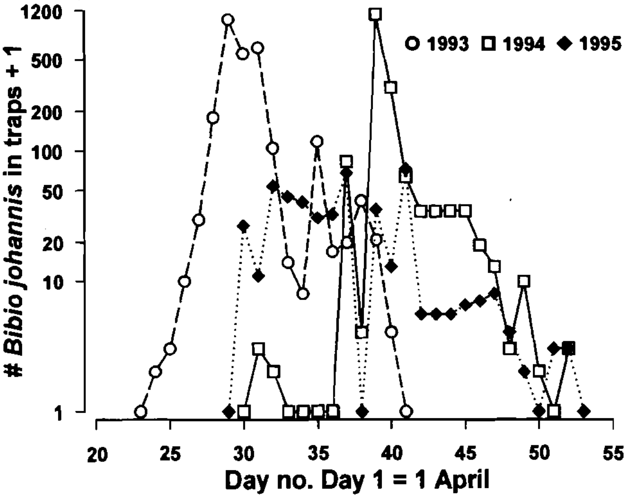

Figure 3. Flight period of *Bibio johannis* at Finnøy in the springs of 1993 (circles), 1994 (squares) and 1995 (diamonds). Note logarithmic scale.

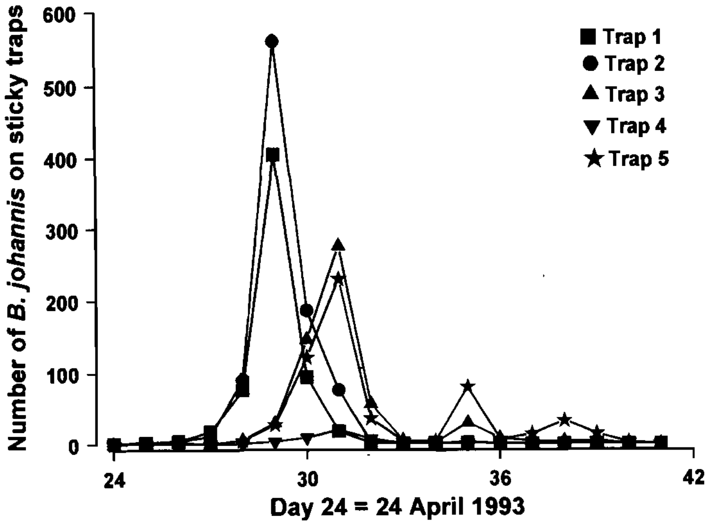

Figure 4. *Bibio johannis* caught in five different sticky traps in the spring of 1993.

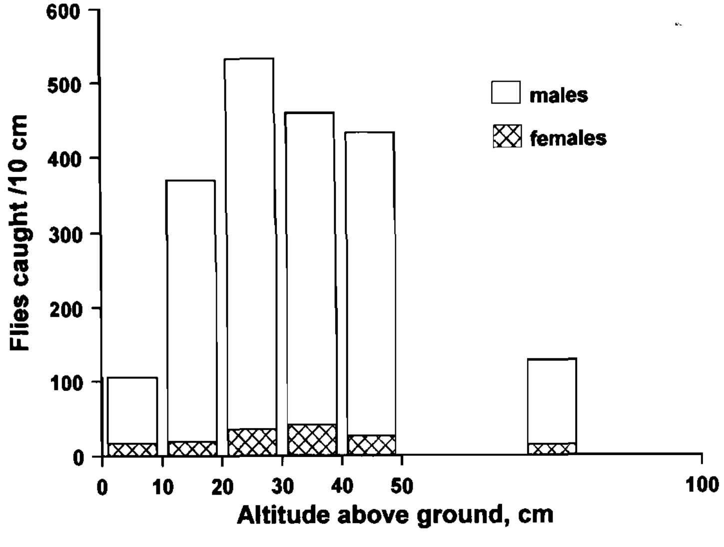

Figure 5. Altitudinal distribution (cm above ground) of *Bibio johannis* males and females on sticky traps in 1993.

Diel swarming activity

No swarming activity was recorded earlier than 0830 hours, and on days with sunny weather the swarming seemed to cease by about 1300 hours. With less optimal weather conditions, some swarming could take place until about 1700 hours. On 30 April and 1 May, both days with warm weather (Figure 6), swarming activity was high between 0930 and 1330 hrs (Figure 7).

Occasionally, males have been seen swarming in sunshine with an air temperature about 8 °C; however they swarmed very close to the ground (10-20 cm) where it was considerably warmer than higher up (Skartveit, unpublished). In 1993, following a period of relatively cool weather (daily maximum temperatures < 12 °C) te temperature increased to nearly 20 °C on 24 April, after which swarming started (Figure 4). On 25 April to 1 May the mid-day temperature was above 20 °C each day, while the day of the second activity peak (Figure 4), 5 May, had a maximum temperature of 12.9 °C. Thus, after swarming had started, swarming activity did not seem to be strongly related to

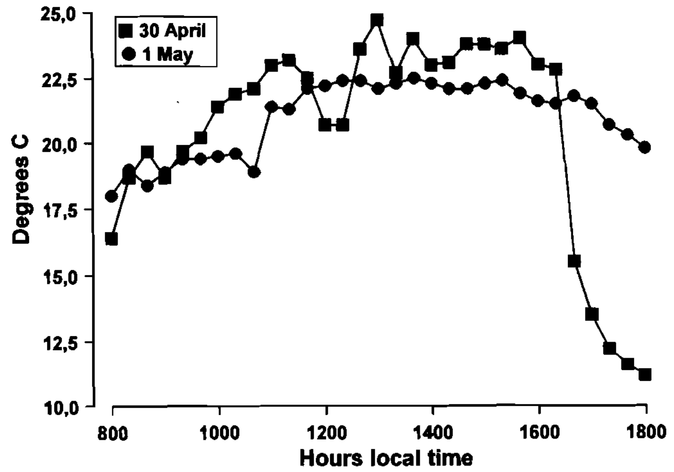

Figure 6. Temperature at the study site on 30 April and 1 May 1993, at the time of the diel-activity experiments.

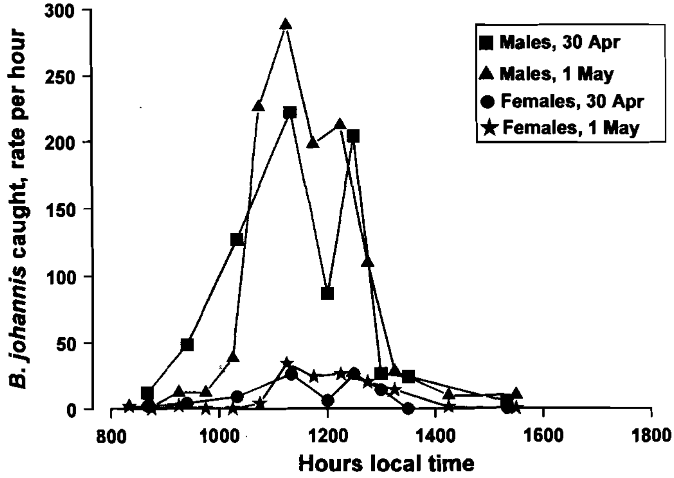

Figure 7. Diel activity of *Bibio johannis* on 30 April and 1 May 1993, flies caught per hour in sticky and water traps.

temperature. Swarming intensity was not significantly correlated with daily maximum temperature throughout the flight period. During the study period in 1993 there was very little wind, generally less than 2 ms^{-1} at 30 cm altitude.

Swarming behaviour

Swarming males did not form definite swarms but loose aggregations above the grass. There were no obvious swarm-marker objects. The number of flies was definitively higher along the edges than in the centre of the field. The sticky trap placed most centrally in the field caught only 47 specimens while those placed more peripherally (four traps) each caught 572-939 specimens.

Pairing stimuli

Males did not respond to rubber septa with extracts from unmated females. Likewise, pinned female specimens placed out in the vegetation also failed to draw any attention from the males; males also seemed to ignore live females sitting on the grass. However, swarming males repeatedly contacted pinned females suspended in fishing line, though without discriminating significantly between males and females (Spearman rank correlation test, N = 6, rs = 0.39, $p > 0.25$ for 28 April results, N = 6, rs = 0.26, $p > 0.25$ for 30 April results). Total number of observed contacts between swarming males and suspended pinned specimens were 148 in 165 min .

Assortative mating and selection for large male size

No significant correlation was found between male mesonotum length and female mesonotum length ($t_{35} = -0.195$, $p = 0.847$) in the 1993 sample. Comparison of field-collected single males and males found in copula showed significant differences between the groups' mean values in the sample collected in 1992 but not in the samples collected in 1993-95 (Table 3).

Imago longevity

Of the 1314 individuals paint-marked in the field, only 27 were recaptured on subsequent days. Twelve were captured the day after marking, 14 two days after marking and a single individual three days after marking. The longest-living individual recorded during this experiment thus had an imago lifespan of at least three days. Imagines kept in the laboratory lived for a maximum of five days. Paint-marking did not seem to affect their lifespan.

DISCUSSION

Sex ratio

The primary sex ratio of *Bibio johannis* is clearly male-biased, with a male proportion of approximately 0.6. Pecina (1982) stated that a male:female sex ratio of about 3:2 is common among bibionids, but did not state which species he had examined or how the result was obtained. Thornhill (1976a, 1980) found a sex ratio near 1:1 for the American species *Dilophus sayi* and for *Plecia nearctica*. Data for several bibionid species (Skartveit, unpublished) suggest that male-biased primary sex ratios are common at least in the genus *Bibio*. The reason for this bias is unknown.

The operational sex ratio, that is, the number of sexually active males per receptive female at the mating sites at any time, is clearly highly male-biased in *B. johannis*. If mate contact takes place in flight then catches in water or collision traps at the swarming site might give suggestions on the operational sex ratio. Sex ratios in trap-samples are strongly dependent upon behaviour and should not be used to estimate population sex ratio if any other method is available. In this investigation trap catches were always strongly male-biased, in one case only two out of 1013 *B. johannis* caught in a water trap were females.

Emergence pattern

The emergence pattern is clearly protandrous. This seems to hold both for the total period of emergence (Figure 1) and for the time of day (Figure 2). Pecina (1982) stated that a protandrous emergence pattern is common among Bibionidae but did not refer to any particular species. Furthermore, Thornhill & Alcock (1983) reported that *Plecia nearctica* had a protandrous emergence pattern.

Imago lifetime

The mark-recapture experiment indicates that male imago lifespan is short, about two days. Captures on the sticky traps (Figure 4) indicated that swarming activity at a given spot only lasts two to three days in suitable weather. This might correspond to the imago lifetime of the males in the larval broods situated near that spot (Hadley 1969).

Table 3. Comparison of mesonotum lengths between single and copulating males.

	1992	1993	1994	1995
N single males	49	76	14	28
N mating males	54	36	14	29
Mesonotum length, mm, mean/SD	1.67/0.08	1.53/0.07	1.46/0.08	1.60/0.11
Mesonotum length, mm, mean/SD	1.73/0.09	1.53/0.07	1.46/0.06	1.62/0.10
Z-value (test for means)	3.13	0.17	0	0.75
p-value (onesided test)	0.001	0.57	>0.90	0.23

Bibio johannis apparently does not feed in the imago stage. Dandelions (*Taraxacum sp.*) and white anemones (*Anemone nemorosa*) were flowering on the study site, and although *B. johannis* males often settled on the petals they did not move towards the center of the flowers nor touch them with their mouthparts. Thornhill (1976c) found that females of *Plecia nearctica*, a species that feeds as imago, lived on average 86 hours under laboratory conditions, and males 105 hours. Average lifespan of *Dilophus sayi* under laboratory conditions, provided with sugar water, was 72 hours for males and 92 hours for females (Thornhill 1976a). As imagines of *B. johannis* do not feed, all imaginal activity must be sustained on energy resources stored during the larval stage. These reserves may limit the imago lifetime.

Directional selection for male size

Based on the present results it is not possible to draw any conclusions whether size is important for male mating success in *Bibio johannis*. Copulating males from the sample collected in 1992 were actually significantly larger than non-copulating males, but this was probably due to a sampling error. Since non-copulating males are much easier found than copulating males, the non-copulating males were collected from a smaller area than the copulating males. Bibionids found within a small area probably emerged from the same patch and shared the same conditions. It is highly plausible that imago size in bibionids varies according to patch quality, and thus very plausible that the non-copulating males in 1992 happened to originate from a low-quality patch with smaller than average adult size. Also, the data does not indicate any correlation between male and female size among copulating *Bibio johannis*. Assortative mating should be expected if males were choosy about the size of females with which they mated or females choosy about which males they allowed to mate with themselves. However, as the operational sex ratio of *Bibio johannis* is male-biased, and each male lives only a short time, males probably cannot afford to be choosy in this species. Any male should use any opportunity for copulation it could get. Swarming males of the genus *Bibio* constantly approach and pursue each other (Zeil 1983), usually turning back at a few centimeters' distance but occasionally bumping together. Zeil (1983) found that swarming bibionid males would approach any small, moving object which passed above them. Contact between the sexes seems most often to take place in air, however males of *Bibio johannis* and other species can often be seen running about on vegetation, probably searching for females. Freshly emerged flies went in copula without flying first, showing that flight is no necessary condition for mating. Observations suggest that when a male gets in contact with a female, he immediately tries to couple with her, which is consistent with strong competition among males for females and a corresponding lack of male selectivity. A male occasionally tries to couple with another male, also under natural conditions, giving further evidence for lack of male selectivity. A high incidence of male-male pairing was also noted by Tokeshi & Reinhardt (1996) for the midge *Chironomus anthracinus* and is probably common among mass-swarming male insects.

Signals promoting contact between the sexes

Pheromones promoting contact between the sexes have been found for many insects (Thornhill & Alcock 1983). Thornhill (1976c) found no positive evidence for emission of sex pheromone in *Plecia nearctica* females. The experiment with *Bibio johannis* does not suggest the presence of any such emissions. Bibionid antennae are short and non-plumose, suggesting that olfactory communication may be poorly developed. Neither is there any pronounced sexual dimorphism in antenna morphology, like that found in many moths, flies and beetles in which pheromones play a role in mating systems. However, it was noted that if a female was introduced into a small container holding several males, the males would usually start running around immediately and several would grasp the female. Introducing a male or an insect of another species did not so excite the males. It is possible that, even though no pheromone is involved in long-range mate detection, one could be involved in close range contact and mate recognition.

Bibio males have enlarged hind tibiae with many rounded coeloconical sensilla. When the males are swarming, the legs are hanging down, and the sensilla might have a function in the location of mates, or they could function otherwise, for instance sensing air movements. It seems that nobody has given evidence for any function of these sensilla.

Bibionid male eyes are large (holoptic) and divided into two divisions, a dorsal with large facets and a ventral with somewhat smaller facets. Female eyes are smaller and not divided. Sexual dimorphism in eye size seems to be correlated with visual mate recognition (Downes 1970). The morphology of the male eyes suggests that visual stimuli play an important role, which is confirmed by the studies of Zeil (1983).

Importance of weather for swarming

Bibionids are found to be swarming only in relatively warm or sunny weather. If temperatures are below ca. 15 °C the flies are active only in sunshine. The period with high swarming activity of *Bibio johannis* in 1993 was a period with extraordinarily warm weather for the season. This may explain the lack of correlation between temperature and swarming intensity in this study. The lack of significant correlation could also be explained by the time lag between onset of high temperatures and start of swarming, and by the rather synchronous emergence of the adults, so that the population of adult flies strongly declined with time, despite optimal weather. The observations indicate that, given suitable temperatures, the flight period of *B. johannis* is very short.

As the smaller bibionids are rather poor fliers wind should lead to cessation of flight activity. During the swarming period long periods of wind speeds above 2 ms^{-1} were not recorded, and no correlation between wind speed and activity was found.

Mass-swarmings of bibionids are most commonly seen on south slopes of hills. Sun exposure will lead to a higher average temperature in the soil at any time, which could enhance larval survival and growth rate as well as attractiveness to ovipositing females. Coulson et al. (1976) found that emergence times of two species of Tipulidae were positively correlated to soil temperature, whereas they found no difference in larval growth rates.

Acknowledgements. The author wishes to thank Odd Skartveit, Finnøy, on whose fields most of the research was conducted. Thanks to Tor de Lange, Institute of Meteorology, Bergen, for loan of and instruction in the use of a datalogger device. Solfrid Kjoberg, Bergen, gave advice on how to conduct a pheromone experiment. Thanks to Torstein Solhøy, Bergen, for suggestions and advice on experiment setups, relevant literature and critical comments on the manuscript. Lita Greve, Lawrence Kirkendall, Jostein Kjærandsen, Ole A. Sæther and Ingrid Wunderle Solhøy, all Bergen, and Geir E.E. Söli, Oslo, gave valuable comments on the manuscript. The Norwegian Research Council supported the author during much of the research period through grant no. 100719/410.

REFERENCES

Andersson, D. 1944. Massförekomst av *Bibio pomonae* F. Ent. Tidskr. 65, 221-222.

Coulson, J. C., Horobin, J. C., Butterfield, J. & Smith, G. R. J. 1976. The maintenance of annual life-cycles in two species of Tipulidae (Diptera); a field study relating development, temperature and altitude. J. Anim. Ecol. 45, 215-233.

Downes, J. A. 1970. The feeding and mating behaviour of the specialized Empidinae (Diptera); observations on four species of *Rhamphomyia* in the high Arctic and a general discussion. Can. Entomol. 102, 769-791.

Freeman, P. & Lane, R. P. 1985. Bibionid and scatopsid flies. Handbooks for the Identification of British Insects. Vol. IX, Part 7. Royal entomological Society of London.

Hadley, M. 1969. The adult biology of the crane-fly *Molophilus ater* Meigen. J. Anim. Ecol. 38, 765-790.

Morris, H. M. 1917. On the larval and pupal stages of *Bibio johannis* L.. Ann. appl. Biol. 4, 91-114.

Pecina, P. 1982. Mass incidence and swarming of the march-flies, Bibionidae and the importance of this group in the ecosystem. Folia Prirodovedecke Faculty University je Purkyne v Brne 23, 107-110.

Savage, M. J. 1977. Damage to cereals by larvae of *Bibio johannis* and *Bibio hortulanus* (Diptera: Bibionidae). Pl. Path. 26, 199.

Schøyen, W. M. 1884. Nogle exempler paa insekters masseoptræden i de siste par aar. Ent. Tidskr. 5, 83-87.

Skartveit, J. 1995. Distribution and flight periods of *Bibio* Geoffroy, 1762 species (Diptera, Bibionidae) in Norway, with a key to the species. Fauna norv. Ser. B 42, 83-112.

Solem, J. O. & Solem, T. 1991. Mate location and premating behaviour in *Apartania fimbriata* Pictet (Trichoptera, Limnephilidae). Aquatic Insects 13, 1-8.

Thornhill, R. 1976a. Biology and reproductive behavior of *Dilophus sayi* (Diptera, Bibionidae). Fla. Entomol. 59, 1-4.

Thornhill, R. 1976b. Dispersal of *Plecia nearctica* (Diptera, Bibionidae). Fla. Entomol. 59, 45- 54.

Thornhill, R. 1976c. Reproductive behavior of the lovebug, *Plecia nearctica* (Diptera, Bibionidae). Ann. ent. Soc. Amer. 69, 843-847.

Thornhill, R. 1980. Sexual selection within mating swarms of the lovebug, *Plecia nearctica* (Diptera, Bibionidae). Anim. Behav. 28, 405-412.

Thornhill, R. & Alcock, J. 1983. The evolution of insect mating systems. 547 pp. Harvard University Press, Cambridge, Massachusetts.

Tokeshi, M. & K. Reinhardt 1996. Reproductive behaviour in *Chironomus anthracinus* (Diptera, Chironomidae), with a consideration of the evolution of swarming. J. Zool. (London) 240, 103-112

Zeil, J. 1983. Sexual dimorphism in the visual system of flies: the free flight behaviour of male Bibionidae (Diptera). J. comp. Physiol. A 150, 395-412.

Received 27 June 2000,
accepted 30 March 2001.

Norw. J. Entomol. 48, 71–76. 2001

Distribution, phenology and habitat characteristics of *Notiophilus germinyi* Fauvel in Grenier, 1863 (Coleoptera: Carabidae) in the Baltic countries

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Barševskis, A. 2001. Distribution, phenology and habitat characteristics of *Notiophilus germinyi* Fauvel in Grenier, 1863 (Coleoptera: Carabidae) in the Baltic countries. Norw. J. Entomol. 48, 71-76.

This article provides information about distribution, phenological peculiarities and habitats specific for *Notiophilus germinyi* Fauvel in Grenier, 1863 (Coleoptera: Carabidae) in the Baltic countries. Special attention is paid to the habitats of this species that are included in the annexes of the European Union Council Directive on the conservation of natural habitats and of wild fauna and flora where this species can be used as indicator for determination of the condition of particular habitats. In order to protect the species it is advisable to work out relevant directives of habitat management that avoid tree and bush overgrowth.

Key words: *Notiophilus germinyi*, distribution, phenology, habitats, Baltic countries.

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INTRODUCTION

Notiophilus germinyi Fauvel in Grenier, 1863 (Coleoptera: Carabidae) is one of 51 species known from this genus (Lorentz 1998). Still, information about the biology and distribution of this species is relatively limited. In the Baltic countries, the distribution and ecological peculiarities of this species have not been specifically investigated. The occurrence of *N. germinyi* is rather seldom and sporadic. In many collections it has not been precisely determined, because the species was mixed with *N. palustris* (Duftschmid, 1812) and was not considered as an independent species. In the Scandinavian countries, *N. germinyi* was mentioned for the first time as a separate species early in the 20th Century: Norway in 1903, Finland in 1907 and Sweden in 1921 (Lindroth 1945-1949, 1988-1992). Information about this species from north-western part of Russia (St. Petersburg) appeared in 1905 (Jacobson 1905), but in Baltic countries it was not published until the middle and second part of 20th Century: Estonia in 1942 (Haberman 1968) and Latvia in 1958 (Stiprais 1958). More information is collected in the Catalogue of Carabidae in Latvia (Spuris 1983), and information about this species in Lithuania is found in the monograph «Beetles of Lithuania» (Pileckis 1975, Pileckis & Monsevicius 1995).

The present study is based on material from 15 years of research in Latvia, several expeditions to Lithuania and Estonia and on faunistic data published in the Baltic states. The study presents an updated distribution of species in Baltic countries and clarifies some parts of the biology of the species and its relation to particular habitats.

MATERIALS AND METHODS

Investigations on the distribution and phenology of *N. germinyi* in the Baltic countries were made during 1985-2000 in Latvia, Lithuania and Estonia. Sampling in Latvia was organized on a whole year basis, winters included. When a snow cover was not present, the beetles were collected under moss, lichen and heather. Research during the winter was organized 1-2 times per season. The number of samplings in different years and different months was different. The material was collected using special plastic glasses dug into the ground and filled with diluted acetic acid, or by checking above the soil layer under lichen, moss, heather and trunks and prongs of fallen trees. In total, more than 450 individuals of this species were found (392 specimens collected and processed; 142 males and 250 females). The genitalia of all specimens were prepared. This was done in order to continue the discussion about the status of *N. stipraisi* Barševskis, 1993 (Barševskis 1999c). Serial analysis of material, however, approves the conclusion of V. Shilenkov (Kryzhanovskij et al. 1995, Silfverberg 1996) that *N. stipraisi* is the junior synonym of *N. germinyi*.

Research on the ecology of *N. germinyi* was started in the year 1999 in three localities of Latvia (the type of habitats are included in the annexes of European Union Council Directive on the conservation of natural habitats and of wild fauna and flora):

1) dry, sedulous inland dunes accreted with *Gypsophila, Calluna, Cladina* some kilometers north of the city of Daugavpils

2) dry, sand heaths on banks of Daugava River in Rugeli (Daugavpils suburb).

3) dry, sedulous open space in pine-tree forest, densely accreted with *Cladina* lichen in Ilgas close to Lake Richu (Silene Nature Park).

The chosen habitats had the common characteristics of dry, sedulous soil very close to pine-tree forests, but differed very much with regards to plants and microclimatic conditions. Research on the ecology of the species during this particular period is only in a starting phase. For this reason, the present article gives only an overall insight in the ecological characteristics of the species and

Table 1. Occurrence of *N. germinyi.* in different habitats in the Baltic countries (+ rare-very rare, ++ quite frequent, +++ very frequent).

Habitats	**Occurrence of *N. germinyi* in Baltic states habitats**
Sedulous seashore of the Baltic Sea and Golf of Riga with or without algae washed ashore	+
Fixed coastal dunes with herbaceous vegetation	++
Decalcified fixed dunes with *Empetrum nigrum*	++
Wooded dunes with open *Corynephorus* and *Agrostis* grasslands	++
Dry sand heaths with *Calluna* and *Empetrum nigrum*	++
Inland dunes with open *Corynephorus* and *Agrostis* grasslands	+++
Inland dunes with open *Cladina* lichen habitats	+++
European dry heaths	++
Juniperus communis formations on heaths or calcareous grasslands	++
Xeric sand calcareous grasslands	++
Drained and degraded lift marsh	+
Coniferous forests on, or connected to, glaciofluvial eskers	+
Open dry sand areas in pine forests with *Cladina* lichens	+++
Dry, sedulous fringes of pine forests with *Cladina* lichen and/or heather	+++
Pinus bengsiana planted forests and fringes of forests in very dry and sedulous places	+++
Other types of forests on dry and sedulous grounds	+
Logging area of pine forests	++

its relations to particular habitats.

Most of the collected material is kept in the collections of the Baltic Institute of Coleopterology and of the author. In several cases, when large numbers of specimens were present in the field, the specimens were counted but all of them were not collected. The counts of specimens are used for compiling the phenogram, but are not included in number of treated specimens.

RESULTS

As a result of the present study, the distribution of *N. germinyi* in the Baltic countries is better known and initial data on the ecology of the species is presented. Data on the phenology of the species in Baltic countries are summarized and quantitative registration of the species in different habitats have been made. Special attention is paid to habitats that are included in the annexes of the European Union directive on Species and Habitats. Table 1 reflects the occurrence of the species in different habitats in the Baltic countries. Figure 1 shows the distribution of the species. New localities that are not mentioned in previous faunistic publications have been established. These localities are included in an article on new and rare species for the fauna of Baltic and Belarus (Barševskis 2001). Figure 2 shows the numbers of specimens of *N. germiniy* collected in the different months of the year.

Figure 1. *N. germiny* distribution in the Baltic countries.

DISCUSSION

Faunistic literature contains few records about the distribution of *N. germinyi* in the Baltic countries and it is concluded that this species is rare or very rare (Stiprais 1958, 1973, Haberman 1968, Smits 1968, Spuris 1983, Barševskis 1994, Pileckis, Monsevicius 1995). In Denmark, this species has been recorded all over the country (Hansen 1996). The situation is similar in the Scandinavian countries, Poland and Belarus, where the species is not too rare, and has been found in adequate habitats (Burakowski et al. 1973, Lundberg 1986, 1995, Silfverberg 1992, Alexandrowitch et al. 1996, Solodovnikov 1999). In general, our research shows that in relevant habitats of the Baltic countries *N. germinyi* is found more often than expected. The frequency may be discussed, since in most fields the species is observed regularly and in rather stable amounts, but on the very dry, sedulous inland dunes close to Daugavpils in Latvia, that are densely accreted with *Cladina* lichen, a massive spawn of the species has been observed.

Processing of phenological data shows that adults of *N. germinyi* have two periods of activity; one in May-June and one in August. In fact, these results are very subjective because they are made on the basis of specimens from insect collections. In May and June the activity of collectors is at the highest and for this reason the number of specimens collected is higher compared with March or October. According to the results of ecological investigations in Latvia, it is concluded that a new generation of *N. germinyi* usually hatches in July-August. In this period, several specimens with

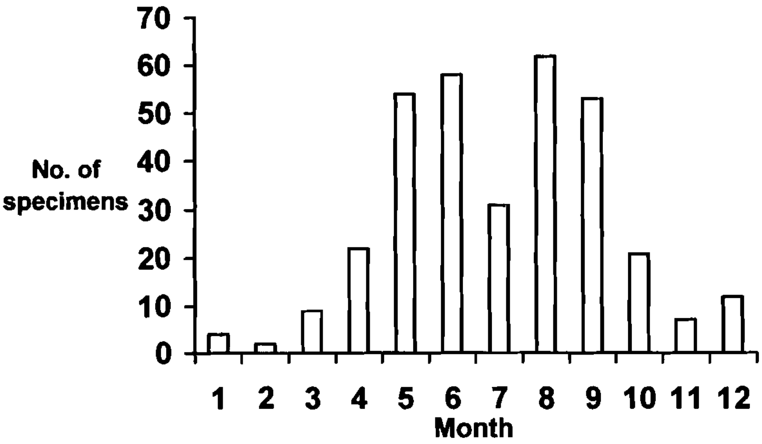

Figure 2. Number of specimens of *N. germinyi* collected in different months.

lightly colored and weekly chitinized cuticle have been found in many fields. In the southeastern part of Latvia (Daugavpils surroundings) this species is observed hibernating in the adult stage. There are no information about the hibernation of the species in Lithuania and Estonia. In general, the present results do not agree with the phenology of the species under the conditions of South Sweden, where Lindroth (1988-1992) gives the following data (month, number of specimens): III,2; IV,13; V,27; VI,64; VII,51; VIII,36; IX,19; X,4; XI,1. From these data it appears that more individuals are found in June-July and fewer in August compared to our results from the Baltic countries.

Regarding the habitats of *N. germinyi* it is concluded that in the Baltic countries this species is found only in very dry, sedulous habitats, that are usually accreted with lichens of *Cladonia* and *Cladina* and scarce grass. The species is most frequently observed on inland dunes, mainly on warm hillsides of southern expositions, moorlands, very dry fringes of pine forests or in sedulous meadows close to the forests. In the southeastern part of Latvia close to the city of Daugavpils, *N. germinyi* was very numerous in the second part of August on southern expositions of inland dunes under lichens (*Cladina, Cladonia*) or plants of *Calluna* and *Gypsophila*. In all three Baltic countries the species is frequently found on dunes along the shore of Baltic Sea, but the author has also found the species on some of the islands in Baltic Sea (e.g. in alvar meadows and seashores under caked algae on Saaremaa Island and on some rocky islands under *Cladina* lichen in the Stockholm archipelago). Some individuals are known from drained turbaries, but we have not found any individual in agrocenosis. In most of the habitats the species is observed together with *N. aquaticus* (L.) and less often with *N. palustris* (Duft.) and *N. biguttatus* (F.). On a few occasions, mainly in the dunes, *N. germinyi* has been observed together with the very rare *N. aesthuans* Motsch. Taking into account that a large part of the individuals of the species are macropterous and able to fly, some specimens are also observed outside the characteristic dry habitats. Several individuals were found in dry turbaries.

N. germinyi is a typical representative of the Carabidae complex from dry sedulous habitats that are situated very close to pine forests and are accreted with the lichens *Cladina* and *Cladonia* and the heather *Calluna*. The species can be used as an indicator for characterizing this kind of habitats. Although *N. germinyi* is frequently found in the Baltic and adjoining areas, protection of its habitats would secure populations of the species as well. The existence of *N. germinyi* can be endangered if pines and other trees overgrow the appropriate habitats. For this reason it is important to work out relevant directives for habitat management activities, that do not allows the overgrowth of trees and bushes.

CONCLUSION

In conclusion we would like to point out that *N. germinyi* is the most common species of the genus *Notiophilus* in the Baltic countries. It occurs mainly in dry, sedulous habitats and is considered as a typical representative of the species complex that lives in lichens (*Cladina, Cladonia*) and heather (*Calluna*) and can be used as the indicator for characterizing this kind of habitats. Most of the habitats that are characteristic to this species are included in the annexes of the European Union's «Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora». For the protection of *N. germinyi* populations, it is necessary to work out relevant directives of habitat management activities, that do not allow the overgrowth of trees and bushes.

REFERENCES

Alexandrovitch, O.R., Lopatin, I.K., Pisanenko, A.D., Tsinkevitch, V.A. & Snitko, S.M. 1996. A Catalogue of Coleoptera (Insects) of Belarus. 103 pp. Fund of Fundamental Investigations of the Republic of Belarus, Minsk

Barševskis, A. 1994. Carabidae of Genus Notiophilus Dumeril, 1806 (Col.: Carabidae) in Latvia. Dabas IzpÂtes vÂstis 1, 1-12.

Barševskis, A. 1999a. Peculiarities of the variability of Notiophilus aquaticus (Linnaeus, 1758) (Coleoptera: Carabidae). Pp. 79-80 in. Collection of Articles of Daugavpils Pedagogical University 7th Annual Scientific Conference A9. Saule, Daugavpils.

Barševskis, A. 1999b. Fauna of Beetles (Insecta: Coleoptera) in Latgalia. Substratum of Adephaga Beetles. Acta Latgalica 10, 325-365.

Barševskis, A. 1999c. Taxonomy, morphology and distribution of groundbeetles Notiophilus Dumeril, 1806 (Coleoptera: Carabidae) in Northern and Eastern Europe. Proc. XXIV Nordic Congr. Entomol., 39-43.

Barsevskis, A. (2001) New and rare species of beetles (Insecta: Coleoptera) in the Baltic countries and Byelorussia. Latv. Entomol., 38. (in press).

Burakowski, B., Mroczkowski, M., Stefanska, J. 1973. Catalogue of Fauna of Poland. Coleoptera, Carabidae, XXIII, 2, 1, 1-232.

Haberman, H. 1968. Groundbeetles of Estonia (Coleoptera, Carabidae). Pp. 140-141. Valgus, Tallinn.

Hansen, M. 1996. Katalog over Danmarks biller. Ent. Meddr. 64, 1-232.

Jacobson, G.G. 1905. Beetles of Russia and West Europe. 1024 pp. A.F.Devrien, St. Petersburg

Kryzhanovskij, O.L., Belousov, I.A., Kabak, I.I., Katajev, B.M., Makarov, K.V. & Shilenkov, V.G. 1995. A Checklist of the Ground-beetles of Russia and Adjacent Lands (Insecta, Coleoptera, Carabidae). 272 pp. Pensoft Publishers, Sofia, Moscow

Lindroth, C.H. 1945-1949. Die Fennoscandischen Carabidae. Medd. Goteb. Mus. Zool., I – III, 709 + 278 + 912.

Lindroth, C. H. 1988-1992. Ground Beetles (Carabidae) of Fennoscandia. A Zoogeografic Study. I – III, 630 + 271 + 814pp. Amerind Publiching Co., New Dehli, New York,

Lorenz, W. 1998. A systematic list of extant ground beetles of the World (Insecta Coleoptera «Geadephaga»: Trachypachidae and Carabidae incl. Paussinae, Cicindelinae, Rhysodinae), First Edition. 502 pp. Typeset and printed by the author at Tutzing.

Lundberg, S. 1986. Catalogus Coleopterorum Sueciae. 155 pp. Naturhistoriska Riksmuseet, Stockholm.

Lundberg, S. 1995. Catalogus Coleopterorum Sueciae. 224 pp. Naturhistoriska Riksmuseet. Entomologiska foreningen, Stockholm.

Pileckis, S. & Monsavièus, V. 1995. The Beetles (Coleoptera). 304 pp. Fauna of Lithuania, Mokslo ir enciklopediju l-kla, Vilnius.

Silfverberg, H. 1992. Enumeratio Coleopterorum Fennoscandiae, Daniae et Baltiae. 94 pp. Helsingin Hyönteisvaihtoyhdistys - Helsingfors Entomologiska Bytesförening.

Silfverberg, H. 1996. Additions and corrections to Enumeratio Coleopterorum Fennoscandiae, Daniae et Baltiae. Sahlbergia 3, 33 - 62.

Smits, V. 1968. Report on materials about Carabidae of Latvia in Museum of Zoology at the Latvian State University. LVU Zool. Muzeja Raksti 3, 27-36.

Solodovnikov, I.A. 1999. Catalogue of the beetles (Coleoptera, Insecta) of Belarus Poozerie. 37 pp. Vitebsk.

Spuris, Z. 1983. Catalogue of Insects in Latvia. 4. Carabidae. Latv. Entomol., 26, 5-67.

Stiprais, M.A. 1958. New facts about fauna of Carabidae in Latvian SSR. Proc. Institute of Biology, Latvian SSR, 5, 91 – 110.
Stiprais, M. 1973. Materials about fauna of insects in Riga. 3. Ground beetles – Carabidae. Latv. Entomol. 15, 18 – 29.

Received 11 September 2000,
accepted 25 October 2000

Norw. J. Entomol. 48, 77–86. 2001

Attractivity of 11-tetradecenyl acetate isomers for *Archips podana* Scopoli and *Aphelia paleana* (Hübner)

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Mõttus, E., Liblikas, I., Ojarand, A., Martin, M. & Borg-Karlson, A.K. 2001. Attractivity of 11-tetradecenyl acetate isomers for *Archips podana* Scopoli and *Aphelia paleana* (Hübner). Norw. J. Entomol 48, 77-86.

In the present study the optimum ratio of Z11-14:Ac and E11-14:Ac in sex attractants for *Archips podana* Scopoli (Lepidoptera, Tortricidae) and *Aphelia paleana* Hübner (Lepidoptera Tortricidae) is estimated using results of field tests, and the pheromone communication channel width is calculated for *Pandemis chondrillana* (Lepidoptera Tortricidae) and *Adoxophyes orana* Hübner (Lepidoptera, Tortricidae). The Gaussian distribution is used to calculate the optimal Z-isomer content x_{max} and the pheromone communication channel width w. For *Archips podana* x_{max} = 60 % of Z11-14:Ac; w = 15.7; for *Aphelia paleana* x_{max} = 89 % of Z11-14:Ac; w = 9.6 and for *Pandemis chondrillana* x_{max} = 60 % of Z11-14:Ac; w =22.3. The activity curves for *A. podana* and *A. paleana* overlap in the region where the content of Z11-14: Ac is 70 –90 %, but the difference in optimal content of Z11-14:Ac for *A. podana* and *A. paleana* is 28%. It confirms that the reproductive isolation of these moths may be based on different attractive maxima as both maxima are outside of the overlapping region. 60:40 mixture of Z11-14:Ac and E11-14:Ac had the highest attractivity for *Pandemis chondrillana* and this blend is the most attractive for *A. podana.* Both species share the same population area and their reproductive isolation is probably based on additional pheromone components. Instead of having a clear attractivity maximum, an area of equal activity is ascertained for *P. chondrillana* that indicates that the optimised mixture of Z11-14:Ac and E11-14:Ac can not be used as a real sex pheromone. However, for many monitoring purposes a low attractivity blend attracting up to 10 – 12 species is preferable. The intersection of activity curves allows to optimise the attractant blends enabling us to monitor groups of moths. A dispenser for monitoring three known species, *A. podana, A. paleana* and *P. chondrillana,* will contain 80 % of Z11-14: Ac and 20 % of E11-14:Ac.

Key word: 11-tetradecenyl acetate, sex attractant, pheromone communication channel, pheromone dispenser, Tortricidae

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INTRODUCTION

There are two different ways in which pheromones are being introduced into agriculture, forest management and environment monitoring: the confusion technique and the use of traps. Traps are used in two different ways:

- to detect and monitor pest population: this allows other methods to be organized more effectively;
- large numbers of pheromone traps can be used to attract and remove as many of the reproductively active males as possible.

In traps a pheromone bait or dispenser is used. The behavior of insects, as they approach, enter, and stop flying close to the bait is affected by the quality of pheromone materials used (David & Horsburgh 1983). It has been demonstrated that in case of many Tortricidae moths only 15 – 20% of attracted insects are trapped (Mõttus & Ivanova 1991). Zvereva et al. (1991) estimated the trapped amount of *A. podana* as 30 % of those attracted. Trapped amount of males, species specificity and aging of dispensers depended on the load amount of substances and their ratio, amount of degradation products and other characteristics of dispenser. Evidently, we need to understand better the theoretical basis of pheromone dispenser design to predict the trapping efficiency of pheromone traps. It has been confirmed that industry is still in great need to make formulations more effective and suitable for a wider range of pests and climate conditions (Arn et al. 1997).

It is rather easy to keep the evaporation rate above the needed minimum. The design of dispenser influences both the evaporation rate and the component ratio and has therefore great significance. Increasing evaporation rate (loading) of attractant does not enhance catches after the necessary minimum is exceeded (Ahmad & Ali 1989, Kamm et al. 1989, Anschelevitch et al. 1994). Consequently, lures in pheromone traps should release attractant at a rate exceeding the needed attractivity threshold.

The efficiency of a dispenser depends on the ratio of active ingredients in effluvia. Due to different evaporation rates, the ratio of attractant components in effluvia will change. Consequently the attractiveness of dispensers is not constant in time and the component ratio of the emitted blend differs from the optimal. Beside of chemical structure of blend compounds the evaporation rate depends on the substrate of dispenser.

It is believed that female insects emit the optimal pheromone. The component ratio of pheromone emitted by an individual has only been studied for a few moth species including *Pectinophora gossypiella, Argyresthia velutinana, Ephestia elutella* and *Yponomeuta* spp. (Witzgall & Frérot 1989, Löfsted 1991, Bäckman et al. 1997). In all cases, the narrow variation in female-produced pheromone component ratios contrasts with the wider distribution in male response. The width of population response may reflect the variation between males, so that the individual males will be attracted to different pheromone compositions. More likely the pheromone channel width calculated from field trap catch data reflects the wider reaction profile of individual male compared with variations in female-produced pheromone component ratio (Löfsted 1991). *Chrysotheuchia topiaria* (Pyralidae) has two-component sex pheromone: 99% of (Z)-11-hexadecenal and 1% of (Z)-9-hexadecenal (Z9-16:Ald). As expected, in field tests the optimum component ratio and the width of communication channel did not vary with dosage. The communication channel was asymmetric and a logarithmic function of Z9-16:Ald dosages was used (Kamm et al. 1989). The diminished trap catches at optimum ratio when using low dosages may indicate a wide reaction profile of individual moths rather than a wide dispersion of male reaction profiles within a population and the dependence of trap catch on dosage can be used as a diagnostic for absence of an important attractant component (Kamm et al. 1989).

If the evaporating compounds are not geometric isomers having very similar evaporation rate constants, the component ratio will change during the aging of dispensers and the optimum ratio of components should be determined in field tests. In most cases even small changes in component ratio cause changes in trap attractivity.

In this paper we report results on finding optimum ratio of attractants for two species: *Archips podana* Scopoli (Lepidoptera, Tortricidae) and *Aphelia paleana* Hübner (Lepidoptera, Tortricidae). Using our earlier research results (Mõttus et al. 1993, Ivanova & Mõttus 1988) we calculate pheromone communication channel width for *Pandemis chondrillana* (Lepidoptera, Tortricidae) and *Adoxophyes orana* Hübner (Lepidoptera, Tortricidae). We used the calculated pheromone communication channel width w to determine the possibility of reproductive isolation of moths and to achieve the desired species specificity of designed dispensers. Using Gaussian distribution (eq. 2) the ratio of optimal Z-isomer content x_{max} of three moth species: *Archips podana*, *Aphelia paleana* and *Pandemis chondrillana* was calculated.

The omnivorous leafroller *A. podana* is a widespread moth, common in Western Europe from

Scandinavia to the Balkan Peninsula and in Central Europe from the White Sea to Caucasus. *P. chondrillana* is widespread in Central Asia, Kazakhstan, Caucasus region and Southern part of Europe; it lives together with *A. podana* on a vast territory. *A. paleana* is widespread in Europe similarly with *A. podana* (Kuznetsov 1978).

Sex pheromone of *A. podana* was identified by Persoons et al. (1974) as 1:1 mixture of Z11-14Ac and E11-14:Ac. Identified ratio of components was estimated as 1:1, later the optimum ratio for Northern Europe has been demonstrated to be 60% of Z11-14:Ac and 40% of E11-14:Ac (Bykhovets et al. 1986, Ryabtchinskaya et al. 1986, Ojarand et al. 2000). Pheromone of *P. chondrillana* is not identified. Mazina & Mõttus (1986) reported attractivity of mixtures of Z11-14:Ac and E11-14:Ac for *P. chondrillana*. Later on the basis of field screening method, the synergistic effect of adding 20 % of Z11-tetradecenol (Z11-14:OH) of was demonstrated, however the content of Z11-14:OH is not optimised in our experiments (Mõttus et al. 1994). These results suggest that other compounds than Z11-14:Ac and Z11-14:Ac may enhance the attractivity and species specificity of attractive blend for *P. chondrillana*.

The sex pheromone for *A. paleana* has not been identified as well. It is known that Z11-14:Ac/E11-14:Ac of 9:1 is attractive to *A. paleana*. (Booij & Voerman 1984). This mixture had the highest attractivity for *A. paleana* in Krasnodar Territory (Russia) but it was attractive for to different blends for Tortricidae moths (Ivanova et al. 1986) as well.

METHODS OF CALCULATION

The pheromone recipient response may be measured as trap catch value in field tests. The more the tested blend differs from the optimum, the more the trap catches should diminish. Having trap catch data for dispensers with different ratios of components (x_i) we tried to use the Gaussian curve to calculate the optimal content of one compound x_{max} in two-component attractant blend (eq. 1).

$$f(x)=\frac{A}{w_c\sqrt{\frac{\pi}{2}}}\exp\left(-\frac{(x_{\max}-x_i)^2}{w^2}\right)+y_0 \qquad (1)$$

where w_c is the width of pheromone communication channel (approximately equal to two standard deviations) and x_{max} is used instead of the central moment of population μ.

The standard deviation is calculated as

$$w_c = 2\sigma = \sqrt{\frac{\Sigma(x_{\max} - x_i)^2}{\Sigma(y_i) - 1}} \qquad (2)$$

where y_i is trap catch if the content of component in effluvia is x_i. Subsequently, the width of pheromone communication channel w_c characterizes the influence of component ratio on trap catches. As seen from equation (1), if the content of a substance is equal to $x_{max} \pm 0.5\, w_c$, the trap catch equals $y = 2e^{-0,5} = 0.61$ or 61% of maximum trap catch. In case the change of the component ratio in effluvia equals to $x_{max} \pm 0.2s$, the mean trap catches are 10% lower than y_{max}. Evidently w_c may be used as a measure of pheromone communication channel width.

For calculations of x_{max} the ratio of pheromone compounds in effluvia is needed. Emission from the dispenser is affected both by diffusion and evaporation processes. If the evaporation speed from the surface of dispenser is slower than diffusion to the evaporating surface, thus being the limiting process, the first order process equation may be used to calculate the pheromone loss (Butler & McDonough 1997, McDonough 1987, Mõttus et al. 2000):

$$c_0 = c_t e^{-kt} \qquad (3)$$

where c_0 is the amount of compound in the dispenser at the beginning of evaporation, c_t is the amount of compound at time t and k is evaporation rate constant.

Constant k characterises the evaporating compound and it is dependent on temperature, wind speed, surface structure and mostly on the shape of the dispenser.

A half of the amount of the substance will be evaporated in time $t_{1/2}$, called half-life

$$\tau_{1/2} = \frac{1}{k}\ln\frac{c_0}{c\tau} = \frac{1}{k}\ln 2 = \frac{0.693}{k} \qquad (4)$$

Table 1. Main characteristics of the dispensers used in the tests

Dispenser type	Weight mg	Evaporation area mm^2	Surface factor mm^{-1}
Feroflor	800 ± 50	900 ± 10%	1.1 ± 10%
Miniket UM	150± 20	133	1.3

Equation (4) indicates that the evaporation rate diminishes two times after a half of the pheromone is evaporated.

Evaporation rate constants of Feroflor dispensers have been measured for most alkenols and alkenyl acetates by Mõttus et al. (1993).

MATERIALS AND METHODS

Chemicals

Compounds were purchased from AS Flora (Tartu, Estonia) and assayed by gas chromatography on Carbowax 20M capillary columns, 30 m, id. 0.25 mm. Z11-14:Ac contained about 0.8% of Z11-14:OH and E11-14:Ac had about 0.4% of corresponding alcohol. Accuracy of ratio in dispensers and in effluvia was ±1 %.

Dispensers

Miniket type dispensers were used for bioassay tests in Estonia (Mõttus et al. 2000). Substrate for Miniket dispensers consists of a mixture of SBR polymer and natural rubber, antioxidants, and as fills carbon black, silicagel and talc. Half-life of tetradecenyl acetates exceeds 11 months, evaporation rate of mixture from dispensers in field did not exceed 50 ng/hr. Collection on Porapak confirmed that ratio of isomers in effluvia corresponds to that in dispensers. Dispensers were loaded with 1 mg of mixture of Z11-14:Ac and E11-14:Ac containing 0, 10, 20, 40, 50, 60, 70, 80 % of Z-isomer.

In earlier experiments with *P. chondrillana,* Feroflor type dispensers from AS Flora were used. Load amount of pheromone was 1 mg. Main characteristics of dispensers are given in Table 1.

Traps and field tests

Plastic deltatraps Atrakon A (AS Flora, Tartu, Estonia) with base area of 225 cm^2 were used. Dispensers were hung in traps 3 cm or more from the bottom. In orchards, the traps were hung at the height of 1.5 – 1.8 m, in meadows traps were suspended on sticks at ca 0.6 m above the ground at 8 - 12 m intervals. Field trap tests were conducted in ten replicates. Field tests were carried out in 1998 and 1999 in a wild apple tree orchard in Uhti, 11 km from Tartu. This former production orchard of about two ha has not been cared for over the last 10 years. Experiments on influence of Z11-14:Ac additions on trap catch of *Adoxophyes orana* were carried out in Krasnodar Territory, orchard Gigant, in 1987. Field tests on activity of mixtures of Z11-14:Ac and E11-14:Ac for *P. chondrillana* were carried out nearby Alma-Ata, Kazakhstan, in 1991.

RESULTS

Width of pheromone communication channel

Trap catch results demonstrate that maximum activity blend attractant for *A. podana* consist of 60 % of Z11-14:Ac and for *A. paleana* of 89 % of Z11-14:Ac (Figure 1). Width of pheromone communication channel is 15.7 for *A. podana* and 9.6 for *A. paleana*. It means that for *A. podana* the blend having 50 % or 65 % of Z11-14: Ac in effluvia will have 49 % smaller attractivity compared with blend 60:40. It is notable that *A. paleana,* having maximum attractivity at 9:1, has a narrower pheromone communication channel compared with *A. podana*. We compared the communication channel parameters of *A. podana* and *A. paleana* with those of *Adoxophyes orana*, having optimum trap catches at ratio of about 8:2 of Z9-14:Ac and Z11-14:Ac (Figure 2). Results of

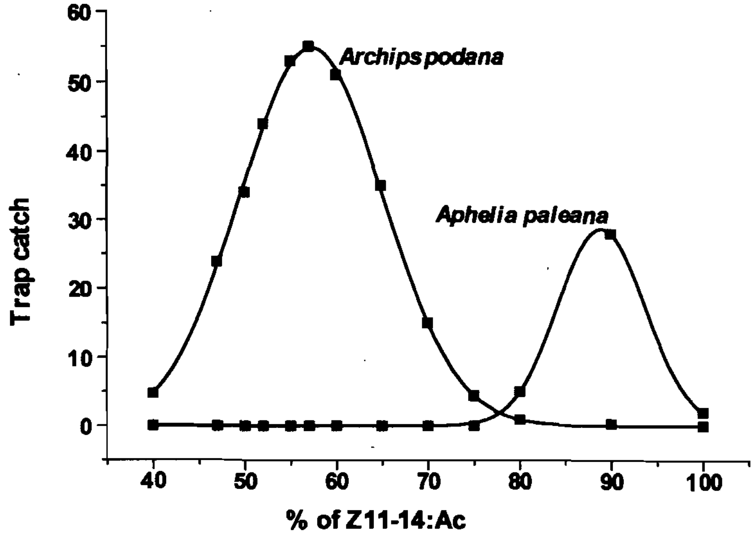

Figure 1. Attractivity of mixtures of Z11-14:Ac and E11-14:Ac for *Archips podana* and *Aphelia paleana* in orchard in Uhti, near Tartu, Estonia. Trap catch is given for 5 traps per summer.

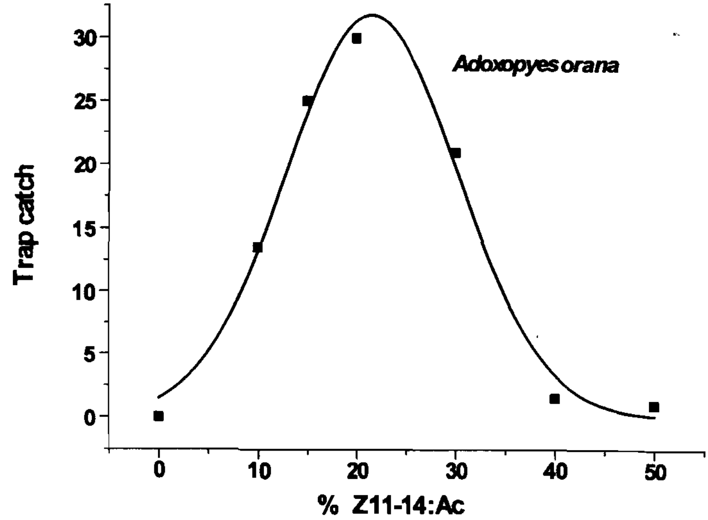

Figure 2. Influence of Z11-14:Ac additions on trap catch of *Adoxophyes orana*. Trap catch is given for 5 Pheroflor type dispensers.

field tests in Krasnodar Region in 1989 were used for calculation of *Adoxophyes orana* communication channel (Ivanova & Mõttus 1988). *Adoxophyes orana* has pheromone communication channel width of 17.5 % of Z11-14:Ac, which is comparable with that of *A. podana*. Maximum activity ratio for *P. chondrillana*, calculated from data given in literature (Mõttus et al. 1993), was 60 % of Z11 14:Ac, *w*=22.3 (Figure 3).

DISCUSSION

The width of communication channel

The activity curves for *A. podana* and *A. paleana* are overlapping in the region where the content of Z11-14: Ac is 70 –90 %. The optimum content of Z11-14:Ac for *A. podana* is 60 % and for *A. paleana* 88 %. It confirms that reproductive isolation of these moths may be based on different attractive maxima, both maxima are outside the overlapping region (Figures 1 and 4). Our practice confirms this finding. In 1984 – 1990 a comparative field screening of numerous Tortricidae dispensers in many locations in FSU was carried out (Krasnodar Territory, the Crimea, Voronezh region, Byelorussia, Carpatian, Armenia) and attraction of *A. paleana* to 60:40 mixture of Z11-14:Ac and E11-14:Ac was not recorded (Kolessova et al. 1993, Bykhovets et al. 1986, Ryabchinskaya et al. 1986, Ivanova et al, 1986). In most cases the reproductive isolation of insects having the same attractant compounds should not be based on component ratio but on other factors such as additional isolation pheromone components, inhibiting attractivity for «alien» species (Mõttus & Ivanova 1991). The existence of isolating pheromone components has been demonstrated experimentally with different species of female moths as baits. Always only one species was attracted, flight of other species was inhibited (Ivanova & Mõttus 1985). It should be noted that different habitats of *A. podana* and *A. paleana* cannot be the isolatiing factor. Beside trees *A. podana* is cued to many grasses, *Taraxacum* spp. and *Trifolium* spp. (Litvinova 1974). *A. paleana* is cued among a number of grasses to *Fleum* spp.

The 60:40 mixture of Z11-14:Ac and E11-14:Ac had the highest attractivity for *Pandemis chondrillana* and this blend attracts *A. podana* and *P. chondrillana* in field experiment. Corresponding Feroflor type dispensers trapped in Armenia 59 *A. podana* and 24 *P. chondrillana* males and in Voronezh district 50 and 37 males respectively (Kolessova et al. 1993). In regions where *P. condrillana* is absent (Central and Northern Europe) the species specificity of 60:40 mixtures for *A. podana* was high and only a small number of *Aleimma loeflingiana, Tortrix viridana, Euhyponomeutoides rufella* were captured (Kolessova et al. 1993). The communication channel of *P. chondrillana* is wider than that of *A. podana* (*w* equals 22.3 and 15.7 respectively, Figure 3). In case of *P. chondrillana,* instead of clear attractivity maximum an area of equal activity was ascertained (Figure 5). This indicates that the optimum mixture 60:40 of Z11-14:Ac and E11-14:Ac probably differs from sex pheromone of *P. chondrillana* and the pheromone needs yet to be identified. Preliminary field tests demonstrated that addition of 20 % of Z11-14:OH elevated trap catch (Mõttus et al. 1994). Evidently, in case of *P. chondrillana* and *A. podana* the reproductive isolation bases mainly on isolating compounds.

Six species of sympatric European small ermine moths (*Yponomeuta* spp.): *Y. cacnagellus, Y. padellus, Y. irrorellus, Y. plumbellus,* and *Y. vigintipunctatus* use a mixture of E11-14: Ac and Z11-14: Ac in different ratios as primary pheromone compo-

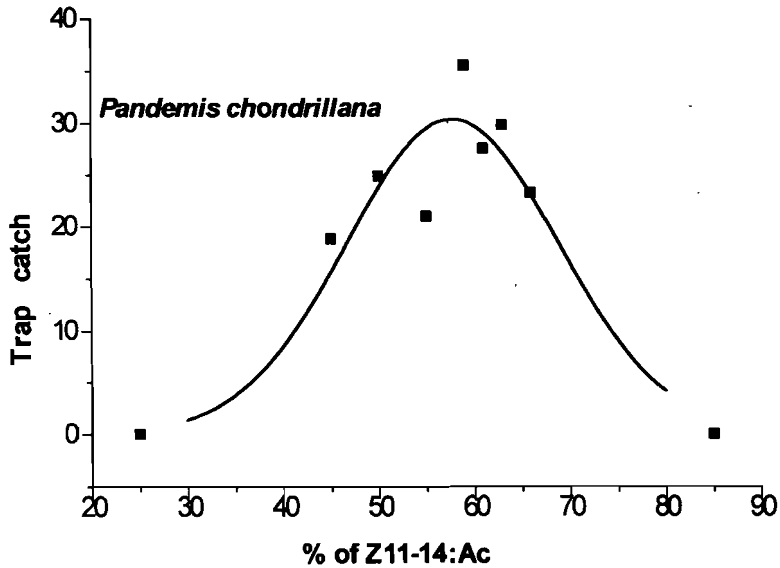

Figure 3. Activity of mixtures of Z11-14:Ac and E11-14:Ac for *P. chondrillana.* Trap catch is given for 6 traps for the second generation of moth.

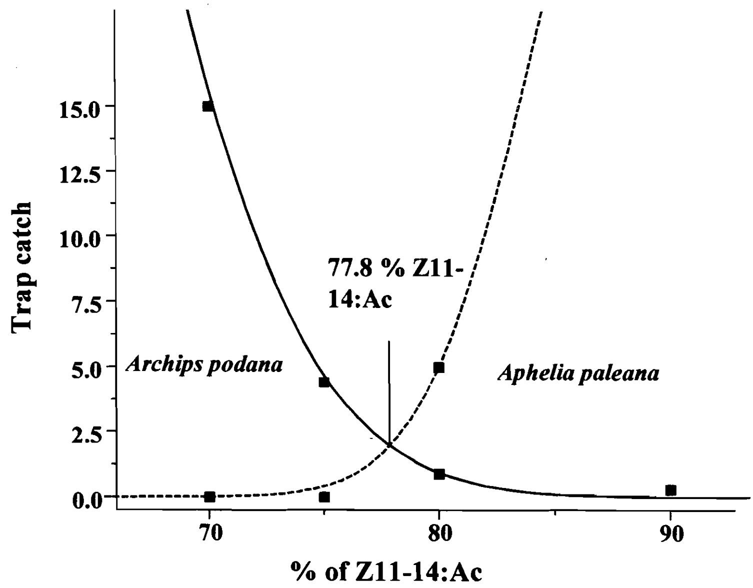

Figure 4. Overlapping activity area for *A. podana* and *A. paleana*. Zoom from Figure 1.

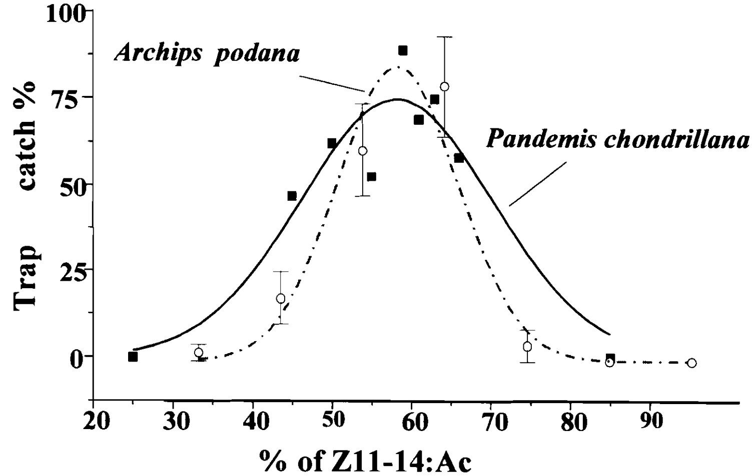

Figure 5. Attractant communication channel width for *P. chondrillana* and *A. podana*

nents. Analysis of component ratios produced by individual females demonstrated significant overlapping in ratios. Separation of the communication niches was achieved by using additional components. It is notable that ranges of pheromone component ratios produced by moths sharing the same host plant, *Y. cacnagellus, Y. irrorellus* and *Y. plumbellus,* did not overlap (Löfsted 1991).

A. paleana has narrower communication channel compared with *A. podana* (*w* equals 9.7 and 15.2, respectively). A smaller width of communication channel or asymmetric activity curve may be assumed for mixtures with a 5-20 % content of the minor component. A typical example is *A. orana.* The activity curve for *A. orana,* calculated from data by Ivanova & Mõttus (1988), revealed a symmetric curve having maximum activity at 20:80

of Z11-14:Ac/Z9-14:Ac. It differs by 10 % from identified pheromone blend but corresponds to reported field tests results. Shape of activity curve for *A. paleana* for different doses in Estonia is to be reinvestigated.

Dispensers having reduced attractivity and species specificity of attractive blends

Experiments with optimal component ratio dispensers for *A. podana* demonstrated species specificity 86 – 99 % (Kolessova et al. 1993) in regions where *P. chondrillana* is absent. Our experiments through several years in Estonia demonstrated that *A. paleana* was not attracted to *A. podana* dispensers and in apple orchards species specificity was about 100 %. Species specificity depends on the type of biocoenosis where dispensers are tested. In Finland the dispensers for *A. podana* of unknown quality trapped more than 50 % of non-target species (Peltotalo & Tuovinen 1986).

Absence of *A. paleana* in traps for *A. podana* is expected as dispensers having less than 70 % content of Z11-14: Ac are unattractive for *A. paleana* (Figure 1). For mass trapping methods and population density calculations optimised dispensers should be used and isolation from high-density concurrent insects is important.

In some situation the optimised dispensers can attract undesirably large number of moths, saturating the traps and making interpretation of catches impossible. Not always the high species specificity is desirable. For instance, to establish the changes in habitats of insects, low attractivity blends, attracting up to 10 – 12 species, can be used. As a result of changes in climate or due to human activity, habitats of some moth species will change (Kozlov & Haukioja 1993). For instance, a dispenser for monitoring three known species, *A. podana, A. paleana* and *P. chondrillana,* will contain 80 % of Z11-14: Ac and 20 % of E11-14:Ac; see intersection of activity curves in Figure 4. This blend will attract 5–10 times less *A. paleana* and *A. podana* males compared with optimised attractant. Our practice has demonstrated that low attractivity blends produce catches high enough to estimate the absence of moth species. For instance, Feroflor dispenser PH-531 with a blend of 0.7 mg Z11-14:Ac, 0.3 mg Z9-14:Ac and 0.2 mg dodecyl acetate was recommended for monitoring *A. crataegana* Hübner, *Pandemis heparana* Denn et Schiffermüller, *Adoxophyes orana*, but in different places trapped *Choristoneura diversana*, *Choristoneura murinana* Hübner, *Eulia ministrana* L., *Cochylis posterana* Zeller, and *Noctua fimbriata* Schreber (Kolessova et al. 1993).

On the basis of present research we have concluded that calculation of pheromone communication parameters is an effective tool for optimisation of attractive blend, estimating the role of blend components in communication and planning field experiments. Calculations based on activity curve may be used to create special blends for monitoring different groups of moths.

Acknowledgements. We would like to thank Sture Stromberg and Peter Bäckstrom from the Royal Institute of Technology, Stockholm, for advice and valuable discussion, and Sirje Kuusik from Ecochemistry laboratory, EAU for chromatographic analyses. We express our special thanks to AS Hevea (Tallinn, Estonia) for the substrate for Miniket dispensers and Marjuka Laanmaa from AS Flora (Tartu, Estonia) of Feroflor type dispensers. Supported by Estonian Government Grant No 0170118s98 and by VISBY program «Ecological chemistry and the control of insect pests».

REFERENCES

Ahmad, T. & Ali, M. A. 1989. Effect of plant type cover and pheromone concentration on movement of codling moth *Cydia pomonella* (L.) (*Lep., Olethreutidae*). J. Appl. Ent. 108, 312-316.

Anschelevich, L., Kehat, M., Dunkelblum, E. & Greenberg, S. 1994. Sex pheromone traps for monitoring the European Wine moth, *Lobesia botrana*: effect of dispenser type, pheromone dose, field ageing of dispenser, and type of trap on males capture. Phytoparasitica 22, 281-290.

Arn, H., Brauchli, J., Koch, U. T., Pop, L.& Rauscher, S. 1997. The need for standards in pheromone technology. Techology transfer in mating disruption. IOBC wpts Bulletin 20, 27-34.

Booij, C. J. H. & Voerman, S. 1984. (Z)-11-Hexadecenyl compounds as attractants for male Microlepidoptera of the subfamilies *Argyresthiinae*, and *Crambinae*. Entomol. Expt. Appl. 36, 47-53.

Butler, L. I. & McDonough, L. M. 1979. Insect sex pheromones. Evaporation rates of acetates from natural rubber septa. J. Chem. Ecol. 5, 825-37.

Bäckman, A.-C., Bengtsson, M. & Witzgall, P. 1997. Pheromone release by individual females of codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae). J. Chem. Ecol. 23, 807-815.

Bykhovets, A. L., Akhrem, A. A., Lakhvitch, F. A., Petrusevitch, I. I., Zolotar, R. M., Zhukov, N. M., Beglyakova, T. M., Antonova, S. V., Kazytsits, A. V., Mõttus, E. R. *&* Laanmaa, M. K. 1986. Field bioassay of moths sex attractants. (in Russian). Pp. 36–48 in Shumakov, Y. M. *&* Mõttus, E. R. (ed.), Feromony listovertok - vreditely selskogo hozhaystva. Tartu.

David, P. J. & Horsburgh, R. L. 1983. Effects of pheromone trap design, placement, and pheromone dispenser and load on male *Platynota flavedana* and *P. idaeusalis* (Lepidoptera: Tortricidae) catches in Virginia Apple orchards. Environ. Entomol. 18, 145-149.

Ivanova, T. V., Mõttus, E. R. & Pralya, I. I. 1986. Survey of research on orchard pest moths pheromones in Krasnodar Territory. (in Russian). Pp. 49-65 in Schumakov, Y. & Mõttus E. (ed.), Moths' pheromones in plant protection, part one. Tartu.

Ivanova, T.V. & Mõttus, E. 1985. Mutual inhibition of the pheromones of codling moth and some leaf rollers. Proc. Acad. Sc. Estonia. 34, 29-34.

Ivanova, T.V. & Mõttus, E. 1988. Unpublished results.

Kamm, I.A., McDonough, L. M. & Rowe, K. E. 1989. Effect of dosage and ratio of sex pheromone components on behavior of *Chrysotheuchia topiaria* (Lepidoptera: Pyralidae). Environ. Entomol. 18, 368-372.

Kolessova, D. A., Ryabchinskaya, T. A., Mõttus, E. R., Rodima, T. K., Laanmaa, M. K., Pristavko, V. P., Buleza, V. V., Petryshova, N. I., Medvedyeva, G. V., Gress, P. Y., Balykina, E. B., Nikolaeva, Z. V., & Grigoryan, E. E. 1993. A set of synthetic sex attractants for the monitoring of the complex of orchard leaf-roller moths (in Russian, English abstr.). Inform. Bull. EPS IOBC 30, 40-54.

Kozlov, M.V. & Haukioja, E. 1993. Density and size of *Archips podana* (Lepidoptera: Tortricidae) males in an air pollution gradient as revealed by pheromone traps. Environ. Entomol. 22, 438-444.

Kuznetsov, V. I. 1978. Tortricidae. Pp. 193-685 in Medvedeva, G. S. (ed.), Opredelitel nasekomykh evropeiskoi chasti SSSR.: tsheshujekrylye., Part 1. (in Russian). Nauka, Leningrad.

Litvinova, A. N. 1974. On the food specificy of *Archips podana* Scop. and some other leafrollers Minsk (in Russian). Pp. 97-112 in Vopr. Entomol. Nauka i Tehnika.

Löfsted, C. 1991. Evolution of moth pheromones. Pp. 57-73 in I. Hardy (ed.), Insect Chemical Ecology, Academia, Haque.

Mazina, V. V. & Mõttus, E. R. 1986. Synthetic sex attractant for *Pandemis chondrillana* H.-S. (in Russian). Pp. 211-214 in Shumakov Y. & Mõttus, E. (ed.), Feromony listovertok - vreditelei selskogo I lesnogo khozaystva. Part II, Tartu.

McDonough, L. M. & Butler, L. I. 1987. Release dynamics of pheromone from a pheromone dispenser. J. Chem. Ecol. 23, 1211-15.

Mõttus, E. & Ivanova, T. V. 1991. Attractant specificity and interactions among pheromone components of orchard moths pests. Pp. 81-96 in: Hardy, I. (ed.), Insect Chemical Ecology, Academia, Haque.

Mõttus, E., Yemelyanov, V. A., Borg-Karlson, A-K., Nikolaeva, Z. V. & Kuusik, S. 2000. Pheromone methods for controlling codling moth, *Cydia pomonella* L. in Northern regions. 2. Dispenser design aspects. Pp. 136-139 in Metspalu, L. & Mitt, S. (eds.), Development of Environmentally Friendly Plant Protection in the Baltic Region. Tartu University Press, Tartu.

Mõttus, E., Kuusik, S. & Nõmm, V. 1993. Calculation of pheromone evaporation rate constant from rubber dispensers (in Estonian, English summary). Pp. 68-73 in Kasearu, P. (ed.), Coll. of scient. Public. of Estonian Agricultural University, Tartu.

Mõttus, E., Mazina, V. & Kuusik, S. 1994. Attraction of *Pandemis chondrillana* H.-S male moths to synthetic pheromone attractant in field (in Estonian). Pp. 93-96 in Kasearu, P. (ed.), Magistrandide ja doktorantide teaduslike tööde kogumik part II. Tartu.

Ojarand, A., Mõttus, E., & Liblikas, I. 2000 Calculation of the width of *Archips podana* pheromone communication channel. Pp. 146-149 in Metspalu, L. & Mitt, S. (ed.), Development of Environmentally Friendly Plant Protection in the Baltic Region. Tartu University Press, Tartu.

Peltotalo, P. & Tuovinen, T. 1986. Specificity of pheromone preparations for Lepidopterous pests. Ann. Agric. Fenn. 25, 139-146.

Persoons, C. J., Minks, A. K., Voerman, S., Roelofs, W. L. & Ritter, F. 1974. Sex pheromone of the moth *Archips podana*: isolation, identification and field evaluation of two synergistic isomers. J. Insect Physiol. 20, 1181-1188.

Ryabchinskaya, T. A., Mõttus, E. R. & Kolessova, D. A. 1986. Pheromone dispensers for *Archips podana* Sc. (Lepidoptera: Tortricidae) (in Russian). Pp. 73-79 in Zaschita selskohoz. kultur ot vrednyh organismov. Voronezh.

Ryabchinskaya, T. A., Kolessova, D. A., Mõttus E. R. 1986. Pheromone blends of orchard pest moths (in Russian). Zool. Zh. 48, 384-389.

Witzgall, P. & Frérot, B. 1989. Pheromone emission by individual females of carnation tortrix, *Cacoecimorpha pronubana*. J. Chem. Ecol. 15, 77-717.

Zvereva, E. L., Kozlov, M. V. & Vrkoc, J. 1991. Methods to describe the parameters of search behavior of *Archips podana* (Lepidoptera, Tortricidae) in field (in Russian). Zool. Zh. 7, 73-81.

Received 30 June 2000,
accepted 22 October 2000

Norw. J. Entomol. 48, 87–90. 2001

Laboratry experiments on cold acclimation in overwintering Colorado potato beetles, *Leptinotarsa decemlineata* (Say)

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Hiiesaar, K., Kuusik, A., Jõudu, J., Metspalu, L. & Hermann, P. 2001. Laboratory experiments on cold acclimation in overwintering Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Norw. J. Entomol. 48, 87-90.

Colorado potato beetle *Leptinotarsa decemlineata* (Say) is a freeze intolerant species hibernating under soil as adult, and being able to supercool to certain degrees. In postdiapause state the mean supercooling point of beetles overwintering in laboratory conditions under soil at 7 °C was –10.5±1.4 °C. In February the beetles were exposed for 8 days to each of the stepwise lowered temperatures, –2, –4 and –6 °C. Following cold acclimation for 24 days at these temperatures the mean supercooling point was lowered to –17.5±2.4 °C. All the beetles survived the prolonged exposures to gradually lowered subzero temperatures. However, without a preliminary acclimation to higher subzero temperatures, all the beetles died if exposed directly to –6 °C for 8 days. All the beetles survived the measuring of their supercooling points if they were removed from the cold within 2-3 minutes after the rebound caused by the crystallization. Subsequently the beetles exhibited an abnormal behaviour at 24 °C and long day conditions, burrowing in the soil for 3-4 weeks. The control beetles began to feed immediately after emerging from soil. The authors suggest the inhibition of juvenile hormone by the chilling and/or freezing of pupae resulting in digging behaviour typical of individuals entering diapause.

Key words: Cold acclimation, *Leptinotarsa decemlineata*

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INTRODUCTION

In the laboratory the supercooling points are useful and convenient values for comparative purposes (Salt 1966a, b). Nevertheless, the supercooling points should not be considered as the only measure of cold hardiness, the effects of prolonged exposures to low temperatures must also be taken into consideration (Sømme 1996).

Several authors have determined the supercooling points of overwintering Colorado potato beetles, but essential variations in these values, from –5 to –13 °C, have been found (Robinson 1928, Mail & Salt 1933, Rodionova 1969, Minder 1981, Kung et al. 1992, Lee et al. 1994, Boiteau & Coleman 1996).

Supercooling points of insects depend on a series of intrinsic and external factors influencing nucleation in the supercooled state. Temperature and time affect the nucleation and freezing extrinsically, functioning together as the rate of cooling (Salt 1966a). Ice-nucleating active bacteria and fungi as normal flora in the gut of overwintering insects also influence the freezing and supercooling points in insects, including the Colorado potato beetle (Lee et al. 1995, 1996). The infection of insects by microorganisms, e.g. Microsporidia, decreases essentially their supercooling ability (Metspalu 1976).

Many freeze intolerant insects from temperate zone are able to acclimate to subzero temperatures. The supercooling points of these insects depends on the temperature and exposure time before the determination of supercooling. In the literature there are only scarce experimetal data on the supercooling points of the Colorado potato beetles depending on the cold hardening by exposure to subzero temperatures. So far there has been few studies on the behavioural reactions in the beetles following survival of supercooling to the supercooling points.

The aim of the present work was to study the cold acclimation in overwintering Colorado potato beetles and to observe their behaviour after determining their supercooling points.

INSECT AND METHODS

The Colorado potato beetles were collected from a potato field near Tartu (Estonia) and a laboratory population was established. The beetles overwintered in laboratory at 7 °C under soil. Supercooling points of the beetles were determined in February and April.

Individual beetles were enclosed in a plastic holder inside an aluminium box with their ventral side in contact with the velding point of a copper-constantan thermocouple (diam. of wires 0.06 mm), and placed in a freezing chamber with a constant temperature of –25 °C. We obtained decelerating rate curves that where reproducible within the freezing range at cooling rates of 0.4 °C to 1.0 °C per minute. All the determinations were made under dry conditions in order to avoid seeding by external ice crystals. All the individuals were frozen only once and the further behaviour of beetles was observed during several months.

By our special tests under the present experimental conditions the Colorado potato beetle did not reveal significant correlation (r <0,1) between supercooling points and cooling rates of 0.3 to 2.0 °C per minute.

RESULTS

Three degrees of cold hardiness were achieved by acclimating the beetles to –2, –4 and –6 °C consecutively, for 8 days at each temperature (Figure 1). In non-acclimated beetles hibernating at 7 °C the mean supercoolig point was –10.6±1.9 °C in February. Following acclimation at the three subzero temperatures, lasting for 24 days alto-

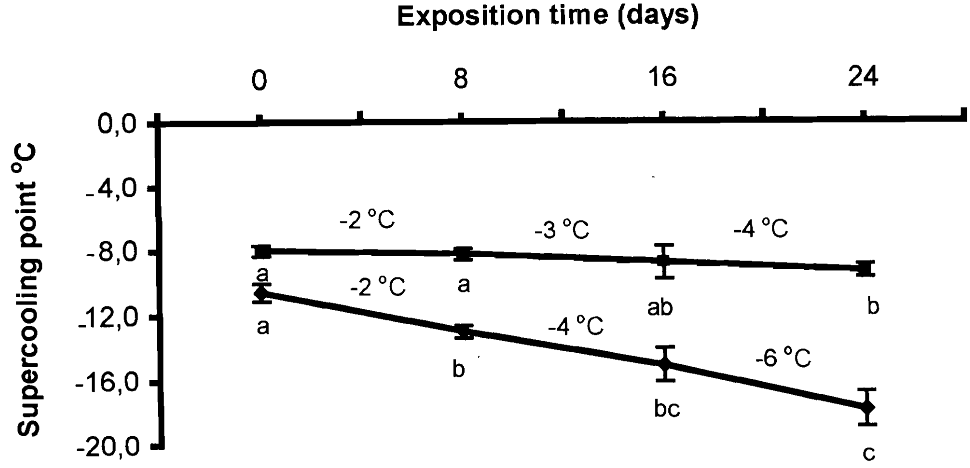

Figure 1. Changing of supercooling points (mean±SEM) during cold acclimation in pupae of Colorado potato beetle, *Leptinotarsa decemlineata* (Say) acclimated at three subzero temperatures in February (lower line) and in April (upper line). Acclimation temperatures are indicated on both lines. Points on each line having no letters in common are significantly different (P<0.05, Student t-test).

gether, the mean supercooling point was significantly lowered, reaching a value of –17.3±3.7 °C (Figure 1, lower line). All the beetles survived the determination of the supercooling point if they were transferred to room temperature within 2-3 minutes after the abrupt rebound caused by heat release due to crystallization. Thus the partial and short time freezing of the tissues was not fatal to beetles.

In another series, supercooling points of the beetles were not determined, but the beetles survived exposure to –2, –4 and –6 °C, each lasting for 8 days. However, all the beetles died if they were exposed to –6 °C for 6 days without their previous exposure to higher subzero temperatures.

One and a half moth later, in April, the hibernating beetles showed somewhat higher supercoolig points (–8.0±1.4 °C) while their cold-hardening ability had decreased. Therefore we used 8 day long exposures to –2, –3 and –4 °C consecutively, resulting in the lowering of the supercoolig points to only –9.6±2.5 °C (Figure 1, upper line).

The beetles hibernating in postdiapause state were transferred to room temperature in February and placed on potato plants, they began to eat after 2-3 days and the first egg clutches were found after 10-12 days.

In February after determining the supercooling points a peculiar behaviour was observed in the beetles when their tissues were partially frozen. All these beetles buried themselves in soil at room temperature in long day conditions and stayed under soil for two to three weeks. Then they emerged from the soil and began to eat. The first egg clutches were found after another three weeks.

The digging behaviour due to acclimation and determination of supercooling points was shown by beetles in April, but in this case they spent only 4-5 days under soil and reproduction begun 10-14 days after their emerging from the soil.

DISCUSSION

In the present study cooling rates from 0.3 to 2.0 °C did not influence the supercooling points of the Colorado potato beetle. For insects weighing up to 1 g, cooling rates between 0.5 °C and 1 °C per minute have been found appropriate by several authors (Robinson 1928, Salt 1966b, Merivee 1978).

In our laboratory tests the mean supercooling point of hibernating beetles was lowered by 7 °C during cold acclimation i.e. from –10 to –17 °C.

The Colorado potato beetles undergo the low temperature acclimation in the postdiapause state (oligopause) during the coldest winter-months (Rodionova 1969, Minder 1981). According to Rodionova (1969), the main cryoprotective compounds in beetles are carbohydrates accumulating at subzero temperatures.

The results demonstrated that the partial freezing did not cause injuries to the Colorado potato beetles, and their ability to reproduce was maintained and their progeny developed normally.

According to Lee et al. (1994, 1995) this beetle is a freeze intolerant species that dies when cooled to its supercooling point. We agree that the Colorado potato beetle is a freeze intolerant species, but according to our observations they survive, if the beetles were removed from the freezing chamber as soon as the temperature increase connected with the initiation of freezing occurred. Thus the beetles survive the first steps of the freezing process which we suppose are mainly extracellular. Intracellular freezing is generally regarded as fatal to both animals and plants or cause injuries of tissues (Salt 1966a).

An essential role in insects hibernating in cold environments is played by the behavioural adaptations which are often associated with the diapause state (Sømme 1982, 1995, Gehrken 1988). Normally, at the beginning of diapause the Colorado potato beetles react negatively to light, and leave their host plant to bury themselves in the soil. The digging behaviour, which results in the beetles being buried under several inches of soil, has been used as a criterion of the onset for diapause (Beck 1968). During the imaginal, i.e. reproductive diapause, the developmental arrest is due to a lack of juvenile hormone (de Wilde 1960, 1965). The lack of juvenile hormone synthesis was observed also as a result of chilling in the adult cockroach, *Diploptera punctata* (Pszczolkowski & Chiang 2000).

Following the determination of their supercooling points, the Colorado potato beetles display a behaviour typical of individuals initiating the diapause. We suggest that the supercooling of beetles exerted some diapause symptoms.

The beetles did not reveal any sign of injuries due to the freezing and their progeny developed normally.

Acknowledgements. This research was supported by grant no. 3535 from the Estonian Science Fundation.

REFERENCES

Beck, S. 1968. Insect Photoperiodism. 288 pp. Academic Press, NewYork, London.

Boiteau, G. & Coleman, W. 1996. Cold tolerance in the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae). Can. Entomol. 128, 1087-1099.

De Wilde, J. 1960. Diapause in the Colorado potato beetle (Leptinotarsa decemlineata Say) as an endocrine deficiency syndrome of the corpora allata. Pp. 226-230 in Hrdy., I. (ed.), The Ontogeny of Insects. Academic Press, New York.

De Wilde, J. 1965. Photoperiodic control of endocrines in insects. Arch. Anat. Microscop. Morphol. Exptl. 54, 547-564.

Gehrken, U. 1988. Mechanisms involved in insect cold tolerance. Dissert., Div. of Biology, University of Oslo, Norway.

Kung, K-J., Milner, M., Wyman, J.A., Feldman, J. & Nordheim, E. 1992. Survival of Colorado potato beetle (Coleoptera: Chrysomelidae) after exposures to subzero thermal shocks during diapause. J. Econ. Entomol. 85, 1695-1700.

Lee, R.E., Costanzo, J.P., Kaufman, P.E., Lee, M.R., & Wyman, J.A. 1994. Ice nucleating active bacteria reduce the cold-hardiness of the freeze-intolerant Colorado potato beetle (Coleoptera. Chrysomelidae). J. Econ. Entomol. 87, 377-381.

Lee, R.E., Jr., Lee, M.R., & Strong-Gunderson, J.M. 1995. Biological control of insect pest using ice-nucleating microorganisms. Pp. 257-269 in Lee, R.E., Warren, G.J. & Gusta, L.V. (eds.), Biological Ice Nucleation and Its Applications. APS Press, St. Paul.

Lee, R.E., Steigerwald, K.A., Wyman, J.A., Costanzo, J.P. & Lee, M.R. 1996. Anatomic site of application of ice-nucleating active bacteria affects supercooling in the Colorado potato beetle (Coleoptera: Chrysomelidae). Environ. Entomol. 25, 465-469.

Mail, G. A. & Salt, R.W. 1933. Temperature as a possible limiting factor in the northern spread of the Colorado potato beetle. J. Econ. Entomol. 26, 1068-1075.

Merivee, E. 1978. Cold-Hardiness in Insects. 188 pp. Acad. Sci. Estonian SSR, Tallinn.

Metspalu, L. 1976. The effect of microsporidiosis on hibernating pupae of noctuids. Proc. Estonian Acad. Sci. Biol. 25, 13-19.

Minder, I.F. 1981. Ecology of the Colorado potato beetle, – general parameters of responses to the abiotic factors of environment. Pp. 72-97. In Ushatinskaya, P.C. (ed.), Colorado Potato Beetle, *Leptinotarsa decemlineata* Say: Phylogeny, Morphology, Physiology, Ecology, Adaptation, Natural Enemies. Nauka Publishers, Moscow.

Pszczolkowski, M.A. & Chiang, A-S. 2000. Effects of chilling stress on allatal growth and juvenile hormone synthesis in the cockroach, *Diploptera punctata*. J. Insect Physiol. 46, 923-931.

Robinson, W. 1928. Determination of the natural undercooling and freezing points in insects. (In Russian) J. Agric. Res. 37, 749-755.

Rodionova, L.Z. 1969. Cryoprotective reactions in overwintering Colorado potato beetles (*Leptinotarsa decemlineata* Say). Pp. 131-139 in Arnoldi, K.V.(ed.), Periodicity of Individual Development in Insects. (in Russian). Nauka Publishers, Moscow.

Salt, R.W. 1966a. Factors influencing nucleation in supercooled insects. Canad. J. Zool. 147, 117-133.

Salt, R.W. 1966b. Effects of cooling rate on the freezing temperatures of the supercooled insects. Canad. J. Zool. 44, 655-659.

Sømme, L. 1982. Supercooling and winter survival in terrestrial arthropods. Comp. Biochem. Physiol. 73A, 519-543.

Sømme, L. 1995. Terrestrial Invertebrates in Hot and and Cold Arid Environments. 275 pp. Springer, Berlin.

Sømme, L. 1996. The effect of prolonged exposures at low temperatures in insects. Cryo-Letters 17, 341-346.

Received 28 June 2000,
accepted 18 October 2000

Norw. J. Entomol. 48, 91–96. 2001

Simultaneous recording of gas exchange cyclicity, body movements and heartbeats by infrared-optical method in pupae of *Leptinotarsa decemlineata* (Say)

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Metspalu, L., Kuusik, A., Hiiesaar, K., Jõudu, J., Tartes, U. & Harak, M. 2001. Simultaneous recording of gas exchange cyclicity, body movements and heartbeats by infrared-optical method in pupae of *Leptinotarsa decemlineata* (Say). Norw. J. Entomol. 48, 91-96.

By means of infrared optical method the microcycles of gas exchange, body rhythmic movements and heartbeats were simultaneously recorded in the pupae of Colorado potato beetle, *Leptinotarsa decemlineata* Say. All the mentioned events are well recognisable on the infrared-optical recordings. Very regular microcycles of gas exchange are reflected on the optical recording as clear spikes due to weak movements in body tissues suggestively due to passive suction ventilation. On the same recording the signals of heartbeats with common rate of 50-70 min^{-1} are superimposed on the slower peaks due to body rhythmic movements. The infrared optical method allows to elucidate the interrelations between gas exchange, body movements and heartbeats in pupal stage.

Key words: *Leptinotarsa decemlineata,* gas exchange, body movements, heartbeats.

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INTRODUCTION

In last decades a close co-ordination between haemolymph circulation and tracheal ventilation has been demonstrated, suggesting an overall autonomic nervous control over circulation, respiration and thermoregulation (see Miller 1985, 1997, Wasserthal 1996, Slama 1999). In the pupae of the mealworm *Tenebrio molitor*, the greater wax moth *Galleria mellonella* and the Colorado potato beetle *Leptinotarsa decemlineata* the periods of pupal heartbeats and rhythmic body movements are synchronised, but the functional meaning of the co-ordination is little elucidated (Tartes & Kuusik 1994, Tartes et al. 1999a, 2000).

In studies of the interrelations between cyclic gas exchange, body stereotypic movements and heartbeats in insects, all three events should be recorded simultaneously. The heartbeats have commonly been recorded by optical and electrical methods (Miller 1985). The contact thermography by thermistors is also a convenient method for recording the heartbeats (Wasserthal 1996), but in certain cases the thermography allows to record the heartbeats and body movements at the same time (Slama 2000, Tartes et al. 2000). However, it must be taken into account that every device attached or contacted to insect body may induce a state of stress and thus an influence on the metabolic rate (Kestler 1984). Besides, the normal patterns of gas exchange, the activity of skeletal muscles and heartbeats in pupae are often affected by stress due to handling and device (Kuusik et al. 1994, 1995, Harak et al. 1998).

According to our observations, the pupae of Colorado potato beetle are very susceptible to several stress factors including the measuring devices. That is the reason why the noncontact infrared-optical method for recording the heart activity in this beetle may have some advantages over the devices attached to the body.

The infrared-optical method has been used for recording the heartbeats in insects (Hetz 1994, Wasserthal 1996). In the present paper we study the patterns of gas exchange cycles, body movements and heartbeats which are simultaneously recorded by infrared-optical method in the pupae of Colorado potato beetle.

INSECTS AND METHODS

We collected Colorado potato beetles (*Leptinotarsa decemlineata* Say) from potato fields in the vicinity of Tartu (Estonia), but a laboratory rearing of beetles was also established in controlled environmental conditions.

The optical method we used was based on the infrared-sensitive diodes, which responded to the changing infrared light transmission of the beating heart and to all other rhythmic movements in pupal tissues (Hetz 1994, Wasserthal 1996). The infrared–optical device we combined either with a continuously recording differential electrolytic respirometer-actograph described earlier (Tartes & Kuusik 1994, Tartes et al. 1999b) or with an infrared gas analyzer - IRGA (Infralyt-4, VEB, Junkalor Dessau). All the measurements were made at 24°C.

RESULTS

The optical device registered all the movements occurring in pupal tissues, including the pulsations of the dorsal vessel (heartbeats) and the contractions of body skeletal muscles. The pupae of the Colorado potato beetle reveal short periods of heartbeats and body active rhythmic movements lasting 3-5 minutes and alternating by pauses for 40-60 minutes. During the common pause of the heartbeats and body movements the weak rhythmic respiratory movements inside body were reflected on the infrared-optical recording line – the microcycles of gas exchange were marked by upward spikes (Figure 1).

The microcycles of discontinuous gas exchange characteristic of the pupae of Colorado potato beetle are well documented on the simultaneous recordings of respirometer-actograph and infrared-optical device (Figures 1 and 2). An upward spike followed at once by a downward one due to the CO_2 microburst (Figure 1) initiated every microcycle by respirometry. The mentioned upward spikes were very rapid (0.1-0.3 sec) suggesting the abrupt air suction intakes into the tracheae.

Every series of 8-24 microcycles of CO_2 was alternated by a larger output of this gas as seen from respirometric recordings (Figure 2, lower line). During the larger CO_2 bursts the microcycles disappeared as it is seen on the simultaneous IR-optical recording (Figure 2, upper line). In this way both the gas exchange microcycles and larger CO_2 outbursts were well recognised on the optical recording line.

It was now essential to make clear whether the CO_2 microbursts occurred with the assistance of muscular ventilating or not. On the recording of gas exchange microcycles no peaks due to body rhythmic movements were noted (Figures 1 and 2). Thus it was obvious that CO_2 microbursts in the pupae of Colorado potato beetle occurred without muscular ventilating.

During the period of the abdominal rhythmic movements the latter were fully independent of the gas exchange cycles (Figure 3). The single abdominal movements were never synchronised with gas exchange microcycles while their frequencies were 5-8 min^{-1} and 7-12 min^{-1}, respectively. During the bout of abdominal movements the gas exchange microcycles were preserved, and thus the unessential role of active body movements in tracheal ventilation was assumed.

In pupae of the Colorado potato beetle we did not ascertain the heartbeat reversals, commonly occur-

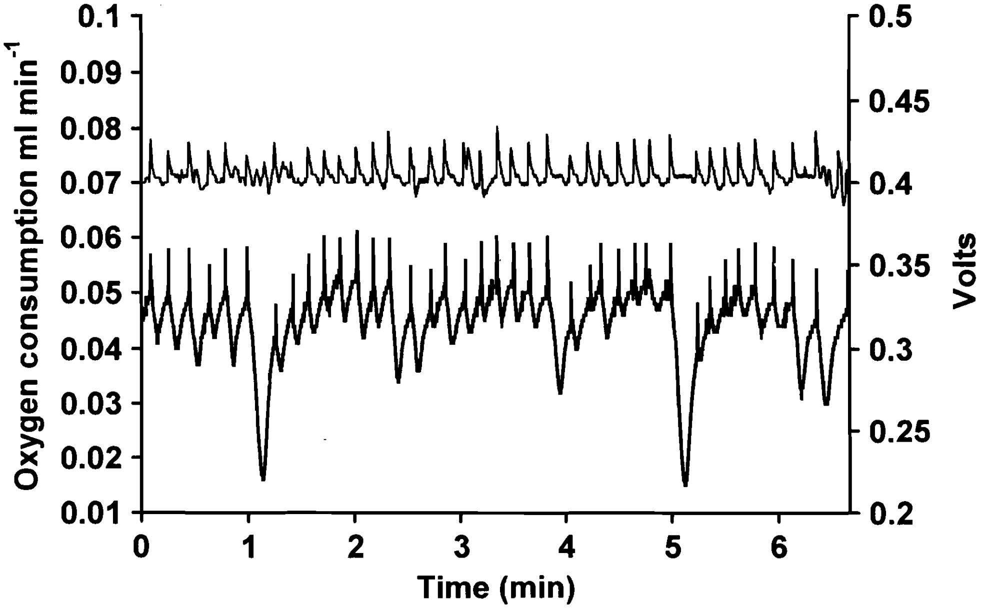

Figure 1. The upper trace (right axis) represents the pattern of spikes due to the gas exchange microcycles in a pupa (♀ 134 mg) of Colorado potato beetle recorded by infrared-optical method. The lower trace (left axis) is the simultaneous recording of the same microcycles by means of the respirometer-actograph.

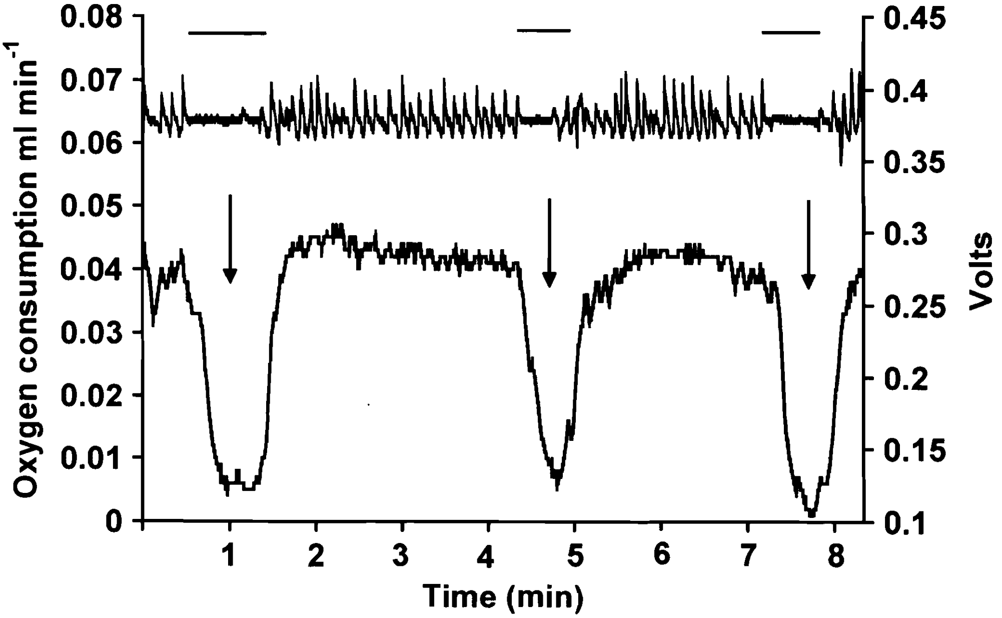

Figure 2. The infrared-optical recording (upper trace, right axis) of spikes due to the gas exchange microcycles and three periods of CO_2 larger outputs (horizontal bars) in a pupa (♀ 142 mg) of Colorado potato beetle. The simultaneous recording of respirometer-actograph (lower trace, left axis) shows the same CO_2 larger bursts, but single microbursts are not resoluted.

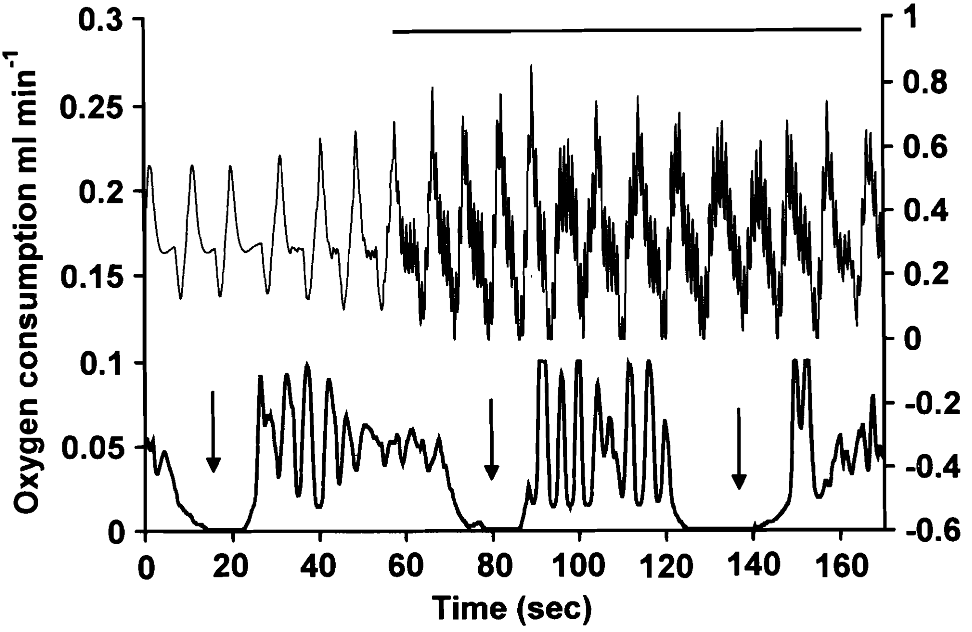

Figure 3. On the infrared-optical recording (upper trace, right axis) there are seen peaks with large amplitude caused by the active abdominal movements of a pupa (♀ 131 mg) and the short spikes with faster frequency of heartbeats. The horizontal bar indicates a period of the heartbeats. A simultaneous recording of respirometer-actograph (lower trace, left axis) showing the gas exchange microcycles and CO_2 larger outputs.

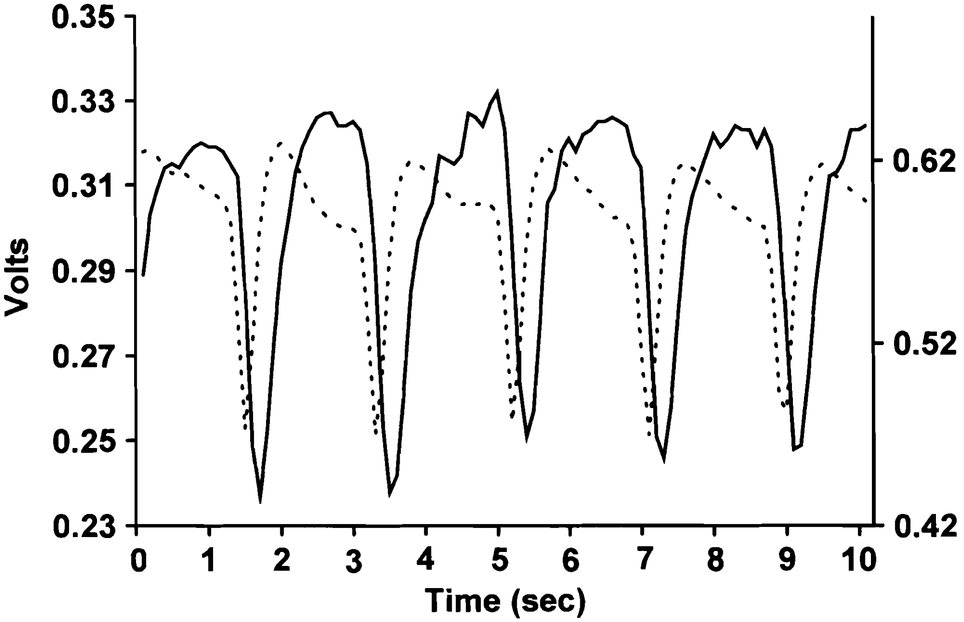

Figure 4. The clear systolic signals from first (solid line) and fourth (dotted line) abdominal segments on infrared-optical recording showing the forward directed heartbeats in a pupa of Colorado potato beetle.

ring in pupal stage, and only forward directed heartbeats of dorsal vessel were observed (Figure 4).

DISCUSSION AND CONCLUSION

In our results not only the signals due to heartbeats and body movements are well recognisable on the IR-optical recordings, but also the gas exchange microcycles and the larger CO_2 outputs. Thus the noncontact optical method allows us to observe the periodicity of cyclic gas exchange, heartbeats and body movements characteristic of the pupae of Colorado potato beetles.

Our present data accord with earlier findings that the main respiration in the pupae of this species occur by the very regular microcycles of gas exchange interrupted at times by larger CO_2 outputs (Tartes et al. 2000). The mentioned microcycles are persisting throughout the pupal development, being fully independent from the active abdominal movements. Thus the microbursts of CO_2 proceed without muscular ventilation.

The gas exchange microcycles were commonly regarded as flutter due to the rather irregular microopenings of the spiracles (reviewed by Miller 1974, Mill 1985, Kestler 1984). The very regular microcycles of the gas exchange in the pupae of Colorado potato beetle are not the typical flutter in our opinion. In this respect the pupae of this species revealed similar features as the pupae of *Galleria mellonella,* exhibiting very regular microcycles of gas exchange due to the passive suction ventilation of tracheae (Kuusik et al. 1991, 1996, 1999).

We conclude from our results that the infrared-optical method allows elucidation of the interrelations between cyclic gas exchange, body active rhythmic movements and heartbeats in the pupal stage.

Acknowledgements. This research was supported by grant no. 3535 and no. 4073 from the Estonian Science Fundation

REFERENCES

Harak, M., Kuusik, A., Hiiesaar, K., Metspalu, L., Luik, A. & Tartes, U. 1998. Calorimetric investigations on physiological stress in *Tenebrio molitor* (Coleoptera, Tenebrionidae) pupae. Thermochimica Acta 309, 57-61.

Hetz, S.K. 1994. Untersuchungen zu Atmung, Kreislauf and Säure-Basen-Regulation an Puppen der tropischen Schmetterlingsgattungen *Ornithoptera, Troides* and *Attacus*. Dissert. Naturwiss. Fak. Friedrich-Alexander-Universität, Erlangen-Nürnberg.

Kestler, P. 1984. Respiration and respiratory water loss. Pp. 137-183 in Hoffmann, K.E. (ed.), Environmental Physiology and Biochemistry of Insects. Springer, Berlin, Heidelberg.

Kuusik, A., Hiiesaar, K., Metspalu, L. & Tartes, U. 1991. Gas exchange rhythms of *Galleria mellonella* L. (Lepidoptera, Pyralidae). Proc. Estonian Acad. Sci. Biol. 40, 145-156.

Kuusik, A., Tartes, U., Harak, M., Hiiesaar, K. & Metspalu, L. 1994. Developmental changes during metamorphosis in *Tenebrio molitor* (Coleoptera: Tenebrionidae) studied by calorimetric thermography. Eur. J. Entomol. 91, 297-305.

Kuusik, A., Harak, M., Hiiesaar, K., Metspalu, L. & Tartes, U. 1995. Studies on insect growth regulating (IGR) and toxic effects of *Ledum palustre* extracts on *Tenebrio molitor* pupae (Coleoptera, Tenebrionidae) using calorimetric recordings. Thermochimica Acta 251, 247-253.

Kuusik, A., Harak, M., Hiiesaar, K., Metspalu, L. & Tartes, U. 1996. Different types of external gas exchange found in pupae of greater wax moth *Galleria mellonella* (Lepidoptera: Pyralidae). Eur. J. Entomol. 93, 23-35.

Kuusik, A., Harak, M., Hiiesaar, K., Metspalu, L. & Tartes, U. 1999. Studies on muscular activity, gas exchange cycles and water loss in pupae of greater wax moth *Galleria mellonella* (Lepidoptera, Pyralidae) during physiological stress. Pp. 77-82. Proc. XXIV Nordic Congress of Entomology, Tartu.

Mill, P.J. 1985. Structure and physiology of the respiratory system. Pp. 517-593 in Kerkut, G.A. & Gilbert, L.J. (eds.), Comprehensive Insect Physiology, Biochemistry and Pharmacology. Pergamon Press, Oxford.

Miller, P.L. 1974. Respiration – aerial gas transport. Pp. 345-402 in Rockstein, M. (ed.), The Physiology of Insecta, Vol. 6. Academic Press, New York, San Francisco, London.

Miller, T.A. 1985. Structure and physiology of the circulatory system. Pp. 289-353 in Kerkut, G.A. & Gilbert, L.I. (eds.), Comprehensive Insect Physiology, Biochemistry and Pharmacology. Pergamon Press, Oxford.

Miller, T.A. 1997. Control of circulation in insects. Gen. Pharmac. 29, 23-38.

Slama, K. 1999. Active regulation in insect respiration. Ann. Entomol. Soc. America, 92, 916-929.

Slama, K. 2000. Extracardiac versus cardiac haemocoelic pulsations in pupae of the mealworm (*Tenebrio molitor* L.). J. Insect Physiol. 46, 977-992.

Tartes, U. & Kuusik, A. 1994. Periodic muscular activity and its possible functions in pupae of *Tenebrio molitor*. Physiol. Entomol. 19, 216-222.

Tartes, U., Kuusik, A. & Vanatoa, A. 1999a. Heartbeat and body movement: roles in gas exchange in *Galleria mellonella* L. (Lepidoptera: Pyralidae) pupae. Internat. J. Insect Morphol. 28, 145-149.

Tartes, U., Kuusik, A. & Vanatoa, A. 1999b. Diversity in gas exchange and muscular activity in insects studied by a respirometer-actograph. Physiol. Entomol. 24, 150-157.

Tartes, U., Kuusik, A., Hiiesaar, K., Metspalu, L. & Vanatoa, A. 2000. Abdominal movements, heartbeats and gas exchange in pupae of the Colorado potato beetle, *Leptinotarsa decemlineata*. Physiol. Entomol. 25, 151-158.

Wasserthal, L.T. 1996. Interaction of circulation and tracheal ventilation in holometabolous insects. Adv. Insect Physiol. 26, 297-351.

Received 28 June 2000,
accepted 9 October 2000.

Norw. J. Entomol. 48, 97–102. 2001

Lower canopy invertebrate diversity in relation to Norway spruce (*Picea abies*) proportion

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Salingre, G. & Heliövaara, K. 2001. Lower canopy invertebrate diversity in relation to Norway spruce (*Picea abies*) proportion. Norw. J. Entomol. 48, 97-102.

Norway spruce branches were sampled from a series of mature managed stands in southern Finland. The proportion of spruce varied from 2% to 100% of the basal tree area. At each sampling area three mature spruces were chosen and from each tree the lowest branches and the vegetation (ground) below the trees were sampled at seven occasions during the growth period. Most of the collected material consisted of psocids (Psocoptera), spiders (Aranae), springtails (Collembola) and true flies (Diptera). No differences were recorded in the invertebrate numbers on the ground, but the number of species on spruce branches decreased by 20%, the number of invertebrates by 40%, and Hurlbert's index of diversity decreased by 10% as the proportion of spruce exceeded 40%.

Key words: biodiversity, forest management, vegetation, boreal forest.

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INTRODUCTION

Norway spruce (*Picea abies* (L.) Karst.) is a dominating tree species in large areas of Europe and northern Asia. For instance in Finland, more than one third of the forests is dominated by Norway spruce (Sevola 1999). Spruce is a shade-tolerant species which forms dense stands in suitable growing sites.

Previous studies dealing with invertebrates living on spruce have mostly been focused on species living on the stem, often dealing with insect pests, but the basic fauna on spruce canopy has been less thoroughly investigated. Recent studies show that habitat structure and quality play an important role in maintaining biodiversity on spruce canopies (Pettersson et al. 1995, Esseen et al. 1996, Pettersson 1996).

Our aim was to determine how the proportion of spruce in commercially managed stands affects canopy invertebrate numbers and insect diversity. However, a large proportion of invertebrates, especially immatures, cannot be assigned to any taxonomically described species. We classified the insects (Insecta) into morphologically recognizable taxonomic units or morphotypes (see Oliver & Beattie 1993).

METHODS

Sampling areas

A series of eight sampling areas was determined in a managed Norway spruce forest in Tuusula, 15 km north of Helsinki (60°21'N, 25°00'E). Standard silvicultural thinning has been carried out during the successional stages of the stands. The sampling areas were chosen on the basis of their proportion of Norway spruce, which varied from 2 to 100 % of the basal tree area (Table 1). All areas were of *Myrtillus* site type (Cajander 1925). For details of the sampling areas, see Müller & Hallaksela (1998).

Sampling of invertebrates and vegetation

Three spruces were selected for sampling in every sampling area, and the same trees were used for collecting invertebrates throughout the study. The sampling was carried out by using an insect net (radius 350 mm) provided with an extended shaft (about 3 m). The net was swung ten times from side to side over the lowest branches of each sample tree. In addition similar samplings were carried out over the vegetation in the ground layer below each tree on a circular area of 2 m^2. Invertebrates were collected on seven occasions between May and September 1996, and the material made up a total of 336 samples. Hurlbert's index Δ_1 (Hurlbert 1971) was used to study the diversity of insect morphotypes in the sample areas. The index value varies between 0 (poor diversity) and 1 (high diversity).

An inventory of vegetation was carried out using a frame (1m x 1m) that was randomly placed on 10 sites on each sample area. The proportion of the ground occupied by the aerial parts of plant individuals was measured as percentage of the cover (see Goldsmith et al. 1986).

RESULTS

Recorded invertebrate orders

The material consisted of 9644 individuals, 6904 (72 %) of these were insects (Insecta) and 2740 arachnids (Acari, Araneae); 4532 individuals were collected from the branch samples and 5112 from the ground samples (Table 2).

On the branches, the most abundant invertebrate orders were psocids (Psocoptera), spiders (Araneae) and flies (Diptera). The rest were springtails (Collembola), bugs (Hemiptera), wasps and sawflies (Hymenoptera), thrips (Thysanoptera), beetles (Coleoptera) and mites (Acari), of which each order made up 1-6 % of the catch. In the Class Insecta, the most abundant orders on the branches were psocids (44 %) followed by true flies (24 %) and homopterans (8 %).

On the ground, the most abundant invertebrate orders were springtails (Collembola), spiders (Araneae), mites (Acari) and psocids (Psocoptera). Flies, hymenopterans, bugs, beetles and thrips made up 1 - 9 % each. In the Class Insecta, the most abundant orders on the ground were springtails (47 %), psocids (17 %), true flies (13 %) and hymenopterans (8 %).

Vegetation

Plant species typical of *Myrtillus* site type covered the areas in a similar way, independent of stand age or proportion of spruce. The most abundant species was bilberry (*Vaccinium myrtillus*) covering 76-100 % of all sample areas. Cowberry (*Vaccinium vitis-idaea*), chickweed (*Trientalis europaea*), may-flower (*Maianthemum bifolium*) and wood cow-wheat (*Melampyrum sylvaticum*) covered at least 25% of the ground in every sample area. However, the four poorest spruce managed stands (proportion of spruce 2-10%) had a distinct shrub layer consisting mainly of birch

Table 1. Characteristics of the study areas.

	Basal area				
Area	Norway spruce %	Scots pine %	Pubescent birch %	Average age of spruce years	Average height of spruce m
1	2	97	1	44	22
2	6	89	5	71	23
3	8	92	0	50	21
4	10	85	5	66	23
5	43	36	21	63	23
6	72	13	15	71	24
7	90	3	7	85	23
8	100	0	0	58	25

Table 2. The most abundant invertebrate orders on branches and ground.

	Branches		Ground	
	n	%	n	%
Psocoptera	1436	32	581	12
Araneae	1098	24	949	19
Diptera	823	18	468	9
Collembola	288	6	1584	31
Hemiptera	269	6	318	6
Hymenoptera	213	5	371	7
Thysanoptera	182	4	65	1
Coleoptera	163	4	143	3
Acari	60	1	633	12
Total	**4532**		**5112**	

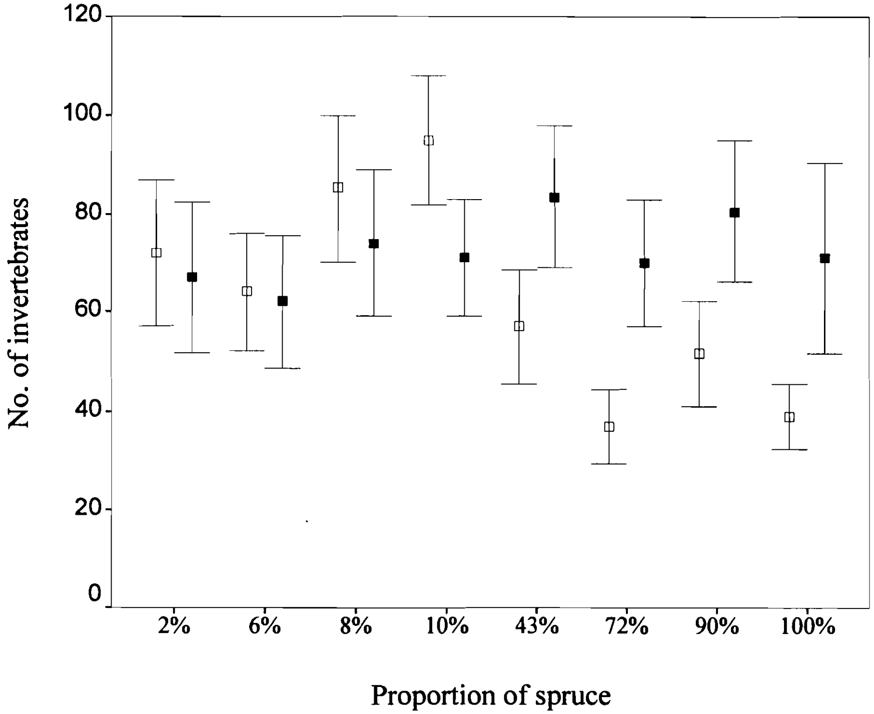

Figure 1. Mean numbers of invertebrates sampled. White squares indicate branch samples, black ones indicate ground samples. Vertical bars indicate standard errors of the mean.

(*Betula pendula*), European aspen (*Populus tremula*), mountain ash (*Sorbus aucuparia*) and undergrowth Norway spruce. When the areas were divided into two different groups according to the proportion of spruce, i.e. 2-10 % (low) and 43-100 (high), the undergrowth turned out to be slightly more luxuriant in areas with low spruce proportions. There were 10 sites with plant coverage more than 50 % in areas with low proportion of spruce, while only six sites had a high proportion of spruce. However, no significant statistical differences were found in the vegetation structure between the areas (Kruskal-Wallis H=0.269, df=1, P=0.604).

Number of invertebrates

The greatest mean number of invertebrates (94.7 per sample) on branches was sampled in area 4 with a 10 % proportion of spruce (Figure 1). The spruce branches in sample area 6 (proportion of spruce 72 %) was poorest for invertebrates (36.7). As a whole, the invertebrate numbers differed satistically significantly between the areas (Kruskal-Wallis H=17.13, df=7, P=0.017). There seems to be no clear relation between the invertebrate numbers and proportion of spruce. However, when the areas were divided into two different groups according to the proportion of spruce (2-10 % and 43-100 %), there is a highly significant statistical difference in the means (H=13.36, df=1, P<0.001). In other words, as the proportion of spruce exceeded 40 %, the number of invertebrates decreased by 40 % on average.

The numbers of invertebrates collected from the ground fluctuated less than the ones on the spruce branches. The mean number of invertebrates collected from the ground varied between 61.9 and 83.7 individuals per area (Figure 1). No statistical differences were found.

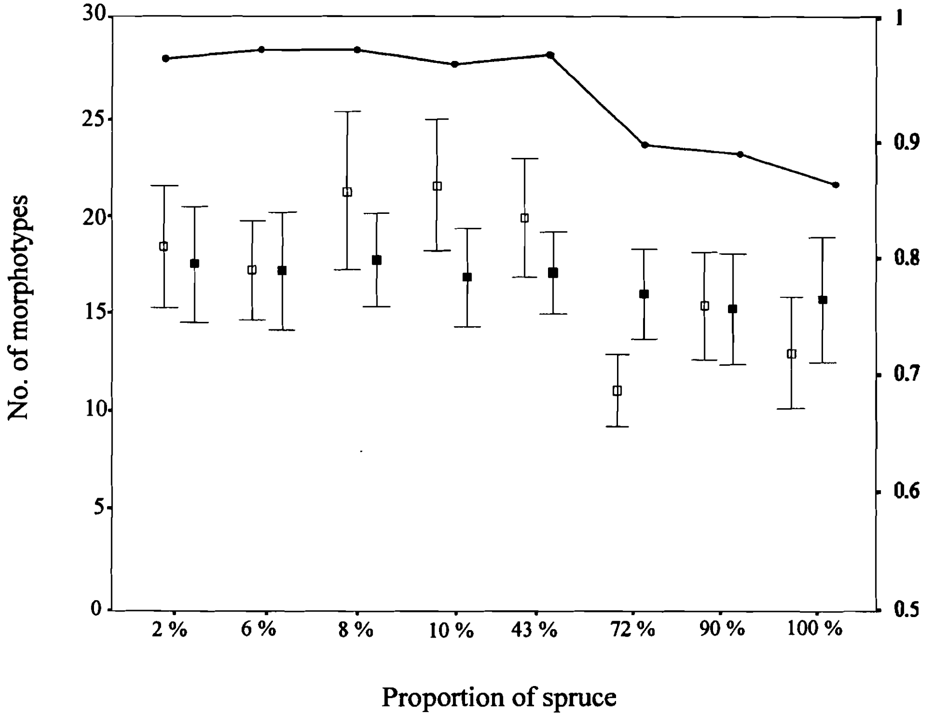

Figure 2. Mean numbers of morphotypes (recognizable taxonomic units, RTUs, y-axis on the left) sampled and Hurlbert's index of insect diversity (line, y-axis on the right). Explanations as in Figure 1.

Number of morphotypes

The highest mean number of insect morphotypes (recognizable taxonomic units) collected from the spruce branches was obtained in area 4 (21.7; proportion of spruce 10 %) and the lowest on area 6 (11.7; proportion of spruce 72 %) (Figure 2). Both the number of insect morphotypes (H=4.55, df=1, P=0.033) and individuals (H=5.85, df=1, P=0.02) differed significantly when the areas were divided into two different groups according to the proportion of spruce (2-10 % and 43-100 %). As the proportion of spruce exceeded 40 %, the number of insect morphotypes decreased 20 % on average. However, the morphotype number dropped most distinctly as the spruce proportion exceeded 72 %. As in the case of invertebrate individuals, greater fluctuations occurred in species numbers in the material collected from the branches than from the ground (Figure 2).

Hurlbert's index of diversity, calculated on the basis of insect morphotypes, showed high values of insect diversity for every sampled area (average 0.942). The highest insect diversity (Δ_1 = 0.977) was found in area 3 with a low proportion of spruce, while the value on area 8 (proportion of spruce 100 %) was the lowest (Δ_1 = 0.866) (Figure 2). Hurlbert's index followed a similar decreasing trend as the number of morphotypes, i.e. insect diversity seems to decrease slightly as the spruce proportion exceeds 40%.

DISCUSSION

Most studies concerning canopy invertebrates in boreal forests have been carried out during winter (Palmgren 1932, Hågvar & Hågvar 1975, Laine et al. 1990, Pettersson et al. 1995) when hibernating invertebrates, though low in numbers, are easily sampled by e.g. surrounding the branches with plastic bags. Our material was caught during summer by less accurate net samples still allowing quantitative analyses with presumably a constant source of error.

The community composition and abundance of invertebrates in Norway spruce canopy have been suggested to be related to the geographical area (Pettersson et al. 1995), time of the year (Jansson & von Brömssen 1981) as well as bird predation (Gunnarsson 1996). In the present study, the dominating invertebrate orders on the Norway spruce branches were Psocoptera, Aranae and Diptera. In Palmgren's (1932) study in Åland, southwest Finland, Aranae and Psocoptera dominated the canopy fauna, and in Hågvar & Hågvar's (1975) study near Oslo, Norway, the most abundant orders were Aranae and Homoptera. Laine et al. (1990, 1995) in northern Finland and Pettersson et al. (1995) in central-northern Sweden listed Acari, Aranae, Collembola, Psocoptera, Homoptera (Hemiptera), Thysanoptera and Diptera in their most abundant orders. In general, our findings of the most abundant orders were in accordance with these results.

The spruce canopy creates poorly lit patches with decreased local availability of water and nutrients, which may increase vegetational heterogeneity under the trees (see Kuuluvainen et al. 1993) and affect invertebrate abundances even on the lower branches. The silvicultural practices of managed forests in northern Europe aim to maintain an even and homogeneous stand throughout the succession of the forest. On the other hand, continuous thinnings contribute to these qualities and no considerable changes will appear in the structure of the undergrowth during forest rotation. Tonteri (1994) showed that species richness of boreal understorey forest vegetation is only weakly related to total crown coverage of trees and shrubs. Also in our study only minor differences in vegetation in relation to spruce proportion were detected, which was also reflected in the uniformity of invertebrate fauna under the study trees.

The present results showed that the number of species on spruce branches decreased by 20 %, the number of invertebrates by 40 %, and Hurlbert's index of diversity decreased by 10 % as the proportion of spruce exceeded 40 %. Epiphytic lichens on spruce branches may be important as they contribute to structural complexity and diversity as well as to the nutrition cycle in the ecosystem (Pettersson et al. 1995). Our results indicated that also the structure of the lowest branches themselves may affect the invertebrate numbers. As the proportion of spruce increases, the competition for space between spruce individuals gets more intense (Takahashi 1996). Consequently, competition-induced natural pruning and lower needle mass in dense Norway spruce stands is reflected in lower invertebrate numbers and insect diversity.

The present study shows that the proportion of spruce affects invertebrate diversity at least at stand level. However, only a little is still known about the relation between spruce stands and the invertebrate fauna the maintain at landscape level.

REFERENCES

Cajander, A. K. 1925. The theory of forest types. Act. For. Fenn. 29, 1-108.

Esseen, P.-A., Renhorn, K.-E. & Pettersson, R. B. 1996. Epiphytic lichen biomass in managed and old-growth forests: effect of branch quality. Ecol. Appl. 6, 228-238.

Goldsmith, F. B., Harrison, C. M. & Morton, A. J. 1986. Description and analysis of vegetation. Pp. 437-524 in Moore, P. D. & Chapman, S. B. (eds.): Methods in Plant Ecology. Blackwell Scientific Publications, London.

Gunnarsson, 1996. Bird predation and vegetation structure affecting spruceliving arthropods in a temperate forest. J. Anim. Ecol. 65, 389-397.

Hågvar, E. B. & Hågvar, S. 1975. Studies on invertebrate fauna on branches of spruce (*Picea abies*) (L.) during winter. Norw. J. Ent. 22, 23-30.

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52, 577-586.

Jansson, C. & Brömssen, A. von 1981. Winter decline of spiders and insects in spruce *Picea abies* and its relation to predation by birds. Holarctic Ecol. 4, 82-93.

Kuuluvainen, T., Hokkanen, T. J., Järvinen, E. & Pukkala, T. 1993. Factors related to seedling growth in a boreal Scots pine stand: a spatial analysis of a vegetation-soil system. Can. J. For. 23, 2101-2109.

Laine, A., Orell, M. & Itämies, J. 1990. Invertebrate fauna on Norwegian spruce (*Picea abies*) branches in northern Finland. Ent. Fenn. 1, 193-199.

Laine, A., Itämies, J., Orell, M. & Kvist, S. 1995. Invertebrate fauna of Norway spruce (*Picea abies*) saplings and its connection with the nitrogen, sulphur and phenolics concentration of the needles. Ent. Fenn. 5, 177-185.

Müller, M. M. & Hallaksela, A. M. 1998. Diversity of Norway spruce needle endophytes in various mixed and pure Norway spruce stands. Mycol. Res. 102, 1183-1189.

Oliver, I. & Beattie, A. J. 1993. A possible method for the rapid assessment of biodiversity. Conserv. Biol. 7, 562-568.

Palmgren, P. 1932. Zur Biologie von *Regulus r. regulus* (L.) und *Parus atricapillus borealis* Selys. Eine vergleichend-ökologische Untersuchung. Acta Zool. Fenn. 14, 1-113.

Pettersson, R. B. 1996. Effect of forestry on the abundance and diversity of arboreal spiders in the boreal spruce forest. Ecography 19, 221-228.

Pettersson, R. B., Ball, J. P., Renhorn, K.-E., Esseen, P.-A & Sjöberg, K. 1995. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biol. Conserv. 74, 57-63.

Sevola, Y. (ed.) 1999. Finnish Statistical Yearbook of Forestry. 352 pp. Finnish Forest Research Institute, Helsinki.

Takahashi, K. 1996. Plastic response of crown architecture to crowding in undersorey trees of two codominating conifers. Ann. Bot. 77, 159-164.

Tonteri, T. 1994. Species richness of boreal understorey forest vegetation in relation to site type and successional factors. Ann. Zool. Fenn. 31, 53-60.

Received 27 June 2000,
accepted 15 October 2000.

Forest insects attracted to ground traps baited with turpentine and ethanol on clear-cuttings

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Voolma, K., Süda, I. & Sibul, I. 2001. Forest insects attracted to ground traps baited with turpentine and ethanol on clear-cuttings. Norw. J. Entomol. 48, 103-110.

During a ten-year study carried out on clear-cuttings in an intensively managed forest area (forest district of Räpina, Estonia) with the use of original ground traps baited with a blend of turpentine and ethanol, a total of 54 951 insect specimens were caught. The percentages of trapped insect individuals were the following: *Hylobius abietis* 68 %, *Hylobius pinastri* 1%, bark beetles of the genus *Hylastes* 21 %, other Scolytidae 3 %, and all other insect species 7 %. A list of insect species trapped on clear-cuttings, and their total number are presented. The traps used to monitor *Hylobius abietis* and associated root-colonizing *Hylastes*-species had relatively weak effects on non-target insects: besides pine weevils (*H. abietis, H. pinastri*) and bark beetles (Scolytidae), only 7 % individuals of other insect species were caught. Several rare or relatively scarce species were also caught with these traps: *Carabus nitens, C. violaceus, Plegaderus saucius, Geotrupes vernalis, Platycerus caprea, Ernobius nigrinus, Coniocleonus hollbergi, Hylurgus ligniperda,* etc. This indicates that species richness has been preserved quite well in spite of current intensive forest management practices. However, felling volume and area have rapidly increased during recent years, which may present threat for some insect species in the future.

Key words: clear-cutting, Coleoptera, Estonia, *Hylobius abietis*, pitfall traps.

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INTRODUCTION

The large pine weevil, *Hylobius abietis* (Linnaeus, 1758) (Coleoptera, Curculionidae) is the major insect pest species affecting reforestation. Its abundance is closely dependent on the exploitation intensity of forests, as far as stumps and roots of recently felled conifer trees offer a suitable breeding substrate for this insect species.

For monitoring the large pine weevil populations, methods with the use of baited pitfall traps of various design have been developed. A standardized method for trapping pine weevils, using pitfall traps baited with alpha-pinene and ethanol, was developed in Sweden (Nordlander 1987). Different modifications of this trap have been applied for monitoring *Hylobius abietis* populations in Europe (Tilles et al. 1986, Zumr & Stary 1991, 1993, Lindelöw et al. 1993) as well as for investigation of relevant native counterpart species in North America (e.g. Raffa & Hunt 1988, Hunt & Raffa 1989, Rieske & Raffa 1993, 1999, Fettig & Salom 1998).

As a side-effect, such traps baited with host volatiles catch a number of other insects among which some species of bark beetles (Coleoptera, Scolytidae) and weevils (Coleoptera, Curculionidae) are the most abundant (Zumr & Stary 1991, Tunset et al. 1993, Voolma 1995, 1998). Since bark beetles, particularly of the genus *Hylastes,* respond to the same host volatiles as *Hylobius abietis,* they should not be included as non-target insects. Although the lure (turpentine and ethanol) used in the traps is intended to attract bark and wood-boring insects, many other insect species can occasionally enter the traps. According to a study carried out in the Czech Republic, some free-living ground beetles

(Carabidae) are the most abundant among them (Zumr & Stary 1991).

In Estonia, we started experiments for trapping *Hylobius abietis* in 1989 (Voolma 1994). The ground traps used were different from those used widely in other countries. Our traps showed good catch results both in the case of the large pine weevil and root-colonizing bark beetles of the genus *Hylastes* (Voolma 1994, 1995, 1998). The aim of this paper was to assess the species composition and relative abundance of non-target insects trapped on pine clear-cuttings during a ten-year monitoring of *Hylobius abietis* in an intensively managed forest area.

MATERIALS AND METHODS

Study area

The study was conducted in the growing season in 1990-1999 in an intensively managed forest area of the forest district of Räpina, Estonia (58°09' N, 27°08' E). Altogether seven clear-cuttings of former pine-dominated stands (ca 90 % of *Pinus sylvestris* and 10 % of *Picea abies*) on dry sandy soil, *Vaccinium* site type, were selected as study sites. On some sites, traps were set out in up to seven consecutive years.

The traps

The traps used mainly in this study were a completed modification of the trap constructed originally for trapping click-beetles, Elateridae (Kudryavtsev et al. 1993). The ground traps (which are further called as Estonian traps) consisted of plastic jars (height 120 mm, upper width 120 mm, bottom width 90 mm, content 1000 ml) capped with a bottomless click-beetle trap. The caps held glass vials (6.5 ml) containing the bait fluid. The jars were inserted in the ground and were filled with water to 1/3 of their volume. The above-ground parts of the traps (click-beetle traps) were white in colour. To enter a trap, insects had to climb along the inclined plane to the top of the trap (Figures 1 and 2). For comparison, Swedish pitfall traps described in Nordlander (1997) were also used in 1993-1995. For *Hylobius abietis*, these two types of traps showed no significant differences in trapping results (Voolma 2000).

A blend of commercial turpentine (containing 73 % alpha-pinene) produced by AS Flora, Estonia, and ethanol (1:5) were mainly used as the bait in the traps. For comparison, alpha-pinene and ethanol in separate vials were also used in 1993-1995. The traps were checked mostly once a week. At each inspection the insects were collected and the baits were renewed. Catches were carried out mostly from late April (early May) to September, in 1997 during May-June. Collected insects were identified and counted in the laboratory.

RESULTS

A total of 54 951 individuals of forest insects were caught during the ten-year study period. Among them were 37 655 individuals of *Hylobius abietis,* 285 individuals of *H. pinastri* (Gyllenhal, 1813), 12 960 individuals of Scolytidae of 18 species and 4051 individuals of other insects (mainly Coleoptera, 147 taxons). The percentages of all trapped insect individuals were the following: *Hylobius abietis*, 68.5 %, *H. pinastri,* 0.5 %, bark beetles of the genus *Hylastes*, 20.6 %, other Scolytidae, 3.0 %, and all other insect species, 7.4 %. A list of insect species caught with traps on the clear-cuttings and their total numbers are presented in Table 1.

DISCUSSION

The traps used for monitoring *Hylobius abietis* had a relatively weak effect on non-target insects: besides pine weevils (*H. abietis, H. pinastri*) and bark beetles (Scolytidae), only 7 % individuals of other insect species were caught. Compared with Estonian traps, Swedish traps trapped more large ground beetles (Carabidae) and particularly the dung beetles *Geotrupes stercorosus* (Scriba, 1791). A disadvantage of Swedish traps is that during heavy rain dirty water from the ground surface can flow into traps through the holes situated at the ground level, while Estonian traps remain clean (Voolma 2000).

To a certain extent, trapping method enables to assess species richness of forest insects on clear-

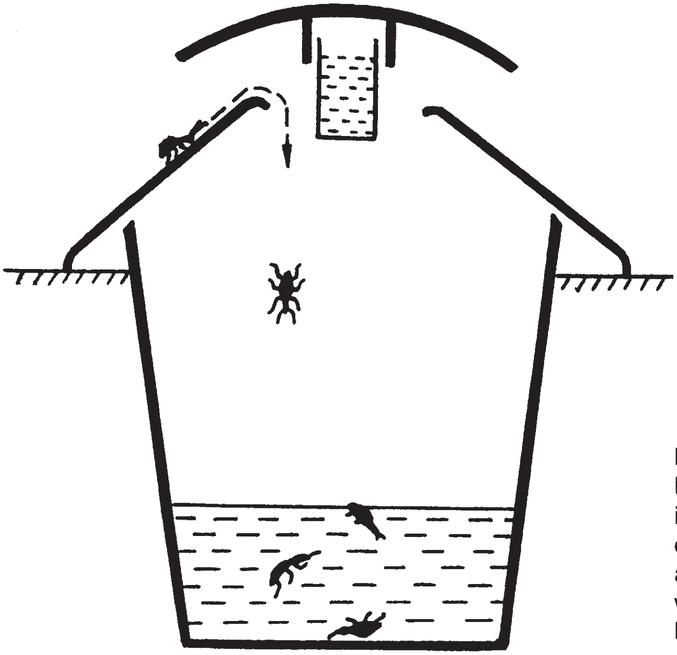

Figure 1. Principled scheme of the Estonian ground trap used for monitoring *Hylobius abietis.* The trap consists of a plastic jar inserted in the ground, and of an above-ground part (cap) which held a glass vial containing the bait fluid.

Figure 2. An Estonian ground trap set out on a clear-cutting for monitoring *Hylobius abietis*. The above-ground part of the trap, which covers a jar inserted in the ground, is visible only. Photo: K. Voolma.

Table 1. A list of insect families, more abundant species (within a family) and numbers of specimens caught with the baited ground traps on pine clear-cuttings in the forest district of Räpina, Estonia, in 1990-1999. Nomenclature follows Silfverberg (1992).

Species	Total number of specimens		%	%
COLEOPTERA				
Carabidae	**444**		**0.81**	
Carabus arvensis Herbst, 1784		11		0.02
Carabus hortensis Linnaeus, 1758		16		0.03
Cicindela sylvatica Linnaeus, 1758		23		0.04
Pterostichus lepidus (Leske, 1785)		16		0.03
Pterostichus cupreus (Linnaeus, 1758)		23		0.04
Pterostichus versicolor (Sturm, 1824)		60		0.11
Pterostichus aethiops (Panzer, 1797)		10		0.02
Pterostichus oblongopunctatus (Fabricius, 1787)		147		0.27
Calathus erratus (Sahlberg, 1827)		42		0.08
Amara sp. (8 species)		16		0.03
Other (22 species)		80		0.15
Dytiscidae	**1**		**0.00**	
Hydroporus sp.		1		0.00
Silphidae	**7**		**0.01**	
Nicrophorus vespillo (Linnaeus, 1758)		4		0.01
Other (2 species)		3		0.01
Cholevidae	**1**		**0.00**	
Catops sp.		1		0.00
Scydmaenidae	**2**		**0.00**	
Unidentified		2		0.00
Staphylinidae	**35**		**0.06**	
Staphylinus sp.		8		0.01
Other (>3 species)		27		0.05
Histeridae	**6**		**0.01**	
Plegaderus saucius Erichson, 1834		1		0.00
Platysoma angustatum (Hoffmann, 1803)		5		0.01
Scarabaeidae	**161**		**0.29**	
Geotrupes stercorosus (Scriba, 1791)		144		0.26
Geotrupes vernalis (Linnaeus, 1758)		14		0.03
Other (3 species)		3		0.01
Lycidae	**1**		**0.00**	
Pyropterus nigroruber (DeGeer, 1774)		1		0.00
Cantharidae	**7**		**0.01**	
Cantharis obscura Linnaeus, 1758		7		0.01
Elateridae	**89**		**0.16**	
Athous subfuscus (Müller, 1764)		46		0.08
Agriotes obscurus (Linnaeus, 1758)		10		0.02
Dalopius marginatus (Linnaeus, 1758)		21		0.04
Other (6 species)		12		0.02
Throscidae	**8**		**0.01**	
Trixagus sp. (2 species)		8		0.01

Table 1. Continued.

Species	**Total number of specimens**		**%**	**%**
Byrrhidae	**6**		**0.01**	
Cytilus sericeus (Forster, 1771)		1		0.00
Byrrhus sp.		5		0.01
Anobiidae	**2**		**0.00**	
Ernobius nigrinus (Sturm, 1837)		2		0.00
Lymexylidae	**1**		**0.00**	
Hylecoetus dermestoides (Linnaeus, 1761)		1		0.00
Cleridae	**41**		**0.07**	
Thanasimus formicarius (Linnaeus, 1758)		41		0.07
Melyridae	**17**		**0.03**	
Dasytes niger (Linnaeus, 1761)		15		0.03
Other (2 species)		2		0.00
Nitidulidae	**1353**		**2.46**	
Epuraea sp.		1026		1.87
Glischrochilus hortensis (Geoffroy, 1785)		39		0.07
Glischrochilus quadripunctatus (Linnaeus, 1758)		13		0.02
Pityophagus ferrugineus (Linnaeus, 1761)		273		0.50
Other (2 species)		2		0.00
Rhizophagidae	**58**		**0.11**	
Rhizophagus depressus (Fabricius, 1792)		31		0.06
Rhizophagus ferrugineus (Paykull, 1800)		25		0.05
Rhizophagus dispar (Paykull, 1800)		2		0.00
Cryptophagidae	**7**		**0.01**	
Unidentified		7		0.01
Coccinellidae	**67**		**0.12**	
Coccinella septempunctata Linnaeus, 1758		63		0.11
Other (3 species)		4		0.01
Latridiidae	**4**		**0.01**	
Corticaria sp.		4		0.01
Byturidae	**1**		**0.00**	
Byturus tomentosus (DeGeer, 1774)		1		0.00
Cisidae	**1**		**0.00**	
Unidentified		1		0.00
Oedemeridae	**34**		**0.06**	
Oedemera virescens (Linnaeus, 1767)		16		0.03
Other (3 species)		18		0.03
Aderidae	**4**		**0.01**	
Anidorus nigrinus (Germar, 1831)		4		0.01
Anthicidae	**40**		**0.07**	
Notoxus monoceros (Linnaeus, 1761)		1		0.00
Anthicus ater (Panzer, 1796)		39		0.07
Tenebrionidae	**13**		**0.02**	
Uloma rufa (Piller & Mitterpacher, 1783)		1		0.00
Lagria hirta (Linnaeus, 1758)		12		0.02

Table 1. Continued.

Species	Total number of specimens		%	%
Scraptiidae	**1**		**0.00**	
Anaspis frontalis (Linnaeus, 1758)		1		0.00
Mordellidae	**1**		**0.00**	
Mordellistena sp.		1		0.00
Cerambycidae	**451**		**0.82**	
Spondylis buprestoides (Linnaeus, 1758)		83		0.15
Asemum striatum (Linnaeus, 1758)		205		0.37
Rhagium inquisitor (Linnaeus, 1758)		51		0.09
Acanthocinus aedilis (Linnaeus, 1758)		84		0.15
Other (7 species)		28		0.05
Chrysomelidae	**47**		**0.09**	
Altica sp.		31		0.06
Other (8 species)		16		0.03
Anthribidae	**2**		**0.00**	
Platystomos albinus (Linnaeus, 1758)		1		0.00
Anthribus nebulosus Forster, 1771		1		0.00
Apionidae	**1**		**0.00**	
Apion cruentatum Walton, 1844		1		0.00
Curculionidae	**38196**		**69.51**	
Otiorhynhcus nodosus (Müller, 1764)		12		0.02
Otiorhynchus scaber (Linnaeus, 1758)		14		0.03
Brachyderes incanus (Linnaeus, 1758)		17		0.03
Strophosoma capitatum (DeGeer, 1775)		178		0.32
Hylobius abietis (Linnaeus, 1758)		37655		68.52
Hylobius pinastri (Gyllenhal, 1813)		285		0.52
Other (15 species)		35		0.06
Scolytidae	**12960**		**23.58**	
Hylurgops palliatus (Gyllenhal, 1813)		273		0.50
Hylastes brunneus Erichson, 1836		7915		14.40
Hylastes cunicularius Erichson, 1836		289		0.53
Hylastes opacus Erichson, 1836		3127		5.69
Hylurgus ligniperda (Fabricius, 1787)		8		0.01
Tomicus piniperda (Linnaeus, 1758)		25		0.05
Orthotomicus proximus (Eichhoff, 1868)		15		0.03
Orthotomicus suturalis (Gyllenhal, 1827)		643		1.17
Orthotomicus laricis (Fabricius, 1792)		53		0.10
Dryocoetes autographus (Ratzeburg, 1837)		535		0.97
Dryocoetes hectographus Reitter, 1913		53		0.10
Trypodendron lineatum (Olivier, 1795)		10		0.02
Other (6 species)		14		0.03
Insects other than Coleoptera	**881**		**1.60**	
HETEROPTERA		**225**		**0.41**
HYMENOPTERA		**553**		**1.01**
Other Orders		103		0.19
Total	**54951**	**54951**	**100.00**	**100.00**

cuttings. The list of non-target insects caught in a pine forest area in South Estonia is quite long (Table 1) compared with those presented from an analogous study conducted in Central Europe (Zumr & Stary 1991). Several rare or relatively scarce species were caught with traps on clear-cuttings: *Carabus nitens* Linnaeus, 1758, *C. violaceus* Linnaeus, 1758, *Plegaderus saucius* Erichson, 1834, *Geotrupes vernalis* (Linnaeus, 1758), *Platycerus caprea* (DeGeer, 1774), *Ernobius nigrinus* (Sturm, 1837), *Coniocleonus hollbergi* (Fåhraeus, 1842), *Hylurgus ligniperda* (Fabricius, 1787), etc. Some of them are among the red-listed species in Sweden and other countries (Gärdenfors 2000). This indicates that the level of species richness is quite high in spite of current intensive forest management practices. However, the felling volume and area have rapidly increased during recent years, which may present threat for some insect species in the future.

Acknowledgements. Many thanks due to Dr. Åke Lindelöw, Swedish University of Agricultural Sciences, for providing the Swedish pitfall traps, to Mrs Sirje Tullus for drawing the traps and to Mrs Ester Jaigma for linguistic help. The study was partly supported by the grant No. 2684 from the Estonian Science Foundation.

REFERENCES

Fettig, C.J. & Salom, S.M. 1998. Comparisons of two trapping methods for *Hylobius pales* (Coleoptera: Curculionidae) in Virginia. *Environ. Entomol.* 27 (3): 572-577.

Gärdenfors, U. (Ed.). 2000. Rödlistade arter i Sverige 2000. The 2000 Red List of Swedish species. ArtDatabanken, SLU. Uppsala.

Hunt, D.W.A. & Raffa, K.F. 1989. Attraction of *Hylobius radicis* and *Pachylobius picivorus* (Coleoptera: Curculionidae) to ethanol and turpentine in pitfall traps. Environ. Entomol. 18 (3), 351-355.

Kudryavtsev, I., Siirde, K., Lääts, K., Ismailov, V. & Pristavko, V. 1993. Specification of areas of harmful click beetle species (Coleoptera, Elateridae) by synthetic sex pheromones. J. Chem. Ecol. 19 (8), 1607-1611.

Lindelöw, Å., Eidmann, H.H. & Nordenhem, H. 1993. Response on the ground of bark beetle and weevil species colonizing conifer stumps and roots to terpenes and ethanol. J. Chem. Ecol. 19 (7), 1393-1403.

Nordlander, G. 1987. A method for trapping *Hylobius abietis* (L.) with a standardized bait and its potential for forecasting seedling damage. Scand. J. For. Res. 2, 119-213.

Raffa, K. & Hunt, D.W.A. 1988. Use of baited pitfall traps for monitoring pales weevil, *Hylobius pales* (Coleoptera: Curculionidae). Great Lakes Entomol. 21 (3), 123-125.

Rieske, L.K. & Raffa, K.F. 1993. Potential use of baited pitfall traps in monitoring pine root weevil, *Hylobius pales, Pachylobius picivorus,* and *Hylobius radicis* (Coleoptera, Curculionidae) populations and infestation levels. J. Econ. Entomol. 86 (2), 475-485.

Rieske, L.K. & Raffa, K.F. 1999. Baited pitfall traps and evaluation of dispensing methods for root weevils (Coleoptera, Curculionidae) in newly established pine plantations in Wisconsin. J. Econ. Entomol. 92 (2), 439-444.

Silfverberg, H. 1992. Enumeratio Coleopterorum Fennoscandiae, Daniae et Baltiae. 94 pp. Helsingin Hyönteisvaihtoyhdistus, Helsinki.

Tilles, D.A., Sjödin, K., Nordlander, G. & Eidmann, H.H. 1986. Synergism between ethanol and conifer host volatiles as attractants for the pine weevil *Hylobius abietis* (L.) (Coleoptera: Curculionidae). J. Econ. Entomol. 79, 970-974.

Tunset, K., Nilssen, A.C. & Andersen, J. 1993. Primary attraction in host recognition of coniferous bark beetles and bark weevils (Col., Scolytidae and Curculionidae). J. Appl. Entomol. 115, 155-169.

Voolma, K. 1994. Use of baited ground traps for monitoring pine weevil, *Hylobius abietis,* and root-colonizing bark beetles. Metsanduslikud Uurimused 26, 96-109 (in Estonian with English summary).

Voolma, K. 1995. Monitoring stump- and root-colonizing weevils and bark beetles (Coleoptera: Curculionidae and Scolytidae) in clear-cuttings. Pp. 97-98 in Caring for the Forest: Research in a Changing World. Poster Abstracts. IUFRO XX World Congress 6-12 August 1995, Tampere.

Voolma, K. 1998. Bark beetle assemblages (Coleoptera, Scolytidae) in pine clearcuttings: changes in the species composition and abundance during the first four years after final felling. SkogForsk. The Forestry Research Institute of Sweden. Report, 1, 147.

Voolma, K. 2000. Comparison of two traps used for monitoring large pine weevil populations, *Hylobius abietis* L. (Coleoptera: Curculionidae). Trans-actions of the Estonian Agricultural University 209, 233-235.

Zumr, V. & Stary, P. 1991. Effects of baited pitfall traps (*Hylobius abietis* L.) on non-target forest insects. J. Appl. Entomol. 112 (5), 525-530.

Zumr, V. & Stary, P. 1993. Baited pitfall and flight traps in monitoring *Hylobius abietis* (L.) (Col., Curculionidae). J. Appl. Entomol. 115, 454-461.

Received 30 June 2000,
accepted 15 March 2001.

Norw. J. Entomol. 48, 111–114. 2001

On the structure of alvar mesofauna on the Island of Saaremaa, Estonia

Mati Martin & Kaupo Elberg

Martin, M. & Elberg, K. 2001. On the structure of alvar mesofauna on the Island of Saaremaa, Estonia. Norw. J. Entomol. 48, 111-114.

The report treats the terrestrial mesofauna of alvars (on limestone ground) on the Island of Saaremaa, Estonia. The material was collected as entomological sieve and net samples. Gastropoda, Isopoda, Myriopoda, Arachnida have dominating systematic groups, as well as several orders of Insecta.

Key words: mesofauna, alvar, Island of Saaremaa, Estonia

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INTRODUCTION

In North Europe, Estonia is the second distribution area of alvars after Sweden. In Estonia, alvars occur in the western archipelago, especially on the Island of Saaremaa, and in the western and northern parts of the mainland. Alvars are characterised by a thin humus layer and mostly very low and sparse plant cover on limestone. Due to such conditions and dryness in the summer period, alvars are an extreme habitat for terrestrial invertebrates.

Our research is greatly influenced by similar research carried out on the Great Alvar on the Island of Öland in Sweden in 1977-1979 (Sylvén 1983, Coulianos & Sylvén 1983). It is important to add, that compared to the Great Alvar, the area of alvars in Estonia is smaller. They are situated like spots separated by areas with different vegetation. Their mesofauna is probably influenced by those neighbouring biotopes.

The alvars in Estonia are becoming overgrown with trees, mainly with pines. However, the alvars in western Saaremaa have mostly remained unchanged: they have maintained their original state – open areas or with sparse juniper shrubs.

The first task of our research is to establish the structure of the large groups (classes and orders) of the mesofauna of different types of alvars on the Island of Saaremaa.

MATERIAL AND METHODS

Investigation of the terrestrial mesofauna was carried out in three alvar areas in western Saaremaa: Kaugatuma, Karala and Undva (Figure 1). The material was collected during seven 4-5 day periods of field study between the end of April and the end of August 1998 and 1999. Quantitative samples (47 entomological sieve samples á 1 m^2 and 77 sweep-net samples á 100 strokes) were collected from typical dry alvar localities and from depressions in the alvar landscape, which are periodically moist or filled with water. Sieve samples all together contained over 2300 specimens and sweep-net samples about 7100 specimens of invertebrates.

LOCALITIES

The Undva sample locality is situated on the Tagamõisa peninsula, on the territory of a late Russian military base, and therefore showing signs of hu-

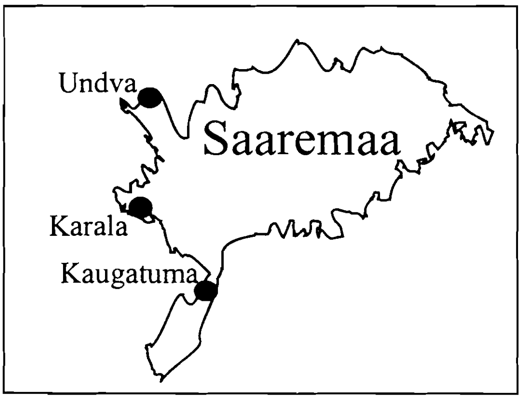

Figure 1. Location of the sample sites.

man influence. The dry sample site is in sparse juniper shrubs. The plant cover is very low and sparse. In summer, numerous plants are flowering, predominantly species of *Centaurea* and *Senecio*. The ground is partly covered with lichens. The moist sample site, *Carex* meadow, is flooded in spring.

The Karala sample locality is situated about 400 m from the seashore and covered with sparse *Juniperetum* (2-5 m high), protecting the habitat from the sea winds. The humus layer is thicker and the plant cover is lusher than at Undva. The moist sample site is mainly covered with *Carex* species,

Table 1. Numbers by collecting sites and dominance (% of totals) of invertebrates in sieve samples from alvars in western Saaremaa.

Group	Dry sites					Moist sites					Total number in all sites
	Karala	Kauga-tuma	Undva	Total	% of total	Karala	Kauga-tuma	Undva	Total	% of total	
Gastropoda	207	68	16	291	20.8	27	318	11	356	38.2	**647**
Isopoda	211	4	15	230	16.5	202	11	8	221	23.7	**451**
Coleoptera	211	43	36	290	20.7	33	53	17	103	11.8	**393**
Aranei	106	22	55	183	13.1	34	77	16	127	13.6	**310**
Dermaptera	85	0	34	119	8.5	3	0	4	7	0.8	**126**
Chilopoda	24	25	39	88	6.3	0	2	3	5	0.5	**93**
Diplopoda	9	2	48	59	4.2	22	1	7	30	3.2	**89**
Lepidoptera	30	2	10	42	3.0	6	4	3	13	1.4	**55**
Hemiptera	12	13	8	33	2.4	4	0	11	15	1.6	**48**
Cicadinea	0	4	10	14	1.0	1	2	13	16	1.7	**30**
Diptera	7	1	6	14	1.0	10	3	1	14	1.5	**28**
Hymenoptera	5	2	6	13	0.9	2	0	2	4	0.4	**17**
Oligochaeta	3	2	2	7	0.5	7	1	2	9	1.0	**17**
Acarina	7	3	2	12	0.9	3	0	1	4	0.4	**16**
Trichoptera	0	0	0	0	0.0	0	5	0	5	0.5	**5**
Opiliones	0	0	1	1	<0.1	0	1	0	1	0.1	**2**
Psyllinea	0	0	1	1	<0.1	0	0	0	0	0.0	**1**
Nematomorpha	1	0	0	1	<0.1	0	0	0	0	0.0	**1**
Thysanura	0	0	0	0	0.0	0	1	0	0	0.0	**1**
Total	**918**	**191**	**289**	**1398**		**354**	**479**	**99**	**932**		**2330**

Table 2. Numbers by collecting sites and dominance (% of totals) of invertebrates in sweep-net samples from alvars in western Saaremaa.

Group	**Dry sites**					**Moist sites**					**Total number in all sites**
	Karala	**Kaugatuma**	**Undva**	**Total**	**% of total**	**Karala**	**Kaugatuma**	**Undva**	**Total**	**% of total**	
Diptera	932	285	552	1769	46.5	604	271	369	1244	37.2	**3013**
Aranei	621	169	345	1135	29.9	458	215	226	899	26.9	**2034**
Orthoptera	29	39	17	85	2.2	57	40	283	380	11.4	**465**
Hemiptera	66	56	60	182	4.8	61	51	139	251	7.5	**433**
Hymenoptera	181	13	71	265	7.0	56	8	56	120	3.6	**385**
Cicadinea	28	65	57	150	3.9	57	54	121	232	6.9	**382**
Coleoptera	112	19	34	165	4.3	86	17	29	132	3.9	**297**
Lepidoptera	21	4	15	40	1.1	35	10	18	63	1.9	**103**
Dermaptera	1	0	1	2	<0.1	9	0	0	9	0.3	**11**
Trichoptera	0	0	3	3	<0.1	0	5	0	5	0.1	**8**
Odonata	3	0	0	3	<0.1	3	0	0	3	<0.1	**6**
Planipennia	1	0	1	2	<0.1	2	1	1	4	0.1	**6**
Isopoda	0	0	0	0	0.0	0	0	2	2	<0.1	**2**
Mecoptera	0	0	0	0	0.0	1	0	0	1	<0.1	**1**
Total	**1995**	**650**	**1156**	**3801**		**1429**	**672**	**1244**	**3345**		**7146**

Graminea and *Inula salicina*.

The Kaugatuma sample locality situated on the Sõrve peninsula about 500 m from the seashore is open to winds, almost without *Juniperus* bushes and characterised by very scanty grass layer. Limestone is partly covered with lichens but in some places it is without any plants. The moist part is covered with thick *Caricetum* and flooded in spring. The Kaugatuma alvar is least influenced by human activity.

RESULTS AND DISCUSSION

The diversity of alvar mesofauna depends on several factors, such as locality, humidity conditions, thickness of the vegetable mould, openness to winds and the diversity of vegetation. The number of invertebrates and the dominance of their systematic groups in sieve and sweep-net samples by the collecting sites are given in Tables 1 and 2.

Ants in sieve samples were not considered as a comparable component of the analyses, although they were numerous in the investigated alvars. On some occasions it was necessary to change the sample place because there were 1-3 ant nests in á 1 m^2 area. Nevertheless, a total of 877 ants were captured. In particular, many ants were collected in the Karala sample locality (with thick humus layer), 493 specimens in its dry and 133 in its humid part. Respective numbers for Undva were 136 and 34, and for Kaugatuma (partly with limestone plates) 74 and 7 specimens.

Sieve sample analyses

In sieve samples the following groups in relation to the total number of specimens predominated: Gastropoda 27.8 %, Isopoda 19.3 %, Coleoptera 16.9 %, Aranei 13.3 %, Dermaptera 5.4 %, Chilopoda 3.9 %, Diplopoda 3.8 %, Lepidoptera 2.4 %. The other groups were represented more scantily. Among the captured Coleoptera, adults made up 82 % and larvae 18 %. The average number of specimens per sieve sample from dry collecting sites was 58.2 and from moist sites 38.9.

Sweep-net sample analyses

Sweep-net samples mainly consisted of Diptera 42.7 %, Aranei 28.0 %, Orthoptera 6.5 %, Hemiptera 5.8 %, Hymenoptera 5.4 %, Cicadinea 5.3 %, and Coleoptera 4.2 %. The average number of specimens per sweep-net sample from dry collecting sites was 103.1 and moist sites 93.2.

REFERENCES

Coulianos, C.-C. & Sylvén, E. 1983. Stora alvarets särart ur entomologisk synpunkt. Ent. Tidskr. 104, 213-234.

Sylvén, E. 1983. Studier över insekts- och spindelfaunan på Ölands Stora alvar – bakgrund, målsättning och uppläggning. Ent. Tidskr. 104, 90-95.

Received 15 September 2000,
accepted 30 October 2000.

Norw. J. Entomol. 48, 115–120. 2001

The effect of application by *Bacillus thuringiensis* var. *israelensis* (H14) on bloodsucking blackflies (Diptera, Simuliidae) in Lithuania

Rasa Bernotiene

Bernotiene, R. 2001. The effect of application by *Bacillus thuringiensis* var. *israelensis* (H14) on bloodsucking blackflies (Diptera, Simuliidae) in Lithuania. Norw. J. Entomol. 48, 115-120.

Bloodsucking blackflies (Simuliidae) have become very abundant in the south-eastern part of Lithuania since the middle of the 1980's. There are 20 species of blackflies recorded from Lithuania and three of them are confirmed being bloodsuckers: *Odagmia ornata* (Meigen, 1818), *Simulium reptans* (L., 1758), and *Byssodon maculatus* (Meigen, 1804). The last one is the most pestiferous species. The larvae of *B. maculatus* are abundant in the Nemunas River from the Belorussian - Lithuanian border to Kaunas water reservoir. Two microbiological preparations based on *Bacillus thuringiensis var. israelensis* (H14) were used. The biopreparation Baktokulicid was sprayed in the Nemunas River in one locality in 1998. The effect of *B. thuringiensis* var. *israelensis* on blackfly larvae was determined in the river 11 km downstream from the place of application. Only few imagines of *B. maculatus* were observed in the locality at a distance of 7 km downstream from the place of application after one week. The biopreparation VectoBac 12AS was sprayed in the middle reaches of the Nemunas River in 1999. A river segment of 90 km was treated. Blackfly larvae were affected by *B. thuringiensis* var. *israelensis* in the whole river segment applied and 96 km downstream. The mortality of blackfly larvae was 99.8±0.8 %. The biopreparation had no significant effect on macrobenthos in the Nemunas River. *B. maculatus* bites from the middle of May to early July in Lithuania. In 1999, it started to attack people from 10 June. The abundance of attacking blackflies correlated with the distance from the investigated localities to the untreated segment of the Nemunas River (in Belarus).

Key words: Simuliidae, Lithuania, pest control, *Bacillus thuringiensis*.

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INTRODUCTION

Bloodsucking blackflies (Diptera, Simuliidae) have become very abundant in the south-eastern part of Lithuania since the middle of the 1980's. The high abundance of bloodsucking blackflies causes problems to people in one of the largest health-resort of Lithuania – Druskininkai. An addition, the bloodsuckers have done much damage to agriculture causing deaths of cattle and domestic birds.

In spite of the fact that the invasions of bloodsucking blackflies were observed in Lithuania earlier: in 1941-1942 in the North of Lithuania (Milaknis 1942), in 1980-1983 (Jakimavicius 1982), only two species of blackflies were known in Lithuania till 1967: *Simulium ornatum* (*Odagmia ornata*) (Lesinskas & Pileckis 1967) and «*Simulium maculatum* s. *columbaczense*» (Milaknis 1942, Sivickis 1959).

The biopreparations, based on *Bacillus thuringiensis* var. *israelensis* (H14), have been used against blackfly larvae first time in Lithuania. The objective of this investigation was to determine the effect of *B. thuringiensis* var. *israelensis* (H14) on blackflies in the Nemunas River in Lithuania.

MATERIAL AND METHODS

Investigations on blackflies were started in 1995 in Lithuania. The extermination of bloodsucking blackflies with biological preparations was started in 1998. Two microbiological preparations: Baktokulicid and VectoBac 12AS were used. The effect of preparations is based on the effect of entomopathogenic bacterium *B. thuringiensis* var. *israelensis* (H14) and toxic protein produced by it. *B. thuringiensis* are found in natural environment. Biopreparations were sprayed in the Nemunas River. The source of the Nemunas River is in Belarus. It is 937 km in length, of which 465 km are in Lithuania.

The time of application was recommended as the time when bloodsucking species of blackflies made up about 70% of the blackflies community in the river, and the II-III larvae instars dominated. The effect of the bacteria on the first instar larvae is very low, since the first instars are not water filteres (Ross & Craig 1979) and it is difficult for them to catch and to eat entomopathogenic bacteria. The bacteria has no effect on eggs.

The biopreparation Baktokulicid was sprayed in the Nemunas River from the banks in one locality in 1998. A larger amount of biopreparation VectoBac 12AS was sprayed from the boat in the middle reaches of the Nemunas River in 1999. The application was started in the territory of Belarus 22 km from the border of Lithuania and was finished in the territory of Lithuania 68 km downstream the border (a segment of 90 km of the Nemunas River was treated) in 1999 (Figure 1).

Larvae and pupae of blackflies were collected from the leaves of water plants (*Glyceria maxima* (Hartman), Poaceae) before and 2, 5 and 10 days after the application. Abundance of larvae was calculated per 1 dm^2 of leaf surface. Macrobenthos was collected from 8 dm^2 of the bottom area before and in 5 days after the application. Investigations were carried out in 8 different localities in the Nemunas River. To compare the abundance of macrobenthos before and after the application, nonparametric Mann – Whitney U- test was used.

The imagines of bloodsucking blackflies were collected using exhauster from the same person in 10 min. period. Two or three samples were taken. The abundance of bloodsucking imagines in different localities was investigated every 5-6 days from May to July.

RESULTS AND DISSCUSION

Bloodsucking species

Twenty species of blackflies are known in Lithuania (Sprangauskaite 1998, Pakalniskis et al. 2000): *Greniera dogieli* (Rubzov, 1961), *Byssodon maculatus* (Meigen, 1804), *Cnetha latipes* (Meigen, 1804), *Nevermania latigonia* (Rubzov, 1956), *N. lundstromi* Enderlein, 1921, *Eusimulium aureum* (Fries, 1824), *Schoenbaueria nigra* (Meigen, 1804) (the first record for Lithuania), *S. pusilla* (Fries, 1824) (the first record for Lithuania). *Wilhelmia balcanica* Enderlein, 1924, *W. equina* (Linnaeus, 1758), *Boophthora erythrocephala* (De Geer, 1776), *Odagmia nitidifrons* (Edwards, 1920), *O. ornata* (Meigen, 1818), *O. pratorum* (Friederichs, 1921), *Simulium (Simulium) austeni* Edwards, 1915, *S. (S.) curvistylum* Rubzov, 1957, *S. (S.) reptans* (L., 1758), *S. (S.) morsitans* Edwards, 1915, *S. (S.) paramorsitans* Rubzov, 1956, *S. (S.) promorsitans* Rubzov, 1956.

Three of the species were found to be bloodsuckers on human and cattle. *Odagmia ornata* is a common species and can be found in many rivers of Lithuania. Bloodsucking *O. ornata* was registered in April in several localities near improved small rivers, where its larvae had developed.

The second bloodsucking species are *Simulium reptans*. Its larvae have been found in seven Lithuanian rivers. The species has one generation per year (May-July) (Sprangauskaite 1998). Bloodsucking imagines of *S. reptans* have been found close to the river, the place of their development.

Byssodon maculatus is the most pestiferous species. The larvae is found only in the two largest rivers of Lithuania; the Nemunas and the Neris. *B. maculatus* has two generations per year (May-June and August-September). The second generation is considerably less abundant than the first one. On the other hand, the second generation has not been observed every year. Imagines of *B. maculatus* can fly long distances from the river in

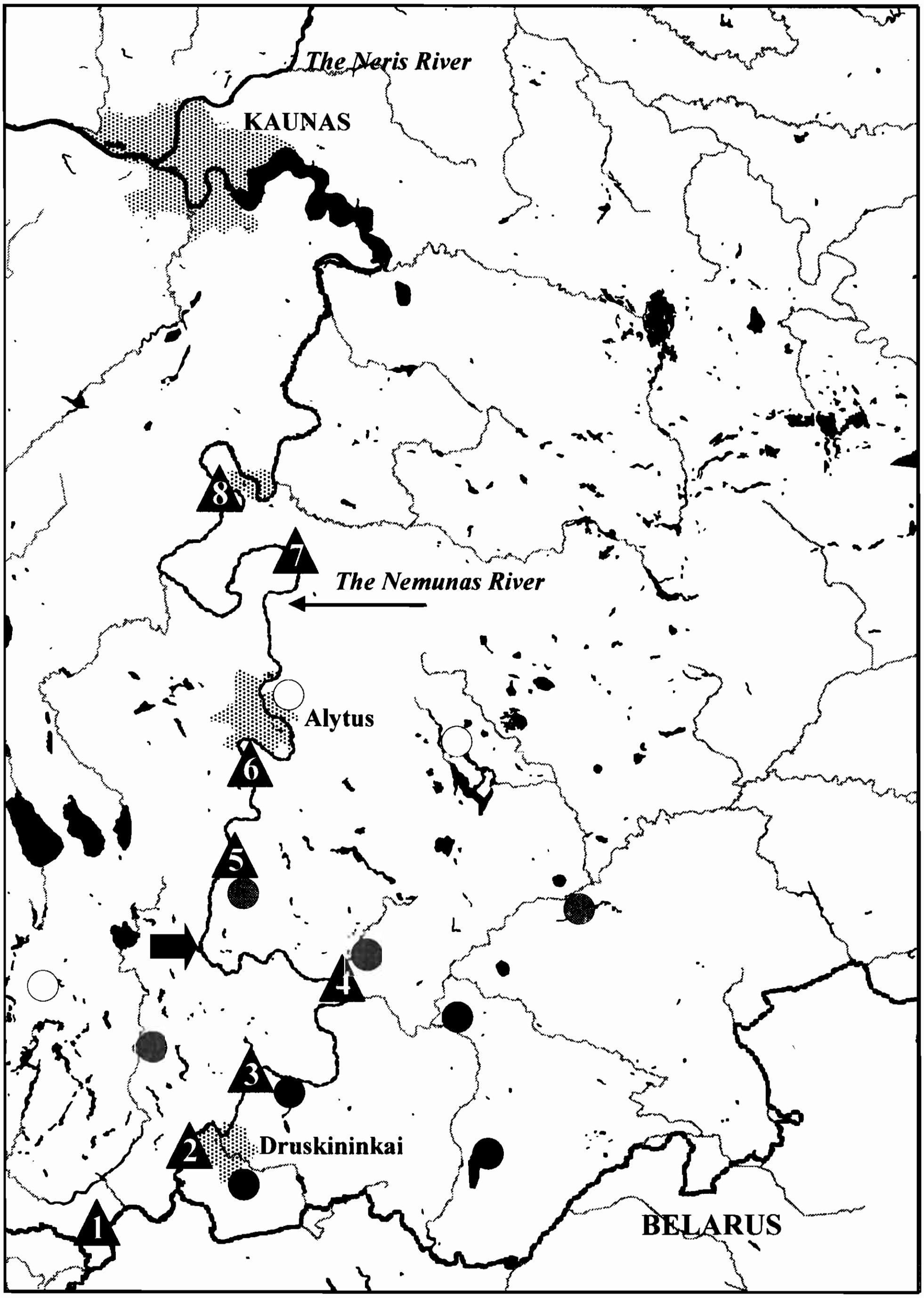

Figure 1. Map of the middle area of the Nemunas River in Lithuania. The study sites for blackfly larvae (May 1999) are numbered 1 to 8 from upstream. The black arrow shows the last point of application by the biopreparation. Localities in which bloodsucking blackflies appeared before 10 June 1999 are marked with black circles, from 10 to 15 June with grey circles and after 15 June with white circles. The abundance of bloodsucking imagines was investigated every 5-6 days from May to July.

Table 1. The effect of the biopreparation Baktokulicid on blackfly larvae in the Nemunas River in 1998. The application was made in one place of the river.

Distance (km) from the place of application	**Mortality of blackfly larvae %**	
	5 days after the application	10 days after the application
0.1	95.7	97
2	69.7	99.98
11	21.0	49.8
19	1.2	2.3

Table 2. The effect of the biopreparation VectoBac 12AS on blackfly larvae in the Nemunas River in 1999. A river segment of 68 km was treated in the territory of Lithuania.

	Distance (km) from		Abundance of larvae on 1 dm² before application Mean±SD	Mortality of blackflies larvae %	
Study sites	Byelorussian – Lithuanian border	last point of application		2 days after application	5 days after application
1	16	52	483±21.2	90.8	97.9
2	24	44	1369±121.3	99.2	99.9
3	31	37	939±57.4	99.8	100
4	49	19	1044±132.1	99.5	99.9
	68	0			
5	81	13	460±54.2	99.3	99.9
6	94	26	135±42.3	99.2	100
7	124	56	331±78.9	91.4	100
8	164	96	889±184.8	13.9	98.6

which they have developed and can be found at the distance of 50-70 km from the Nemunas or the Neris River. For this reason they are abundant in the whole southern part of Lithuania.

Great numbers of blackfly larvae are found in the 150 km segment of the Nemunas River from Belorussian - Lithuanian border to Kaunas water reservoir. The number of blackfly larvae is quite small in the river segment from Kaunas to the Baltic sea (6.4±3 larvae/dm^2). The abundance of the larvae in the Neris was rather less than in the Nemunas (124±84 larvae/dm^2 in the Neris and 831.1±616 larvae/dm^2 in the investigated segment of the Nemunas in first ten-day period of May). Imagines did not cause trouble to the local population around the Neris River. The abundance of blackfly larvae in the Nemunas was not investigated in the territory of Belarus.

Effect of *B. thuringiensis* var. *israelensis* on blackflies

In 1998, the effect of *Bacillus thuringiensis* var. *israelensis* on blackfly larvae was determined in the river segment of 11 km downstream from the point of the application. The mortality of the larvae varied from 49.8 % to 99.98 % (Table 1). Imagines of *B. maculatus* were observed from 25 May in 1998 in Lithuania. Only few imagines of *B. maculatus* were observed in Druskininkai (the locality at a distance of 7 km downstream from the point of application) since 10 June. Later the number of bloodsucking blackflies became similar in the entire investigated region (Figure 2).

The effect of *B. thuringiensis* var. *israelensis* on blackfly larvae was established in the entire applied river segment and 96 km downstream from

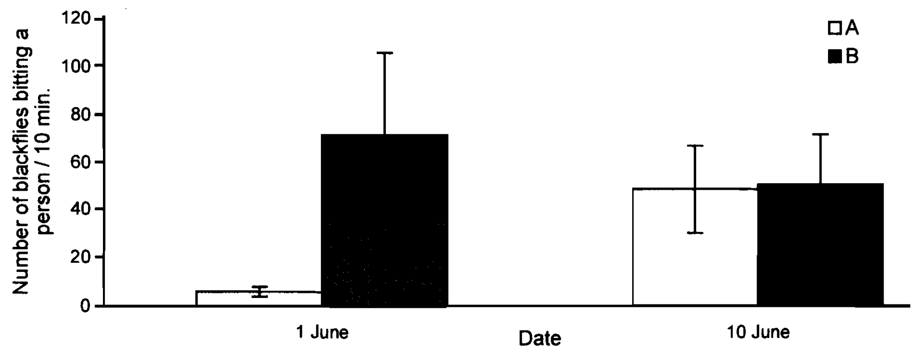

Figure 2. The number of blackflies *B. maculatus* biting one person per 10 min. after the application by the biopreparation Baktokulicid in 1998. A. 7 km from the place of application, B. 33 km from the place of application. Imagines of *B. maculatus* were observed from 25 May in 1998 in Lithuania.

Table 3. The difference in amount of macrobenthos before and after the application in the Nemunas River in 1999. The abundance of blackflies in 1 dm^2 of water plants leaf surface, the abundance of other groups in 8 dm^2 of bottom area. P; value of Mann -Whitney test.

Hydrobionts	Abundance (mean±SD) before application	Abundance (mean±SD) after application	P<	Difference
Hirudinea	3.88±1.5	2.63±1.3	0.7984	n.s.
Mollusca	8±2.5	12±4	0.1949	n.s.
Crustacea	2.88±1.1	5.38±3.4	0.4418	n.s.
Trichoptera	1.63±0.9	2.25±1.2	0.2786	n.s.
Ephemeroptera	1.25±0.9	1.13±0.7	0.8785	n.s.
Odonata	0.63±0.4	0.13±0.1	0.5054	n.s.
Chironomidae	39.1±8.7	29.8±9.8	0.3823	n.s.
Simuliidae	831.1±616	10.6±8.7	0.001	sign.

the last point of the application in 1999. The mortality of blackfly larvae was 99.8±0.8% five days after the application in the whole investigated segment of the river (Table 2). Later the amount of *B. maculatus* larvae increased, because some larvae developed from the egg, some larvae migrated downstream from the segment of the Nemunas, which was not treated with biopreparation. Thus in one month after the application, the mortality of *B. maculatus* larvae in the investigated segment of the river was 80.8 %.

Massive attack of *B. maculatus* imagines began in the middle of May in Belarus, where the river was not applied with VectoBac (G. A. Borodinskaya and A. Petkevicius, pers. comm.). At this time only 0.7±0.47 blackflies were observed to attack one person per 10 min in the applied region. *B. maculatus* started to attack people in the villages of south-eastern part of Lithuania from 10 June (478.7±288.9 blackflies /10 min.) (Figure 1).

The coefficients of correlation between number of attacking blackflies in the localities, the distance from the investigated localities to the River Nemunas, the number of *B. maculatus* larvae left in the river and the distance of the investigated localities to the untreated segment of the Nemunas were investigated. The abundance of attacking blackflies correlated only with the distance to the untreated segment of the Nemunas River (R = -0.92, $P<0.05$). It is thought that the imagines of *B. maculatus* were carried by warm air to the North from untreated segment of the river in the territory of Belarus (Bartninkaite et al. 2000).

Effect of *B. thuringiensis* var. *israelensis* on macrobenthos

B. thuringiensis var. *israelensis* had no effect on leeches (Hirudinea), caddis flies (Trichoptera), molluscs (Gastropoda, Bivalvia), crustaceans (Crustacea, Malacostraca), mayflies (Ephemeroptera) and dragon-flies (Odonata) larvae in the Nemunas River (Table 3).

The biopreparation could effect the number of dipterous larvae. Larvae of families Tipulidae, Limoniidae, Ceratopogonidae, Dixidae, Ephydridae, Stratiomyidae were found before and after the application in the Nemunas. The number of them was too low for statistically significant conclusions. Biopreparation had no statistically significant effect on larvae of the most abudant family Chironomidae in the Nemunas River (Table 3).

Microbiological investigations (Bartninkaite et al., 2000) on water plants and silt have shown that bacterium *Bacillus thuringiensis* var. *israelensis* from the preparation VectoBac 12AS was eliminated in 4 months after the application.

Acknowledgements. The author is very grateful to Dr. S. Pakalniskis (Institute of Ecology, Vilnius) and Dr. M. Zygutiene for the assistance during the investigations.

REFERENCES

Bartninkaite, I., Bernotiene, R., Pakalniskis, S. & Zygutiene, M. 2000. The problem of bloodsucking blackflies in the south - eastern part of Lithuania and the way to solve it (in Lithuanian). Pp. 115–122 in Tricys, V. (ed.), Ekologija: Socialinis ir Pedagoginis Aspektai. SU leidykla, Siauliai.

Jakimavicius, A. 1982. What is the cattle simuliotoxicoses (in Lithuanian). Zemes Ukis 5, 24.

Kaplich, V. M., Suchomlin, E. B. & Usova, Z. V. 1992. Fauna i ekologiya moshek Polesja. 263 pp. Uradzhaj, Minsk.

Lesinskas, A. & Pileckis, S. 1967. Vadovas Lietuvos Vabzdziams Pazinti. 372 pp. Mintis, Vilnius.

Milaknis, A. 1942. Poisonous flies in Lithuania (in Lithuanian). Zemes Ukis 5, 8.

Pakalniskis, S., Rimsaite, J., Sprangauskaite–Bernotiene, R., Butautaite, R., Podenas, S. 2000. Checklist of Lithuanian Diptera. Acta Zool. Lituanica 10, 3 – 59.

Ross, D. H. & Craig, D. A. 1979. The seven larval instars of *Prosimulium mixtum* Syme and Davies and *P. fuscum* Syme and Davies (Diptera: Simuliidae). Can. J. Zool. 57, 290 – 300.

Rubzov, I. A. & Yankovski, A. V. 1988. Family Simuliidae. Pp. 114–186 in Soos, A. (Ed.), Catalogue of Palaearctic Diptera, 3. Akademiai Kiado, Budapest.

Sivickis, P. 1959. Parazitu apibudinimas. 322 pp. VPML leidykla, Vilnius.

Sprangauskaite, R. 1998. Blackflies (Diptera, Simuliidae) and some notes on their ecology in five rivers of the Dzukija National Park. Acta zoologica Lituanica. Entomologia. 8(3). 63–72.

Zygutiene, M.& Sprangauskaitė, R. 1998. Bloodsucking blackflies (Diptera, Simuliidae) in Lithuania (in Lithuanian). Ekologija. 2, 43–46.

Received 1 July 2000,
accepted 15 January 2001

Norw. J. Entomol. 48, 121–128. 2001

Diversity index of nocturnal Macrolepidoptera applied to vegetation zones in Norway

Alf Bakke, Leif Aarvik & Kai Berggren

Bakke, A., Aarvik, L. & Berggren, K. 2001. Diversity index of nocturnal Macrolepidoptera applied to vegetation zones in Norway. Norw. J. Entomol. 48, 121-128.

Total number of species and individuals of nocturnal moths of the superfamilies Hepialoidea, Cossoidea, Lasiocampoidea, Bombycoidea, Drepanoidea, Geometroidea and Noctuoidea (Macrolepidoptera) from light trap catches from 19 sites in 5 vegetation zones and of the family Noctuidae from 4 additional sites, in Norway, were fitted to log-series frequency distribution. In three sites the catches continued for three successive years. The α-index for Macrolepidoptera and for Noctuidae in the boreonemoral zone exceeds the average known from Britain and northern part of the European continent. The α-index for the family Noctuidae, dropped from about 30 in the boreonemoral zone in South Norway to about 5 in the north boreal zone. In two west coast sites in the boreonemoral zone, with oceanic climate, the α-index was 12 and 14. We suggest that calculation of α-diversity in the north boreal zones should include catches from at least two successive years because some of the dominating species fly only every second year.

Key words: Biodiversity, Lepidoptera, Light traps, α-diversity index, Norway.

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INTRODUCTION

The distribution in Norway of Lepidoptera species is fairly well known, particularly because of the extensive work in recent years with the Norwegian Lepidoptera Database (Aarvik et al. 2000). Less data are available on species frequency distribution. Catching with light traps has been a common way of collecting moths since the 1950-ies, but collectors have desisted from sorting and counting the total catches. Moreover, there are few sites where light traps have been run throughout an entire season, which is required to obtain the data needed to describe the frequency distribution or diversity of species in an area.

A large number of statistical methods are available to measure diversity (Magurran 1988).

To utilise for comparison, the extensive number of species and individuals from seasonal light trap catches, Fischer et al. (1943) suggested a log-series distribution, which has two basic parameters. One of these takes out the sample size effect and the other, α, describes the basic shape of the distribution. It was suggested that α could act as a suitable «index of diversity» which gives information about the species richness of a moth community, whilst having the extremely useful property of being independent of sample size (William 1964). Further studies in England (Kempton & Taylor 1974, Woiwod & Riley 1996) have demonstrated that the log-series index α is a highly efficient and robust site discriminant, yielding reasonable values with only moderate distribution fit. Furthermore, the large number of investigations into the behaviour of α and its satisfactory performance in a wide range of circumstances, makes it an excellent candidate for a universal diversity statistic (Southwood 1978, Magurran 1988). Following an extensive moth monitoring scheme in Finland for three years, Södermann (1996) concluded that the α-index is very useful for mapping regional biodiversity and in the examination of hotspots, both continentally in Europe, regionally within the countries and more locally within the ecozones. Süsserbach & Fiedler (1999) tested the model on noctuid moths, with good results at two sites in northeastern Bavaria, using red-wine based bait.

In the present work this model is applied to light trap catches from sites in different vegetation zones in Norway (Figure 1) (Ahti et al. 1968, Moen 1998). Most of the data were obtained from a project on forest Lepidoptera at the Norwegian Forest Research Institute. The aim of that project was to characterise the fauna of moths in various types of boreal forest. In addition, traps were deployed in other parts of southern Norway to cover districts other than typical boreal coniferous forests. Some data from catches made about 30 years ago in Grimstad and Åmli (Bakke 1974), in Sotra in 1978 (Andersen 1982), unpublished data provided by Geir E. E. Søli from Porsgrunn 1983, and unpublished data from a previous study on mire invertebrate fauna project at Eidskog in 1974/76 (Pedersen et al. 1976) are also included.

The aim of this paper is to present the first comparative data on the diversity of moth populations in Norway based on the model developed by Williams (1964).

MATERIAL AND METHODS

Selection of trap site

The sites are distributed from coastal forest in the nemoral zone to mountain forest in the northern boreal zone of mid-Norway (figure 1). Most sites were selected inside the forest, but mostly less than 30 m from a stand edge or from an opening. The location of the twenty-three selected sites, with short information on dominating vegetation, are given in Table 1. One of the sites in mountain forest and two sites from the previously published study (Bakke 1974) have 3 years of continuous catches, which is valuable to estimate the site stability.

The traps

The light-traps were modified models of Robinson trap (Robinson & Robinson 1950) with a funnel and baffles. Most traps were connected to 220V electric power and had a HPL 125 W mercury-vapour bulb. Some had 40 W actinic tubes. Sites situated distant from electric power connection were fitted with 11 W actinic tube and powered from 12 Volt batteries connected to solar panels (Table 1). The traps had their light source about 1 m above the ground.

Trap catches

The periods of catches are given in Table 1. The intention was to have the traps operating when the spring flight started. This time differs between April and June depending on altitude and latitude. The trapping was finished in September or October when most flight had ended. The traps were emptied every second week, or, when flight activity was intensive, every week and even more often at some of the sites. The catches were kept in a freezer until they were sorted, identified and counted.

Lepidoptera

The calculations are based on light trap catches of moths from the superfamilies Hepialoidea, Cossoidea, Lasiocampoidea, Bombycoidea, Drepanoidea, Geometroidea and Noctuoidea as presented in Catalogus Lepidopterorum Norvegiae (Aarvik et al. 2000). The α-index is calculated for two different groups: 1. All species from the superfamilies mentioned. They are named nocturnal Macrolepidoptera, and 2. Only species from the family Noctuidae. Numbers of specimens of each species collected throughout the season were added up.

Calculation of α-index

The α-diversity index were calculated in the model, $S = \alpha \log (1+N/\alpha)$ (Fisher et al. 1943, Williams 1964), where S = number of species and N = number of individuals. The α cannot be expressed explicitly by S and N in a simple formula. The work of Taylor and his colleagues (Taylor et al. 1976)

Figure 1. Sites where light trap collecting was conducted.

Table 1. Location of sites, dominating vegetation, trapping equipment and time of trapping.

Veg.zone	Municipality	Site	Latitude	Altitude	EIS	Dominating vegetation	Period of catch	Year	Trap and ligth
Nemoral	Farsund	Sellegrod	58.07	15	1	*Quercus / Larix / Abies* / agriculture	09.05-24.10	1999	1 trap, HPL 125W
Boreonemoral	Grimstad	Dømmesmoen	58.21	50	6	*Quercus / Picea* / agriculture	15.04-30.09	1969	1 trap, HPL 125W
	Grimstad	Dømmesmoen	58.21	50	6	*Quercus / Picea* / agriculture	15.04-30.10	1970	1 trap, HPL 125W
	Grimstad	Dømmesmoen	58.21	50	6	*Quercus / Picea* / agriculture	10.04-08.11	1971	1 trap, HPL 125W
	Arendal	Bjelland,Tromøy	58.28	10	6	Coastal mixed conifer. / decid.	20.04-11.11	1999	1 trap, HPL 125W
	Froland	Lyngroth	58.30	100	6	*Picea / Quercus / Populus*	21.04-19.10	1997	1 trap, HPL 125W
	Åmli	Åmli stasjon	58.50	200	9	*Picea / Pinus / Populus / Betula*	15.04-30.09	1969	1 trap, HPL 125W
	Åmli	Åmli stasjon	58.50	200	9	*Picea / Pinus / Populus / Betula*	15.04-30.10	1970	1 trap, HPL 125W
	Åmli	Åmli stasjon	58.50	200	9	*Picea / Pinus / Populus / Betula*	10.04-08.11	1971	1 trap, HPL 125W
	Porsgrunn	Dammane	59.05	40	11	Basiphilous pine forest	01.05-04.11	1983	1 trap, HPL 125W
	Porsgrunn	Gravastranda	59.05	10	18	Termophilous deciduous forest	01.05-04.11	1983	1 trap, HPL 125W
	Aremark	Bøenseter	59.19	110	21	*Picea / Pinus / Populus*	28.04-14.10	1997	1 trap, HPL 125W
	Aremark	Tjøstøl	59.19	105	21	*Picea / Pinus / Betula*	09.05-22.09	1996	2 traps, 11W
	Sotra	Austervågen	60.22	20-50	39	Grassland / *Betula / Salix / Sorbus*	31.03-05.11	1978	2 traps, HPL 125 W
	Sotra	Austre Loftmyra	60.22	20-50	39	Heathland / *Calluna / Erica / Juniperus*	31.03- ?.09	1978	3 traps, HPL 125 W
South boreal	Bygland	Skore	58.50	360	9	*Picea / Pinus / Populus / Betula*	30.04-10.10	1998	1 trap, HPL 125W
	Eidskog	Helgesjøen	59.90	170	38	*Picea / Betula* / peat bog	05.06-07.08	1974/76	1 trap, HPL 125W
Middle boreal	Valle	Rygnestad	59.16	480	16	*Picea / Pinus*	30.04-10.10	1998	1 trap, HPL 125W
	Skien	Sondalsfjell	59.20	555	18	*Picea / Pinus / Betula / Vaccinium*	20.05-16.09	1996	2 traps, 11W actinic tube
	Ringerike	Oppkuven	60.00	670	36	*Picea / Betula / Vaccinium*	13.06-19.09	1996	2 traps, 11W actinic tube
	Åsnes	Sønsterud	60.30	210	47	*Picea / Pinus / Larix / Vaccinium* / moss	08.05-03.09	1998	1 trap, HPL 125W
	Trysil	Floen	61.09	510	65	*Picea / Pinus / Populus / Betula*	20.06-01.09	1998	1 trap, HPL 125W
	Namsos	Almdalen	64.36	10	106	*Picea / Betula*	05.06-09.09	1996	2 traps, 40W
North Boreal	Bykle	Breive	59.35	780	25	*Betula / Salix*	30.04-10.10	1998	1 trap, HPL 125W
	Trysil	Smoldalen	61.20	770	65	Virgin *Picea / Betula / Vaccinium*	17.06-11.09	1996	2 traps,11W actinic tube
	Trysil	Smoldalen	61.20	770	65	Virgin *Picea / Betula / Vaccinium*	03.06-18.09	1997	2 traps,11W actinic tube
	Trysil	Smoldalen	61.20	770	65	Virgin *Picea*	20.06-01.09	1998	1 trap, 11W
	Engerdal	Sømådal	62.06	650	73	*Pinus / Cladonia / Calluna*	20.05-31.08	1998	1 trap, HPL 125W
	Lierne	Østborg	64.07	370	104	*Picea / Vaccinium*	01.07-10.09	1996	2 traps, 40W actinic tube

Table 2. Nocturnal moth catches and estimated log-series parameters from Norway.

Veg.zone	Site	Year	Noctuids			Macros		
			Species	Individuals	α-index	Species	Individuals	α-index
Nemoral	Sellegrod	1999	126	6193	**22.4**	264	12944	**47.0**
Boreonemoral	Dømmesmoen	1969	153	6212	**28.4**			
	Dømmesmoen	1970	142	3385	**29.9**			
	Dømmesmoen	1971	154	5327	**29.7**			
	Dømmesmoen	1969-71	184	14927	**29.6**			
	Bjelland,Tromøy	1999	143	2820	**31.8**	310	6982	**66.6**
	Lyngroth	1997	166	7077	**30.5**	370	18186	**66.0**
	Åmli station	1969	137	5596	**25.4**			
	Åmli station	1970	139	4139	**27.8**			
	Åmli station	1971	138	2917	**30.0**			
	Åmli station	1969-71	165	12652	**26.8**			
	Gravastranda	1983	140	8156	**24.0**			
	Dammane	1983	133	3131	**28.2**			
	Bøensæter	1997	136	3124	**29.0**	295	6648	**63.2**
	Tjøstøl	1996	69	1241	**15.8**	188	4886	**38.8**
	Austervågen	1978	83	5076	**14.1**	159	7427	**28.5**
	Austre Loftmyra	1978	74	5130	**12.2**	124	8636	**20.5**
South boreal	Skore	1998	111	2857	**23.8**	221	5939	**45.2**
	Helgesjøen	1974/76	89	3322	**16.8**	225	5612	**47.0**
Middle boreal	Rygnestad	1998	109	4834	**19.8**	226	17080	**36.8**
	Sondalsfjell	1996	36	297	**10.8**	77	2127	**15.6**
	Oppkuven	1996	46	690	**11.0**	105	9350	**16.6**
	Sønsterud	1998	68	853	**17.0**	167	3023	**38.0**
	Floen	1997	51	2476	**9.0**	114	5654	**20.2**
	Almdalen	1996	31	1737	**5.4**	72	9914	**10.5**
North Boreal	Breive	1998	53	2598	**9.4**	96	11205	**14.4**
	Smoldalen	1996	18	810	**3.2**	50	20365	**6.0**
	Smoldalen	1997	24	1485	**4.0**	49	10147	**6.7**
	Smoldalen	1998	11	342	**2.2**	34	1512	**6.2**
	Smoldalen	1996-98	31	2637	**5.0**	69	31926	**8.4**
	Sømådal	1998	30	537	**7.0**	58	1313	**12.4**
	Østborg	1996	29	1410	**5.2**	57	11997	**7.9**

provides strong support for the adoption of α as the standard diversity statistics (Magurran 1998).

RESULTS AND DISCUSSION

Geographical distribution

The number of species and individuals and the α-index are presented in Table 2. Three of the sites, Dømmesmoen, Bjelland (Tromøy) and Lyngroth, listed in the boreonemoral (hemiboreal) zone are situated at the borderline of the nemoral zone. The figures must be seen on the background of altitude, light source and trap location. In the boreonemoral zone, in sites where the light source with HPL 125W bulb, the α-index for Noctuids are between 25 and 30, and between 63 and 66 for Macrolepidoptera. Sellegrod, which is in the nemoral zone, but more western and with a more oceanic climate, has lower figures. The same is obvious for the two sites, Austervågen and Austre Loftsmyra, on the island of Sotra, on the west coast, which have a typical oceanic climate (Andersen 1982).

The species richness and α-index are clearly highest in the two southern vegetation zones and decrease towards north. This is evident both for the population of Noctuidae and Macrolepidoptera (Table 2).

The distinct differences in α-index between sites closely situated, like Tjøstøl and Bøensæter, can be explained by differences in light source (Table 1) and site location.

The correlation with the latitude differs from what Söderman (1996) found in Finland, where the α decreases gradually from south to north. The reason may mostly be, due to the difference in topography between Finland and Norway, but also to the stronger oceanic gradient in Norway.

The species richness and diversity of nocturnal moths in the boreonemoral zone in southern Norway is at a level similar to and even above sites in central Europe. Süssenbach & Fiedler (1999) and Mörtter (1988) give diversity figures for Noctuidae from Germany, which are mostly lower than those from southern Norway. The highest figures for Macrolepidoptera from England, presented by Kempton & Taylor (1974) are about similar to the highest from the boreonemoral zone in southern Norway. Biogeographically, this zone with mixed forests of southern Scandinavia is assumed to be the richest in birds in Europe (Nilsson 1992) and to include «hot spots» of insect diversity in northern Europe (Väisänen & Heliövaara 1994). High α-diversity figures for nocturnal moths are found in the Baltic area (Viidalepp 1996, Sulcs & Savenkov 1996). The highest α-index for Macrolepidoptera (above 100) in the Nordic-Baltic area is recorded in the middle of the boreonemoral zone in Latvia (Söderman 1996). This is considered to be high, even from a Pan-European point of view.

Site stability

In three sites the catches continued for three successive years (Table 2). The site environment was highly stable during that period in all three sites, of which Smoldalen was in a mountain forest of the North Boreal zone and Dømmesmoen and Åmli station in the boreonemoral zone. The two latter are represented by catches of noctuids from 1969, 1970 and 1971. The α-index values for noctuids in the Dømmesmoen catches were fairly stable. The Åmli station catches differ due to a very high number of individuals of some species in 1969 and 1970, mainly *Agrotis exclamationis* (Linnaeus, 1758), whereas the number of species was stable.

The α-index of the Smoldalen catches differs among the noctuids but was stable for the Macrolepidoptera, despite the great difference in number of individuals. Two species of geometrids, *Entephria caesiata* (Dennis & Schiffermüller, 1775) and *Eulithis populata* (Linnaeus, 1758) were caught in great numbers, particularly in 1996. The difference in α-index among the noctuids may be caused by the fact that only one trap was operating in 1998, compared to two the other years.

The α-index for noctuids in Dømmesmoen and Åmli station is stable also if we add up the total catches for all three years (Table 2). The same is not true for the site in Smoldalen where the α-index increases for the noctuids and Macrolepidoptera. There may be at least two explanations for these differences. The light source in Smoldalen was weaker (Table 1), and the short nights in the more northern latitude caused less attraction to the traps. Some species have a 2-year life cycle and fly only every second year (Mikkola 1979). Three species of *Xestia* made up more than half of the total number of individuals in Smoldalen in 1996 and 1998, but none in 1997. Another species, *Lithomoia solidagines* (Hübner, 1803), accounted for two-thirds of the specimens caught in 1997. None of this species were caught in 1998. This means that calculation of population size in the northern boreal zone will require trapping over at least two successive years, to obtain a rational α-index value.

The number of trapping sites is small in Norway compared to the coverage in Finland. There is an obvious need for an extension of trapping sites in Norway. We need more sites in western and northern Norway and more sites in different altitudes and habitats in middle and southern Norway.

Result from the Moth Monitoring Programme in Finland (Söderman et al. 1999) reveals that moths are a very suitable group for measuring quantitative biodiversity of various habitats. Up to now lichens, fungi and saproxylic beetles have been the key organisms for evaluation of potential areas for nature conservation. Nocturnal moths may deserve a higher status in this work.

CONCLUSION

The species richness and α-index are clearly highest in the two southern vegetation zone and decrease towards north. Sites at the west coast, with oceanic climate, had lower α-index than sites further east in the same vegetation zone.

The species richness and diversity of nocturnal moths in the boreonemoral zone in southern Norway is at a level similar to and even above sites in Britain and northern parts of central Europe.

The α-index values for the family Noctuidae in two sites in the boreonemoral zone were fairly stable during three successive years of trapping.

Calculation of population size in the northern boreal zone will require trapping over at least two successive years, to obtain a rational α-index value, because some of the abundant species fly only every second year.

Acknowledgements. We wish to thank Lars Strand for assistance in the statistical calculation, Geir E. E .Søli for permission to include unpublished data from his Cand. Scient. Thesis. Sigurd Andreas Bakke for giving us his data from his catches in Arendal and Torstein Kvamme for valuable assistance during the fieldwork. We also extend our thanks to Kaare Aagaard at the Norwegian Institute for Nature Research for the support of some of the light traps.The study is part of the research project «Lepidoptera of boreal spruce forest in Norway» which was supported by the Research Council of Norway (Project no. 111800/130).

REFERENCES

Aarvik, L. , Berggren, K. & Hansen, L. O. (Eds.) 2000 Catalogus Lepidopterorum Norvegiae. 192 pp. Lepidopterologisk arbeidsgruppe, Zoologisk museum, Universitetet i Oslo, Norsk institutt for skogforskning, Ås.

Ahti, T., Hämet-Athi, L. & Jalas, J. 1968. Vegetation zones and their sections in northwestern Eursêe. Ann. Bot. Fennici 5, 169-211.

Andersen, T. 1982. Some studies on Macrolepidoptera in coastal heathland habitats in Western Norway. Fauna norv. Ser. B 29, 85-104.

Bakke, A. 1974. Abundance and diversity in the fauna of nocturnal moths at two sites in South Norway. Norsk ent. Tidsskr. 21, 173-184.

Fisher, R. A., Corbet, A. S. & Williams, C. B. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. J. Anim. Ecol. 12, 42-58.

Kempton, R. A. & Taylor L. R. 1974. Log-series and log-normal parameters as diversity discriminants for the Lepidoptera. J. Anim. Ecol. 43, 381-399.

Lundsten, K.-E. 1996. Western Russian moth monitoring report. TemaNord 1996: 630, 40-47.

Magurran, A. E. 1988. Ecological Diversity and Its Measurement. 179 pp. Croom Helm, London Sidney.

Mikkola, K. 1976. Alternate-year flight of northern Xestia species (Lep. Noctuidae) and its adaptive significance. Ann. Ent. Fenn. 42, 191-199.

Moen, A. 1998. Nasjonalatlas for Norge: Vegetasjon. 199 pp. Statens kartverk, Hønefoss.

Mörter, R. 1988. Vergleichende Untersuchungen zur Faunistik und Ökologie der Lepidopteren in unterschidlich strukturierten Waldflächen im Kottenforst bei Bonn. Neue ent. Nachr. 21, 1-182.

Nilsson, S. G. 1992. Forests in the temperate-boreal transition-natural and man-made features. Pp. 373-393 in: Hansson, l. (ed.), Ecological principles of nature conservation. Elsevier Applied Science. London and New York.

Pedersen, A., Hågvar, S. & Bakke, A. 1976. Mire invertebrate fauna at Eidskog, Norway. I. Aim, methods, and habitat description. Norw. J. Entomol. 25, 173-180.

Robinson, A. S. & Robinson, P. J. M. 1950. Some notes on the observed behavior of Lepidoptera in flight in the vicinity of light traps designated to take entomological samples. Ent. Gaz. 1, 3-20.

Söderman, G. 1996. Alpha-diversity of log-series applied to the Moth Monitoring Scheme. TemaNord 1996; 630, 22-31.

Söderman, G., Leinonen, R., Lundsten, K-E. & Tuominen-Roto, L. 1999. Moth Monitoring 1993-97. (In Finnish). Suomen ympäristö 303, 64 pp.

Southwood, T. R. E. 1978. Ecological methods with particular reference to the study of insect populations. 2.ed. 524 pp. Chapman & Hall, London.

Sulcs, I. & Savencov, N. 1996. Latvian moth monitoring report. TemaNord 1996, 630, 52-58.

Süssenbach, D. & Fiedler, K. 1999. Noctuid moths attracted to fruit baits: testing methods and methods of estimating species diversity. Nota. Lepid. 22, 115-154.

Tayler, L. R., Kempton, R. A. & Woiwod, I. P. 1976. Diversity statistics and the log-series model. J. Anim. Ecol. 45, 255-271.

Väisänen, R. & Heliövaara, K. 1994. Hot-spots of insect diversity in northern Europe. Ann. Zool. Fenn. 31, 71-81.

Viidalepp, J. 1996. Estonian moth monitoring report. TemaNord 1996: 630, 48-51.

Williams, C. B. 1964. Patterns in the Balance of Nature. 324 pp. Academic Press, London.

Woiwod, I. P. & Riley, A. M. 1996. Moth diversity and long-term trends. TemaNord 1996: 630, 13-21.

Received 30 June 2000,
accepted 18 October 2000.

Norw. J. Entomol. 48, 129–146. 2001

A survey of the saproxylic beetles (Coleoptera) in Dividalen, Troms county, northern Norway

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Olberg, S., Andersen, J., Huse, Ø., Fossli, T.-E., Haugen, L. & Brattli, J. G. 2001. A survey of the saproxylic beetles (Coleoptera) in Dividalen, Troms county, northern Norway. Norw. J. Entomol. 48, 129-146.

The saproxylic beetle fauna in Dividalen (68.5-69°N), a tributary valley to Målselvdalen in the county Troms, has been investigated in the period 1993-1999 with nine different collecting methods. Dividalen is in the northern boreal forest region and has a mixture of pine (*Pinus sylvestris* L.) and different species of hardwoods, among which birch (*Betula pubescens* Ehr.) dominates. The collected material comprises more than 22.800 individuals (larvae, pupae and imagines) of 189 obligatorily saproxylic species. This constitutes more than 75% of all the saproxylic species found in the county. Twenty-four of the obligatorily saproxylic species found in Dividalen are redlisted in Norway. Fourteen species are reported for the first time from Troms county. A survey of the saproxylic beetles occurring in the inner parts of Troms gives the following grouping: a) northern species, i.e. absent in South Norway, b) ubiquitous species, i.e. species distributed throughout Norway and c) species with a gap in their distributions between South/Central Norway and Troms. Since a number of plant and animal species have a real break in their distribution between South/Central Norway and Troms (Finnmark), it is possible that several saproxylic species show the same pattern. We argue that the topography between Nordland county and Sweden gives a combination of factors which might contribute to these possible breaks.

Key words: Saproxylic beetles, Coleoptera, biogeography, northern Norway

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INTRODUCTION

Beetles constitute the most species-rich part of the saproxylic fauna in boreal forests. Although many of these species are very common and have been regarded as pests (Schwenke 1974), other species are rare and more or less threatened in Scandinavia (Ehnström et al. 1993, Direktoratet for naturforvaltning 1999). Knowledge of distribution and autecology of the saproxylic beetles is therefore very important to elucidate processes and factors determining species-richness in boreal forests. In this context North Norway is climatically and vegetationally unique. This area has some of the northernmost forests in the world; only parts of Siberia have forested areas extending further north where other tree species such as *Abies sibirica* Ledeb. and *Larix gmelinii* (Rupr.) Kuzeneva are present (Mitchell 1977). In northern Fennoscandia *Pinus sylvestris* L. and *Picea abies* (L.) Karst are the only indigenous, tree-building conifers. The northern boreal forests of Fennoscandia are furthermore characterised by the presence of *Betula pubescens* Ehr. This is the dominating tree species at many places in northern Norway. *B. pubescens* has an amphi-atlantic distribution (Lid 1985) and is only present at a few places outside Fennoscandia.

Målselvdalen in the province TRI in Troms county in North Norway is situated in the northern boreal forest zone (Nordiska Ministerrådet 1984). The valley has been visited many times by entomologists (Strand 1946, Zachariassen 1972, Nilssen 1993). However, until recently, very little attention has been paid to the tributary valley Dividalen, despite the fact that the southernmost part of the valley is in a national park (Ryvarden 1997). Investigations were therefore made in 1993-1999 of the saproxylic fauna in the southern part of the valley. This paper gives a faunistic-zoogeographical survey of these results. The occurrence in the valley of *Enicmus lundbladi* Palm and *Corticaria pineti* Lohse, which have exceptional distributions in Fennoscandia, has already been reported (Andersen et al. 2000). Since Dividalen is a tributary valley to Målselvdalen and the immigration history of the species is discussed, we found it natural to include the saproxylic beetle species occurring in Målselvdalen and to give a brief account of the distribution of all the species in Scandinavia.

STUDY AREA

Dividalen (68.5-69°N) is a valley running from SE to NW and high mountains (up to about 1700 m a. s. l.) surround it (Figure 1 and 2). Dividalen has a continental climate with very low yearly precipitation (mean 282 mm in the period 1961-90 at Frihetsli) (Førland 1993). Mean January temperature is between -9.4 and -10.0°C for the period 1961-90, whereas the mean temperature in July is between 12.8 and 13.0°C for the same period (Aune 1993). At low altitudes large areas are dominated by pine (*Pinus sylvestris*), usually mixed with birch (*Betula pubescens*) and willows (*Salix* spp.). In W and SW facing positions in the valley side aspen

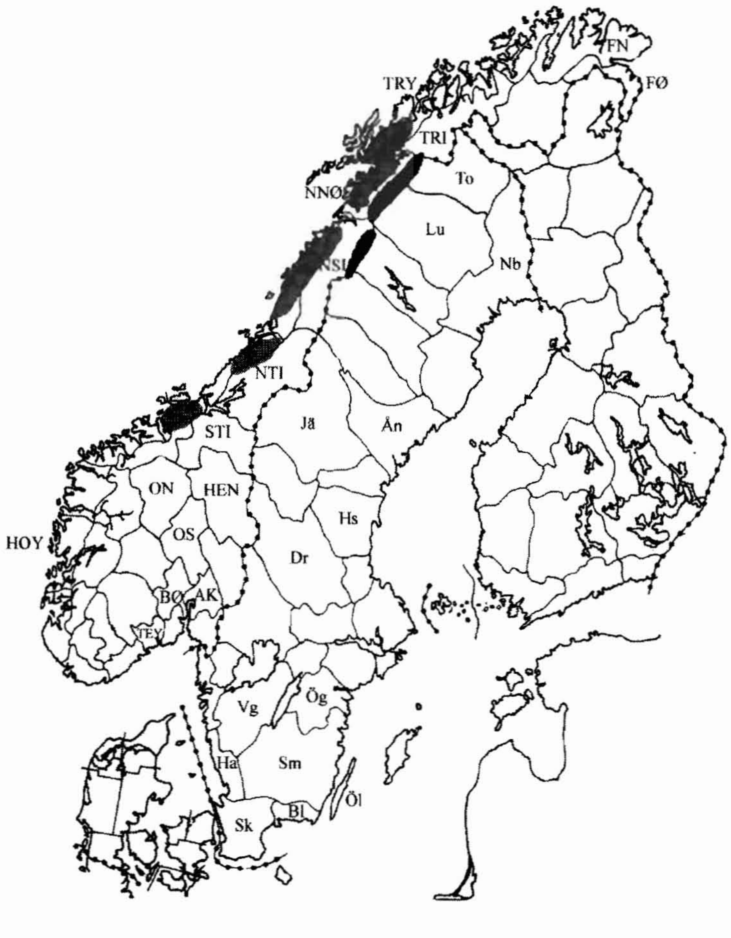

Figure 1. Map of Scandinavia showing the position of the province mentioned in the text and Table 1. The black areas denote mountain barriers (above timberline) in northern Norway, whereas grey coloured areas are areas in Trøndelag and northern Norway with yearly precipitation sums above 1500 mm. Data are from Lindroth (1949), Nilssen (1978), Nordiska Ministerrådet (1984) and Førland (1993).

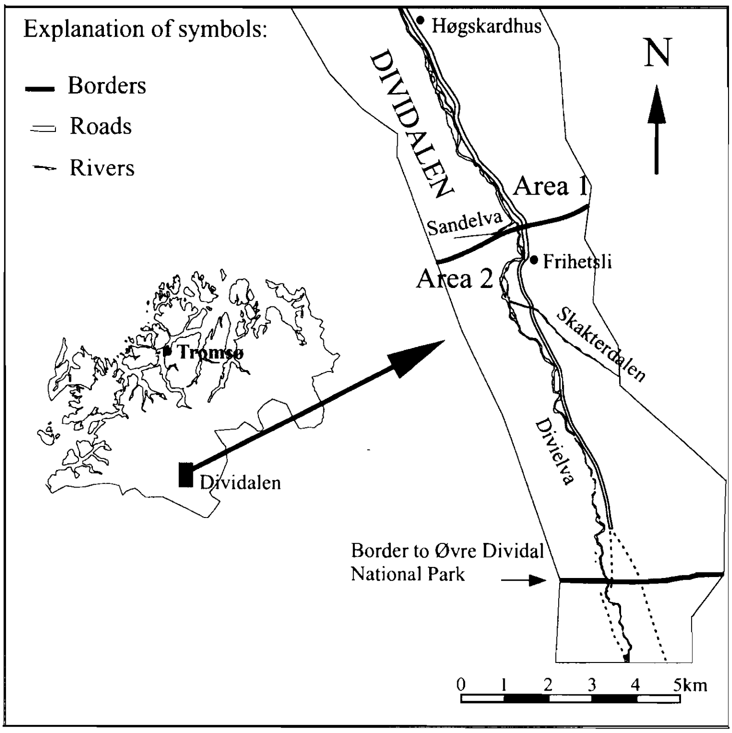

Figure 2. Map of Troms county (left) and Dividalen with the two investigated areas (right).

(*Populus tremula* L.) is the dominating tree species in some areas. At higher altitudes birch substitutes pine, and along brooks, small rivers and on slopes, grey alder (*Alnus incana* (L.) Moench) and willows are the dominating trees. *Fomes fomentarius* (L.: Fr.) Kickx, *Piptoporus betulinus* (Bull.: Fr.) P. Karst., *Phellinus igniarius* (L.: Fr.) Quel., *P. lundellii* Niemelä, *Trametes hirsuta* (Fr.) Pilat, *T. ochracea* (Pers.) Gilb. & Ryvarden, *Cerenna unicolor* (Bull.: Fr.) Murr., *Antrodia xantha* (Fr.: Fr.) Ryv., *Trichaptum fusco-violaceum* (Schwein. In Fr.) Donk, *Polyporus* spp., *Stereum sanguinolentum* (Alb. & Schw.: Fr.) Fr., *S. hirsutum* (Willd.: Fr.) S. F. Gray and *Chondrostereum purpureum* (Pers. ex Fr.) Pouz are common tree-inhabiting fungi, whereas sporocarps of e.g. *Gloeophyllum sepiarium* (Wulf.: Fr.) Karst., *Fomitopsis pinicola* (Schwartz: Fr.) Karst., *Phellinus viticola* (Schwein. in Fr.) Donk, *Oxyporus populinus* (Schumach.: Fr.) Donk and *Trichaptum abietinum* (Dicks.: Fr.) Ryvarden are found scatterly in the valley.

The collecting was performed within two main areas (Figure 2): 1) Between Høgskardhus and the outlet of the river Sandelva and 2) The area between Sandelva and the border of the National Park. Both areas are highly heterogeneous and contain many different vegetation types. Parts of area 1 are situated in SW-W-facing positions in the valley side and contain forests dominated by either aspen or pine. Especially the pine forests are dry and fairly open. Areas situated close to the river are often rather flat, semiexposed and forested by a mixture of pine and deciduous trees. Most of the investigated sites in area 2 are situated in relatively flat terrain. On dry places pine is the predominating tree species, whereas forests dominated by alder and willows occur along brooks, small rivers and the river Divielva. The state of the forests varies. Some localities, especially in area 2, have much dead wood in different stages of decomposition and may have forests of a primeval type. Other places have managed forests with little dead wood. One locality in area 2 (Frihetsli) is situated close to farmland, but all the other sites lie far from human settlement.

MATERIAL AND METHODS

The material comprises >22 800 individuals of saproxylic species (both larvae, pupae and imagines) sampled with the following nine methods: 1) Collections of tree-inhabiting fungi and rearing of beetles in the laboratory. For further details see Fossli & Andersen (1998). Collections were made in 1993-1996. 2) Use of fungus traps mounted around sporocarps of the polypores *Fomes fomentarius*, *Phellinus igniarius* or *P. lundellii*. Further details are given in Olberg & Andersen (2000). Collections were made in 1994-1995. 3) Collection of beetles on the surface of sporocarps of tree-inhabiting fungi. Practised in 1997-1999. 4) Use of window traps in 1994-1996. Huse (1997) gives further details. 5) Use of billet traps in 1994. A description of the traps is given in Brattli et al. (1998). 6) Handcollecting and sieving under bark and in wood of trees in various decompositional stages. The method was used in 1994 and 1997-1999. 7) Collecting on flowers of *Sorbus aucuparia* L., and different herbs, mostly *Achillea millefolium* L., *Epilobium angustifolium* L., *Valeriana officinalis* L. and *Filipendula ulmaria* (L.) Maxim. Practised in 1997-1999. 8) Pitfall trapping in 1996. 9) Specimens collected flying.

THE SPECIES

A list of the saproxylic species of Dividalen and Målselvdalen is given in Table 1. We have omitted the species that are confined to spruce (*Picea abies*) since this tree species is introduced in the county. The saproxylic beetle fauna of spruce in Troms is treated by Nilssen (1978) and Johansson et al. (1994). A synopsis of the most notable species (rare, mostly redlisted species and species with new provincial records) collected in Dividalen is given below. Species not previously reported from TRI (with locality) are marked with +.

Trachypachidae

Trachypachus zetterstedti (Gyllenhal)

Two specimens were found under loose bark of fallen, rotten stems of pine in swampy, primeval forest dominated by pine. One further specimen was collected on the ground in mixed forest. Although *T. zetterstedti* has frequently been found on the ground, it may be saproxylic as supposed by Lundberg (1973) and Ehnström (1983).

Leiodidae

Agathidium pallidum (Gyllenhal)

Eight specimens were collected in fungus traps in Dividalen. The only other Norwegian records are from **TRI** Målselv: Rundhaug (Strand 1938, 1946) and **NTI** Mosvik: Kilen (Tømmerås et al. 1997). *A. pallidum*, which is a very rare species, is probably obligatorily saproxylic. Thus, it has been sieved from litter below logs of spruce or birch or from birchwood (Palm 1947), whereas it otherwise is reported from polypores (Lundberg 1975).

A. discoideum Erichson

The species was rather numerous in fungus- and window traps. Descriptions in Strand (1946) suggest that the species is obligatorily saproxylic, whereas Koch (1989a) also mentions occurrence among foliage and in detritus. We have therefore not regarded the species as completely saproxylic.

Staphylinidae

Gabrius expectatus Smetana

Nineteen specimens were found in fungus traps and window traps in Dividalen. Apart from Troms, the species has only been recorded from a few provinces in South Norway.

+ *Phloeonomus monilicornis* (Gravenhorst)

Four specimens were collected under bark of pine logs attacked by the bark beetle *Tomicus piniperda* (L.). Previous northernmost record of the species was **NNØ** Narvik: Skjomen (Nilssen & Andersen 1977).

Table 1. List of obligatorily and facultatively (in parenthesis) saproxylic species collected in Målselvdalen (M), Bardudalen (Ba), Dividalen (D) (I = area 1, II = area 2) (see Figure 2), in Nordland (N), Trøndelag (T) and south Norway (S), (Lindroth 1960, Strand 1970, 1977, Vik 1991). The northernmost provinces in Sweden (SW) (see Figure 1) is given in the last column. Cm describes collection methods in Dividalen. b are boreal species, while d denotes beetles confined to deciduous trees and p those confined to conifers (pine). * denotes species on the Norwegian Red List. The nomenclature and province divisions of Sweden are according to Lundberg (1995).

Species	M	Ba	DI	D II	Cm	N	T	S	SW
Trachypachidae									
(*Trachypachus zetterstedti*) *	+	-	-	+	6	+	-	-	To
Carabidae									
Tachyta nana	+	-	-	-		-	-	+	Nb,Lu
Dromius agilis	+	-	-	+	2,3,4	+	+	+	To
Histeridae									
Plegaderus vulneratus p	+	-	+	-	6	+	-	+	To
Ptiliidae									
Pteryx suturalis	+	+	+	+	2,6	+	+	+	To
Leiodidae									
Anisotoma humeralis	+	-	+	-	4	+	+	+	To
A. axillaris	+	-	+	+	2,4	+	+	+	To
A. castanea	+	-	+	+	2,3,4,6	+	+	+	To
A. glabra	+	-	+	+	2,3,4,6	+	+	+	To
(*Amphicyllus globus*)	+	-	-	-		-	+	+	Nb,Lu
Agathidium pallidum *	+	-	-	+	2	-	+	-	Nb,Lu
(*A. rotundatum*)	+	-	+	+	2,3,4	+	+	+	To
(*A. confusum*)	+	-		+	3,4	-	+	+	Nb,Lu
(*A. discoideum*) *	+	-	-	+	2,4	+	+	-	Nb,Lu
(*A. nigripenne*)	+	-	-	+	2,4	+	+	+	Nb,Lu
(*A. pisanum*)	+	-	-	-		+	+	+	To
Scydmaenidae									
(*Eutheia linearis*)	+	-	+	-	2	-	+	+	To
(*Stenichnus bicolor*)	+	-	+	+	2,3,4,6	+	+	+	To
Staphylinidae									
Gabrius expectatus *	+	-	+	+	2,4	-	-	+	To
Quedius plagiatus	+	+	+	+	2,3,4,6	+	+	+	To
Atrecus pilicornis p	+	-	+	+	2,3,4,6	+	+	+	To
Bibloporus bicolor	+	-	+	+	2,4	+	+	+	To
Euplectus decipiens	+	-	-	-		+	+	+	Nb,Lu
E. punctatus	+	-	-	-		-	-	+	Nb,Lu
(*E. karsteni*)	+	-	?	+	2,3,4	+	+	+	To
E. fauveli	+	-	+	+	2,4,6	+	+	+	To
(*Acrulia inflata*)	+	+	+	+	1,2,3,4	+	+	+	To
Hapalaraea melanocephala d	+	-	+	+	2,3,4	+	+	+	Nb,Lu
H. linearis	-	-	+	+	2,3,4,6	+	+	+	To
H. clavigera * b p	-	+	-	-		-	-	+	Nb,Lu
Phloeonomus monilicornis p	-	-	+	-	6	+	+	+	Nb

Table 1. Continued.

Species	**M**	**Ba**	**DI**	**D II**	**Cm**	**N**	**T**	**S**	**SW**
P. lapponicus p	+	-	+	+	2,3,4,6	+	+	+	To
P. pusillus p	+	-	+	+	2,4,6	+	+	+	To
(*Coryphium angusticolle*)	+	-	+	+	2,4,6	+	+	+	To
Eudectus giraudi b	+	-	+	+	2,4,6	-	+	+	To
Scaphisoma agaricinum	+	-	+	+	2,3,4	-	+	+	To
Scaphisoma subalpinum d	+	-	+	+	2,3,4	+	-	+	To
S. assimile	+	-	-	-		-	+	+	Nb,Lu
S. boleti * d	+	-	-	-		-	+	+	Ån
Olisthaerus megacephalus * b p	+	+	+	+	2,4,6	+	+	+	To
O. substriatus * b p	+	-	-	+	6	-	+	+	To
Lordithon trimaculatus * b d	-	-	-	+	2	-	+	+	To
L. speciosus b d	+	-	+	+	2,3,4	-	+	+	To
Ischnoglossa elongatula b	?	-	+	+	2,4	?	+	?	To
Thyasophila wockii	+	-	-	+	4	+	-	+	Nb,Lu
Phloeopara testacea	+	-	-	-		+	+	+	To
P. concolor	+	-	+	+	2,3,4,6	-	+	+	To
Dadobia immersa	+	-	+	+	4,6	+	+	+	To
Atheta (*Alaobia*) *taxiceroides* *	+	-	-	-		-	-	-	Nb
A. (*Atheta*) *basicornis*	+	-	-	-		-	-	+	Nb,Lu
(*A.* (*Atheta*) *boletophila*)	+	-	-	-		-	-	+	Nb,Lu
(*A.* (*Atheta*) *pilicornis*)	+	-	-	-		+	+	+	To
(*A.* (*Traumoecia*) *picipes)*	+	-	+	+	4,6	-	+	+	To
Dinaraea aequata	+	-	-	+	6	+	+	+	To
D. linearis	+	+	-	-		+	-	+	To
D. arcana	+	-	+	+	4,6	+	+	+	To
Leptusa pulchella	+	-	+	+	2,4,6	+	+	+	To
Euryusa castanoptera *	+	-	-	-		-	-	+	Nb,Lu
Anomagnathus cuspidatus	+	-	-	+	2,4	-	+	+	Nb,Lu
Placusa depressa	?	-	+	+	4,6	-	+	+	To
P. tachyporoides	+	-	-	+	3	-	+	+	Nb,Lu
P. atrata	+	-	-	-		-	-	+	Nb,Lu
Scarabaeidae									
Trichius fasciatus d	+	-	+	+	4,7,9	+	+	+	To
Lycidae									
Dictyoptera aurora	+	-	+	+	2,4	+	+	+	To
Lygistopterus sanguineus d	-	-	+	-	4,7	+	+	+	To
Cantharidae									
Malthinus frontalis	+	-	+	+	2,4	+	+	+	To
Malthodes guttifer	+	+	+	+	2,4	+	+	+	To
M. maurus	+	-	+	+	2,7	-	+	+	To
M. brevicollis	+	-	+	-	2,4	-	+	+	Nb,Lu
M. mysticus	+	-	+	+	4,7	-	-	+	To
M. fuscus	+	-	-	+	?	+	+	+	To
M. flavoguttatus	+	-	-	+	4	+	+	+	To

Table 1. Continued.

Species	M	Ba	DI	D II	Cm	N	T	S	SW
Elateridae									
Harminius undulatus *	+	+	+	+	2,4,6	+	+	+	To
Denticollis linearis d	+	-	+	+	2,4,7	+	+	+	To
D. borealis * b d	+	-	+	+	2,4	-	+	+	To
Orithales serraticornis	+	-	+	+	4	+	+	+	To
(*Anostirus castaneus*)	-	-	+	+	4,7	+	+	+	Nb,Lu
Ampedus pomorum	+	-	-	-		+	+	+	Nb,Lu
A. balteatus	+	-	-	-		+	+	+	Nb,Lu
A. tristis	+	-	+	+	4,6,9	+	+	+	To
A. nigrinus	+	-	+	+	2,4,6,9	+	+	+	To
Buprestidae									
Oxypteris acuminata *	-	-	-	+	9	+	-	+	To
Agrilus viridis d	+	-	+	-	4	+	+	+	To
Dermestidae									
Globicornis emarginata * d	-	-	+	-	4	-	-	+	Nb,Lu
Megatoma undata	+	-	+	+	2,4	+	+	+	To
Anobiidae									
Episernus angulicollis p	+	+	-	-		+	-	+	To
Ernobius longicornis p	+	-	+	+	4	-	-	+	Dr
E. nigrinus p	+	-	+	+	2,4	+	+	+	Nb,Lu
E. explanatus p	-	-	-	+	4,6	-	+	+	To
Hadrobregmus pertinax p	+	-	+	+	4,6	+	+	+	Nb,Lu
Dorcatoma dresdensis d	+	+	+	+	2,4	-	+	+	Nb,Lu
D. robusta * d	+	-	+	+	2,4	-	-	+	Nb,Lu
Lymexylidae									
Hylecoetus dermestoides d	+	-	+	+	2,4,5,6,9	+	+	+	To
Trogossitidae									
Calitys scabra * b p	-	-	+	+	6	-	+	+	To
Ostoma ferruginea p	+	-	+	+	4,6	+	+	+	To
Thymalus subtilis * d	+	-	+	+	2,3,4	-	-	-	To
Cleridae									
Thanasimus femoralis p	+	-	+	-	4	+	+	+	To
T. formicarius p	+	-	+	-	6	+	+	+	To
Melyridae									
Aplocnemus tarsalis b p	+	-	+	+	2,4,9	+	-	+	To
Dasytes niger	+	-	+	+	4	+	+	+	Nb,Lu
D. obscurus	+	-	+	+	4,7	-	+	+	To
Nitidulidae									
Epuraea pallescens	+	-	?	+	4,7	+	+	+	To
E. laeviuscula p	-	-	+	+	4	-	+	+	To
E. thoracica p	-	-	+	-	4	-	+	+	Nb,Lu
E. angustula	+	+	+	+	2,3,4,6	+	+	+	To
E. fussi * b	+	-	-	-		-	-	+	To

Table 1. Continued.

Species	**M**	**Ba**	**DI**	**D II**	**Cm**	**N**	**T**	**S**	**SW**
E. boreella	+	+	+	+	2,3,4,6	+	+	+	To
E. marseuli	+	-	+	-	4	+	+	+	To
(*E. binotata*)	+	-	-	-		-	+	+	To
E. longiclavis d	+	-	-	+	4	-	+	+	Nb
E. biguttata	+	+	+	+	2,3,4	+	+	+	To
E. variegata	+	-	+	+	3	+	+	+	To
E. silacea d	+	-	+	+	2,3,4	+	+	+	To
E. rufomarginata	+	-	+	+	2,3,4,6	-	+	+	To
E. contractula b d	+	-	+	+	2,3,4	+	+	+	To
Glischrochilus quadripunctatus p	+	-	+	+	2,3,6	+	+	+	To
Aspidiphoridae									
Sphindus dubius p	+	-	+	+	4,6	-	-	+	To
Arpidiphorus orbiculatus p	+	-	+	+	2,3,4,6	+	+	+	Nb,Lu
Monotomidae									
Rhizophagus grandis	-	-	?	+	4	-	+	+	Nb,Lu
R. ferrugineus p	+	-	+	+	2,4	+	+	+	To
R. dispar	+	+	+	+	1,2,3,4,6	+	+	+	To
R. nitidulus	?	-	-	-		+	+	+	Nb,Lu
R. parvulus d	+	-	+	+	2,3,4,6	+	+	+	To
Silvanidae									
Dendrophagus crenatus p	+	-	+	+	2,4,6	+	+	+	To
Pediacus fuscus	+	+	+	+	2,4,6	+	+	+	To
Cryptophagidae									
Cryptophagus angustus p	-	-	+	-	4	-	-	+	Nb,Lu
Cryptophagus quercinus * d	?	-	+	+	2,4	-	-	+	Nb
(*C. badius*)	+	-	+	+	2,4	+	+	+	To
(*C. lysholmi*) *	+	-	-	-		-	-	+	To
C. dorsalis p	+	-	+	+	2,4	-	-	+	To
C. corticinus * d	+	-	+	-	3	-	+	+	To
Atomaria umbrina	+	-	-	-		+	+	+	To
A. subangulata * b	+	-	-	-		-	+	+	Nb,Lu
A. affinis b	+	-	-	+	4	?	+	+	To
A. pseudoaffinis * b	+	-	-	-		-	-	+	Nb,Lu
A. bella	+	-	-	-		+	-	+	Nb,Lu
(*A. pulchra*)	+	-	?	+	4	+	+	+	To
A. atrata	+	-	+	+	4	+	+	+	Nb,Lu
A. procerula	+	-	+	+	4	+	+	+	To
Erotylidae									
Triplax aenea d	+	-	+	+	2,4	+	+	+	To
T. russica d	+	+	+	+	2,3,4	+	+	+	To
T. scutellaris d	+	-	+	+	2,3,4	+	+	+	To
Cerylonidae									
Cerylon histeroides	+	+	+	+	2,3,4,6	+	+	+	To
C. ferrugineum d	+	+	+	+	2,4,6	+	+	+	To

Table 1. Continued.

Species	**M**	**Ba**	**DI**	**D II**	**Cm**	**N**	**T**	**S**	**SW**
C. deplanatum d	+	-	-	-		+	-	+	To
Endomycidae									
Endomychus coccineus d	+	+	+	+	1,2,3,4,6	+	+	+	To
Corylophidae									
Orthoperus punctatus *	+	-	+	+	2,3	-	-	+	To
Corticariidae									
Latridius hirtus	+	-	+	+	1,2,3,4	+	+	+	To
L. consimilis	+	-	+	+	1,2,3,4	+	+	+	To
Enicmus lundbladi * d	-	-	+	+	4	-	-	+	Ån
E. fungicola	+	-	+	+	2,3,4,6	-	+	+	To
E. apicalis *	-	-	+	+	2,4	-	+	-	To
Corticaria pineti * p	-	-	+	-	6	-	-	-	Ha,Sm
C. lapponica * b d	+	-	+	+	2,3,4	+	+	+	To
C. orbicollis b d	+	-	+	+	1,2,3,4	+	+	+	To
C. rubripes	+	-	+	+	4	-	+	+	To
Cisidae									
Cis lineatocribratus d	+	-	+	+	1,2,3,4,8	-	+	+	To
C. jacquemartii d	+	+	+	+	1,2,3,4	+	+	+	To
C. comptus d	+	-	+	+	1,2,3,4	-	+	+	To
C. hispidus d	+	+	+	+	1,2,3,4,6	+	+	+	To
C. boleti d	+	+	+	+	1,2,3,4,6	+	+	+	To
C. punctulatus p	-	-	+	+	1,3,6	+	+	+	Nb,Lu
C. bidentatus	+	-	+	+	1,2,3,4	+	+	+	To
Ennearthron cornutum d	-	-	+	+	1,2,6	-	-	+	Nb,Lu
Orthocis alni d	+	-	+	+	2,4,6	+	+	+	To
O. linearis * d	+	-	-	+	4	-	+	+	To
Sulcacis affinis d	-	-	?	+	1	-	+	+	Nb,Lu
S. fronticornis d	+	-	?	+	1	-	-	+	Nb,Lu
Ropalodontus strandi * b d	+	-	+	+	1,2,3,4	-	-	+	To
Octotemnus glabriculus d	+	-	+	+	1,3,4	+	+	+	Nb,Lu
Mycetophagidae									
Mycetophagus multipunctatus	+	-	+	+	1,2,4	-	-	+	To
Pythidae									
Pytho depressus p	+	+	+	+	4,6	+	+	+	To
Pyrochroidae									
Schizotus pectinicornis d	+	+	+	+	4,6	+	+	+	To
Salpingidae									
Rabocerus foveolatus d	+	+	+	+	2,4,6	+	+	+	To
Salpingus ruficollis d	+	+	+	+	2,4,6	+	+	+	To
Stenotrachelidae									
Stenotrachellus aeneus b d	+	-	-	+	2	+	+	+	To
Tenebrionidae									
Bolitophagus reticulatus d	+	-	+	+	1,2,3,4	+	+	+	To

Table 1. Continued.

Species	M	Ba	DI	D II	Cm	N	T	S	SW
(*Scaphidema metallicum*)	+	-	-	+	3	+	+	-	To
Corticeus linearis p	+	-	+	+	4	+	+	+	Nb,Lu
Mycetochara obscura *	-	-	+	+	2,4	-	-	-	Nb,Lu
Scraptiidae									
Anaspis bohemica	+	-	+	+	2,4	-	-	+	Nb,Lu
A. marginicollis	+	-	+	+	4,7	-	+	+	Nb,Lu
A. arctica b	+	+	+	+	2,3,7,9	+	+	+	To
A. rufilabris	+	+	+	+	4,7	+	+	+	To
Mordellidae									
Curtimorda maculosa p	-	-	+	-	4	-	+	+	Nb,Lu
Tetratomidae									
Tetratoma ancora	+	-	+	+	1,2,3,4	+	+	+	To
Melandryidae									
Hallomenus binotatus	?	-	-	+	2,3,4	-	+	+	Nb,Lu
H. axillaris	+	-	-	+	3	-	-	+	Nb,Lu
Orchesia micans	+	-	+	+	2,3,4	+	+	+	To
O. minor	+	-	+	+	2,4	+	+	+	Nb,Lu
O. fasciata * p	-	-	-	+	2	-	+	+	Nb,Lu
Abdera affinis d	-	-	+	+	2,4	-	+	+	To
A. flexuosa d	+	-	-	+	1,2,3,4	+	+	+	Nb,Lu
A. triguttata p	-	-	-	+	1	-	+	+	Nb,Lu
Xylita laevigata p	+	-	+	+	2,4	+	+	+	To
Zilora ferruginea p	-	-	+	+	1,4	+	+	+	To
Cerambycidae									
Asemum striatum p	+	-	+	+	4,5,6,9	+	+	+	To
Rhagium mordax d	+	+	+	+	2,4,5,6,7	+	+	+	To
R. inquisitor p	+	+	+	+	2,4,5,6,9	+	+	+	To
Oxymirus cursor p	+	-	-	-		+	+	+	Nb,Lu
Pachyta lamed p	-	-	-	+		+	+	+	To
(*Brachyta interrogationis*)	+	-	-	-		+	+	+	To
Acmaeops septentrionis * b p	+	-	-	-		+	+	+	To
A. smaragdula * b p	+	-	-	-		+	-	-	To
A. pratensis p	+	-	-	-		+	+	+	To
Allosterna tabacicolor d	+	+	+	+	4,7	+	+	+	Nb,Lu
Anoplodera reyi p	?	-	-	+	4,5	+	+	+	To
A. virens p	+	-	+	+	4,7	+	+	+	To
Judolia sexmaculata p	+	+	+	+	4,5,7,9	+	+	+	To
Necydalis major * d	-	+	-	-		+	-	+	Nb,Lu
Callidium violaceum p	+	+	-	+	6	+	+	+	To
Monochamus sutor p	+	-	+	+	6,9	+	+	+	To
Pogonocherus fasciculatus p	+	-	+	+	4,5,6	+	+	+	To
Acanthocinus aedilis p	+	+	+	+	5,6,9	+	+	+	To
Saperda scalaris d	+	+	-	+	2,5	+	+	+	To
Tetrops praeusta d	+	-	-	-		+	+	+	Nb

Table 1. Continued.

Species	M	Ba	DI	D II	Cm	N	T	S	SW
Anthribidae									
Platystomus albinus d	+	-	-	-		+	+	+	To
Curculionidae									
Rhyncolus ater	+	-	+	+	2,6	+	+	+	To
Magdalis phlegmatica p	+	-	+	+	4,5	+	+	+	To
M. linearis p	+	-	-	-		+	-	+	Nb
M. duplicata p	+	-	+	+	2,4	+	+	+	To
M. frontalis p	+	-	-	-		-	-	+	To
M. carbonaria d	+	+	+	+	2,4,5	+	+	+	To
M. ruficornis d	+	-	-	-		+	+	+	Nb,Lu
Hylobius abietis p	+	+	+	+	2,4,5,6,9	+	+	+	To
H. piceus p	+	-	-	+	5,6	+	+	+	To
Pissodes pini p	+	-	+	+	2,4,5,6,9	+	+	+	To
P. piniphilus p	-	-	+	-	6	+	+	+	To
Cryptorhynchus lapathi d	+	-	-	+	4	+	+	+	To
Hylurgops palliatus p	+	-	+	+	2,4,5,6	+	+	+	To
Hylastes brunneus p	+	-	+	+	2,4,5,6,9	+	+	+	To
Tomicus piniperda p	+	+	+	+	2,4,5,6,9	+	+	+	To
Dendroctonus micans p	+	-	-	-		-	+	+	To
Scolytus ratzeburgi d	+	+	+	+	2,4,5,6	+	+	+	Nb,Lu
Pityogenes quadridens p	+	+	+	+	4,5,6	+	+	+	To
P. bidentatus p	+	+	+	+	2,5,6	+	+	+	To
Orthotomicus suturalis p	+	-	-	+	5	+	-	+	To
Ips acuminatus p	+	-	+	+	4,5,6	+	+	+	To
I. sexdentatus p	+	-	+	-		+	-	+	To
Dryocoetes alni d	+	-	+	+	4,5,6	+	+	+	To
Trypodendron proximum b p	+	-	-	-		-	-	+	Nb,Lu
T. lineatum p	+	-	+	+	2,4,5	+	+	+	To
T. signatum b d	+	-	+	+	2,4,5,6	+	+	?	To
Trypophloeus alni * d	+	-	-	+	4,5	-	-	-	-
Pityophthorus lichtensteinii p	+	-	+	-	4,5	+	-	+	To

Olisthaerus substriatus (Paykull)

Two individuals were found under bark of pine logs together with *O. megacephalus* (Zetterstedt). The species occurs in moist, shady, primeval coniferous forest (Palm 1948).

Lordithon trimaculatus (Paykull)

Two specimens were collected in fungus traps with *Fomes fomentarius*. *L. trimaculatus* is only known from a few provinces in Norway: **AK, STI, TRI** and **FØ** (Vik 1991).

+ *Ischnoglossa elongatula* (Mannerheim)

Until recently only one species of the genus *Ischnoglossa (I. prolixa* (Gravenhorst)) was recognised in Fennoscandia (see e.g. Lundberg 1986). Gillerfors (1993) revised the Swedish material of the genus and found that it contained three species: I. *obscura* Wundele, *I. prolixa* and *I. elongatula*. The two first species have southern distributions in Sweden; *I. obscura* is known north to Hälsingland (Hs), *I. prolixa* to Jämtland (Jä), whereas *I. elongatula* has a mainly northern distribution from Småland (Sm) to Torne lappmark (To). Lundberg

(1995) reports both *I. prolixa* and *I. elongatula* from Norway, but no systematic revision of the Norwegian material of the genus seems to have been made. All the specimens from Dividalen belong to *I. elongatula*. The same is the case with the material from **NTI** Mosvik (Tømmerås et al. 1997). According to the distribution in Sweden it is most likely that *I. elongatula* is the only species of the genus present in Troms and Finnmark. A revision of the Norwegian material of *Ischnoglossa* is necessary to elucidate the distribution of the species in the country.

Elateridae

Denticollis borealis (Paykull)

Five specimens were found in window traps and one in a fungus trap in Dividalen. This rare species prefers fire-damaged wood, especially of *Betula* (Palm 1959, Koch 1989b).

Harminius undulatus (De Geer)

The imagines were rather numerous in window traps whereas larvae and pupae were collected under bark of stems of birch, alder and pine. *H. undulatus* is regarded as quite rare (redlisted both in Norway and Sweden), but it is widely distributed in northern Norway (Strand 1946).

Buprestidae

Oxypteris acuminata (De Geer)

One individual swarmed around a fire in area 2 in Dividalen (see also Nilssen & Andersen 1977). The species is only known from a few localities in Norway (Zachariassen 1990). *O. acuminata* develops in burnt wood, and it is attracted by for-

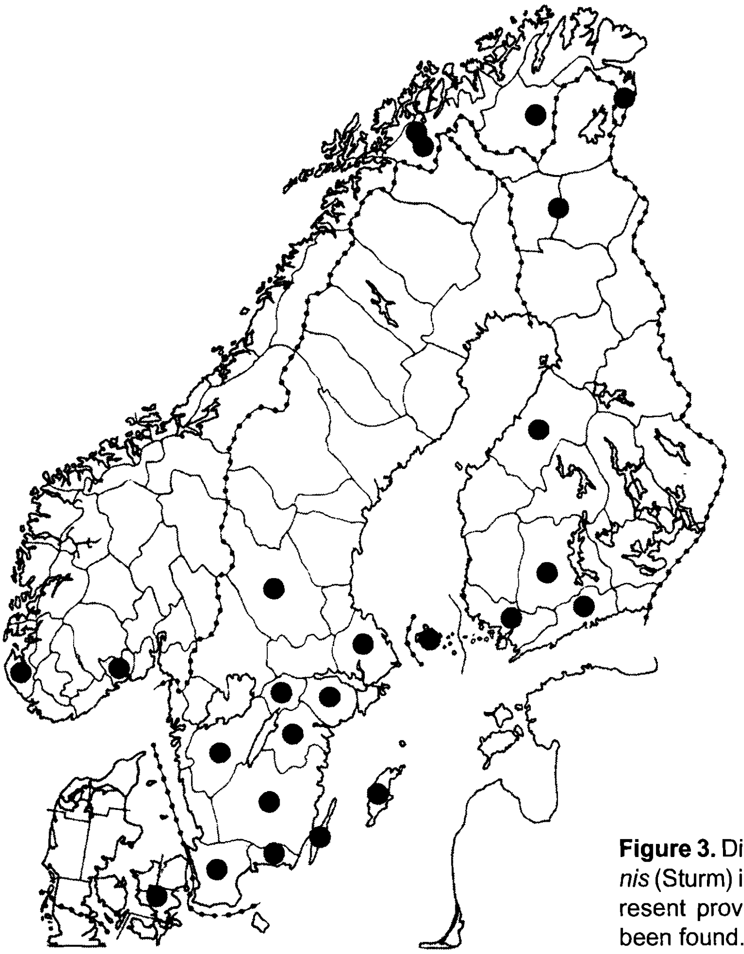

Figure 3. Distribution of *Ernobius longicornis* (Sturm) in Fennoscandia. The dots represent provinces where the species has been found.

est fires (Palm 1959, Schwenke 1974, Bíly 1982).

Dermestidae

+ *Globicornis emarginata* (Gyllenhal)

The species was previously known north to **ON** in South Norway (Vik 1991). A single specimen was found in a window trap in Dividalen.

Anobiidae

Ernobius longicornis (Sturm)

Several specimens were collected in window traps in Dividalen. The only other place where the species has been reported in Troms is **TRI** Målselv: Solvang (Strand 1946). *E. longicornis* seems to have a highly discontinuous distribution in Norway (Figure 3).

+ *E. explanatus* Mannerheim

A few specimens were found in window traps in Dividalen, and one individual was found under bark of a fallen pine. The only other record from northern Norway is from **FØ** Strand in Sør-Varanger (Strand 1946).

Hadrobregmus pertinax (L.)

Information in Strand (1946) indicates that this species may be associated with man in northern Norway, but our data from Dividalen show that *H. pertinax* occurs naturally in the county. Thus, we have collected some specimens in window traps far from human settlement in the valley. Furthermore, a remnant of a specimen was found in a fallen, rotten pine log.

Dorcatoma robusta Strand

The species was abundant in fungus traps in Dividalen (Olberg & Andersen 2000).

Trogositidae

+ *Calitys scabra* (Thunberg)

Three specimens were found on the lower side of a rotten, dry, fallen log of pine infected with *Antrodia xantha* in area 2 in Dividalen. A fourth specimen was found in area 1 (leg. W. Mahler & O. Hanssen). The species has previously been recorded north to **STI** (O. Hanssen pers. comm.).

Thymalus subtilis Reitter

Besides the finds of seven specimens in fungus and window traps, one specimen was collected on *F. fomentarius* and one on *Cerenna unicolor*. The only other Norwegian records of the species are from **TRI** Målselv: Øverbygd and **FN** Porsanger: Lakselv (Strand 1946).

Nitidulidae

+ *Epuraea laeviuscula* (Gyllenhal)

Two specimens were found in window traps. Previous records of the species are from South and Central Norway (Vik 1991, Tømmerås et al. 1997).

+ *E. thoracica* Tournier

Previously only recorded from the southern part of the country north to **NTI** (Vik 1991, Tømmerås et al. 1997). Three specimens were collected in window traps in Dividalen.

Monotomidae

+ *Rhizophagus grandis* Gyllenhal

Two specimens were found in window traps in Dividalen. Otherwise the species is only found in South and Central Norway (Zachariassen 1990, Tømmerås & Breistein 1995). The presence of *R. grandis* in Dividalen is somewhat enigmatic. The species is known to be a specific predator of the bark beetle *Dendroctonus micans* (Kugelann) (Ehnström 1963, Koch 1989b, King et al. 1991, Evans & Fielding 1994). However, viable populations of *D. micans* have not been found in northern Norway, although a single specimen was found in a spider web in Målselvdalen (Strand 1946). The bark beetle attacks *Picea* spp. and *Pinus sylvestris* in northern Scandinavia (Lekander et al. 1977). There is a possibility, therefore, that *D. micans* may be established in Dividalen. Alternatively, *R. grandis* may live of other species of bark beetles in northern Norway.

Cryptophagidae

Cryptophagus quercinus Kraatz

In Norway this rare species has only been recorded from the provinces **HEN**, **BØ** and **TRI** (Vik 1991).

Four specimens were found in window traps in Dividalen.

+ *C. angustus* Ganglbauer

Three specimens were collected in window traps in Dividalen. Previous Norwegian records are from the southernmost parts of the country north to **ON** (Vik 1991).

Corylophidae

Orthoperus punctatus Wankowicz

A single specimen was found in a window trap, whereas seven specimens were collected on sporocarps of *Piptoporus betulinus*.

Corticariidae

+ *Enicmus apicalis* J. Sahlberg

Several specimens were collected in window traps and fungus traps in Dividalen. The only other Norwegian record is from **NTI** Lierne (O. Hanssen, pers. comm.).

E. lundbladi Palm

The species was found in fourteen specimens in window traps at two localities within area 1. This occurrence is very isolated from the rest of its distribution. *E. lundbladi* is treated in detail by Andersen et al. (2000).

Corticaria pineti Lohse

A single specimen was collected in area 1 in Dividalen. This is the only reported locality of the species from Norway (Andersen et al. 2000).

C. lapponica (Zetterstedt)

This was one of the most frequently encountered species in fungus traps with *F. fomentarius* in Dividalen (Olberg & Andersen 2000).

Cisidae

+ *Sulcacis affinis* (Gyllenhal)

The species was found in a few sporocarps of *Trametes* sp. in Dividalen. It has also been collected in **TRI** Storfjord: Skibotn and in **TRY** Tromsø: Oldervikdalen (Fossli & Andersen 1998). Previously *S. affinis* has been reported from South and Central Norway (Vik 1991, Tømmerås & Breistein 1995).

+ *Ennearthron cornutum* Gyllenhal

Some sporocarps of *F. fomentarius* and *Phellinus* sp. collected in Dividalen were infected with this species. Previous northernmost occurrence in Norway was **OS** (Vik 1991).

Orthocis linearis (Gyllenhal)

A few specimens were found in window traps in Dividalen. The other reported records in Norway are from **TRI** Målselv; Moen, Rundhaug and Framnes, Nordreisa; Bilto, **FØ** and **BØ** (Strand 1953, Vik 1991).

Ropalodontus strandi Lohse

The species is common in sporocarps of *F. fomentarius* on standing birch trees in Dividalen (Fossli & Andersen 1998). *R. strandi* is only known from two districts in South Norway: **HEN** and **ON** (Vik 1991, Andersen unpublished).

Mycetophagidae

Mycetophagus multipunctatus Fabricius

Five specimens were collected in fungus traps. We have also reared the species from sporocarps of *P. betulinus*. *M. multipunctatus* has only been found in a few provinces in Norway, and it is probably quite rare.

Tenebrionidae

Mycetochara obscura (Zetterstedt)

More than thirty specimens were found in window traps in Dividalen. The only other published record from Norway is from flotsam in **TRI** Nordreisa: Bilto (Strand 1953).

Mordellidae

+ *Curtimorda maculosa* (Naezen)

A single specimen was found in a window trap in Dividalen. In Norway it is otherwise found north to **NTI** Lierne (O. Hanssen, pers. comm.).

Melandryidae

Orchesia fasciata (Illiger)

Two specimens were collected in fungus traps in Dividalen. This rare species is only reported from a few districts in Norway: **TEY, HOY, NTI, TRI** and **FØ** (Strand 1946, Zachariassen 1990).

+ *Abdera triguttata* (Gyllenhal)

A single specimen was found in *Trichaptum fusco-violaceum* on a stub of pine. In Norway it is otherwise recorded from FØ and South Norway north to NTI (Tømmerås & Breistein 1995).

Zilora ferruginea (Paykull)

Three specimens have been found in *T. fusco-violaceum* besides a few in window traps in Dividalen. In Troms previously only reported from flotsam collected in Reisaelva (Strand 1953).

Cerambycidae

Pachyta lamed (L.)

There is an old record of this species from Frihetsli in Dividalen (Strand 1946), but it has later not been found in Målselvdalen or its tributary valleys.

Curculionidae

Trypophloeus alni (Lindemann)

Two specimens – one in a window trap and one in a billet trap – were found in Dividalen. The only other Norwegian find of the species was in flotsam at **TRI** Målselv: Rundhaug. *T. alni* is known from a few localities in Finland, but it seems to be absent in Sweden (Lekander et al. 1977, Lundberg 1995).

DISCUSSION

Three of the saproxylic species that were collected in Dividalen (*Mycetochara obscura, Zilora ferruginea* and *Trypophloeus alni*) have previously only been found in flotsam in Troms. There are reasons to interpret such finds with care, since the occurrence of species in flotsam and other debris may be the result of long-distance anemohydrochore dispersal (Palmén 1944, Palm 1949, Nilssen 1978, Andersen 1984). However, the circumstances around the finds of these species in Dividalen indicate that they really are indigenous in the county. Thus, they have either been collected in their natural host (*Z. ferruginea*) or in traps. We find it much more likely that specimens found in traps, especially in billet traps, represent the local fauna more than those found in various types of debris washed ashore.

The number of obligatorily saproxylic species collected in Dividalen is 189, which constitute more than 75 % of all the saproxylic species found in the county. Fourteen of these species are new to Troms county. Twenty-four of the obligatorily saproxylic species and two of the facultatively saproxylic species collected in Dividalen in the present investigation are redlisted in Norway. A majority of the species of Dividalen has also been recorded in the main valley Målselvdalen, but at least 25 species are exceptions. Nevertheless, it is quite likely that at least some of the latter species also occur at other sites in continental parts of the county. Altogether Målselvdalen and its tributary valleys have at least 91 % of the saproxylic species (those confined to spruce are excluded) found in Troms county. The rest of the species are either recorded from the valley Reisadalen, or from the coast or fjord districts. For some of the species, information about locality was not available.

The obligatorily saproxylic species of TRI may be divided in the following groups according to their geographical distribution: a) northern species, b) ubiquitous species and c) species with a gap in their known distribution between South/ Central Norway and Troms.

The northern species (group a) seem to be absent in South Norway. *Agathidium pallidum, Atheta taxiceroides* (Münster), *Thymalus subtilis, M. obscura, Enicmus apicalis* and *T. alni* constitute this group. The three first mentioned species are not recorded south of about 61°N in Sweden whereas *M. obscura* and *E. apicalis* are distributed as far south as to Småland (Sm) and Östergötland (Ög) (between 56 and 58°N), respectively. *T. alni* is absent in Sweden, but it occurs in the southernmost part of Finland. The three latter species therefore show more eastern than northern distributions in Fennoscandia. In addition, *Erno-*

bius longicornis has a mainly eastern distribution in Fennoscandia although it extends as far west as to SW Norway in the southern part of its range (Figure 3).

The ubiquitous species (group b) are present in South-Central Norway as well as in Nordland and Troms (many also in Finnmark). This is a large group containing >150 species.

The species in group c have not been found in Central Norway and/or Nordland county although several are present in Finnmark. This group consists of at least 72 species. Nearly all occur north to Torne lappmark (To) or Lule lappmark (Lu), a few only to Norrbotten (Nb) in Sweden. Nb is a very large province, extending from about 65 to 68°N so the degree of isolation of the actual species in Troms is unknown to us. Since TRI is situated much closer to the provinces Lu, To and northern parts of Nb than to Central or South Norway, most of the species of group c therefore show a more or less continuous distribution in Scandinavia via Sweden. *Scaphisoma boleti* Panz, *Enicmus lundbladi* and *Corticaria pineti*, which have very isolated distributions in Troms, are treated in detail by Andersen et al. (2000).

Although the species of group b and c are present in South Norway, several of them are absent in the southernmost part of Sweden (roughly south of 59°N) or in the nemoral zone of South Sweden, i.e. in the districts Skåne (Sk), Blekinge (Bl), Halland (Ha) and Öland (Öl). In South Sweden most of them occur only in the highland of Småland, Östergötland and Västergötland (Vg). Thus, among the obligatorily saproxylic species of Troms at least 32 may be regarded as boreal species (denoted as b in Table 1). Several of them are absent in the lowland areas in Central Europe but are present further south and therefore have a boreomontane distribution (Freude et al. 1964, 1967, 1969, 1979).

The possibility that several saproxylic species may be absent in Nordland, eventually even in Central Norway (ST, NT) is supported by the fact that there are a number of plant and animal species with a break in their distribution between South/Central Norway and the northernmost parts of the country (Troms and/or Finnmark counties), whereas they are continuously distributed through Sweden and/or Finland. Among taxa whose distributions are comparatively well known, this applies to several plants (*Cicuta virosa* L., *Ledum palustre* L. (a single locality in Nordland), *Veronica longifolia* L., *Eriophorum gracile* Roth., *Carex heleonastes* L., *C. tenuiflora* Wahlenb., *C. caespitosa* L., *C. disperma* Dew., *C. globularis* L. and *C. laxa* Wahlenb.) (Hultén 1971, Lid 1985), to the lizard *Lacerta vivipara* Jacq. (Andersen 1971) and several carabid beetles (Andersen 1980, Lindroth 1985-86).

For those species of group c which have a real gap in Nordland, a partial explanation of the distribution pattern may be the following: Since most of the saproxylic species of Troms are also present in the provinces Lu and To in Sweden (Table 1), it is likely that they at least partly have spread to northern Norway from S and SE. In accordance with this, a dispersal route from S-SE was demonstrated for saproxylic, spruce-living beetles in Troms (Nilssen 1978). Spruce is introduced in the county since the beginning of the twentieth century and its fauna is of a recent origin. The colonisation of the beetles has mainly been by anemochore dispersal, but this has been more successful in Troms than in Nordland north of Saltdalen, indicated by the fact that the number of species found in Troms is higher than in Nordland (Nilssen 1978). The reason for this difference in the colonisation success of Troms and Nordland may be that there is a mountain barrier between large parts of Nordland and Sweden (Figure 1, Nilssen 1978). This area exhibits mountain massifs of a greater magnitude than the counties of Trøndelag, Troms and Finnmark. That anemochore dispersal to northernmost Norway is more likely from S and SE than from SW is in accordance with the fact that S and SE winds are warm, whereas those coming from SW are cool and wet. The flight activity is highest during warm weather and more insects are therefore probably borne by the air from S and SE than from SW (Baranowski & Gårdenfors 1974, Nilssen 1978).

The climate of most of Nordland is also less continental than that of Troms and Finnmark with much higher precipitation, both annually (Figure 1) and during the summer months (Nordiska Ministerrådet 1984, Førland 1993). Although not documented, it is possible that high rainfall and more wetting of the substratum in summer lead to a less favourable microclimate in the habitats of the saproxylic species (Andersen et al. 2000).

Acknowledgement. We are greatly indebted to Oddvar Hanssen and Frode Ødegaard for identification or verification of several taxonomically difficult species and for information about distribution of species. A thank also goes to Rob Barret who corrected our language and to an anonymous referee for valuable comments on the manuscript.

REFERENCES

Andersen, J. 1971. Utbredelsen av firfisle, *Lacerta vivipara*, i Troms fylke. Fauna (Oslo) 24, 38-40.

Andersen, J. 1980. The geographical distribution of the members of the tribe Bembidini (Col. Carabidae) in northern Norway. Fauna norv. Ser. B 27, 9-16.

Andersen, J. 1984. Om vurdering av tilfeldige funn i faunistisk sammenheng. Insektnytt 9, 9-12.

Andersen, J., Olberg, S. & Haugen, L. 2000. Saproxylic beetles (Coleoptera) of Troms and western Finnmark, northern Norway with exceptional distribution in Fennoscandia. Norw. J. Entomol. 47, 29-å0.

Aune, B. 1993. Temperaturnormaler, normalperiode 1961-90. 63 pp. DNMI, Oslo.

Baranowski, R. & Gärdenfors, U. 1974. Vinddrift av jordlöpare i sydöstra Skåne (Col., Carabidae). Entomologen 3, 35-52.

Bíly, S. 1982. The Buprestidae (Coleoptera) of Fennoscandia and Denmark. Fauna Ent. Scand. 10, 1-109.

Brattli, J. G., Andersen, J. & Nilssen, A. C. 1998. Primary attraction and host tree selection in deciduous and conifer living Coleoptera: Scolytidae, Curculionidae, Cerambycidae and Lymexylonidae. J. Appl. Ent. 122, 3å5-352.

Direktoratet for Naturforvaltning 1999. Norwegian Red List 1998. DN-rapport 3, 1-161.

Ehnström, B. 1963. Iaktagelser över granskalbaggar i Västerdalarna. Ent. Tidskr. 84, 69-72.

Ehnström, B. 1983. Faunistiska anteckningar om granskalbaggar. Ent. Tidskr. 104, 75-79

Ehnström, B., Gärdenfors, U. & Lindelöv, Å. 1993. Swedish Red List of Invertebrates 1993. 69 pp. Databanken før hotade arter. Uppsala.

Evans, H. F. & Fielding, N. J. 1994. Integrated management of *Dendroctonus micans* in the UK. Forest Ecol. Managem. 65, 17-30.

Fossli, T.-E. & Andersen, J. 1998. Host preference of Cisidae (Coleoptera) on tree-inhabiting fungi in northern Norway. Entomol. Fenn. 9, 65-78.

Freude, H., Harde, K. W. & Lohse, G. A. 1964. Die Käfer Mitteleuropas. 4. 264 pp. Goecke & Evers, Krefeld.

Freude, H., Harde, K. W. & Lohse, G. A. 1967. Die Käfer Mitteleuropas. 7. 310 pp. Goecke & Evers, Krefeld.

Freude, H., Harde, K. W. & Lohse, G. A. 1969. Die Käfer Mitteleuropas. 8. 388 pp. Goecke & Evers, Krefeld.

Freude, H., Harde, K. W. & Lohse, G. A. 1979. Die Käfer Mitteleuropas. 6. 367 pp. Goecke & Evers, Krefeld.

Førland, E. J. 1993. Nedbørnormaler, normalperiode 1961-90. 63 pp. DNMI-Klimaavdelingen, Oslo.

Gillerfors, G. 1993. Nya kortvingar før Sverige. Ent. Tidskr. 114, 107-110.

Huggert, L. 1967. Några sällsynta Coleoptera. Ent. Tidskr. 88, 170-173.

Hultén, E. 1971. Atlas øver växternas utbredning i Norden. Fanerogamer och ormbunksväxter. 531 pp. Generalstabens Litografiska Anstalts Förlag, Stockholm.

Huse, Ø. 1997. Kan mengden ynglemateriale i et skogsområde gi informasjon om artsrikdom og individantall av obligatorisk saproxyliske biller? En undersøkelse på to skalaer. 46 pp. Thesis, University of Tromsø, Tromsø.

Johansson, L., Andersen, J. & Nilssen, A. C. 1994. Distribution of bark insects in «island» plantations of spruce (*Picea abies* (L.) Karst.) in subarctic Norway. Polar Biol. 14, 107-116.

King, C. B., Fielding, N. J. & O`Keefe, T. 1991. Observations on the life cycle and behaviour of the predatory beetle, *Rhizophagus grandis* Gyll. (Co., Rhizophagidae) in Britain. J. Appl. Ent. 111, 286-296.

Koch, K. 1989a. Die Käfer Mitteleuropas. Ökologie 1. 440 pp. Goecke & Evers, Krefeld.

Koch, K. 1989b. Die Käfer Mitteleuropas. Ökologie 2. 382 pp. Goecke & Evers, Krefeld.

Lekander, B., Bejer-Petersen, B., Kangas, E. & Bakke, A. 1977. The distribution of bark beetles in the Nordic countries. Acta Ent. Fenn 32, 1-102.

Lid, J. 1985. Norsk-svensk-finsk flora. 837 pp. Det Norske Samlaget, Oslo.

Lindroth, C. H. 1949. Die fennoscandischen Carabidae III. Allgemeine Teil. Göteborgs K. Vetensk. – Vitterh. Samh. Handl. Ser. B. 4, 1-911.

Lindroth, C. H. 1960. Catalogus Coleopterorum Fennoscandiae et Daniae. 478 pp. Entomol. Sälsk., Lund.

Lindroth, C. H. 1985-86. The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Ent. Scand. 15 (1-2).

Lohse, G. A. & Lucht, W. H. 1992. Die Käfer Mitteleuropas 13. 375 pp. Goecke & Evers, Krefeld.

Lundberg, S. 1973. En lokal för *Trachypachus zetterstedti* Gyll. vid Messaure i Lule lappmark (Col. Carabidae). Ent. Tidsskr. 94, 34-36.

Lundberg, S. 1975. Bidrag til kännedomen om svenska skalbaggar 15. Ent. Tidsskr. 96, 8-13.

Lundberg, S. 1986. Catalogus Coleopterorum Sueciae. 155 pp. Entomologiska Föreningen i Stockholm och Naturhistoriska Riksmuseet, Stockholm.

Lundberg, S. 1995. Catalogus Coleopterorum Sueciae. Naturhistoriska Riksmuseet & Entomologiska Föreningen i Stockholm, Stockholm.

Mitchell, A. 1977. Trær i skog og hage. 408 pp. Tiden Norsk Forlag, Oslo.

Nilssen, A. 1978. Development of a bark fauna in plantations of spruce (*Picea abies* (L.) Karst.) in North Norway. Astarte 11, 151-169.

Nilssen, A. 1993. Distribution of phytophagous beetles (Scolytidae, Cerambycidae, Curculionidae) living in the bark and wood of Scots pine (*Pinus sylvestris* L.) in northern Norway. Fauna norv. Ser. B 40, 13-31.

Nilssen, A. & Andersen, J. 1977. Finds of Coleoptera from northern Norway. Norw. J. Entomol. 24, 7-9.

Nordiska Ministerrådet 1984. Naturgeografisk registrering av Norden. 289 pp. Berlings, Arlöv.

Olberg, S. & Andersen, J. 2000. Field attraction of beetles (Coleoptera) to the polypores *Fomes fomentarius* and *Phellinus* spp. (Fungi: Aphyllophorales) in Northern Norway. Entomol. Gen. 24, 217-236.

Palm, T. 1947. För Sverige nya Coleoptera. IX. Ent. Tidsskr. 68, 37-44.

Palm, T. 1948. Skalbaggar. Coleoptera. Kortvingar: fam. Staphylinidae 9(1). 133 pp. Svensk Insektsfauna 38.

Palm, T. 1949. Et eksempel på anemochor insektspridning vid Torneträsk. Ent. Tidsskr. 70, 65-74.

Palm, T. 1959. Die Holz- und Rindenkäfer der Süd- und Mittelschwedischen Laubbäume. Opusc. ent. Suppl. 16, 1-374.

Palmån, E. 1944. Die anemohydrochore Ausbreitung der Insekten als zoogeographischer Faktor. Ann. zool. Soc. zool. bot. fenn. Vanamo 10, 1-262.

Ryvarden, L. 1997. Norges nasjonalparker. 196 pp. Universitetsforlaget, Olso.

Schwenke, W. 1974. Die Forstschädlinge Europas. Käfer. 500 pp. Parey, Hamburg.

Strand, A. 1938. *Agathidium pallidum* Gyll. (Col. Liodidae) als gute art. Norsk ent. Tidsskr. 5, 82-83.

Strand, A. 1946. Nord-Norges Coleoptera. Tromsø Mus. årsh 67 (1944), 1-699.

Strand, A. 1953. Coleoptera fra Nordreisa. Norsk ent. Tidsskr. 4, 63-70.

Strand, A. 1970. Additions and corrections to the Norwegian part of catalogus Coleopterorum Fennoscandia et Daniae. Norsk ent. Tidsskr. 17, 125-145.

Strand, A. 1977. Additions and corrections to the Norwegian part of catalogus Coleopterorum Fennoscandia et Daniae. Second series. Norw. J. Entomol. 24, 159-165.

Tømmerås, B. Å. & Breistein, J. 1995. Fragmenteringsforsøk i granskog. Problemstillinger og metoder samt resultater fra feltsesongen 1994. NINA oppdragsmelding 342, 1-43.

Tømmerås, B. Å., Ødegaard, F., Breistein, J., Wilman, B. & Gjershaug, J. O. 1997. Fragmentation experiments in boreal spruce forest, the Mosvik project. NINA oppdragsmelding 488, 1-33.

Vik, A. 1991. Catalogus Coleopterorum Norvegica. 157 pp. Stig Otto Hansen, Larvik.

Zachariassen, K. E. 1972. Notes on distribution of Coleoptera in Norway. Norw. J. Entomol. 19, 169-170.

Zachariassen, K. E. 1990. Sjeldne insektsarter i Norge. 2. Biller 1. 83 pp. NINA Utredning 017.

Received 1 July 2000,
accepted 28 February 2001.

Norw. J. Entomol. 48, 147–152. 2001

Water mites (Hydrachnidia) of the rivers Teno and Kemi, Finnish Lappland

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Bagge, P. 2001. Water mites (Hydrachnidia) of the rivers Teno and Kemi, Finnish Lappland. Norw. J. Entomol. 48, 147-152.

Water mite fauna of subarctic streams (R. Teno and its tributaries) was compared with fauna of silvatic streams situated in the middle parts of Kemijoki river system, Finnish Lapland. A total of c. 26-27 mite species were recorded; 16-17 of these in subarctic streams and 23-24 in silvatic streams. Species rich mite families in northern streams are Sperchonidae (6 taxa in silvatic and 3 in subarctic streams), Lebertiidae (3-4 taxa in both stream types) and Hygrobatidae (8 taxa in silvatic and 6 in subarctic streams). In silvatic streams, the catches of water mites (ind./sample) were higher in June-July than in autumn while the situation was opposite in R. Teno and its tributaries were catches of water mites as well as other invertebrates were very low in June perhaps depending on strong floods. New water mites to Limnofauna area 21 are *Sperchonopsis verrucosa*, *Sperchon glandulosus*, *Teutonia cometes*, *Hygrobates calliger*, *Atractides nodipalpis*, and *A. tener*.

Key words: northern streams, water mites, diversity, phenology.

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INTRODUCTION

Seasonal and regional occurrence of macroinvertebrates in the subarctic River Teno and its tributaries were studied by a team from Vaasa water- and environmental district and University of Jyväskylä in 1989 (Lax et al. 1993).

A similar study was carried out in the middle parts of River Kemi (the Vuotos area) by Riku Paavola et al. in 1994 (Paavola 1995). Since both materials contained plenty of water mites which were insufficiently analysed or ignored, I have continued the analysing and one of main tasks was to compare the regional and seasonal occurrence of water mites in subarctic and silvatic streams. A great help in the comparison has been an older water mite material collected by Prof. Stammer in August 1938 from the Luiro area (Viets 1940) which is situated to the North of Vuotos area. The Hydrachnidia (water mites) are the most diversified group of the Acari in freshwaters and are abundant and speciose also in lotic habitats. Lower-order streams of Central Europe may contain up to 50 species (Van der Hammen & Smit 1996). The life cycle of most european water mites is univoltine. The larvae parasite mainly insect hosts while adults and deutonymphs are voracious predators feeding mainly on insect eggs, insect larvae and microcrustacea (Di Sabatino et al. 2000).

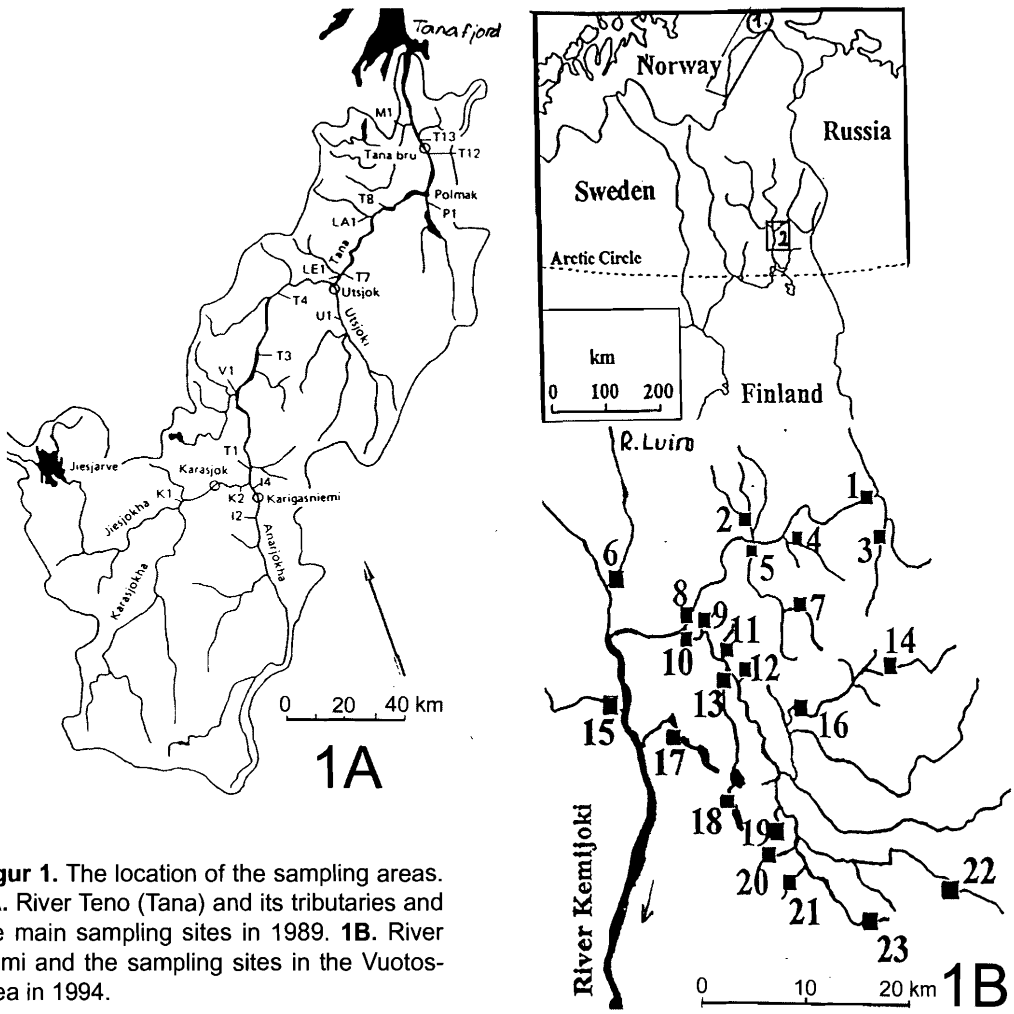
STUDY AREAS

River Teno (Tana) which is one of the most famous salmon streams in Fennoscandia is situated in the border of Norway and Finland and flows to the Arctic Ocean (Figure 1). The length of the river is c. 300 km, flow 30-400 m^3/s (mean 36 m^3/s) and the water is clear (colour 10-35 mg Pt/l). At present, the river may be characterised as oligotrophic (total P 2-10 µg/l) though there are signs of slight eutrophication below the settlements (Lax et al. 1993, Bagge 2000).

Most of the river valley is covered by subalpine birch forest but there are isolated stands of pine along the tributaries. Other characteristic features of the river are a high transport of sand, short growing period and strong seasonal fluctuations of temperature and runoff (Lax et al. 1993). Four of the sampling sites in 1989 were situated in small tributaries, 4 in larger tributaries and 7 in the main reach of R. Teno (Figure 1).

River Kemi: the Vuotos-area

Macroinvertebrates from 23 stream sites of River Kemi and its tributaries (Figure 1) were sampled by Paavola et al. in June-July and August-September 1994 (Paavola 1995). Water mites were recorded at 18 sampling sites (Figure 1). Of these, seven are situated in small brooks (mean flow < 0.2 m^3/s, five in larger brooks (mean flow 0.2-0.8 m^3/s), three in small rivers (mean flow 1.1-7.5 m^3) and three in large rivers (R. Luiro and R. Kemi) with mean flow 16 and 112 m^3/s (Figure 1). Owing to the rich occurrence of peat bogs in the catchment area, most of the streams of the Vuotos area are brown water streams (colour >80 mg Pt/l). Clear water streams with low concentration of total P include Taklamo-oja (No. 4), Serrijoki (No. 5 sand 7), Messinkioja (No. 12) and Siuliojoki (No. 16). Opposite to the situation in R.Teno and its tributaries, the riffle areas of the streams of Vuotos area usually had a rich cover of aquatic moss (cf. Paavola 1995).



Figur 1. The location of the sampling areas. **1A.** River Teno (Tana) and its tributaries and the main sampling sites in 1989. **1B.** River Kemi and the sampling sites in the Vuotos-area in 1994.

METHODS

In R. Teno and its tributaries, three kick samples (30 s. kicking) were taken from each sampling site (one near the shore and two in deeper water) in June and in September 1989. Moreover, several water mites were found in some colonization boxes settled on the bottom during the summer. They are included to the pooled material. In R. Kemi and its tributaries, four kick samples (30 s. kicking) were taken from different flood velocities, substrata and moss cover in June-July and in August-September 1994 (Paavola 1995). The subsamples were then pooled to form one kick sample of 2 min duration per site.

RESULTS

Water mite fauna of R.Teno and its tributaries

Water mites were found in 14 sampling sites (Table 1). In most sites, the catches (ind./pooled samples) were higher in September than in June.

In small tributaries, the vernal catches ranged from 0-4 ind. and the autumnal catches from 6 to 260 ind./stream. In large tributaries, the seasonal differences in catches were small. In River Teno, the autumnal catches were c. 3 fold compared with vernal catches, but the number of samples was somewhat higher in September than in June (cf. Table 1).

A total of c. 16 taxa of water mites was observed in R. Teno and its tributaries (Table 1). Species-rich

Table 1. Catches (ind./pooled samples) of water mites from River Teno (Tana) and its tributaries in 1989. Small tributaries: Niemelä-brook (N), Laksjokha (LA1), Polmakelva (P1), Masjokha (M1). Large tributaries: Utsjoki (U1), Anarjokha (I2), Karasjokha (K1, K2). R. Teno (T1-T13).

	TRIBUTARIES		R. TENO	SITES
	SMALL	LARGE	(TANA)	Where present
Sites studied:	4	4	7	cf. Figure 1
Number of samples:	18	30	47	
HYDRACHNIDIA (indet.)	283	-	-	M1, P1
SPERCHONIDAE				
Sperchonopsis verrucosa (Protz)	-	2	-	K2, I2
Sperchon brevirostris Koenike	-	-	1	T12
S. glandulosus Koenike	3	2	5	N, M1, K1, T12, T13
TEUTONIIDAE				
Teutonia cometes (Koch)	1	-	-	LA1
LEBERTIIDAE				
Lebertia spp. (3-4 taxa)	13	11	96	all, except U1
HYGROBATIDAE				
Hygrobates calliger Piersig	-	-	14	T4, T12, T13
H. fluviatilis (Ström)	1	9	4	N1, K2, I2, T4, T13
H. foreli (Lebert)	2	-	35	LA1, T1, T7, T12, T13
H. nigromaculatus Lebert	-	4	7	I2, T3, T8, T12, T13
Atractides nodipalpis (Thor)	1	2	-	LA1, K2, I2
A. tener (Thor)	1	4	2	K1, K2, I2, T1, T3
FELTRIIDAE				
Feltria minuta Koenike	-	1	-	K2
PIONIDAE				
Piona pusilla (Neuman)	1	-	-	LA1

families in the catches were Sperchonidae (3 taxa), Lebertiidae (3-4 taxa) and Hygrobatidae (6 taxa).

Widespread species in the subarctic streams were *Sperchon glandulosus*, *Hygrobates fluviatilis* and *H. foreli*. *Atractides*-species were more common in tributaries than in R. Teno, while *Hygrobates calliger* and *H. nigromaculatus* were mainly recorded in the lower reaches of R. Teno.

New water mites to the Limnofauna area 21 are *Sperchonopsis verrucosa*, *Sperchon glandulosus*, *Teutonia cometes*, *Hygrobates calliger* and both *Atractides*-species (cf. Viets 1978, Bagge 1989).

Water mite fauna of R. Kemi and its tributaries

Water mites were observed at eighteen sampling sites (Table 2); in seven small brooks (mean flow < 0.2 m^3/s), in five larger brooks (0.2-0.7 m^3/s), and in 6 river sites (1.1-112 m^3/s). The total catches of water mites were clearly higher in June-July than in autumn.

In small brooks (n=7), the number of mites/pooled sample ranged from 0 to 57 in June and from 0 to 14 during the autumn. In some brooks with high Fe-content and (or) high total load of phosphorus, no water mites were observed. In larger brooks (n=5) the catches ranged from 2 to 77 in June-July and from 2 to 14 in autumn. In eutrophied habitats (Säynäjäjoki No. 13 and Pikku-Karjala No. 23) the catches were small. In small rivers (n=3) the sampling partly failed in June owing to high flood but in larger rivers (n=3) the catches in July were three fold compared with the autumnal catches.

Table 2. Catches (ind./pooled samples) of water mites from R. Kemi and its tributaries (Vuotos area) in 1994. Sampling sites are presented in Figure 1.

	BROOKS		RIVERS		SITES
	Small	Large	Small	Large	Where present
Sampling sites	7	5	3	3	(cf. Figure 1)
SPERCHONIDAE					
Sperchonopsis verrucosa	2	1	-	2	8, 12, 13
Sperchon brevirostris	1	1	-	5	1, 3, 4, 8
S. glandulosus	51	34	1	1	totally 11 sites
S. papillosus Thor	-	-	5	2	1, 10, 22
S. setiger Thor	1	-	-	-	2
S. squamosus Kramer	-	5	5	-	5, 22
S. spp. (indet nymphs)	3	-	-	-	7
LEBERTIIDAE					
Lebertia spp. (3-4 taxa)	42	58	26	33	totally 15 sites
TORRENTICOLIDAE					
Torrenticola amplexa (Koenike)	-	-	1	3	1, 10
HYGROBATIDAE					
Hydrobates calliger	-	-	-	1	10
H. fluviatilis	5	5	8	51	totally 11 sites
H. foreli	51	22	1	7	totally 10 sites
H. norvegicus (Thor)	8	-	-	-	4
Mesobates forcipatus Thor	-	-	-	3	6
Atractides nodipalpis	7	5	10	16	totally 10 sites
A. tener	9	1	-	-	2, 4, 5, 7, 12
ARRENURIDAE					
Arrenurus sp.	1	-	-	-	20

A total of c. 18 taxa of water mites was found in the streams of the Vuotos area (Table 2) In the Luiro area, which is situated upstream of the Vuotos area, the total number of water mite taxa collected by Stammer in August 1938 was 14 (Viets 1940) and additionally three species (*Hygrobates norvegicus*, *Mesobates forcipatus* and *Piona disparilis* (Koenike) were detected in the emergence trap material collected by prof. Hirvenoja in 1959-60 from R. Luiro and its tributaries (Bagge, unpubl.)

Thus the total number of water mite taxa found in R. Kemi and its tributaries is c. 23-24.

Species-rich water mite families in the silvatic streams are Sperchonidae (6 taxa), Lebertiidae (3-4 taxa) and Hygrobatidae (8 taxa).

Widespread and abundant species in the small streams of the Vuotos area are *Sperchon glandulosus*, *Hygrobates foreli* and *Atractides tener*. Abundant taxa in the rivers are *Hygrobates fluviatilis* and *Atractides nodipalpis*. *Lebertia* spp. occurred abundantly in small and large streams. According to Viets (1941), *Lebertia lineata* Thor is common in small streams of Luiro area while *L. insignis* Neum. and *L. inaequalis* (Koch) (= *L. riabuschinskii* Thor) were observed in R. Luiro.

DISCUSSION AND CONCLUSIONS

The water mite fauna of the northern streams consists mainly of rheophilous species belonging to the families Sperchonidae, Torrenticolidae and Feltriidae. Among Hygrobatidae several taxa are rheophilous but e.g. *Hydrobates foreli* and *H. nigromaculatus* occur abundantly also in northern lakes (Bagge 1989). Mainly lacustrine families such as Pionidae and Arrenuridae were observed only occasionally in the streams and Unionicolidae were totally absent. The species richness of water mites was somewhat higher in silvatic streams than in the subarctic R. Teno and its tributaries. This may depend on the low temperature of subarctic waters and the lower number of host insects available for larvae of water mites.

The composition of lotic water mite communities seems primarily effected by temperature, current speed and substratum composition (Di Sabatino et al. 2000).

Within both stream systems, the number of species was almost equal in small and larger streams c. 10-14 taxa/stream type but within each stream we find mite rich and mite poor habitats. In the R. Teno area, rich habitats were eg. riffles of Laksjokha, Karasjokha and the lowermost localities of R. Teno (T12 and T13). In the Vuotos area, rich mite fauna occurred in both small clear water streams (Taklamo-oja (No. 4), Serrioja, Serrijoki (No. 5 and 7)) and in brown water rivers (Vuotosjoki, Luiro, R. Kemi). In some small streams with high content of phosphorus and (or) Fe, the mite fauna was poor.

In the subarctic streams, the total catches of water mites were considerably higher in autumn than in June while the situation was opposite in the silvatic streams.

Another factor highly affecting on catches was the moss cover of the habitats. In the subarctic R. Teno, the amount of aquatic moss growing on stones was usually very low perhaps owing to strong erosion and high transport of sand during the floods. In several silvatic streams, the moss cover was tight also after the flood periods (Paavola 1995). The relation of catches to the moss cover of the habitat is usually positive, but there are some exceptions as R. Taklamo-oja (No. 4) were moss was absent but catches were relatively high during both sampling periods. According to Paavola (pers. comm.) R. Taklamo-oja is a spring-fed stream with plenty of algae on stones.

Acknowledgement. The work was financed by the Finnish & Norwegian commission of boarder waters and the Academy of Finland.

REFERENCES

Bagge, P. 1989. Abundance and vertical distribution of watermites in the lakes of Finnish Lapland (Acari, Hydrachnellae). Fauna norv. ser. B 36, 45-52.

Bagge, P. 2000. Composition and relative abundance of feeding groups in the trichopteran fauna of the subarctic River Teno and its tributaries. Verh. Internat. Verein. Limnol., 27,1-7.

Di Sabatino, A., Gerecke, R. & Martin, P. 2000. The biology and ecology of lotic water mites (Hydrachnidia). Freshwater Biology 44, 47-62.

Lax, H.G., Koskenniemi, E., Sevola, P. & Bagge, P.

1993. Macrozoobenthos in the subarctic river Tenojoki as an environmental indicator. Vesi- ja ympäristöhallinnon Julk. Ser. A 131, 3-80 (in Finnish and Swedish).

Paavola, R. 1995. Patterns in the structure of benthic invertebrate communities of streams in the Vuotos area, Finnish Lapland; a multivariate approach. 48 pp. Master of Science Thesis, University of Oulu.

Van der Hammen, H. & Smit, H. 1996. The water mites (Acari: Hydrachnidia) of streams in the Netherlands: distribution and ecological aspects on the regional scale. Netherl. J. of Aquat. Ecol. 30 (2-3), 175-185.

Viets, K. 1940. Wassermilben (Hydrachnellae und Porohalacaridae, Acari) aus dem nördlichen Finnland. Zool. Anzeiger 131: 44-46.

Viets, K.O. 1978. *Hydracarina*. Pp. 154-181 in Illies, J. (ed.). *Limnofauna Europaea* 2nd edition. Fischer Verlag. Stuttgart, New York; Swets & Zeilinger B.V. Amsterdam.

Received 1 July 2000,
accepted 25 March 2001.

Norw. J. Entomol. 48, 153–160. 2001

Epigeic spider (Arachnida, Araneae) communities in exploited peatbogs of Lithuania

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Rėlys, V. & Dapkus, D. 2001. Epigeic spider (Arachnida, Araneae) communities in exploited peatbogs of Lithuania. Norw. J. Entomol. 48, 153-160.

Epigeic spider communities were studied in four exploited peatbogs by the means of pitfall traps in eastern and southwestern Lithuania during 1999. Comparison between the communities showed no large differences in the similarity of species making up more than 2% of the individuals in each community, but there were distinct differences in the abundance of species. Nine species had a relative abundance of above 5%. Only *Xerolycosa nemoralis* dominated in all spider communities. Eight spider species which were caught in exploited peatlands seemed to be typical for Lithuanian peatbog spider communities. Most of them were found only as single individuals except *Antistea elegans* which was a dominant (6.6% of all individuals) species in peatlands overgrown with *Eriophorum* sp. 28 spider species are new to Lithuania.

Key words: Araneae, exploited peatbogs, communities, Lithuania

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INTRODUCTION

As in many European countries, many peatbogs in Lithuania were drained for many years and transformed into exploited areas. Although there are large areas of former peatbogs, their spider fauna is poorly investigated in comparison with other European habitats (Hänggi et al. 1995). After exploitation, the open areas of former bogs undergo diverse ways of further development. The outcome of this process depends on surrounding habitats, hydrological regime and further anthropogenic impact. Such changes have an effect on arthropods, including spiders. Comprehensive studies of spider communities of peatlands have been carried out in northern England (Coulson et al. 1984a b, Coulson & Butterfield 1986). Anthropogenic impact on peatbog spiders have been studied in Finland (Koponen 1979). Curtis & Corrigan (1990) have investigated spider communities in relation to peatland management. In most cases, old former peatbogs have been studied. Only sparse data on spider communities formed shortly after completion of peat extraction was available. The aim of the present paper is to present the results of the research of spider communities in various peatland habitats.

MATERIAL AND METHODS

The study was carried out in exploited former peatbogs. Part of the research was carried out in the Baloša peatland (the total area 621 ha), located in eastern Lithuania (54°54’ N, 25°48’ E). This is a former peatbog with the remaining fragment of a raised bog (approximately 15% of the total area). Two study sites were chosen:

Baloša *Eriophorum* (BE). This is at the edge of an intensively exploited peatland area. Only tussocks of *Eriophorum* sp. cover part of the open peat area, which is the wettest of the sites, and was left after exploitation for 3-5 years.

Balošа *Calluna* (BC). This is an area mainly covered with dense shrubs of *Calluna vulgaris* (L.) and sparse birch trees (0.5 - 7 m height). Exploitation of this area was discontinued approximately 12 - 15 years ago.

Another two study sites were chosen in the Palios peatland (total area 1573 ha). The peatland is located in southwestern Lithuania (54°35' N, 23°42' E). The major part of this bog is already exploited. Only about 120 ha of partly drained raised bog remains in the site. The research was carried out in two sites:

Palios Peat (PP). This is a dry open peat area at the edge of the intensively exploited peatland area. Only small patches are overgrown with dry green mosses. It has not been exploited for 3-4 years.

Palios Birch (PB). This area is planted with rows of birches up to 4 m high and borders the previous study site. Other vegetation is very sparse, mostly in the form of dry green mosses. The earth surface is homogenously covered with birch leaves. The area is developing into a dense young birch stand. The exploitation stopped 5-7 years ago.

Spiders were collected by the means of pitfall traps (plastic jars with a volume of 300 ml and opening of 7 cm filled with 100-120 ml of 5% formaldehyde solution mixed with some drops of detergent). Six pitfall traps were mounted in each study site, and placed on a line with 5 m intervals. Traps were operated from the 14 April till the 11 October during 1999 and were emptied every three weeks.

The usage of the pitfall trap method has been widely discussed (Uetz & Unzicker 1976, Baars 1979, Curtis 1980, Topping & Sunderland 1992, Andersen 1995). It has been showed that this method gave a realistic estimate of a number of species in a ground living spider communities. The similarity between each pair of sites has been counted using qualitative Soerensen's coefficient of similarity QS = 2j/(a+b), where a and b were the number of species in two samples, and j the number of species common to both samples. QS has been counted for the two sets of data: for the whole species list and for the set of species representing more than 2% of the individuals in the community, as temporal vagrant individuals had an influence on the results.

Information concerning ecological peculiarities of spiders was obtained from Maurer & Hänggi (1990) and Hänggi et al. (1995). The nomenclature of spiders follows Platnick (1993).

RESULTS

A total of 1296 spider specimens belonging to 97 species and 15 families were registered in the investigated sites during 1999 (Table 1). The comparison of the communities showed large differences in the number of species and individuals. The number of species ranged from 36 (PP) to 51 (BE). The largest number of individuals was found in the community with the lowest number of species (PP, 36:425). A different situation was observed in the birch stand (PB) where the ratio of species to individuals was 48:231. Nine species had a relative abundance of more than 5% of the individuals in some investigated communities. Dominating species in most communities were *Pardosa pullata, Trochosa ruricola* and *Xerolycosa nemoralis*, although the last two species did not reach a very high level of dominance. *Pardosa pullata, Pachygnatha degeeri, Trochosa ruricola* and *Xerolycosa nemorlais* were common in all study sites, and *X. nemoralis* made up more than 5% of the individuals in each site. In three communities, one or two species made up more than 20% of all specimens. These spiders were *Pardosa pullata* (30.3% in BE), *Pachygnatha degeeri* (21.3% in BC), *Centromerita bicolor* (32.7% in PP) and *Oedothorax apicatus* (39.1% in PP).

Comparison of the whole set of species has showed that the most similar species composition was within each peatland (BE/BC – 0.49 and PP/PB – 0.48) (Table 2). The highest similarity of species between the communities of different peatlands was found between BC and PB (0,46), and the lowest one was found between BE and PP (0.37).

Species making up more than 2% of the individu-

Table 1. Number of specimens (N) and relative abundance (%) of spider (Araneae) species in the communities of the exploited peatbogs of Lithuania (BE: Balosa *Eriophorum*, BC: Balosa *Calluna*, PP: Palios Peat and PB: Palios Birch). An asterisk (*) marks species new to Lithuania.

Sites	**BE**	**BC**	**PP**	**PB**	**BE**	**BC**	**PP**	**PB**
Families/Species	**N**	**N**	**N**	**N**	**%**	**%**	**%**	**%**
Theridiidae								
Euryopis flavomaculata (C.L. Koch)				1				0.4
Robertus arundineti (O. P.- Cambr.)		5	6	4		1.8	1.4	1.7
Robertus lividus (Blackwall)	2	3		1	0.5	1.1		0.4
Steatoda albomaculata (De Geer)	1		1		0.3		0.2	
Linyphiidae								
* *Bathyphantes approximatus* (O. P.- Cambr.)			2				0.5	
* *Bathyphantes gracilis* (Blackwall)		3	1			1.1	0.2	
Bathyphantes parvulus (Westring)				1				0.4
* *Centromerita bicolor* (Blackwall)	10	89		20	2.7	**32.7**		**8.7**
* *Centromerus aequalis* (Westring)	1				0.3			
* *Centromerus sylvaticus* (Blackwall)		3	2	16		1.1	0.5	**7.0**
* *Diplostyla concolor* (Wider)		1	1			0.4	0.2	
Drepanotylus uncatus (O. P.- Cambr.)	1				0.3			
* *Lepthyphantes angulatus* (O. P.- Cambr.)	1	2			0.3	0.7		
* *Lepthyphantes cristatus* (Menge)				1				0.4
* *Lepthyphantes insignis* O. P.- Cambr.				2				0.9
Lepthyphantes mengei Kulczynski				4				1.7
* *Meioneta beata* (O. P.- Cambr.)		2				0.7		
Meioneta rurestris (C.L. Koch)		3	9	7		1.1	2.1	3.0
* *Porrhomma microphthalmum* (O. P.- Cambr.)			1				0.2	
Stemonyphantes lineatus (Linnaeus)		3				1.1		
Tallusia experta (O. P.- Cambr.)	10				2.7			
Araeoncus humilis (Blackwall)			1				0.2	
Dicymbium nigrum (Blackwall)				2				0.9
* *Diplocephalus picinus* (Blackwall)	1				0.3			
Erigone atra Blackwall		3	20	1		1.1	4.7	0.4
Erigone dentipalpis (Wider)		1	24	2		0.4	**5.7**	0.9
* *Erigonella ignobilis* (O. P.- Cambr.)	2				0.5			
Gnathonarium dentatum (Wider)			1				0.2	
Gonatium rubellum (Blackwall)	1				0.3			
Metopobactrus prominulus (O. P.- Cambr.)	1	1			0.3	0.4		
Micrargus herbigradus (Blackwall)				1				0.4
* *Micrargus subequalis* (Westring)			2	1			0.5	0.4
* *Minicia marginella* (Wider)	1				0.3			
* *Mioxena blanda* (Simon)	1				0.3			
Oedothorax apicatus (Blackwall)	9	3	165	4	2.5	1.1	**39.1**	1.7
* *Pocadicnemis pumila* (Blackwall)	2				0.5			1.7

Table 1. Continued.

Sites	BE	BC	PP	PB	BE	BC	PP	PB
Families/Species	**N**	**N**	**N**	**N**	**%**	**%**	**%**	**%**
Savignia frontata (Blackwall)	2				0.5			
* *Tapinocyba biscissa* (O. P.- Cambr.)				1				0.4
Tapinocyba insecta (L. Koch)				1				0.4
* *Troxochrus scabriculus* (Westring)	1		1	1	0.3		0.2	0.4
Walckenaeria antica/alticeps	6	1		2	1.6	0.4		0.9
* *Walckenaeria unicornis* (O. P.- Cambr.)	1				0.3			
Walckenaeria nudipalpis (Westring)			1	1			0.2	0.4
* *Walckenaeria vigilax* (Blackwall)	2		1		0.5		0.2	
Tetragnathidae								
Pachygnatha clercki Sundevall	3		10	3	0.8		2.4	1.3
Pachygnatha degeeri Sundevall	40	58	16	10	**10.9**	**21.3**	3.8	4.3
Araneidae								
Araneus quadratus Clerck	1	1			0.3	0.4		
Lycosidae								
Alopecosa cuneata (Clerck)			1	7			0.2	3.0
Alopecosa pulverulenta (Clerck)	4	2			1.1	0.7		
Arctosa leopardus (Sundevall)		1				0.4		
* *Aulonia albimana* (Walckenaer)				1				0.4
Pardosa agrestis (Westring)	2		4		0.5		0.9	
Pardosa amentata (Clerck)			1				0.2	
Pardosa lugubris (Walckenaer)				2				0.9
Pardosa paludicola (Clerck)	1		6	3	0.3		1.4	1.3
Pardosa palustris (Linnaeus)	1		13		0.3		3.1	
Pardosa prativaga (L. Koch)	2	9	9	3	0.5	3.3	2.1	1.3
Pardosa pullata (Clerck)	111	7	37	15	**30.3**	2.6	**8.8**	**6.5**
Pardosa sphagnicola (Dahl)		1				0.4		
Pirata tenuitarsis Simon	1				0.3			
Trochosa ruricola (De Geer)	58	16	19	32	**15.8**	**5.9**	4.5	**13.9**
Trochosa spinipalpis (F. O. P.- Cambr.)		3				1.1		
Trochosa terricola Thorell	2	2		1	0.5	0.7		0.4
Xerolycosa miniata (C. L. Koch)			10				2.4	
Xerolycosa nemoralis (Westring)	19	20	35	38	**5.2**	**7.4**	**8.3**	**16.5**
Agelenidae								
Agelena labyrinthica (Clerck)	1				0.3			
Hahniidae								
Antistea elegans (Blackwall)	24	2			**6.6**	0.7		
Dictynidae								
Cicurina cicur (Fabricius)				1				0.4

Table 1. Continued.

Sites	BE	BC	PP	PB	BE	BC	PP	PB
Families/Species	**N**	**N**	**N**	**N**	**%**	**%**	**%**	**%**
Liocranidae								
Agroeca brunnea (Blackwall)		1				0.4		
Agroeca proxima (O. P.- Cambr.)	3	7			0.8	2.6		
Phrurolithus festivus (C. L. Koch)	1			11	0.3			4.8
* *Scotina palliardi* (L. Koch)		1				0.4		
Clubionidae								
* *Cheiracanthium erraticum* (Walckenaer)			2				0.4	
Clubiona diversa (O. P.- Cambr.)	1				0.3			
Clubiona neglecta (O. P.- Cambr.)	1		1		0.3		0.2	
Clubiona pallidula (Clerck)				1				0.4
Clubiona phragmitis C. L. Koch				1				0.4
Gnaphosidae								
Drassodes pubescens (Thorell)	5				1.4			
Drassyllus lutetianus (L. Koch)	1				0.3			
Drassyllus praeficus (L. Koch)	5		1		1.4		0.2	
Drassyllus pusillus (C. L. Koch)	1				0.3			
Haplodrassus signifer (C. L. Koch)	12	5		1	3.3	1.8		0.4
Micaria pulicaria (Sundevall)			2	2			0.5	0.9
Micaria silesiaca L. Koch	1		3	1	0.3		0.7	0.4
* *Zelotes aeneus* (Simon)				11				4.8
Zelotes electus (C. L. Koch)	1			2	0.3			0.9
Zelotes latreillei (Simon)	3	1			0.8	0.4		
Zoridae								
Zora spinimana (Sundevall)	1	1		1	0.3	0.4		0.4
Philodromidae								
Philodromus histrio (Latreille)		2				0.7		
* *Thanatus striatus* C. L. Koch				1				0.4
Thomisidae								
Xysticus cristatus (Clerck)	4	3	15	3	1.1	1.1	3.6	1.3
Xysticus lanio C. L. Koch	1	2			0.3	0.7		
Xysticus sabulosus (Hahn)		2	1			0.7	0.2	
Xysticus ulmi (Hahn)				2				0.9
Salticidae								
Aelurillus v-insignitus (Clerck)	1	1		2	0.3	0.4		0.9
**Euophrys petrensis* C. L. Koch		1		1		0.4		0.4
**Sitticus rupicola* (C. L. Koch)				1				0.4
Total	**368**	**272**	**425**	**231**				
Number of species	**51**	**39**	**36**	**48**				

Table 2. Soerensen's coefficient of similarity (QS) between spider communities in Lithuanian peatlands. The first number means QS for the whole set of species and the second one the set of species making up more than 2% of the individuals in the community.

Sites	BE	BC	PP	PB
BE	-	0.49 / 0.73	0.37 / 0.60	0,40 / 0.63
BC	0.49 / 0.73	-	0.40 / 0.73	0,46 / 0.81
PP	0.37 / 0.60	0.40 / 0.73	-	0,48 / 0.81
PB	0.40 / 0.63	0.46 / 0.81	0.48 / 0.81	-

als in the communities have been compared as well. The number of such species ranged from 7/ BC to 13/PP. High similarity was registered between PP and PB (0.81) and between BC and PB (0.81). The results were similar comparing with QS of the whole set of species. More remarkable was the fact that similarity of abundant species (>2%) between the communities of the Balošа peatland (BE/BC = 0.73) was much lower than between the communities of the Palios peatland (PP/PB = 0.81).

A large part of species (33% - 49%) found in the communities were represented by one individual only. 28 spider species found during the investigation were new to Lithuania.

DISCUSSION

The recent studies have revealed that four epigeic spider communities were more different if the whole set of data was used in the comparison. The comparison of abundant species (>2%) did not show marked differences between the communities. Coulson & Butterfield (1986) stressed that spider communities living in peatlands could be defined by the set of abundant species. In contrast to our data, they found differences between these parts of communities. Relative abundance of dominant species was different, but they constantly occurred in all communities. If the similarity of abundant species is taken into account, the results differ from those obtained by Koponen (1979), Coulson & Butterfield (1986) and Curtis & Corrigan (1990). That could be caused by differences in habitats or in the regional spider faunas of Britain, continental Europe and Fennoscandia (Coulson et al. 1984a,b). We investigated former peatbogs in Lithuania, while natural peatlands were studied in northern England. The comparison of species shows that only some species are common for the regions mentioned above. Abundant eurytopic or open areas inhabiting species such as *Pardosa prativaga, Pardosa pullata, Trochosa ruricola, Xerolycosa nemoralis, Pachygnatha degeeri, Xysticus cristatus, Centromerita bicolor, Meioneta rurestris, Erigone atra, Erigone dentipalpis* and *Oedothorax apicatus* were characteristic for the investigated spider communities. Most of these species were found in grasslands but they were rare or absent in peatland communities investigated earlier (Coulson & Butterfield 1986, Curtis & Corrigan 1990).

Abundance or occurrence of spider species depends on characteristics of a habitat such as vegetation, litter structure or wetness (Noorgard 1951, Duffey 1975, Malfait 1995, Malfait et. al. 1997, Merkens 1997). High ground water level caused some differences in species composition in the wettest (BE) site. Hygrophilous species *Antistea elegans* became dominant (6.6%) only in this site. Other hygrophilous species such as *Drepanotylus uncatus, Tallusia experta, Diplocephalus picinus, Erigonella ignobilis, Gonatium rubellum* and *Pirata tenuitarsis* were found in this site as well.

Comparison of the number of spider species occurring in the open peatland (PP/36 species) and other habitats having more complex architecture (BE/51 and PB/48) reveals that the diversity of spiders depends on the habitat structure. Meanwhile, Coulson & Butterfield (1986) point out that complex habitat structure does not necessarily support the greatest spider diversity. This statement is better confirmed if only the sets of abundant species are compared (PP/13, PB/10 and BC/7).

Comparison of spider communities of the same peatland (BE/BC and PP/PB) shows higher similarity than the communities of different peatlands, especially if the whole sets of species are compared. Some species occur only in both habitats of the same peatland. Eight such common species were found only in BE and BC and four only in PP and PB.

Many species were presented as one or two specimens in two or three studied communities. Most of these species could be called accidental immigrants or «accessory colonisers» (Ysnel et al. 1996). A high number of such species could influence on the similarity level if the whole set of species is compared. They can occur in untypical habitats and should be treated separately in the analysis.

Unpublished data obtained from the studies of peatbogs and their fragments in Lithuania during 1999 allow some conclusions on typical peatbog species occurring in peatland communities. It should be stressed that only one typical peatbog species *Antistea elegans* became a dominant one in BE. The influence of peatbog species immigrating from adjacent pine bog wood in BC is revealed by the presence of three individuals of *Trochosa spinipalpis*, two of *Zora spinimana* and *Antistea elegans,* and single individuals of *Pardosa sphagnicola, Arctosa leopardus, Agroeca brunnea* and *Scotina palliardi*. The peatbog fragment is located in a distance from the study site in the Palios peatland. So only one specimen of *Aulonia albimana* and *Zora spinimana*, and two of *Walckenaeria nudipalpis* were registered there. This means that diverse habitats arising after peat extraction are not suitable for typical peatbog spider species.

REFERENCES

Andersen, J. 1995. A comparison of pitfall trapping and quadrat sampling of Carabidae (Coleoptera) on river banks. Entomol. Fennica 6, 65-77.

Baars, M.A. 1979. Catches in pitfall traps in relation to mean density of carabid beetles. Oecologia (Berlin) 41, 25-46.

Coulson, J.C., Butterfield, J. & Ungpakorn, R. 1984a. The spiders and harvestmen of some peat areas and upland grasslands in Co. Durham and adjacent areas of Cumbria. Vasculum 69, 101-109.

Coulson, J.C., Butterfield, J. Barratt, B. & Harrison, S. 1984b. The spiders and harvestmen of some peat and upland grassland sites in Yorkshire. Naturalist 109, 103-110.

Coulson, J.C. & Butterfield, J. 1986. The spider communities on peat and upland grasslands in northern England. Holarct. Ecol. 9, 229-239.

Curtis, D.J. 1980. Pitfalls in spider community studies (Arachnida, Araneae). J. Arachnol. 8, 271-280.

Curtis, D.J. & Corrigan, H. 1990. Peatland spider communities and land management on a scottish island. Pp. 97-102 in Celerier, M-L., Heurtault, J., & Rollard, C. (ed.), Comptes rendus du XIIème Colloque européen d'Arachnologie, Paris.

Duffey, E. 1975. Habitat selection by spiders in man-made environments. Pp. 53-67 in Proc. 6th Intern. Arachnol. Congr. Free University of Amsterdam, Amsterdam.

Hänggi, A., Stöckli, E. & Nentwig, W. 1995. Habitats of Central European spiders. Characterisation of the habitats of the most abundant spider species of Central Europe and associated species. 460 pp. Miscell. Faun. Helvet. 4, Centre suisse de cartographie de la faune, Neuchatel.

Koponen, S. 1979. Differences of spider fauna in natural and man-made habitats in a raised bog. Pp. 104-108 in Hytteborn, H. (ed.), The Use of Ecological Variables in Environmental Monitoring. The National Swedish Environment Protection Board, Report PM 1151, Uppsala.

Malfait, J.-P. 1995. Analysis of the spider fauna of the riverine forest nature reserve 'Valenbos' (Flanders, Belgium) in relation to hydrology and vegetation. Pp. 125- 136 in Ruzicka, V. (ed.), Proc. 15th Europ. Colloq. Arachnol. Institute of Entomology, Ceske Budejovice.

Malfait, J.-P., Baert, L. & Desender, K. 1997. Effects of groundwater catchment and grassland management on the spider fauna of the dune nature reserve 'De Westhoek' (Belgium). Pp. 221-236 in Zabka, M. (ed.), Proc. 16th Europ. Colloq. Arachnol. Wyzsza Szkola Rolniczo – Pedagogiczna, Siedlce.

Maurer, R. & Hänggi, A. 1990. Katalog der schweizerischen Spinnen. 412 pp. Doc. Faun. Helvet. 12, Centre suisse de cartographie de la faune, Neuchatel.

Merkens, S. 1997. Influence of environmental factors on the community structure of spiders in a humidity gradient of extensively managed, moist pastures. Pp. 237-248 in Zabka, M. (ed.), Proc. 16th Europ. Colloq. Arachnol. Wyzsza Szkola Rolniczo – Pedagogiczna, Siedlce.

Noorgard, E. 1951. On the ecology of two lycosid spiders (*Pirata piraticus* and *Lycosa pullata*) from Danish Sphagnum bog. Oikos 3, 1-21.

Platnick, N. 1993. Advances in spider Taxonomy 1988 – 1991. With synonymies and transfers 1940-1980. 846 pp. Entomol. Soc. & Am. Mus. Nat. Hist., New York.

Topping, C.J. & Sunderland, K.D. 1992. Limitations to the use of pitfall traps in ecological studies as exemplified by a study of spiders in a field of winter wheat. J. appl. Ecol. 29, 485-491.

Uetz, G.W. & Unzicker, J.D. 1976. Pitfall trapping in ecological studies of wandering spiders. J. Arachnol. 3, 101-111.

Ysnel, F., Canard, A. & Tiberghien, G. 1996. The shrub layer spider communities: variation of composition and structure of the gorse clump communities in western France. Rev. suisse Zool. Vol. hors serie II, 383-397.

Received 1 July 2000,
accepted 4 October 2000

Norw. J. Entomol. 48, 161–166. 2001

Macrolepidoptera of Lithuanian peatbogs

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Dapkus, D. 2001. Macrolepidoptera of Lithuanian peatbogs. Norw. J. Entomol. 48, 161-166.

This article deals with the relict Lepidoptera of Lithuanian peatbogs. A list of 21 tyrphobiontic and 23 tyrphophilous species is presented. Phenological aspects concerning Lithuanian peatlands' tyrphobiontic Macrolepidoptera are commented on. It was revealed that mid June was the peak in the flight activity of heliophilous tyrphobiontic Lepidoptera (9 species), while nocturnal tyrphobionts were observed flying in 2 peaks (Primo July (5 species) and Medio August (6 species)). Ecology of 3 tyrphobiontic species (*Oeneis jutta*, *Clossiana frigga* and *Aspitates gilvaria*) in Lithuania is presented. The need for conservation actions in order to preserve relict species living in Lithuanian peatbogs is emphasized.

Key words: Macrolepidoptera, peatbogs, Lithuania.

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INTRODUCTION

Peatlands are unique ecosystems whith unique ecological conditions, flora and fauna, and they play a stabilizing role of the landscape. Wetlands occupy approximately 415 000 ha of Lithuania, which make up 6.4 % of the whole territory (Janukonis 1995). There are 6685 peatlands (not including fens up to 3 ha) in Lithuania (Urboniene 1995). Minerotrophic fens make up the largest part of Lithuanian peatland area (71 %), oligotrophic peatbogs about 22 % and mesotrophic bogs 7 %.

Research of Lithuanian Lepidoptera fauna started in the beginning of the 20th century and some major works have been published (Palionis 1932, Prüffer 1947, Kazlauskas 1984, Ivinskis 1993) but these publications emphasized the list of Lepidoptera species providing few facts on their ecological peculiarities.

Peatbogs are isolated ecosystems which are very sensitive to negative anthropogenic impact. Thence, relict species living there need strict conservation actions based on scientific research. Tyrphobiontic species of Lepidoptera are considered to be good indicators of the quality and uniqueness of isolated post glacial peatbogs, so they may be used to justify the conservation of peatbogs as habitat islands (Tillotson & Spitzer 1998). For this reason it is very important to investigate and monitor relict Lepidoptera with the aim to prepare suitable strategy for conservation of peatlands.

MATERIAL AND METHODS

The collection of Macrolepidoptera was carried out during research expeditions throughout Lithuanian peatbogs in 1998–1999. Day flying butterflies and moths were registered during transect counts. Nocturnal moths were collected by use of light lamps and bait. Larvae of Lepidoptera were collected by examining *Ledum palustre* L., *Vaccinium uliginosum* L. shrubs and various herbivorous plants (*Andromeda polifolia* L., *Oxycoccus palustris* Pers., *Empetrum nigrum* L., *Calluna vulgaris* (L.), etc.), and reared in the laboratory. Only Lepidoptera belonging to the superfamilies Lasiocampoidea, Bombycoidea, Hesperioidea, Papilionoidea, Drepanoidea, Geometroidea and Noctuoidea were used in the analysis. The nomenclature follows Karsholt

& Razowski (1996); ecological terminology is according to Mikkola & Spitzer (1983), Spitzer (1992), and Spitzer & Jaroš (1993).

RESULTS AND DISCUSSION

Twenty one tyrphobiontic (strongly associated with peatbogs) and twenty three tyrphophilous Lepidoptera species (mainly living in peatbogs but found in other habitats too) were revealed during the study (Table 1). *Xestia alpicola* (Zetterstedt) and *Rheumaptera subhastata* (Nolcken) are not included in the list, as only few specimens have been found in Lithuania, but these species are associated with peatbogs in Central Europe (Spitzer & Jaroš 1993). The present list of Lithuanian tyrphophilous Macrolepidoptera species is not complete. This problem requires future studies, and the comparison of abundance of species living in various habitats should be done.

There is a general trend to a weaker tyrphobiontic association towards the northern and alpine timber lines (Mikkola & Spitzer 1983). Lepidoptera species which are weakly associated with peatbogs in Northern Europe, are strongly associated with peatlands in Central and Eastern Europe. Macrolepidoptera species (*Clossiana frigga* (Thunberg), *Oeneis jutta* (Hübner), *Eupithecia gelidata* Möschler, *Chloroclysta infuscata* (Tenström), *Macaria carbonaria* (Clerck), *Anarta cordigera* (Thunberg), *Syngrapha microgamma* (Hübner) and *Orgyia antiquoides* (Hübner)) are very strongly associated with peatbogs and have never been found outside the boundaries of raised bogs in Lithuania, while they can be found in other habitats in northern Fennoscandia. *Colias palaeno* (L.), *Boloria aquilonaris* (Stichel), *Vacciniina optilete* (Knoch), *Rheumaptera hastata* (L.), *Amphipoea lucens* (Freyer), *Acronicta menyanthidis* (Esper), *Celaena haworthii* (Curtis), *Coenophila subrosea* (Stephens), *Lithophane lamda* (Fabricius) and *Lithomoia solidaginis* (Hübner) are tyrphobiontic species in Lithuania, but they live in the margins of bogs too, or occasionally migrate to foreign habitats. Most of these species are tyrphophilous in northern countries (Mikkola pers.comm. 2000).

Table 1. Tyrphobiontic and tyrphophilous Macrolepidoptera species recorded in Lithuania.

Species	**Ecological group**[1)]	**Association with peatbogs**[2)]	**Flight period**[3)]	**Status**
Pieridae				
Colias palaeno (L., 1761)	TB	1	b VI - e VII	Rare
Nymphalidae				
Boloria aquilonaris (Stichel, 1908)	TB	1	VI	Rare
Clossiana frigga (Thunberg, 1791)	TB	1	m V - m VI	Very rare
Clossiana euphrosyne (L., 1758)	TF	3	e V - e VI	Common
Proclossiana eunomia (Esper, 1799)	TB	1	VI	Rare
Oeneis jutta (Hübner, 1806)	TB	1	e V - m VI	Very rare
Coenonympha tullia (Müller, 1764)	TF	2	m VI - M VII	Rare
Lycaenidae				
Vacciniina optilete (Knoch, 1781)	TB	1	m VI - m VII	Rare
Callophrys rubi (L., 1758)	TF	2	e IV - e VI	Abundant
Plebejus argus (L., 1758)	TF	3	m VI - e VII	Abundant
Geometridae				
Macaria carbonaria (Clerck, 1759)	TB	1	b V - b VI	Rare
Ematurga atomaria (L., 1758)	TF	3	e IV- e VII	Abundant

Table 1. Continued.

Species	Ecological group[1]	Association with peatbogs[2]	Flight period[3]	Status
Arichanna melanaria (L., 1758)	TF	2	e VI - e VII	Abundant
Aspitates gilvaria (Denis et Schiffermüller, 1775)	TB	1	VII	Very rare
Chloroclysta infuscata (Tengström, 1869)	TB	1	m VI - m VII	Very rare
Carsia sororiata (Hübner, 1813)	TB	1	e VI - e VII	Common
Eupithecia gelidata Möschler, 1860	TB	1	e V - b VII	Rare
Rheumaptera hastata (L., 1758)	TB	1	b V - m VI	Common
Idaea muricata (Hufnagel, 1767)	TF	2	m VI - m VII	Common
Jodis putata (L., 1758)	TF	3	m V - e VI	Abundant
Perconia strigillaria (Hübner, 1787)	TF	3	e V - e VI	Common
Scopula virgulata (Denis et Schiffermüller, 1775)	TF	2	e VI - e VII	Rare
Thalera fimbrialis (Scopoli, 1763)	TF	2	b VII - b VIII	Common
Itame brunneata (Thunberg, 1784)	TF	3	b VI - b VII	Abundant
Noctuidae				
Anarta cordigera (Thunberg, 1788)	TB	1	b V - b VI	Rare
Anarta myrtilli (L., 1761)	TF	3	m V - e VI	Rare
Amphipoea lucens (Freyer, 1845)	TB	1	VIII	Common
Acronicta menyanthidis (Esper, 1789)	TB	1	m V - m VIII	Common
Celaena haworthii (Curtis, 1892)	TB	1	e VII - e IX	Common
Coenophila subrosea (Stephens, 1829)	TB	1	e VII - b IX	Common
Lithophane lamda (Fabricius, 1787)	TB	1	b IV - m V	Rare
Lithomoia solidaginis (Hübner, 1803)	TB	1	b VIII - m IX	Common
Syngrapha microgamma (Hübner, 1823)	TB	1	VI	Rare
Syngrapha interrogationis (L., 1758)	TF	2	b VII - e VIII	Rare
Hyppa rectilinea (Esper, 1788)	TF	3	m V - e VI	Common
Hypenodes humidalis Doubleday, 1850	TF	3	e VI - e VIII	Abundant
Lycophotia porphyrea (Denis et Schiff., 1775)	TF	3	e VI - b VIII	Abundant
Papestra biren (Goeze, 1781)	TF	2	m V - e VI	Rare
Orthosia opima (Hübner, 1809)	TF	2	IV	Common
Protolampra sobrina (Duponchel, 1843)	TF	2	VIII	Rare
Arctiidae				
Rhyparia purpurata (L., 1758)	TF	2	e VI - e VII	Common
Coscinia cribraria (L., 1758)	TF	3	b VII - e VIII	Common
Lymantriidae				
Orgyia antiquoides (Hübner, 1822)	TB	1	e VI - m VII	Rare
Nolidae				
Nola aerugula (Hübner, 1793)	TF	2		

1) TB – tyrphobiont, TF – tyrphophilous species
2) 1 – strong; 2 – moderate; 3 – weak
3) b – beginning; m – middle; e – end

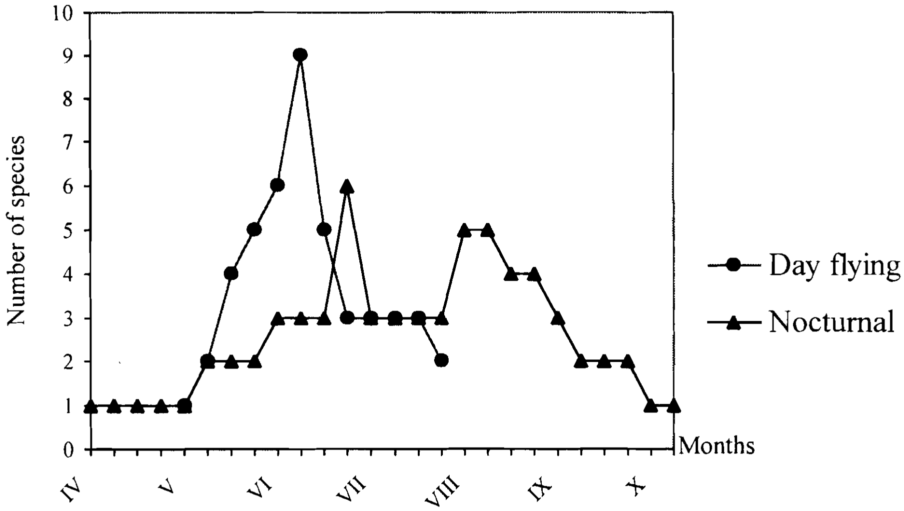

Figure 1. Phenology of tyrphobiontic Macrolepidoptera in Lithuania.

The weak conductivity of the peat layer leads to conditions with extreme temperature amplitudes: the days are hot and the nights cold (Mikkola & Spitzer 1983, Spitzer 1994, Vepsäläinen et al. 2000). This feature explains the flight activity of tyrphobiontic Lepidoptera. Eleven heliophilous and ten sciophilous tyrphobiontic species live in Lithuanian peatbogs. Cold/hot and wet/dry microclimatic conditions of peatbogs influenced 5 Heterocera species (*Rheumaptera hastata*, *Macaria carbonaria*, *Anarta cordigera*, *Syngrapha microgamma* and *Orgyia antiquoides*) becoming exceptionally heliophilous. The research has shown that diurnal tyrphobionts fly from the beginning of May till the end of July (Figure 1). Only tyrphoneutral species (e.g. *Nymphalis antiopa* (L.), *Inachis io* (L.), *Pieris napi* (L.), etc.) are recorded in peatbogs in early spring and late summer. All heliophilous tyrphobionts are univoltine. The peak of flight of specific Lepidoptera is the middle of June when 9 species (*Colias palaeno*, *Boloria aquilonaris*, *Clossiana frigga*, *Proclossiana eunomia*, *Oeneis jutta*, *Vacciina optilete*, *Rheumaptera hastata*, *Orgyia antiquoides* and *Syngrapha microgamma*) are found. The flight period of heliophilous Lepidoptera coincide with the blossom of typical bog plants, such as *Andromeda polifolia*, *Oxycoccus palustris*, *Ledum palustre* and *Vaccinium uliginosum*. Some adult tyrphobionts feed on these flowering plants.

The flight activities of nocturnal tyrphobiontic Lepidoptera start in early spring and end in late autumn (Figure 1). *Lithophane lamda* is the earliest tyrphobiont which starts flying from the beginning of April. In fact, it starts flying after hi-

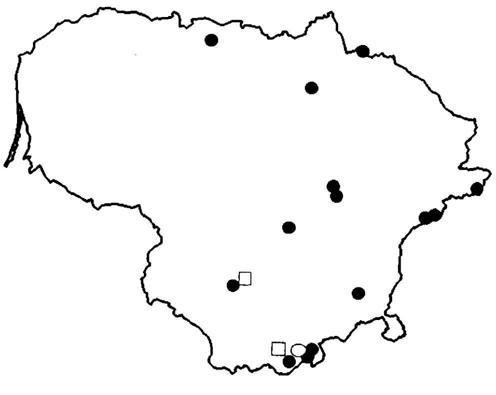

Figure 2. Distribution of *Oeneis jutta* (●), *Clossiana frigga* (O) and *Aspitates gilvaria* (□) in Lithuania.

bernation. This species is rarely found flying in autumn, but is more abundant in spring. Spitzer and Jaroš (1993) recorded *Lithophane lamda* only in spring and early summer during fifteen years of studies in one of Central European peatbogs. Probably, a small proportion of specimens emerges in autumn, while the larger part emerges in spring.

Two flight peaks of nocturnal tyrphobionts can be singled out. The first starts in the beginning of July (*Aspitates gilvaria* (Denis et Schiffermüller), *Carsia sororiata* (Hübner), *Chloroclysta infuscata*, *Eupithecia gelidata* and *Acronicta menyanthidis*), and the second in the middle of August (*Amphipoea lucens*, *Acronicta menyanthidis*, *Celaena haworthii*, *Lithomoia solidaginis* and *Coenophila subrosea*). Only *Acronicta menyanthidis* is a bivoltine species, so it falls into the both peaks. The results show that the middle of summer is the most suitable period for tyrphobiontic geometrids, as days and nights are warm in June and July. Meanwhile, days are hot and nights are cold in August, so only noctuids are recorded during that season, as they are better adapted to extreme microclimatic conditions.

Some species of Lepidoptera are good indicators of habitat quality. Due to intensive but not very successful drainage of wetlands in Lithuania, many peatbogs were partially or totally destroyed during recent decades. This process still goes on. Mature forests surrounding peatlands are cut down. Negative anthropogenic impacts such as picking of berries, fishing in inner lakes of peatbogs and tracking, lead to the destruction of bog vegetation, especially *Sphagnum* layer, which needs years to recover. Due to this, most of the tyrphobiontic Lepidoptera species are rare and endangered in Lithuania. *Oeneis jutta, Clossiana frigga* and *Aspitates gilvaria* seem to be very sensitive to habitat change. *Oeneis jutta* is found in some peatbogs bigger than 300 ha in the north-eastern and southern parts of Lithuania (Figure 2), and will become extinct if only a small part of these peatbogs is drained (Kazlauskas 1984). Scattered populations of *Clossiana frigga* live only in the largest mire complex (5858 ha) located in southern Lithuania, while populations of *Aspitates gilvaria* are found in two large peatbogs (5858 and 3400 ha). There is no doubt that populations of rare tyrphobionts should be monitored, but such a work still is not begun in Lithuania.

To maintain the hydrological conditions is the main way to preserve wetlands. Spitzer (1994) proposed «No action strategy» as the best conservation strategy for peatbogs and their Lepidoptera communities – other than preserve good hydrological conditions. According to the strategy, untouched bogs should be protected as conservation priority. As most Lithuanian peatbogs are ditched, it is necessary to stop flowing of water from bogs by strewing on canals in the margins of peatbogs. Beavers (*Castor fiber* L.) build dams on such ditches, and prevent bogs from getting dried, so it is necessary to support their populations in peatbogs.

Acknowledgements. I am obliged to Dr. Eduardas Budrys for the assistance during preparation of the article. I would like to thank Dr. Karel Spitzer (Czech Republic) and Dr. Kauri Mikkola (Finland) for every kind of help.

REFERENCES

Ivinskis, P. 1993. Check-list of Lithuanian Lepidoptera. 210 pp. Vilnius.

Janukonis, A. 1995. Resources of peat. Pp. 21-22 in Liužinas, R. (ed.). Cadastre of Lithuanian peatlands (in Lithuanian). Vilnius.

Karsholt, O. & Razowski, J. (eds). 1996. The Lepidoptera of Europe. 380 pp. Apollo Books, Stenstrup.

Kazlauskas, R. 1984. Butterflies and moths of Lithuania. 190 pp. Vilnius.

Mikkola, K. & Spitzer, K. 1983. Lepidoptera associated with peatlands in central and northern Europe: a synthesis. Nota Lepid. 6 (4), 216-229.

Palionis, A. 1932. Beitrag zur Kenntnis der Lepidopterenfauna Litauens. Mem. Fac. Sci. Univ. Vytautas le Grand, VI. 182 pp. Kaunas.

Prüffer, J. 1947. Studia nad Motylami Wilenszczyzny. 491 pp.Torun.

Spitzer, K. & Jaroš, J. 1993. Lepidoptera associated with Cervene Blato bog (Central Europe): conservation implications. Eur. J. Entomol. 90, 323-336.

Spitzer, K. 1994. Biogeographical and ecological determinants of the central European peatbog Lepidoptera: the habitat island approach to conservation. Nota Lepid. 5, 45-49.

Tillotson, I.J.L. & Spitzer, K. 1998. The Rosy Marsh moth, *Coenophila subrosea* (Stephens, 1829) (Lepidoptera: Noctuidae) – a review of its bionomics, distribution and conservation status with special reference to Britain. Entomologist's Gazette 49, 75-89.

Urboniene, J. 1995. Check-list of peatlands. Pp. 30-1280 in Liužinas, R. (ed.). Cadastre of Lithuanian peatlands (in Lithuanian). Vilnius.

Vepsäläinen, K., Savolainen, R., Tiainen, J. & Vilen, J. 2000. Successional changes of ant assemblages: from virgin and ditched bogs to forests. Ann. Zool. Fennici 37, 135-149.

Received 1 September 2000,
accepted 15 November 2000.

Norw. J. Entomol. 48, 167–174. 2001

Changes in structure of ground-living spider (Araneae) communities on peatbogs along a transect from Lithuania to Lapland

Seppo Koponen, Vygandas Relys & Dalius Dapkus

Koponen, S., Relys, V. & Dapkus, D. 2001. Changes in structure of ground-living spider (Araneae) communities on peatbogs along a transect from Lithuania to Lapland. Norw. J. Entomol. 48, 167-174.

Ground-living spiders were studied on peatbogs from southern Lithuania (54°N) to northern Finland (70°N). Communties of hunting spiders and web-building Linyphiidae (s.lat.) were compared at different latitudes. Geographical trends in the composition of species were found. Certain southern species were found only on Lithuanian bogs (e.g. *Aulonia albimana* and *Phrurolithus minimus*) and some other southern species were observed from Lithuania to southern Finland (*Maro minutus* and *Sintula corniger*). Of northern species, many were found only in Lapland (northernmost Finland), others occur in whole of Finland (*Gnaphosa lapponum* and *Mecynargus sphagnicola*), and some also in Estonia (*Pardosa atrata*). Species caught throughout the area include e.g. *Pardosa sphagnicola* and *Lepthyphantes angulatus.*

Key words: Araneae, peatbogs, Finland, Lithuania, Estonia

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INTRODUCTION

Peatbogs, like all types of mires, are endangered habitats especially in Central and Southern Europe. Also in Northern Europe many organisms living on mires are nowadays considered as threatened; this is true also for spiders (e.g. Koponen 1985). For example, in the recent Finnish Red Data Book (Rassi et al. 2000) six of the total 34 listed spider species are inhabitants of mires: *Emblyna brevidens* (Kulczynski), *Ceraticelus bulbosus* (Emerton), *Mecynargus (*sub *Rhaebothorax) foveatus* (Dahl), *Satilatlas britteni* (Jackson), *Ozyptila gertschi* Kurata, and *Zora parallela* Simon.

In the present paper we compare ground-living spider communities on peatbogs in Lithuania, Estonia and Finland. Large-sized hunting spiders (families Gnaphosidae, Liocranidae, Lycosidae, Pisauridae and Zoridae) and the dominant web-builders (Linyphiidae s.lat.) are included. Special attention will be paid to distribution patterns of bog spiders.

STUDY AREAS, MATERIAL AND METHODS

Material has been collected by pitfall traps in Lithuania and Finland (Figure 1). Trapping periods, years of sampling as well as number of traps (10-20 traps/site) varied markedly between sites, thus statistical analyses have not been done and the comparisons are based on percentages of species in each study site. Comparative data from

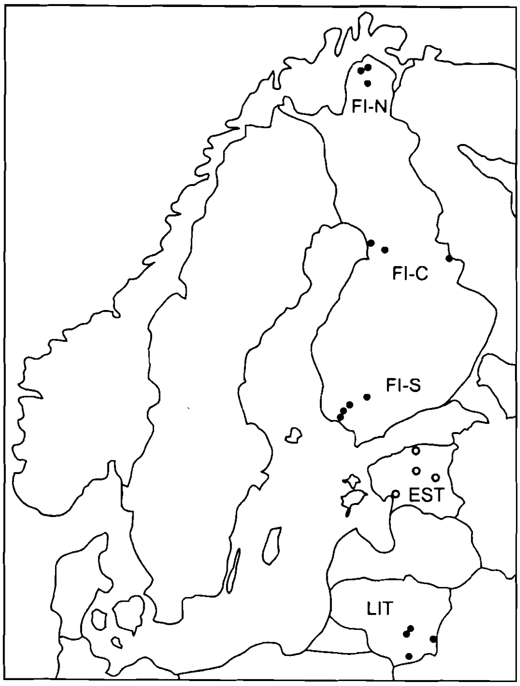

Figure 1. Study (trapping) sites in Lithuania (LIT), southern Finland (FI-S), central Finland (FI-C) and northern Finland (Lapland, FI-N). Main study peatbogs in Estonia (EST) are marked by open circles (from Vilbaste 1980-81).

Estonia originates from Asta Vilbaste's investigations (Vilbaste 1980-81); due to different collecting methods, mainly sieving of moss and sweep-netting, the comprehensive data from Estonian peatbogs was difficult to involve in our analysis (Table 1). These and additional data on Estonian spiders (Vilbaste 1987) however, were used to compile Table 2.

The material studied is from five regions along a transect from southern Lithuania to northern Finland. In south and south-east Lithuania (LIT) both open (treeless) and pine peatbogs included: 1) State Strict Nature Reserve «Čepkeliai» (Distr. Varėna), 2) Laukėnai (Distr. Ukmergė); two separately studied pine peatbogs are: 3) Baloša (Distr. Švenučionys), 4) Kertušas (Distr. Ukmergė). Coordinates for the area are 54°00' - 55°11'N, 24°30'-25°50'E. Sites in southern Finland (FI-S), both open and pine peatbogs are: 1) Masku Karevanrahka, 2) Vahto Rehtisuo, 3) Pöytyä Kontolanrahka; only open peatbog was studied in 4) Renko Seitsemänlamminsuo; coordinates for the area are 60°20'– 60°50'N, 22°15'– 24°20'E. Open peatbog sites in central Finland (FI-C) include: 1) Pudasjärvi Hirvisuo, 2) Ii Yli-Ii, 3) Suomussalmi Malahvia; coordinates: 64°45'– 65°20'N, 25°30' – 29°40'E. Open peatbog sites in northern Finland (Lapland) (FI-N) are: 1) Inari Säytsjärvi, 2) Utsjoki Puksalansuo, 3) Utsjoki Vaisjäggi; coordinates for the area are 69°20' – 69°50'N, 27°00' – 27°20'E.

Open peatbogs in Finland are characterized by *Sphagnum, Eriophorum* and *Carex* species as well as by *Andromeda, Calluna, Ledum palustre, Vaccinium oxycoccos, Betula nana, Rubus chamaemorus*. One site in Lapland (Vaisjäggi) is a palsa bog (Eurola et al. 1984). In pine peatbog sites, *Pinus sylvestris* is naturally the dominant additional plant species. Open areas are sparse and most peatbogs are influenced by pines in east and south Lithuania. Of the plant species typical of Finnish peatbogs, only *Rubus chamaemorus* and *Betula nana* are rare on Lithuanian bogs. *R. chamaemorus* was present only in one of the studied peatbogs (Laukėnai). On open bogs in Lithuania, *Sphagnum fuscum* is less common than in Finland.

Nomenclature used is according to Platnick (1997) and the material from Finland and Lithuania is deposited in the Zoological Museum, University of Turku and in the Department of Zoology, Vilnius University, respectively.

RESULTS AND DISCUSSION

Faunal differences and distribution patterns

Relative abundance of common species in epigeic spider communities of peatbogs in three regions (southern, central and northern) of Finland and in Lithuania is shown in Table 1. Of these «typical» peatbog spiders, only one lycosid (*Pardosa sphagnicola*) and some linyphiid species (*Agyneta cauta, Centromerus arcanus, Lepthyphantes angulatus, Meioneta mossica, Cnephalocotes obscurus, Pocadicnemis pumila, Walckenaeria nudipalpis*) can be stated as regularly occurring on peatbogs without remarkable changes in their dominance level along the whole transect (Table 1). For most other species clear differences in dominance level can be noticed along the transect. *Arctosa alpigena* and *Pardosa hyperborea* are typical dominant species on peatbogs investigated in Finland, but are not so important on Lithuanian peatbogs. In Finland, *P. hyperborea* is dominating in almost all peatbog spider communities, while in Lithuania this species was present only in one of the peatbogs where this generally northern species was dominant. Some abundant species (*Pirata uliginosus, Trochosa spinipalpis*) occur on peatbogs in central Finland and southwards, and are typical of all peatbogs in the south (southern Finland and Lithuania). Similarly occurring common but less numerous species in most communities are *Alopecosa pulverulenta, Pardosa pullata, Pirata insularis, Drassodes pubescens, Haplodrassus signifer, Tallusia experta* and *Walckenaeria atrotibialis*.

Also *Notioscopus sarcinatus* occurs on peatbogs from central Finland to Lithuania. Records only from single communities in regions point on local (patchy) distribution of this species; it was caught in marked numbers on a pine bog in Lithuania (Table 1). *Agroeca dentigera* is a rarely collected bog-dweller, found in Lithuania and Finland. Other large group of species are typical elements of peatbog communities only in southern Finland and southwards, e.g. *Gnaphosa nigerrima, Zelotes latreillei, Agroeca proxima, Maro minutus, Sintula corniger* and *Walckenaeria nodosa*; many of these being typical particularly on peatbogs in Lithuania, e.g. *Drassyllus pusillus* and *Scotina palliardi* (Table 1 and 2). Only three of the species that are abundant in Lithuania were not found in southern Finland (*Drassyllus lutetianus, Phrurolithus minimus* and *Aulonia albimana*).

Despite of high similarity in species composition between spider fauna of peatbogs in southern Finland and Lithuania, very remarkable differences in abundances can be recognised (Table 1). The high dominance of *Aulonia albimana* in Lithuania is the most striking example (in some communities up to 46.8 % of individuals). On peatbogs of Lithuania, compared with those in southern Finland, typical features are lower abundance of *Arctosa alpigena, Drassodes pubescens* and *Phrurolithus festivus*, rare occurrence of *Pardosa hyperborea*, absence of *P. atrata* and *Zora parallela*, the last-mentioned known from peatbogs in southern Fennoscandia (Lohmander 1956, Koponen 1979). On the other hand, *Hygrolycosa rubrofasciata, Drassyllus pusillus* and *Scotina palliardi* were caught in higher numbers on the Lithuanian peatbogs than in Finland.

Some differences in species composition can be explained by the known distribution patterns of species. A generally northern lycosid *Pardosa atrata* is known (besides Finland) from Estonia, but absent in Lithuania. Also northern *P. hyperborea*, common in Estonia, is in Lithuania near its limit. Linyphiid species *Hilaira nubigena, H. herniosa, Wabasso questio* and *Pelecopsis mengei*, which are known to have a northern range are dominating on peatbogs in northern regions (FI-N, FI-C). Other northern species, e.g. *Gnaphosa lapponum* and *Mecynargus sphagnicola* (Holm), are found also in southern Finland.

Some species, not included in Table 1, are numerous on one single bog, but do not occur on other peatbogs of that region or in other regions investigated, e.g. *Gnaphosa bicolor* (Hahn) (FI-S/3, 1.2 % of catch in Pöytyä Kontolanrahka), *Porrhomma microphthalmum* (O.P.-Cambridge) (FI-S/2, 1.7 %), *Glyphesis cottonae* (La Touche) (FI-S/2, 2.0%) and *Hypselistes jacksoni* (O.P.-Cambridge) (FI-N/2, 3.0 %).

Some rare species (not included in Table 1), known to be typical inhabitants of peatbogs, were caught. For example, *Taranucnus setosus* (O.P.-Cambridge) is common on peatbogs in Lithuania, but never in high number of individuals, and the situation is similar in southern Finland. *Hypselistes jacksoni* shows high abundance on one peatbog in northern Finland (see above). In Lithuania this species is common on west Lithuanian peatbogs (Relys, personal data), and was found to be abundant in lagg zone of Estonian peatbogs (Vilbaste 1980-81). *Aphileta misera* (O.P.-Cambridge) is sparsely trapped along the transect

Table 1. Relative abundance of typical species in epigeic peatbog spider communities (% of individuals in community). The lowest and highest values are given for each region; an asterisk (*) indicates that the species has been found only in one community. See text for explanation to regions.

Region	FI - N	FI - C	FI - S		LIT	
Number of communities investigated	**3**	**3**	**4**	**3**	**2**	**4**
Species	**open bog**	**open bog**	**open bog**	**pine bog**	**open bog**	**pine bog**
Alopecosa pulverulenta (Clerck)		0.6 - 5.5	0.6 - 8.7	0.6 - 10.1	2.1*	0.7 - 6.9
Arctosa alpigena (Doleschall)	0.5 - 12.8	4.4 - 8.3	0.3 - 30.6	0.3 - 3.1	5.8*	0.1 - 1.3
Aulonia albimana (Walckenaer)					1.2 - 19.2	17.1 - 46.8
Hygrolycosa rubrofasciata (Ohlert)				0.6*		0.2 - 5.1
Pardosa atrata (Thorell)	0.5 - 36.3	1.5 - 3.2	0.3 - 13.2	0.6*		
Pardosa hyperborea (Thorell)	4.4 - 45.4	0.6 - 36.1	3.7 - 21.2	19.9 - 29.3	12.7*	
Pardosa prativaga (L. Koch)					0.3 - 4.3	0.5*
Pardosa pullata (Clerck)		0.2*	0.4 - 3.1	0.7*	0.1 - 0.8	0.1 - 1.0
Pardosa riparia (C. L. Koch)			0.3 - 0.7	0.9 - 2.4		
Pardosa sphagnicola (Dahl)	17.2*	22.0 - 68.5	1.4 - 62.4	0.6 - 2.6	14.0 - 21.7	9.1 - 23.0
Pirata hygrophilus Thorell			0.2*			0.2 - 0.3
Pirata insularis Emerton		2.0*	0.6 - 1.4		3.5*	0.2 - 2.0
Pirata piraticus (Clerck)	1.8*	2.3*	0.2 - 0.3			0.1*
Pirata piscatorius (Clerck)			0.2 - 0.9	0.9*	1.2*	
Pirata uliginosus (Thorell)		0.4 - 3.3	0.4 - 44.8	0.6 - 10.7	2.1 - 5.4	5.8 - 16.5
Dolomedes fimbriatus (Clerck)			0.25*		0.1 - 0.4	0.3*
Trochosa spinipalpis (F. O. P. - Cambr.)		4.1*	0.3 - 1.8	3.4 - 10.4	1.9 - 2.3	2.3 - 7.3
Drassodes pubescens (Thorell)		0.4*	0.2 - 0.6	2.3 - 5.5	0.1	0.1 - 0.2
Drassyllus lutetianus (C. L. Koch)					0.1 - 1.2	0.2 - 0.5
Drassyllus pusillus (C. L. Koch)			0.1 - 0.3		0.2 - 0.8	0.7 - 5.3
Gnaphosa lapponum (L. Koch)		0.3 - 2.9	0.7 - 2.0			
Gnaphosa microps Holm			0.1 - 4.6		0.8 - 3.0	0.2 - 6.0
Gnaphosa nigerrima L. Koch			0.3 - 0.4		1.3 - 2.7	0.2 - 0.5
Haplodrassus moderatus (Kulczynski)	0.2*		0.2*			0.1*
Haplodrassus signifer (C. L. Koch)		0.2 - 0.6	0.2 - 0.4	0.6 - 0.7	0.6*	0.1 - 0.4
Haplodrassus soerenseni (Strand)	0.2*	0.2*	0.1 - 0.2	0.6*		
Zelotes latreillei (Simon)			0.4 - 0.6	0.9 - 4.7	0.2*	0.1 - 0.3
Agroeca brunnea (Blackwall)			0.3 - 0.4	0.6 - 0.9	1.1*	0.1 - 4.2
Agroeca dentigera Kulczynski		0.1*			0.8*	0.3 - 0.9
Agroeca proxima (O. P. - Cambr.)			0.3 - 0.7	0.6 - 9.6	0.3*	0.1 - 1.1
Phrurolithus festivus (C. L. Koch)			0.4 - 0.6	0.6 - 6.1		0.2*
Phrurolithus minimus C. L. Koch					0.2*	0.1 - 0.3
Scotina palliardi (L. Koch)			0.2 - 1.4	4.3 - 9.4	10.9 - 11.0	0.5 - 14.2
Zora parallela Simon			0.4 - 0.9			
Zora silvestris Kulczynski				12.8*		0.1 - 0.7
Zora spinimana (Sundevall)			0.3*	1.2*	0.1 - 2.7	0.1 - 0.6
Agyneta cauta (O. P. - Cambr.)	0.9*	16.9*	1.4 - 6.9	0.9 - 11.6	1.2*	0.1 - 11.7
Agyneta conigera (O. P. - Cambr.)	0.4*	0.2*	0.9*	0.6 - 5.4		
Agyneta decora (O. P. - Cambr.)	0.2*	2.6*	0.7*		0.9*	0.3*
Bathyphantes gracilis (Blackwall)		0.4*	0.8*		0.8*	0.3*

Table 1. Continued.

Region	**FI - N**	**FI - C**	**FI - S**		**LIT**	
Number of communities investigated	**3**	**3**	**4**	**3**	**2**	**4**
Species	**open bog**	**open bog**	**open bog**	**pine bog**	**open bog**	**pine bog**
Centromerus arcanus (O. P. - Cambr.)	1.8*		0.2 - 2.9	2.0 - 3.1	4.2*	1.2 - 4.5
Centromerus levitarsis (Simon)		0.2 - 0.9			0.1 - 1.9	0.4 - 1.1
Drepanotylus uncatus (O. P. - Cambr.)	0.2 - 1.0	0.8*			7.0*	
Hilaira nubigena Hull	1.0 - 23.5					
Hilaira herniosa (Thorell)	1.3 - 9.6					
Lepthyphantes angulatus (O. P. - Cambr.)	1.0 - 6.6	0.4 - 2.0	0.3 - 2.9	0.6 - 3.8	0.8 - 2.2	0.9 - 1.0
Macrargus carpenteri (O. P. - Cambr.)		0.6*	0.7*	0.6*		
Maro minutus O. P. - Cambr.				0.6 - 4.0	0.1 - 0.8	0.4*
Meioneta affinis (Kulczynski)		2.3*	0.3*	0.3 - 0.6		
Meioneta mossica Schikora	0.4*	0.3 - 1.0	0.4*		0.5 - 0.8	0.2*
Sintula corniger (Blackwall)			0.3 - 0.6	0.6*		0.4 - 0.4
Tallusia experta (O. P. - Cambr.)		0.2 - 0.8	0.2 - 0.8		0.2 - 0.8	0.2 - 1.2
Cnephalocotes obscurus (Blackwall)	0.4*	0.4 - 1.2	0.2 - 0.7		0.3 - 0.4	0.1 - 1.3
Gonatium rubens (Blackwall)			0.1 - 0.6		2.5*	0.3 - 1.8
Latithorax faustus (O. P. - Cambr.)	1.7*	1.7*				
Micrargus herbigradus (Blackwall)	6.1*	0.2 - 1.5	0.1 - 0.3			0.2*
Notioscopus sarcinatus (O. P. - Cambr.)		0.6*			0.1*	2.5*
Pelecopsis mengei (Simon)	8.4 - 13.4					
Pocadicnemis pumila (Blackwall)	0.4*	0.9*	0.2 - 0.3		0.2 - 0.4	0.1 - 1.9
Tapinocyba pallens (O. P. - Cambr.)	0.4 - 0.9		0.9*	2.0*		0.1*
Wabasso questio (Chamberlin)		0.6 - 5.9				
Walckenaeria antica/alticeps	0.2*	0.4 - 0.9	0.6 - 3.6	1.8 - 11.4	0.2*	0.2 - 1.2
Walckenaeria atrotibialis (O. P. - Cambr.)		3.2*	0.3 - 0.6		0.2*	0.1 - 0.9
Walckenaeria nodosa O. P. - Cambr.			0.1*	0.3*	0.7 - 0.8	0.6 - 0.8
Walckenaeria nudipalpis (Westring)	1.7 - 3.1	0.1 - 2.0	0.3 - 1.1	0.9	0.1 - 0.4	0.2 - 0.3

(LIT– FI-S). The real abundance of *A. misera* could be estimated only by using other sampling methods as it is living in deep moss (*Sphagnum*) layer. *Centromerus unidentatus* Miller, two males of this rare species were found on an open bog in Lithuania (LIT/1). Records in Finland are from boggy forests (Palmgren 1975), in Czech Republic and Germany from moist forest moss (Blick & Hendricks 1995).

Occasional immigrants or species from surrounding areas are more typical for southern study regions. On Lithuanian peatbogs immigration from forests was noticed for single specimens of *Acantholycosa lignaria* (Clerck), *Trochosa terricola* Thorell, *Haplodrassus silvestris* (Blackwall), and *Zelotes clivicola* (L. Koch). *Pardosa palustris* (L.) occurs on three Finnish peatbogs. Other species from the surrounding areas and occurring seldom on peatbogs are *Zelotes subterraneus* (C.L. Koch), *Alopecosa aculeata* (Clerck), and *Erigone atra* Blackwall.

Ecological remarks on species

Aulonia albimana, the most dominant species on Lithuanian peatbogs, can be found in a wide range of habitats in Central Europe, preferring dry open areas (Hänggi et al. 1995). The species is known in southern Finland only in such dry habitats; it is included in the Finnish Red Data Book (Rassi et

Table 2. Distribution of bog spiders along the transect from N Finland to S Lithuania. Asterisk (*) indicates that the species is known on other peatbogs or types of habitats in the region.

Species/Region	FI - N	FI - C	FI - S	EST	LIT
Hilaira nubigena	x				
Hilaira herniosa	x	*			
Pelecopsis mengei	x	*			
Wabasso questio	*	x			
Gnaphosa lapponum	*	x	x		
Pardosa atrata	x	x	x	x	
Latithorax faustus	x	x	*	*	
Arctosa alpigena	x	x	x	x	x
Pardosa hyperborea	x	x	x	x	x
Pardosa sphagnicola	x	x	x	x	x
Pirata piraticus	x	x	x	x	x
Agyneta cauta	x	x	x	x	x
Cnephalocotes obscurus	x	x	x	x	x
Micrargus herbigradus	x	x	x	x	x
Pocadicnemis pumila	x	x	x	x	x
Walckenaeria antica/alticeps	x	x	x	x	x
Haplodrassus moderatus	x	*	x	x	x
Centromerus arcanus	x	*	x	x	x
Tapinocyba pallens	x	*	x	x	x
Agyneta decora	x	x	x		x
Lepthyphantes angulatus	x	x	x	*	x
Meioneta mossica	x	x	x		x
Walckenaeria nudipalpis	x	x	x	*	x
Haplodrassus soerenseni	x	x	x	x	*
Drepanotylus uncatus	x	x	*	*	x
Agyneta conigera	x	x	x	*	*
Haplodrassus signifer	*	x	x	x	x
Alopecosa pinetorum	*	x	x	x	*
Erigone atra	*	x	x	x	*
Bathyphantes gracilis	*	x	x	*	x
Gnaphosa microps	*	*	x	*	x
Gonatium rubens	*	*	x	x	x
Alopecosa pulverulenta		x	x	x	x
Pardosa pullata		x	x	x	x
Pirata insularis		x	x	x	x
Pirata uliginosus		x	x	x	x
Trochosa spinipalpis		x	x	x	x
Tallusia experta		x	x	x	x
Dolomedes fimbriatus		*	x	x	x
Drassodes pubescens		x	x	*	x
Walckenaeria atrotibialis		x	x	*	x
Centromerus levitarsis		x	*	*	x
Macrargus carpenteri		x	x	x	*
Meioneta affinis		x	x	x	*

Table 2. Continued.

Species / Region	**FI - N**	**FI - C**	**FI - S**	**EST**	**LIT**
Notioscopus sarcinatus		x	*	x	x
Pelecopsis parallela		x	*	x	*
Agroeca dentigera		x	*		x
Hygrolycosa rubrofasciata		*	x	x	x
Pirata hygrophilus			x	x	x
Phrurolithus festivus			x	x	x
Scotina palliardi			x	x	x
Zora spinimana			x	x	x
Sintula corniger			x	x	x
Pirata piscatorius			x	*	x
Drassyllus pusillus			x	*	x
Gnaphosa nigerrima			x	*	x
Zelotes latreillei			x	*	x
Agroeca brunnea			x	*	x
Agroeca proxima			x	*	x
Zora silvestris			x	*	x
Maro minutus			x	*	x
Walckenaeria nodosa			x	*	x
Pardosa prativaga			*	x	x
Pardosa riparia			x	*	*
Zora parallela			x		
Drassyllus lutetianus				*	x
Phrurolithus minimus				*	x
Aulonia albimana			*		x

al. 2000). Records on occurrence of *A. albimana* on bogs, fens or other wet sites are known e.g. from Germany (Hiebsch 1984), Austria (Freudenthaler 1989), and France (Villepoux 1993). At the moment there are no records of this species either in Estonia and Latvia or in dry habitats in Lithuania.

Pirata piraticus occurs in all study regions, but reaches higher abundance only in some communities. In three regions the species was found only in one community (Table 1) and seems to have special kind of microhabitat, similar to *P. piscatorius* found only in southern Finland and Lithuania (see Nørgaard 1952). *Haplodrassus moderatus* is typical of fenlands and very humid areas, but occurs as single specimens on peatbogs along the whole transect. *Phrurolithus minimus* is reported for the first time in Lithuania. Due to insufficient arachnological investigations in Lithuania it is difficult to state, if peatbogs are typical habitat of this species in southern part of the studied transect. According to the material studied, *Meioneta mossica* is spread through peatbogs along the transect. Probably part of earlier records of *M. saxatilis* (Blackwall) from peatbogs refers to *M. mossica* (see also Schikora 1993). A few species, like *Hygrolycosa rubrofasciata* and *Pardosa riparia*, seem to prefer pine peatbogs instead of open bogs (Table 1).

Acknowledgements. The Academy of Finland supported the visits of VR and DD to Turku, and Rauno Mannila helped in pitfall trapping at the Renko site.

REFERENCES

Blick, T. & Hendricks, K. 1995. *Centromerus unidentatus* neu für Deutschland (Araneae: Linyphiidae). Arachnol. Mitt. 10, 11-13.

Eurola, S., Hicks, S. & Kaakinen, E. 1984. Key to Finnish mire types. Pp. 11-117 in Moore, P.D. (ed.), European mires. Academic Press, London.

Freudenthaler, P. 1989. Ein Beitrag zur Kenntnis der Spinnenfauna Oberösterreichs: Epigäische Spinnen an Hochmoorstandorten bei St. Oswald. Linzer Biol. Beitr. 21, 543-575.

Hänggi, A., Stöckli, E. & Nentwig, W. 1995. Habitats of Central European spiders. Miscell. Faunistica Helv. 4, 1-459.

Hiebsch, H. 1984. Beiträg zur Spinnenfauna des Naturschutzgebietes «Dubringer Moor». Veröff. Mus. Westlausitz 8, 53-68.

Koponen, S. 1979. Differences of spider fauna in natural and man-made habitats in a raised bog. Nat. Swedish Envir. Protec. Board, Rep. PM 1151, 104-108.

Koponen, S. 1985. On changes in the spider fauna of bogs. Mem. Soc. Fauna Flora Fennica 61, 19-22 (in Finnish).

Lohmander, H. 1956. Faunistiskt fältarbete 1955 (huvudsakligen Södra Värmland). Göteborgs Musei Årstryck 1956, 32-94.

Nørgaard, E. 1952. The habitats of the Danish species of *Pirata*. Ent. Meddr. 26, 415-423.

Palmgren, P. 1975. Die Spinnenfauna Finnlands und Ostfennoskandiens VI. Linyphiidae 1. Fauna Fennica 28, 1-102.

Platnick. N.I. 1997. Advances in spider taxonomy 1992-1995. 976 pp. New York Ent. Soc. & Am. Mus. Nat. Hist., New York.

Rassi, P., Alanen, A. Kanerva, T. & Mannerkoski, I. (eds.) 2000. Suomen lajien uhanalaisuus 2000 (Red data book of Finland 2000). 432 pp. Ministry of Environment, Helsinki. (http://www.vyh.fi/luosuo/lumo/lasu/uhanal/uhanal.htm [23.10.2000]).

Schikora, H-B. 1993. *Meioneta mossica* sp.n., a new spider close to *M. saxatilis* (Blackwall) from northern and central Europe (Araneae: Linyphiidae). Bull. Br. Arachnol. Soc. 9, 157-163.

Vilbaste, A. 1980-81. The spider fauna of Estonian mires. ENSV TA Toim. Biol. 29, 313-327 and 30, 7-17.

Vilbaste, A. 1987. Eesti ämblikud. 114 pp. Valgus, Tallinn (in Estonian).

Villepoux, O. 1993. Étude de la répartition des araignées d'une zone humide. Boll. Acc. Gioenia Sci. Nat (Catania) 26 (345), 361-370.

Received 30 June 2000,
accepted 18 September 2000.

Norw. J. Entomol. 48, 175–180. 2001

Continuous trapping of nocturnal *Macrolepidoptera* in Estonia, 1995-1998: primary results

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Kruus, M. & Viidalepp, J. 2001. Continuous trapping of nocturnal Macrolepidoptera in Estonia, 1995-1998: primary results. Norw. J. Entomol. 48, 175-180.

Recent changes in the European fauna of Lepidoptera have been considered as a northward shift of entire distribution areas, caused by global warming. Northern territories are invaded by temperate species, and the process seemingly has a cyclic nature. An invasion of a new species is often followed by a rapid growth of its population and followed by its penetration into the neighbouring areas. A change of voltinism in numerous species is another effect observed in recent decades.

Key words: Estonia, Lepidoptera, distribution, voltinism.

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INTRODUCTION

Having collected butterflies and moths since late 1940s or early 1950s, we have followed the changes in Estonian Lepidoptera fauna (Viidalepp, 1970, a.o.).

The present communication is based on personal observations as well on data collected by other, amateur and professional entomologists. Partially published in an aperiodical journal, «Lepidopterological Information», these data have been used for compiling local catalogues (Möls & Viidalepp 1969; Remm & Viidalepp 1977, 1986; Viidalepp 1995; Jürivete et al. 2000). The catalogue of 1995 reviews the species' distribution according to UTM grid squares.

MATERIAL AND METHODS

Continuous trapping of moths by using Jalas type light traps on 8 Estonian sites (in the framework of the project *Nature Monitoring in the Eastern Baltics*) has resulted in phenological data consisting of 531 857 specimens of 647 species (Table 1). This represents about two-thirds of all Macrolepidoptera listed from Estonia (Viidalepp 1995). Among those not recorded in the present study, 50 % are probably diurnal species.

Continuous trapping (Karvonen et al. 1979) is an effective method. This is illustrated by the Lepidoptera checklist of Viidumäe Nature Reserve, Saaremaa, which is based on multiple visits and field work of professional and amateur researchers in the years 1932 to1986. This checklist included 604 species, but 56 more species (9.3 %) were added by the present study.

RESULTS AND DISCUSSION

The accumulation of phenological data is the most significant result of this project, as the weekly emptying of network traps is too infrequent to obtain moths of collection quality. Nevertheless, some controversial aspects have to be taken into account. The yearly catches from the second year on, show diminishing on 5 of the trapping sites. On three sites, the number of specimens caught in 1996 exceeded that of 1995 but decreased clearly in 1997, and again in 1998. Could this be caused by a regional short-period fluctuation in Estonian fauna, or is it a case of improverishment of the fauna on the trapping sites? Three of the eight trapping sites are in nature reserve areas.

A five-year periodicity in abundance of moth populations has earlier been mentioned in Ahola et al. (1983), the alternate-year abundance is known in case of boreal species of moths and butterflies, and for butterflies in South Urals as well (Olschwang, 1998).

The yearly fluctuation in the number of resident species is another obscure issue. Egg-laying females often survive in the vicinity of the traps. If food plants are present for their larvae, it results in a temporary rise in population density (e.g. numerous *Spilosoma lutea* Hufnagel, 1766 larvae have been observed in vicinity of the traps in Puka, South Estonia, in 1998 and 1999 by J. Viidalepp, and also the number of trapped *Spilosoma* moths has increased in subsequent years).

A change of voltinism in numerous species is another effect observed in recent decades. In insects the life cycle is ruled by the induction of diapause and controlled by the length of photoperiod (which is longer in higher latitudes) and temperature (Danilevskii 1965, Dennis 1993) during crucial periods of the metamorphosis. In a warming environment, the eclosion of potentially bivoltine butterflies and moths is shifted to an earlier season and thus to a longer photoperiod. It results in a partial or complete, depending on the diapause type in the concrete taxa, bivoltinism. In 1999, specimens of second broods of bivoltine species had increased to 10 percent in some catches (Figures 1 & 2).

An increase in the number of species with a bivoltine life cycle was first observed in Estonia in the 1990s, and the percentage of second brood specimens in local populations has grown progressively. The process is seemingly accelerating.

Numerous species are characterized by an univoltine development cycle along the northern border of their distribution area, being bivoltine in the southern part. A prolonged light-day regime on a trapping site might shift the development cycle of nearby growing larvae towards bivoltinism. The success of the larval development of the second brood then depends on the quality of the hostplants. In the case of a exceptionally numerous second brood of *Calospilos sylvata* Scopoli, 1763 in 1999, the first brood of this species in the year 2000 has been as common as it has been in 1999 (Figure 3). In earlier years, a second brood has only been observed once, represented by a single specimen of *C. sylvata* caught in 1993. In the season 2000, this species appeared bivoltine and numerous in southern Estonia, while in northern trapping sites the second brood was rare or absent.

Another example, *Campaea margaritata* Linnaeus, 1767, was recorded first time for Estonia in

Table 1. Species richness and numbers of specimens trapped in Estonian moth monitoring sites, 1995-1998.

Trapping site	UTM square	Number of species	Number of specimens
Vilsandi	EK	298	23,244
Viidumäe	EK	509	85,434
Ahtma	LF	506	75,889
Jalase	LF	457	46,288
Palmse	MF	473	79,291
Tooma/Endla	MF	456	60,610
Elva	ME	454	29,408
Puka	ME	494	131,693
Total:		**647**	**531,857**

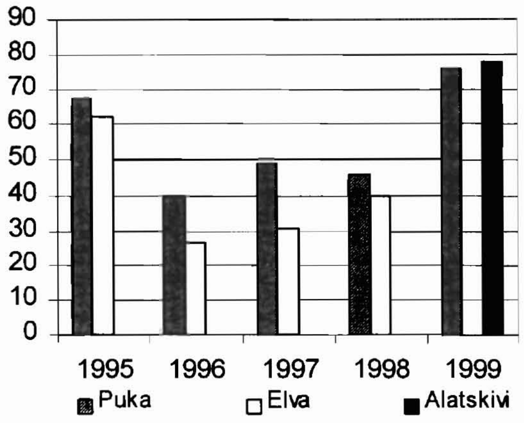

Figure 1. Number of bivoltine species in yearly catches in some south Estonian moth monitoring sites.

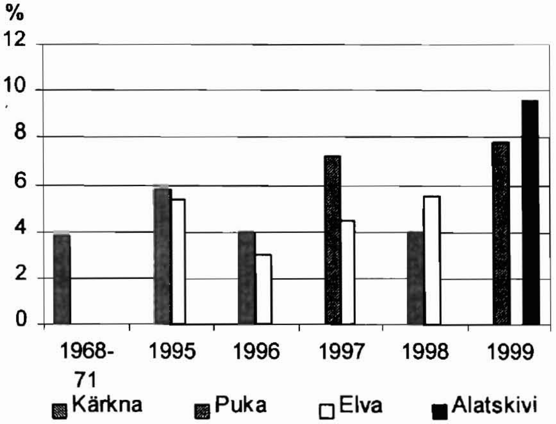

Figure 2. Percent of second brood specimens in yearly catches in southern Estonia, both in Kärkna (1968-1971), and in the studied sites, 1995-1999.

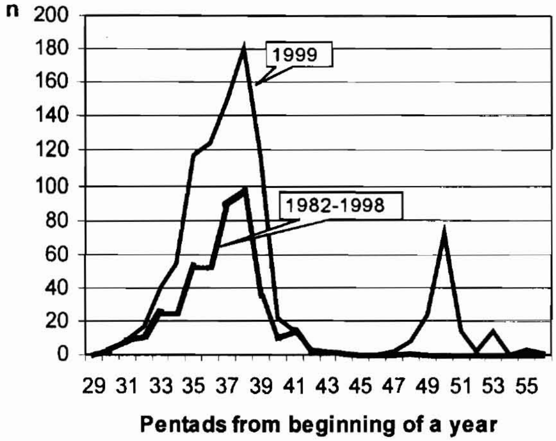

Figure 3. Phenology of *Calospilos sylvata* Scopoli in Puka, southern Estonia, 1982-1998, and in 1999.

Table 2. Additions to the Macrolepidoptera fauna of Estonia according to decades, 1921-1999

Years	Number of species
1921-1930	16
1931-1940	30
1941-1950	9
1951-1960	10
1961-1970	42
1971-1980	14
1981-1990	14
1991-1999	24

1995, in Viidumäe Nature Reserve. Subsequently the species was recorded univoltine in Ahtma trapping site, 1996 (Kruus 1996) and in Hiiumaa, 1997. The abundance of studied populations increases, in 1999 and 2000 the species was recorded bivoltine in northwestern Estonia.

Recent changes in the European fauna of butterflies have been considered a northward shift of entire distribution areas, caused by global warming (Parmesan 1996, Mikkola 1997, Parmesan et al. 1999, Ryrholm 2000). Northern territories are thus invaded by temperate species. This process seems to have a cyclic character, it culminated in the 1930s, '60s and '90s of the 20th century (Table 2).

First record of any new species is detached from subsequent distribution records in the other UTM squares. Two periods from 1961 to 1970, and from 1971 to 1980 show similar patterns. A species that first occurred close to the southern boundary of Estonia, having invaded Estonia from South, has to 1999 also invaded the northern part of the country (Figure 4).

The complementation of fauna in Finland has been analysed by Kaisila (1962), and critically reassessed by Mikkola (1997) and Huldén et al. (2000). It may be concluded that the data are running in a concordance. In the latitudes of Estonia and southern Finland there is the transition zone between nemoral European vegetation, and boreal taiga of Eurasia, reflected by northern distribution limits of many plant and animal taxa. A spatial coinciding of this zone and that of most remarkable change in faunas cannot be an occasion. The phenomenon (Table 3) thus has a biogeographical background.

The opposite process, i.e. retreating species, is not easy to document. Nevertheless, many stenochorous boreal species known to have inhabited Estonia have not been caught in the network of continuously working light traps during the last five years. Hence, we can conclude that the population density of such species is decreasing: e.g. *Xanthorhoe decoloraria* Esper, 1806 has not been recorded since 1966, *Boloria freija* Thunberg, 1791 not since the 1940s, *Xestia sincera* Denis & Schiffermüller, 1775 and *Entephria caesiata* Denis & Schiffermüller, 1775 not since the 1970s. The probable extinction of the univoltine populations of *Lythria purpuraria* Linnaeus, 1758 along the coastal dunes in north-eastern and western Estonia may have been caused by climatic change instead of stress caused to their habitat by recreation. The decline of *Alcis jubata* Thunberg, 1788 might reflect the degradation of epiphytic lichens in old forests, a result of acid rains.

CONCLUSION

The influence of an artificially prolonged light day regime in trapping sites must be a local effect. The «additional» broods in more than one and a half hundred species must have a more sound basis as they appear after warmer spring months.

It may be concluded that the changes in the Estonian fauna of butterflies and moths have been caused by global warming. Its most pictoresque becoming apparent in Estonia and southern Finland spatially corresponds with the transition zone between temperate and boreal forests. Accordingly, it is now the time to calculate and predict further changes and examine the behaviour of both economically important and vulnerable boreal species.

Acknowledgements. Authors acknowledge all Estonian private collectors of Lepidoptera who have taken part in the local faunistic study. Ms. T. Peil kindly has revised the English of the text.

REFERENCES

Ahola, M., Silvonen, K. & Vilén, J. 1983. Koski Hl (EH) pitäjän suurperhoset vuosina 1969-1982. Not.

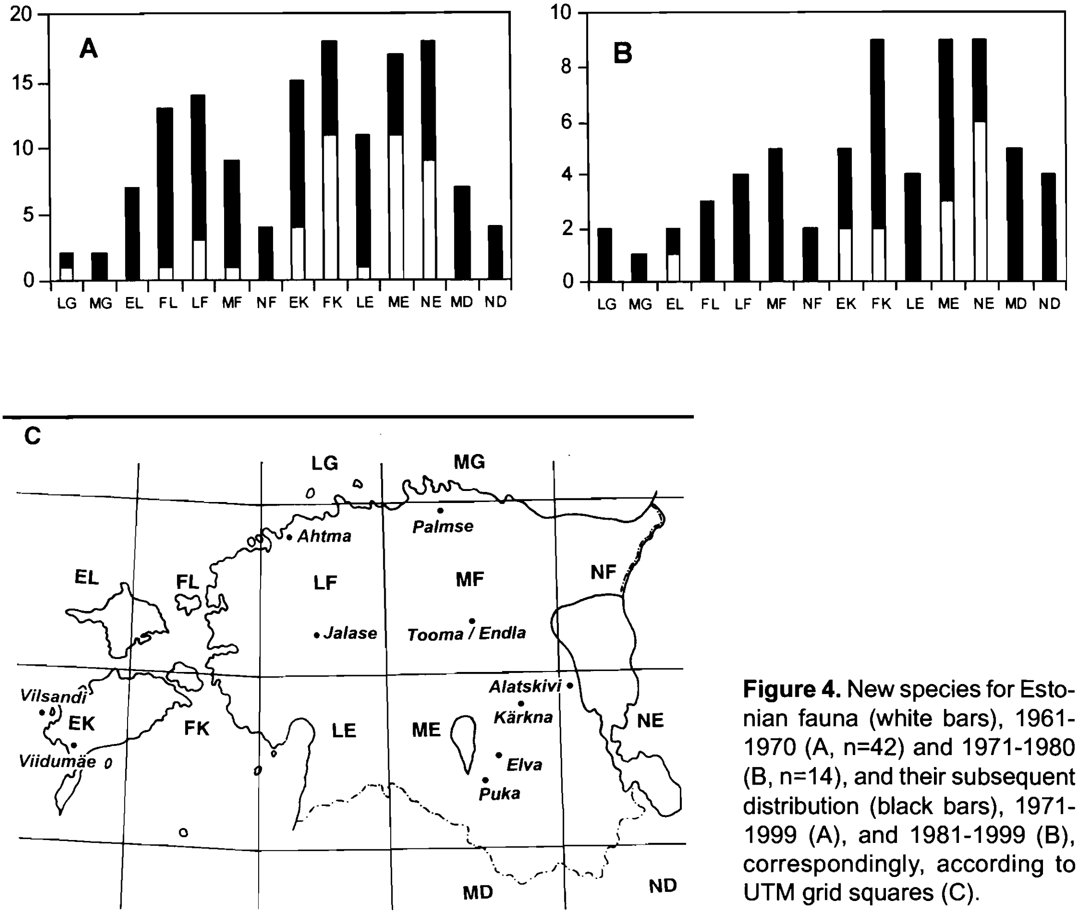

Figure 4. New species for Estonian fauna (white bars), 1961-1970 (A, n=42) and 1971-1980 (B, n=14), and their subsequent distribution (black bars), 1971-1999 (A), and 1981-1999 (B), correspondingly, according to UTM grid squares (C).

Table 3. The climate change and the change in fauna are in concordance

Climate change	Change in fauna
The mean **yearly temperature** has risen about 0.65° C compared with the year 1955[1]	**Fauna**: Invasion of southern species of moths and butterflies
The **snow cover** is thawing ca 25 days earlier in average than before.	**Populations**: invaders turn sedentary, and their population density increases
The average **temperature of spring** months has increased about 2.5° C.	**Voltinism**: a shift of larval growth towards longer light-day conditions results in higher density of second broods of species with a facultative or labile diapause

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[1] Kivi (1990).

Entomol. 63, 145-175.

Danilevskii, A. S. 1965. Photoperiodism and Seasonal Development of Insects. Oliver & Boyd, Edinburgh.

Dennis, R. L. H. 1993. Butterflies and climate change. 302 pp. Manchester Univ. Press, Manchester & New York.

Huldén, L. (ed.), Albrecht, A., Itämies, J., Malinen, P. & Wettenhovi, J. 2000. Suomen suurperhosatlas. Finlands storfjärilatlas. Atlas of Finnish Macrolepidoptera. 328 pp. Helsinki.

Jürivete, U., Kaitila, J., Kesküla, T., Nupponen, K., Viidalepp, J. & Õunap, E. 2000. Eesti liblikad. Kataloog. Estonian Lepidoptera. Catalogue. 151 pp. Eesti Lepidopteroloogide Selts. Tallinn.

Kaisila, J. 1962. Immigration und Expansion der Lepidopteren in Finnland in den Jahren 1869-1960. Acta Entomol. Fenn. 18, 1-452.

Karvonen, J., Laasonen, E. M., Aalto, A., Kerppola, S. & Karvonen, E. V. 1979. Lepidoptera species new to Finland, caught with continuous light trapping. Not. Entomol. 58, 153-158.

Kivi, R. (ed.). 1990. Tartu kliima ja selle muutumine viimastel kümnenditel. 182 pp. Eesti TA AAI.

Kruus, M. 1996. Tükike Lääne-Eestit Tallinna lähistel. Pp.154-168 in Eensaar, A. & Sander, H. (eds.) Human impact on the environment of Tallinn, III. Tallinn.

Mikkola, K. 1997. Population trends of Finnish Lepidoptera during 1961-1996. Entomol. Fenn. 8, 121-143.

Möls, T. & Viidalepp, J. 1969. Catalogus Macrolepidopterorum Estoniae. Eesti suurliblikate nimestik. 32 pp. Tartu.

Olschwang, V. 1998. Rhopalocera from the south Urals: Biodiversity and Population Dynamics. Mem. Koninkl. Belg. Ver. Entomol. 38, 145-154.

Parmesan, C. 1996. Climate and species range. Nature 382, 765-766.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T., Tennet, J., Thomas, J.A. & Warren, M. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature 399, 579-583.

Remm, H. & Viidalepp, J. 1977. Catalogus Macrolepidopterorum Estoniae. Eesti suurliblikate nimestik. ELUS. Abiks loodusevaatlejale, 72, 1-40.

Remm, H. & Viidalepp, J. 1986. Catalogus Macrolepidopterorum Estoniae. Eesti suurliblikate nimestik. III ed. ELUS. Abiks loodusevaatlejale, 84, 1-34.

Ryrholm, N. 2000. Poleward shifts in geographical ranges of Scandinavian butterflies – more global warming? XIIth European Congress of Lepidopterology. Programme and abstracts. Bialowieża, 55.

Viidalepp, J. 1970. Veränderungen in der Makrolepidopteren-Fauna Estlands. Eesti TA Toimetised Bioloogia 19, 53-77. (in Russian with German summary).

Viidalepp, J. 1995. Catalogus Macrolepidopterorum Estoniae. Eesti suurliblikate nimestik levikutabelina. IV ed. ELUS. Abiks loodusevaatlejale, 95, 1-64.

Received 27 July 2000,
accepted 22 December 2000.

Norw. J. Entomol. 48, 181–184. 2001

True bugs (Heteroptera) on monocultures in Latvia

Inara Turka

Turka, I. 2001. True bugs (Heteroptera) on monocultures in Latvia. Norw. J. Entomol. 48, 181-184.

A comprehensive material of Heteroptera was collected from various crops, mainly potatoes, cereals and sugar beets, in Latvia during the periode 1974-1999. The damage caused by Heteroptera varied greatly between years, especially on potato. Some year the bugs caused only cosmetic damage and only on leaves; while in other years, severe damage was found on the main sprout and stem, both early feeding of flowers and necrosis of leaves and stems were observed. Two sampling methods were used in the field, sweep nets and beating sheet. In total, about 360 species of Heteroptera have been recorded from Latvia; of these 30 species have been found in crops of potato, 13 on winter and spring wheat, and 20 on sugar beet. Before 1990, when monocultures began to dominate in Latvia, only 7 species of Heteroptera were found on potato, 12 on different cereals, and 12 on sugar beet. In total, 8 families of Heteroptera families were found in the studied crops, but only two species were dominating, *Lygus rugulipennis* and *Orthotylus flavosparsus*, both belonging to the family Miridae. One of the main objectives in our project was to identify adult Miridae and, in particular, to study feeding and oviposition preferences in species of *Lygus* in monocultures of potato when enough wild plants of monocotyledons and dicotyledons were present in the surroundings.

Key words: Heteroptera, *Lygus* spp., monocultures.

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INTRODUCTION

Monitoring of the insect fauna on the haulm level has been carried out for the purpose of practical plant protection. Hopefully, the obtained long-term data will not only be used in applied entomology, but will also be valuable for a better understanding of the general ecology of insects. A list of species and fluctuations in the abundance of Heteroptera have been analysed in different crops applying different sampling methods.

Due to significant changes in farming practice in Latvia, the results obtained from the monitoring have been separated in two periods, 1974-1989 and 1990-1999. The first period was characterized by large-scale farming, with rotation of crop as an agricultural practice; the second is characterized by a more specialized production, growing monocultures and using different farming technologies as in previous time.

Altogether, about 360 species of Heteroptera have so far been recorded from Latvia (Spuris 1957, Kiricenko 1951).

MATERIALS AND METHODS

The general insect fauna on the potato haulm level was collected by use of sweep net. For collecting Heteroptera two sampling methods were used, sweep net and beating sheet. The diameter of the sweep net was 30 cm, and the length of the handler was 120 cm. The collecting was performed by use of 50 double strokes per field, and the area covered per sweep was estimated to be about 2 m^2. The net was swept over the potato haulm in a simple arc, estimated to be about 3 m. The same area was tested by use of a beating sheet. The sheet was placed under the haulm, and the insects falling down on the sheet after a slight struck by a wooden stick were collected. Using this method, it was possible to catch nymphs that fed on the potato. Sampling was made every seventh day between 1 pm and 2 pm, when the bugs were more active. In total, 12 samplings have been made per season on four monocultures, viz. potato, spring and winter wheat, and sugar beets.

In order to state more precisely when the nymphs start to appear in the potato fields, the beating sheet were tested during one season year. It was concluded that the beating sheet was well suited for nymph registration so to follow their development dynamics. It is not equally well suited for sampling of imagines as 18 species were found using net, but only 8 with the beating sheet (Table 1). On average 2.35 and 18.4 nymphs were captured with the sweep net and beating sheet, respectively (Figure 1).

The sample size before and after 1990 was the same, 12 samplings on 2 m^2 during the growing season.

RESULTS

The number of species in the catches varied between the different crop fields. In the years 1974-1989 30 (±2.1) species were found in potato fields, 13 (±2.1) in fields of spring and winter wheat, and 20 (±2.1) in fields of sugar beet. In the last 9-10 years, the number of species found in some crops decreased; only 7 (±0.8) species were found on the potato, 12 (±0.8) on sugar beets, and 12 (±0.8) on spring and winter wheat.

Among the species recorded, only two, *Lygus rugulipennis* Popp. and *Orthotylus flavosparsus* C. Sahlb, were dominant and abundant (Table 2), both belonging to the family Miridae. During the study three species of Miridae, *Lygus rugulipennis, Lygus pratensis, Plagiognathus chrysanthemi*, and one predaceous bug, *Anthocoris nemorum*, have been recorded from all years in each of the studied crops.

The achieved results indicate that the first nymphs start to appear in mid-July with week's interval in 1998. These findings fit well with results obtained form a study in Sweden (Jurisoo1964). In accordance with a common assumption, the western tarnished plant bug do not prefer to feed on grasses when broadleaf plants are available (Barlow et al. 1999).

DISCUSSION

It is well known that Heteroptera, in particular Miridae, by feeding on potato cause a decrease in the plant's starch content; on cereals by impairing the grain's baking quality, and on sugar beet by seriously damaging the leaves. Consequently, Heteroptera is a common target for monitoring in agricultural fields so to prepare forecasts and warning services. The study of sampling methods showed that sweep nets were best in order to obtain samples of imagines, while nymphs were

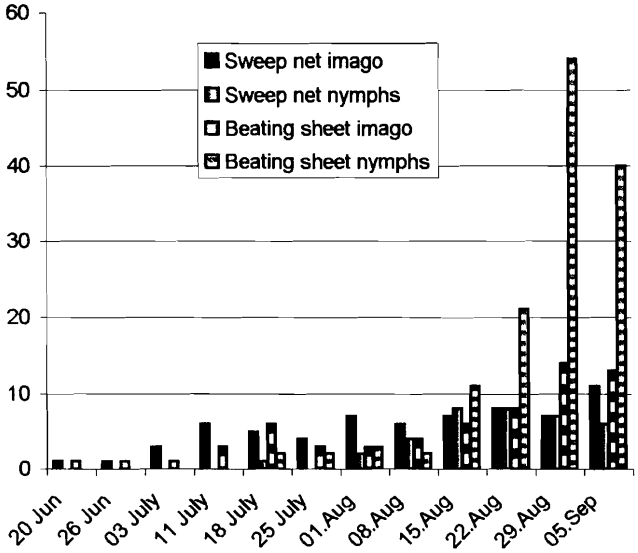

Figure 1. Number of *Miridae* found using sweep net and beating sheet.

Table 1. Mean number of true bugs Heteroptera in the season of agricultural crops during 1974-1989 and 1990-1999.

Species	Potato		Spring and winter wheat		Sugar-beets	
	1974-89	1990-99	1974-89	1990-99	1974-89	1990-99
Nabidae						
Nabis ferus (L.,1758)	18	63	45	14	0	0
Nabis rugosus (L.,1758)	2	0	15	9	0	0
Nabis nymphs	18	32	60	32	0	0
Anthocoridae						
Anthocoris nemorum (L.,1761)	170	126	80	3	111	89
Anthocoris nymphs	179	20	53	18	45	10
Orius minutus (L.,1758)	59	9	0	0	9	5
Miridae						
Charagochilus gullenhali (Fallen,1807)	7	0	0	0	0	0
Lygus lucorum (Meyer-Dur,1843)	11	0	0	0	3	7
Lygus rugulipennis (Poppius,1911)	1001	2022	163	571	1006	2000
Lygus pratensis (L., 1758)	117	196	131	65	303	214
Lygus punctatus (Zetterstedt,1839)	51	4	1	0	2	0
Lygus sp. nymphs	1444	1788	246	1300	1111	816
Orthops kalmi (L.,1758)	1	1	0	0	15	0
Calocoris norvegicus (Gmelin,1788)	9	0	0	0	9	0
Adelphocoris lineolatus (Goeze,1778)	5	9	0	0	24	13
Adelphocoris annulicornis (F. Sahlberg, 1848)	4	0	0	0	5	0
Adelphocoris sp.nymphs	5	2	0	0	13	8
Stenodema calcaratum (Fallen, 1807)	2	1	7	4	0	0
Stenodema laevigatum (L.,1758)	3	1	17	22	0	0
Notostira elongata (Geoffroy,1758).	4	0	31	15	0	0
Trigonotylus ruficornis (Geoffroy,1758)	1	19	46	19	0	0
Leptoterna dolobrata (L.,1758)	1	0	11	2	0	0
Orthotylus flavosparsus (C. Sahlberg, 1842)	999	888	0	0	314	109
Orthotylus flavosparsus nymphs	433	149	0	0	78	65
Plagiognathus chrysanthemi Wolff,1864)	44	24	117	99	156	195
Plagiognathus arbustorum (Fabricius,1794)	1	10	73	22	47	33
Plagiognathus sp. nymphs	13	6	13	18	37	16
Chlamydatus pullus (Reuter,1870)	26	6	0	0	0	0
Campylomma verbasci (Meyer.-Dur, 1843)	222	22	0	0	119	71
Tingidae						
Tingis cardui (L.,1758)	1	0	0	0	0	0
Piesmidae						
Piesma maculata (Laporte,1832)	16	0	0	0	16	18
Lygaeidae						
Nysius thymi (Wolff, 1804)	12	0	0	0	0	0
Kleidocerys resedae (Panzer, 1797)	1	0	0	0	0	0
Pentatomidae						
Dolycoris baccarum (L.,1758)	11	0	0	0	13	0
Palomena viridissima (Poda, 1761)	6	0	0	0	21	0
Eurydema oleracea (L., 1758)	6	0	0	0	6	0
Total	**4903**	**5398**	**1109**	**2322**	**3463**	**3669**

Table 2. Plant bug species Heteroptera found, sampling with the net and beating sheet on 1m^2 in 1998.

Species	Net	Beating sheet
Nabis ferus L.,1758	+	+
Anthocoris nemorum L.,1761	+	+
Orius minutus L.,1758	+	0
Lygocoris lucorum (Meyer.-Dur, 1843)	+	0
Lygus rugulipennis (Poppius, 1911)	+	+
Lygus pratensis L.	+	+
Lygus punctatus (Zetterstedt, 1839)	+	0
Orthops kalmi L.	+	0
Calocoris norvegicus (Gmelin,1788)	+	+
Adelphocoris lineolatus (Goeze,1778)	+	0
Trigonotylus rufficornis (Geoffroy,1758).	+	0
Orthotylus flavosparsus (C.Sahlberg,1842)	+	+
Plagiognathus chrysanthemi (Wolff 1864)	+	0
Plagioghathus arbustorum (Fabricius,1794)	+	0
Chlamydatus pullus (Reuter, 1870).	+	0
Campylomma verbasci (Meyer.-Dur, 1843)	+	+
Piesma maculata (Laporte,1832)	+	+
Nysius thymi (Wolff,1804)	+	0

more successfully sought for by using the beating sheet (Figure 1).

The most abundant species of Heteroptera on crops of potato, wheat and sugar beets is *Lygus rugulipennis* Popp. (Table 2). During the last years other species have been less important as pests and are today only of interests in more general surveys of the entomological fauna. In the study, specimens of Miridae have been found on sown and natural grasses growing close to potato, cereal or sugar beet fields, but they are never common.

In conclusion, the shift in farming practice has influenced the composition and number of species, but not the overall abundance of Heteroptera.

REFERENCES

Barlow, J. et al. 1999. *Lygus* bug population dynamics on weeds. J. Econ. Entomol. 92, (4), 848-851.

Jürisoo, V. 1964. Agro-ecological studies on leafhoppers (Auchenorrhynca, Homoptera) and bugs (Heteroptera) at Ekensgard farm in the province of Halsingland, Sweden. 140 pp. National Institute of Plant Protection Contributions, Stockholm.

Tischler, W. 1965. Agrarökologie. 492 pp. VEB Gustav Fischer Verlag, Jena.

Spuris, Z. 1957. Local plant bugs. 62 pp. Academy of Sciences, Riga. (In Latvian).

Kiricenko, A.N., 1951. Nactojaschie klopi Evropeiskoi chasti SSR AN SSR, M.-L. 423 pp. (In Russian)

Received 28 June 2000,
accepted 8 March 2001.

Norw. J. Entomol. 48, 185–190. 2001

Water beetles (Coleoptera) of the Pechora river basin in Russia

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Rogovtsova, E.K. 2001. Water beetles (Coleoptera) of the Pechora river basin in Russia. Norw. J. Entomol. 48, 185-190.

We analyzed water beetles from benthos samples and fish stomachs collected in autumn and summer period of 1980 - 2000 by the research staff of the Institute of Biology Komi Science Center and by Dutch researchers. Samples were gathered in different kinds of water bodies in the river basin of the Pechora. According to the available literature and the author's own data, the fauna of water beetles in the Pechora basin includes 97 species from 31 genera and 8 families. The family Dytiscidae has the highest number of species (65). Three species, *Haliplus immaculatus* Gerhardt, 1877, *Hydroporus neglectus* Schaum, 1845 and *H. brevis* F. Sahlberg were noticed for the first time in the Pechora river basin. In watercourses of the Pechora basin, rheophilic beetles: *Elmis aenea* (Müller, 1806), *Limnius volckmari* (Panzer, 1793), and *Oulimnius tuberculatus* (Müller, 1806) dominate in number. In all rivers they find optimal conditions in moss thickets over stony substrates.

Thirty-four beetle species were found in stagnant water bodies. Seventeen species of water beetles were found in fish stomachs. Fish stomachs provided samples of additional species not registered previously: *Haliplus confinis* Stephens, 1829, *Hydroporus brevis* F.Sahlberg, 1834, *Nebrioporus depressus* (Fabricius, 1775) and *Colymbetes dolabratus* (Paykull, 1798).

Key words: water beetles, ecology, faunistics, fish, Pechora river

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INTRODUCTION

The water-beetle fauna of the Pechora river basin remained unknown for a long time. The first reports about certain beetles caught in the Pechora basin were given Yakobson (1913). Later came the data on the role of Coleoptera in the water bodies of the Pechora basin and their species diversity. These data originated from hydrobiological research, which established that larvae and adults of beetles are an important component of the bottom biocenoses. Beetles regulate the number of bottom organisms, and some species serve as fish food (Nikolsky et al. 1947, Zabolotsky 1959, Zakharenko 1962, Solovkina 1963, 1964, Zvereva 1969, Shubina 1986, 1995, Rogovtsova & Shubina 1998, etc.). Lists of water-beetle species obtained on the basis of hydrobiological and ichtyological sampling were considerably increased by special faunistic collections performed in the Ukhta river basin (Zakharenko & Sedykh 1962).

This article is aimed at summarizing the author's own data and the available literature concerning the distribution and habitat preferences of water beetles in the Pechora river basin.

MATERIAL AND METHODS

We have scanned water beetles from quantitative and qualitative samples of benthos and fish stomachs (grayling, young salmon and whitefish) collected by the author and the research staff of the Institute of Biology, Komi Science Center and the Dutch researchers during autumn and summer of

1980 - 2000. Samples were collected in different kinds of water bodies in the Pechora river basin (Figure 1).

The Pechora is one of the largest rivers of northern European. It springs from the Northern Urals at an elevation of 676 m above sea level and flows into the Pechora Bay of the Barents Sea. The total length of the Pechora is 1809 km, including 1596 km in the territory of the Komi Republic (Vlasova 1988). Almost all large tributaries of the Pechora (the Ilych, the Shugor and the Usa) originate in the Ural Mountains. Left-hand tributaries of the Pechora (the Izhma, the Tsilma and the Pizhma) flow from the Timan ridge (Iljina & Grakhov 1987). All studied rivers, fourteen Ural and twelve Timan watercourses, have stable pebble-boulder bottoms, high current speed and low water temperatures (Shubina 1983). The water-beetle fauna in the lakes of the Pechora basin are less studied, except for stagnant water bodies in the Pechora Delta and the Protochnoje Lake in the Usa river basin. Within the Pechora Delta, the territory of the Barents coastline was studied, i.e. seashore plain, the hills of the eastern coastline, the Nenets Ridge, the Ortina river and the Pechora Delta floodplain (Noordhuis 2000). There are large (25-150 ha) and small (<0.1-9.4 ha) deepwater lakes. The bottom sediments are sandy with admixture of silt and clay or silty/peaty with admixture of sand. The Protochnoje lake (ca. 90 ha) is situated in the upper part of the Malaya Usa river, and is connected with this river by a channel. In the littoral, where the channel springs out, the bottom consists of pebble tinged with silt. The bottom of the greater part of the lake is covered by compact

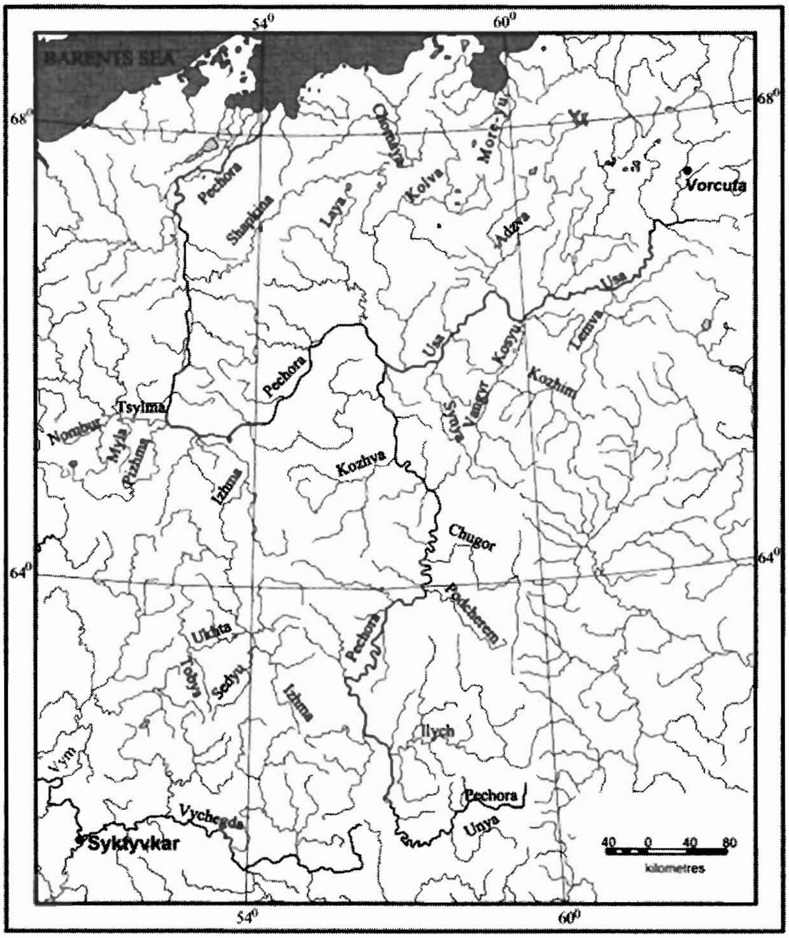

Figure 1. The location of the main studied rivers.

sand tinged with silt. The water is transparent down to the bottom. Species composition of water beetles of the Protochnoje Lake was specified on the basis of grayling and whitefish stomachs.

RESULTS AND DISCUSSION

Ecology

In the studied rivers, water beetles are widespread and relatively numerous bottom organisms (according to hydrobiological data provided by V.N. Shubina). The average frequency, number and biomass of beetle larvae and imago in river benthos are: 60-100 % and 33-78 %; 160-2800 ind./m^2 and 10-410 ind./m^2; 0.09-0.77 g/m^2 and 0.02-0.35 g/m^2, respectively. Larvae and imagines of beetles inhabit various biotopes in the river bed. Stable stony bottoms overgrown by moss are the most favorable habitats for the beetles. Maximal density of beetles (34,200 ind./m^2) was registered in the Pizhma river. High similarity (71.8 %) of faunas of water beetles in the Timan and Ural rivers is established, based on the Sørensen's coefficient of similarity (Sørensen 1948). Numbers of beetles in the Timan rivers were higher than in the Ural rivers, because the Timan ones are more quiet, their waters are more mineralized and the prevailing stony bottoms are overgrown with moss.

The beetles reveal ecological differences according to the water current. Both rheophilic and limnophilic species were found. The number and biomass are dominated by typical rheophilic species: *E. aenea*, *L. volckmari* and *O. tuberculatus*. *Brychius elevatus* (Panzer, 1794), *O. sanmarkii*, *Hydraena gracilis* Germar, 1824, *Normandia nitens* (Müller, 1817) and *Riolus cupreus* (Müller, 1806) are also typical rheophilic species. The species *Haliplus fluviatilis* Aubé, 1836, *Hydroporus planus* (Fabricius, 1781), *Oreodytes alpinus* (Paykull, 1798), *Nebrioporus depressus* (Fabricius, 1775), *N. assimilis* (Paykull, 1798) and *Platambus maculatus* (L., 1758) can inhabit both rivers and pure lakes. There were only single individuals of limnophilic species in the studied rivers.

A list of 97 species of water-beetles are given in Table 1.Thirty-four beetle species were found in stagnant water bodies. The water-beetle fauna of the Pechora Delta includes 21 species, thirteen of them were found in stagnant water bodies. Floodplain water bodies with an area less than 1.4 ha contained the highest number of species (9). Only two species, *Agabus arcticus* (Paykull, 1798) and *Gyrinus natator* (L., 1758) were found in water bodies (area 3.7 – 9.3 ha) located on the hills of the Eastern coastline. Certain beetles were confined to specific bottoms. Thus, *Haliplus fulvus* (Fabricius, 1801), *H. lineolatus* Mannerheim, 1844 and *Suphrodytes dorsalis* (Fabricius, 1787) prefer silty bottom, *Hydroporus lapponum* (Gyllenhal, 1808) prefers peaty bottoms, and *Hydrobius fuscipes* (L., 1758), *Ilybius angustior* (Gyllenhal, 1808) and *Rhantus exsoletus* (Forster, 1771) prefer sandy bottoms. *A. arcticus* can be attributed to eurytope limnophils, for it has been found in water bodies of different size (<0.1-9.3 ha) and with different bottom sediments (sand, peat, clay). Nine beetle species were found in stomachs of fish (grayling, roach and whitefish) from the Ortina river. Fish food samples were dominated by *O. sanmarkii* and *B. elevatus* in quantitative indices both in frequency, number and biomass.

In the Protochnoje lake 80 % of the beetle fauna was represented by the rheophilic species *B. elevatus*, *O. alpinus*, *O. sanmarkii*, *N. depressus* and *P. maculatus*.

Food for fishes

In order to get a more complete concept of their faunistic composition, water beetles should be also studied in fish food. It is established, that the role of the beetles in fish food depends on such factors, as a species and the age of a fish, temperature conditions of year, feature of development of the beetles in water bodies, etc. The importance of larvae and imagines of the beetles in fish food varies during a season. The greatest number of larvae in fish nutrition was found in June and August, imagines - in May, July and September.

Fish stomachs displayed 17 species of water beetles from three families: Haliplidae (*B. elevatus*, *H. fulvus*, *H. confinis* Stephens, 1829), Dytiscidae (*H. brevis*, *Hydroporus* sp., *O. alpinus*, *O. sanmarkii*, *P. maculatus*, *N. depressus*, *N. assimilis*, *A. arcticus*, *Ilybius* sp., *C. dolabratus*), Elmidae (*E.

Table 1. List of water-beetle species in the Pechora river basin.

GYRINIDAE
Gyrinus minutus Fabricius, 1798*
G. opacus Sahlberg, 1819
G. aeratus Stephens, 1835*
G. marinus Gyllenhal, 1808*
G. natator (L., 1758)*

HALIPLIDAE
Brychius elevatus (Panzer, 1794)
Haliplus confinis Stephens, 1829
H. varius Nicolai, 1822*
H. fluviatilis Aubé, 1836
H. lineolatus Mannerheim, 1844
H. ruficollis (De Geer, 1774)*
H. immaculatus Gerhardt, 1877
H. fulvus (Fabricius, 1801)

DYTISCIDAE
Hygrotus inaequalis (Fabricius, 1777)
H. quinquelineatus (Zetterstedt, 1828)
H. polonicus (Aubé, 1842)
H. impressopunctatus (Schaller, 1783)*
Hyphydrus ovatus (L., 1761)*
Hydroporus nigrita (Fabricius, 1792)*
H. brevis F.Sahlberg, 1834
H. discretus Fairmaire, 1859*
H. planus (Fabricius, 1781)
H. nigellus Mannerheim, 1853
H. obscurus Sturm, 1835
H. erythrocephalus (L., 1758)
H. rufifrons (Müller, 1776)*
H. angustatus Sturm, 1835*
H. lapponum (Gyllenhal, 1808)
H. umbrosus (Gyllenhal, 1808)
H. tristis (Paykull, 1798)
H. striola Gyllenhal, 1826
H. palustris (L., 1761)
H. neglectus Schaum, 1845
Graptodytes granularis (L., 1767)*
Oreodytes sanmarkii (Sahlberg, 1826)
O. alpinus (Paykull, 1798)
O. septentrionalis (Gyllenhal, 1826)*
Suphrodytes dorsalis (Fabricius, 1787)
Stictotarsus griseostriatus (De Geer, 1774)*
Nebrioporus assimilis (Paykull, 1798)
N. depressus (Fabricius, 1775)
Platambus maculatus (L., 1758)
Agabus striolatus (Gyllenhal, 1808)*
A. wasastjernai (Sahlberg, 1824)*
A. opacus Aube, 1837*
A. neglectus Erichson, 1837*
A. subtilis Erichson, 1837
A. sturmi (Gyllenhal, 1808)*
A. arcticus (Paykull, 1798)
A. congener (Thunberg, 1794)*
A. lapponicus (Thomson, 1867)*
A. confinis (Gyllenhal, 1808)
A. fuscipennis (Paykull, 1798)*
A. serricornis (Paykull, 1799)
A. bifarius (Kirby, 1837)*
Ilybius vittiger (Gyllenhal, 1827)*
I. angustior (Gyllenhal, 1808)
I. crassus Thomson, 1856*
I. subaeneus Erichson, 1837
I. ater (DeGeer, 1774)*
I. guttiger (Gyllenhal, 1808)
I. aenescens Thomson, 1870
I. fenestratus (Fabricius, 1781)*
I. fuliginosus (Fabricius, 1792)*
Rhantus suturellus (Harris, 1828)
Rh. frontalis (Marsham, 1802)*
Rh. exsoletus (Forster, 1771)
Colymbetes striatus (L., 1758)*
C. dolabratus (Paykull, 1798)
C. paykulli Erichson, 1837*
Graphoderes zonatus (Hoppe, 1795)*
Acilius canaliculatus (Nicolai, 1822)*
A. sulcatus (L., 1758)*
Dytiscus dimidiatus Bergstrasser, 1778*
D. marginalis L., 1758*
D. latissimus L., 1758*
D. circumcinctus Ahrens, 1811*
D. lapponicus Gyllenhal, 1808*

HYDRAENIDAE
Hydraena pulchella Germar, 1824*
Hydraena gracilis Germar, 1824

HELOPHORIDAE
Helophorus nubilis Fabricius, 1777*
H. aquaticus (L., 1758)*
H. brevipalpis Bedel, 1881*
H. granularis (L., 1761)*
H. laticollis Thomson, 1853*

SPERCHEIDAE
Spercheus emarginatus (Schaller, 1783)*

Table 1. Continued.

HYDROPHILIDAE	**ELMIDAE**
Anacaena globulus (Paykull, 1798)*	*Elmis aenea* (Müller, 1806)
A. limbata (Fabricius, 1792)*	*Oulimnius tuberculatus* (Müller, 1806)
Laccobius minutus (L., 1758)*	*Limnius volckmari* (Panzer, 1793)
L. bipunctatus (Fabricius, 1775)*	*Normandia nitens* (Müller, 1817)
Enochrus fuscipennis (Thomson, 1884)*	*Riolus cupreus* (Müller, 1806)
Hydrobius fuscipes (L., 1758)	

Note: *According to the literature (Zakharenko & Sedykh 1962, Zvereva 1964, Sedykh 1974, Shubina 1986).

aenea, *L. volckmari*, *O. tuberculatus* and *N. nitens*). *B. elevatus cristatus*, *Haliplus* sp., *H. brevis*, *N. depressus*, *N. assimilis*, *P. maculatus*, *O. alpinus*, *O. sanmarkii*, *Ilybius* sp. and *E. aenea* were discovered in whitefish food, while *O. sanmarkii*, *E. aenea*, *L. volckmari*, *O. tuberculatus* and *N. nitens* were present in of stomachs young salmons. Grayling fed upon all mentioned species. The contents of fish stomachs allowed to identify additional species; *H. confinis*, *H. brevis*, *N. depressus* and *C. dolabratus* that were not present in hydrobiological samples. According to quantitative values, grayling stomachs content was dominated by *E. aenea* in the Timan rivers and by *B. elevatus cristatus* and *L. volckmari* in the Ural rivers. Stomachs of young salmon in the Timan and the Ural rivers were dominated by *E. aenea* both in number and biomass. Food of grayling in the water bodies in the Pechora Delta was prevailed by *P. maculatus*, food of whitefish by *O. sanmarkii*.

CONCLUSION

At present, the fauna of water beetles of the Pechora basin includes 97 species from 31 genera and 8 families, as it comes from the author's own survey and available literature (Table 1). Three species, *Haliplus immaculatus* Gerhardt, 1877, *Hydroporus neglectus* Schaum, 1845 and *H. brevis* were noticed for the first time in the Pechora river basin. With 65 species the family Dytiscidae is most numerous. It comprises genera *Hydroporus* dominating in species number (15). Other families are represented by a few species: Haliplidae by 8, Hydrophilidae by 6, Gyrinidae and Helophoridae by 5 each, Hydraenidae by 2, family Spercheidae by 1 species.

Acknowledgments. The author thanks her colleagues G.P. Sidorov, Yu.P. Shubin, V.N. Shubina, O.A. Loskulova, Yu.V. Leshko, V.I. Ponomarev, Ya.S. Kuzmina, M.A. Baturina, E.B. Fefilova, A.B. Zakharov and V.Sh. Kamalov who made data on water beetles available. The author also expresses deep gratitude to A.O. Benkovsky, Institute of Ecology and Evolution Problems, Moscow), to P.N. Petrov, Moscow State University for the help in Coleoptera identification and to S.V. Balina (Institute of Biology, Syktyvkar) for translation from Russian to English.

REFERENCES

Avdeev, A.S. 1964. Floating rivers of the Komi ASSR. (In Russian). 204 pp. Moscow.

Iljina, L.L. & Grakhov, A.N. 1987. Northern Rivers. (In Russian).128 pp. Leningrad.

Nikolsky, G.V., Gromchevskaya, N.A., Morozova, G.I. & Pikuleva, V.A. 1947. Fishes of the Upper Pechora basin. (In Russian). 224 pp. Moscow.

Noordhuis, R. 2000. Limnological ecology. Pp. 197-215 in van Eerden, M.R. (ed.), Pechora Delta. Structure and dynamics of the Pechora Delta ecosystems (1995-1999). Lelystad.

Rogovtsova, E.K. & Shubina V.N. 1998. Water beetles (Insecta, Coleoptera) in the Ural and the Timan rivers. Pp. 276-278 in Utkin, N.A. (ed.), Invertebrates of the South Sub-Urals and adjacent territories. (In Russian). Kurgan.

Sedykh, K.F. 1974. Fauna of the Komi ASSR. Invertebrates. (In Russian). 192 pp. Syktyvkar.

Shubina, V.N. 1983. Inference of hydrobiological studies in the mountain tributaries of the Pechora river. Pp. 21-30 in Zaboeva, I.V. (ed.), Proc. Komi Dept. AS USSR. 57. (In Russian). Syktyvkar.

Shubina, V.N. 1986. Hydrobiology of a salmon river in the Northern Urals. (In Russian). 158 pp. Leningrad, Science

Shubina, V.N. 1995. Changes in benthos structure of salmon rivers of the Pechora basin under anthropogenic contamination. (In Russian). Pp. 51-68 in Zakharov, A.B. (ed.), Proc. Komi SC UrD RAS. 142. Syktyvkar.

Solovkina, L.N. 1963. Additional materials to hydrobiology of the Upper Pechora. (In Russian). Pp. 56-67 in Vityazeva, V.A. (red.), News Komi Filial All-Union Geogr. Soc. 8. Syktyvkar.

Solovkina, L.N. 1964. Growth and summer nutrition of young salmons in the Pechora Pizhma river. (In Russian). Zool. Journ. 43, 1499-1509.

Sørensen, T. 1948. A method of establishing groups of equal amplitudae in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biol. Scr. 5. 1-34.

Vlasova, G.G. 1988. Hydrochemistry of principle rivers of the Komi ASSR. (In Russian). 150 pp. Syktyvkar.

Yakobson, G.G. 1913. Beetles of Russia and West Europe. (In Russian). 412 pp. St.Petersburg.

Zabolotsky, A.A. 1959. Benthos of the Podcherem river and its role in young salmon nutrition. (in Russian). Pp. 44-64 in Nikiforova, N.D. (ed.), Reports of All-Union NII lake and river fishery. 48. Syktyvkar.

Zakharenko, V.B. 1962. Water beetles in the Usa basin and their role as fish food. Pp. 248-252 in Fishes of the Usa basin and their food resourses. Moscow-Leningrad (in Russian).

Zakharenko, V.B. & Sedykh, K.F. 1962. Fauna of water and sub-water beetles of the Ukhta district of the Komi ASSR. (In Russian). Pp. 82-87 in Vityazeva, V.A. (red.), News Komi Dept. All-Union Geogr.Soc. 7. Syktyvkar.

Zvereva, S. 1969. Pecularities of Biology of principal rivers of the Komi ASSR. (In Russian). 279 pp. Leningrad, Science.

Received 29 June 2000,
accepted 7 February 2001.

Norw. J. Entomol. 48, 191–198. 2001

Stoneflies (Plecoptera) in the rivers of the Pechora Basin flowing from the Timan Ridge and the Urals, Russia

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Loskutova, O.A. 2001. Stoneflies (Plecoptera) in the rivers of the Pechora Basin flowing from the Timan Ridge and the Urals, Russia. Norw. J. Entomol. 48, 191-198.

Results of the long-term (1980-1999) research carried out by the author in the Pechora tributaries are presented. 33 Plecoptera species from 19 genera and 6 families were recorded in the tributaries flowing from the Timan Ridge and the Urals. More than half of species (17) were widely distributed European species; 10 were Palearctic species and 6 Holarctic species. The highest densities of Plecoptera were observed in the benthos when the new generation appeared at the end July and in August. Maximum biomass was in April and May. In June and July the proportion of Plecoptera in the benthos was low. Plecoptera were most abundant in cold years with high floods, when *Capnia pygmaea* (Zetterstedt, 1840) dominated. In warmer years law numbers and biomass of Plecoptera was observed. In the studied rivers, seven fish species (primarily grayling and young salmon) feed on Plecoptera. 22 plecopteran species were recorded in fish stomaches. Plecoptera were consumed by young salmon and grayling during sammer, but also served as a main element in fish diet in winter when the rivers were covered with ice.

Key words: stoneflies, zoogeography, Pechora Basin, benthos, fish.

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INTRODUCTION

The tributaries of the Pechora Basin play a major role in forming the water quality and biodiversity of this, the largest river of Northern Europe. The watercourses have a high fishery value, in particular Atlantic salmon *Salmo salar* L. The major part of water catchment of the Pechora Basin is a strictly preserved natural area of the Komi Republic. Nevertheless, under increasing technological impacts, ore mining, oil-and gas extraction, the timber industry and household and agricultural use of the floodplain problems of conservation of the natural regime of these watercourses have arisen. Under these conditions an assessement of the production the spawning and feeding grounds of the salmon rivers is urgently needed.

Stoneflies, alongside with other aquatic insects (mayflies, caddisflies and chironomids), are major components of the benthic biocenoses of the Pechora tributaries (Shubina 1986, Loskutova & Zhiltzova 1993). Plecopteran nymphs show rapid response to environmental change and therefore can be used as indicators of quality. Nevertheless, the functional role of Plecoptera in regional water ecosystems of the Pechora basin and their importance as fish food organisms has been underestimated owing to insufficient knowledge of the Plecoptera. The nymphs are common during summer, but they are small and difficult to identify.

The research was aimed at improving knouledge of the faunistic composition and ecology of Plecoptera in the Pechora tributaries. In particular the following topics were studied identify species composition in the Pechora tributaries of the Plecoptera; the role of Plecoptera in the benthos and in the food chain; their distribution.

MATERIALS AND METHODS

The article is based on a long study (1980-1999) by the author on the Pechora tributaries. The following right-hand tributaries of the Pechora River (arising from the Urals) were investigated: Ilych, Podcherem, Shugor, Unja, Kosju (an arm of the Usa), Vangyr and Kozhym. Among left-hand Pechora tributaries (originating in the Timan Ridge), we surveyed the Tsilma and the Izhma, with its arms (the Ukhta, the Sedju, the Suzju, the Kedva), together with above 40 small watercourses flowing into them (Figure 1). The Plecoptera fauna of the main Pechora River was studied the Upper Pechora section (Nikolsky et al. 1947).

Registration of seasonal and long-term dynamics of Plecoptera number and biomass studies were performed adjacent to a station in the middle part of the Shugor River belonging to the Laboratory of Aquatic Organisms Ecology, Institute of Biology Komi Science Centre Ural Division of Russian Academy of Sciences.

Quantitative samples were taken and processed according to methods described in Shubina (1986). Benthos was sampled by a scraper with blade length 30 cm and a net with mesh size of 0,23 mm. Water depth, temperature, current speed and kind of substrats were recorded at the sampling site. Nymphs were also collected from wood and stones picked up from the river bottom. Nymphae collections were fixed in 4 % of formaldehyde, while imagos were fixed in 76 % ethanol. Adult Plecoptera composition were caught with a sweep net in grass and riverbank shrubs, as well as on trees and shoreline stones.

Stomach contents were studied in fish caught by nets or by angling. Stomachs contents were fixed in 4 % formaldehyde, then counted and weighed (Methods manual 1974).

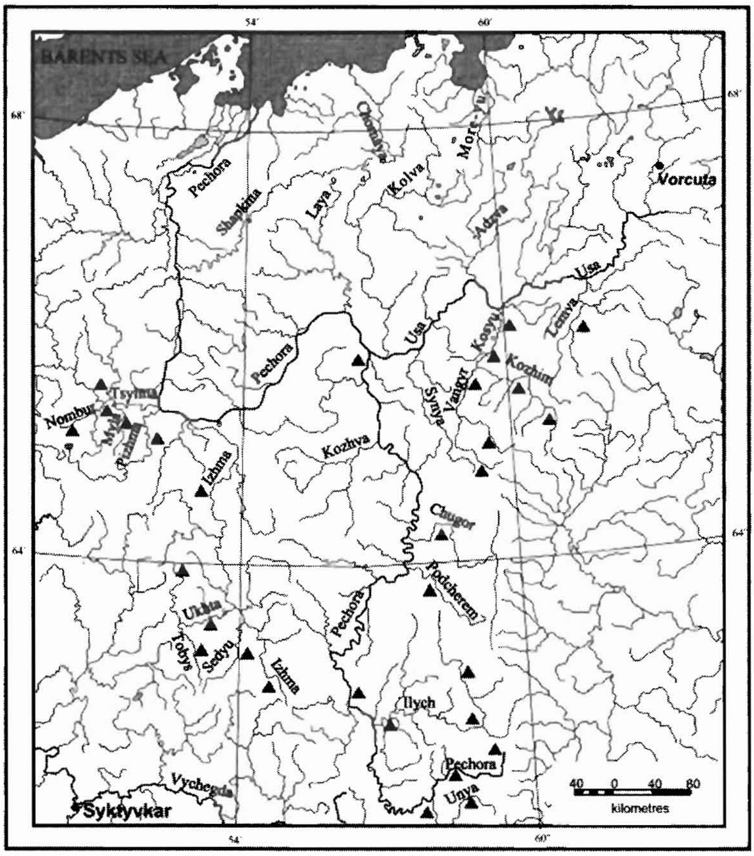

Figure 1. The location of the main sampling sites (▲) in the Pechora Basin.

Plecoptera were identified using Zhiltzova (1964, 1977), Zhiltzova and Teslenko (1997), Brinck (1952), Illies (1955) and Lillehammer (1988).

The Pechora Basin belongs to the Eastern physical-geographical district (Rikhter 1946), representing a vast lowland between the Timan Ridge, the Urals and the Arctic Ocean (62-66° N). The studied rivers are 120-400 km long and contain both rhitral and potamal zones (Illies 1961,1971). Most watercourses are middle-sized rivers (catchment areas 5000-50000 km^2) (Nezhikhovsky 1988). Only the Podcherem, Vangyr, Ukhta and Myla are small rivers (catchments 10-5000 km^2).

RESULTS AND DISCUSSION

The plecopteran fauna of the Pechora Basin was previously investigated by Zhiltzova (1966) and Sedykh (1974).

A total of 33 Plecoptera species from 19 genera and 6 families were identified in the Timan and the Ural tributaries allowed to specify (Table 1).

The family Nemouridae was the most species rich (9), followed by the Perlodidae (8), Capniidae (6), Leuctridae (4), Taeniopterygidae (3) and Chloroperlidae (3). The plecopteran fauna of the Pechora tributaries was typical of streams of northern Europe with many widely distributed species. 14 species are common throughout Europe, 10 Palearctic and 6 Holarctic circumboreal. *Siphonoperla burmeisteri* (Pictet, 1841), *Isoptena serricornis* (Pictet, 1841) and *Rhabdiopteryx acuminata* Klapalek, 1905 are European species with limited distributions (Zhiltzova & Loskutova 1999).

In the Ural tributaries 29 species were recorded compared to 24 in the Timan tributaries. Coefficient of fauna similarity between the two areas was 80% (Chekanovsky-Sørensen 1948).

Some species (*Capnia bifrons* (Newman, 1839), *C.vidua* Klapalek, 1904, *Brachyptera braueri* (Klapalek, 1900), *Protonemura intricata* (Ris, 1902) and *Leuctra nigra* (Olivier,1811)) were rare in the Pechora basin, in contrast *Taeniopteryx nebulosa* (L., 1758), *Amphinemura borealis* (Morton,1894), *Nemurella pictetii* Klapalek, 1900, *Capnia pygmaea* (Zetterstedt, 1840), *Leuctra fusca* L.,1758, *Arcynopteryx compacta* (McLachlan, 1872), *Diura nanseni* (Kempny, 1900) and *Isoperla obscura* (Zetterstedt, 1840) were widely distributed.

Seasonal dynamics of numbers and biomass of Plecoptera

Together with dipterans and mayflies, stoneflies were a most typical group in benthic communities of the Timan and the Ural rivers. Plecoptera accounted for 50-100 % of the benthos during the open-water season (Table 2).

In May, after ice break, mass emergence of *C. pygmaea* and *C. atra* Morton, 1896 was observed, together with *T. nebulosa, Leuctra hippopus* Kempny, 1899 and various Nemouridae. In spite of the decrease in numbers, Plecoptera biomass remained high, owing to large, mature nymphs of *A. compacta* and two species of *Diura*. In early June, these species also emerged. Thus, both numbers and biomass were minimal in June (in the Shugor – 55.2 ind./m^2 and 12.8 mg/m^2). In late June, small nymphs of *Arcynopteryx* and in mid – July nymphs of *Diura, Capnia* and *Taeniopteryx* hatched. Numbers and biomass of Plecoptera were then 64.8 ind./m^2 and 67.7 mg/m^2, respectively.

Plecoptera numbers increased sharply owing to hatching of *Capnia*, although biomass changed only slightly despite maturation of autumn emerging *Leuctra*.

In the Shugor River the highest plecopteran densities 600 ind./m^2 was recorded in late August 1983 (a year with average temperature conditions). After emergence of *L. fusca* and *L. digitata* Kempny, 1899 (early September), numbers and biomass of Plecoptera declined and then increased again to ice cover. In the samples collected prior to ice cover the plecopteran biomass was 0.7 g/m^2 and density was ca. 300 ind./m^2.

Densities were thus highest in late August, but maximal biomass was recorded in April during ice-cover when the plecopteran fauna was dominated by *A. compacta, D. nanseni, C. pygmaea* and *T. nebulosa.*

The highest relative frequency of Plecoptera in

Table 1. Species Composition of the Plecoptera in the Pechora Basin.

Species	Ural	Timan
	tributaries	
PERLODIDAE		
Arcynopteryx compacta (McLachlan)	+	+
Diura bicaudata (L.)	+	+
Diura nanseni (Kempny)	+	+
Isogenus nubecula Newman	-	+
Perlodes dispar (Rambur)	-	+
Isoperla difformis (Klapalek)	+	+
Isoperla grammatica (Poda)	+	+
Isoperla obscura (Zetterstedt)	+	+
CHLOROPERLIDAE		
Siphonoperla burmeisteri (Pictet)	+	+
Xanthoperla apicalis (Newman)	+	+
Isoptena serricornis (Pictet)	-	+
TAENIOPTERYGIDAE		
Brachyptera braueri (Klapalek)	+	+
Taeniopteryx nebulosa (L.)	+	+
Rhabdiopteryx acuminata Klapalek	-	+
NEMOURIDAE		
Amphinemura borealis (Morton)	+	+
Amphinemura standfussi (Ris)	+	+
Protonemura intricata (Ris)	+	-
Nemoura arctica Esben-Petersen	+	-
Nemoura avicularis Morton	+	+
Nemoura cinerea (Retzius)	+	+
Nemura flexuosa Aubert	+	+
Nemoura sahlbergi Morton	+	-
Nemurella pictetii Klapalek	+	-
CAPNIIDAE		
Capnia atra Morton	+	+
Capnia bifrons (Newman)	+	-
Capnia pygmaea (Zetterstedt)	+	+
Capnia vidua Klapalek	+	-
Capnopsis schilleri (Rostock)	+	-
Mesocapnia variabilis (Klapalek)	+	-
LEUCTRIDAE		
Leuctra digitata Kempny	+	+
Leuctra fusca L.	+	+
Leuctra nigra (Olivier)	+	-
Leuctra hippopus Kempny	+	+

the benthos was recorded in 1979, the coldest year and also the year with the highest discharge (Table 3). In June and July, plecopteran numbers were low (<1 % of total benthos). This value increased sharply in early August and persisted until the end of the survey (20 September). Then Plecoptera constituted 8.3 % of the benthos. Young nymphs of genus *Capnia* formed a major share (94 %) of the Plecoptera. Biomass also increased and reached to 5.6-11.1 % of benthis biomass in August-September. An Abrupt increase was seen on 10 – 20 September. When biomass reached 1.4 g/m^2.

In 1989, an extremely warm year, the lowest Plecoptera number were recorded and plecoptera constituted only 0.2% of total benthos numbers. Biomass was also low, although in September – late October it increased to 0.4 g/m^2.

Plecoptera in fish nutrition

Atlantic salmon (*Salmo salar* L.), whitefish (*Coregonus lavaretus pidschian* Gm.), european grayling (*Thymallus thymallus* L.), burbot (*Lota lota* L.), bullhead (*Cottus gobio* L.), european minnow (*Phoxinus phoxinus* L.) and ruff (*Gimnocephalus cernuus* L.) fed on Plecoptera in the Pechora river basin. In all the fish stomachs studied, 90 % of the Plecoptera were nymphs, the remaining 10 % were adults.

The plecopteran share in the summer food of grayling and young salmon was low, generally below 10 % (Table 4). In September and October the plecopteran share in the stomachs was a little higher than in summer.

In wintertime the role of Plecoptera is greater (90-100 %) in the Ural tributaries and 80 % in the Timan tributaries. After ice break in May Plecoptera still played a major role in fish nutrition accounting for 63.5 % in grayling and 23.8 % in young salmon.

Table 2. Frequency, number and biomass of Plecopteran nymphs in benthos of Pechora tributaries during the ice free period.

Rivers	**Sampling date**	**Number of samples**	**Frequency (%)**	**Density**		**Biomass**	
				Ind./m^2	**% of total**	**mg/m^2**	**% of total**
The Ural tributaries							
Shugor	30.06.83	5	80	95.4	0.5	32.2	0.6
	10.07-30.07.83	16	75	119.8	0.2	38.2	0.8
	10.08-30.08.83	13	85	395.4	2.1	79.8	2.0
	10.09-30.09.83	15	87	153.1	0.3	208.2	1.2
	9.10.83	5	80	277.6	0.5	654.1	5.1
Shugor	30.06.89	4	75	23.4	<0.1	14.0	0.5
	10.07-30.07.89	15	60	38.1	0.1	58.0	1.4
	10.08-30.08.89	14	79	87.5	0.2	71.3	0.9
	10.09-30.09.89	14	79	42.1	0.1	223.0	2.8
	10.10-20.10.89	10	40	50.8	0.2	284.5	4.0
U.Pechora	11.08.81	7	100	475.3	2.3	275.7	5.7
	18.07-24.07.93	8	78	74.4	0.7	36.7	3.3
Shaitanovk	11.08.81	2	100	348.7	3.0	168.8	6.6
Unja	19.08-20.08.81	12	100	202.5	0.9	150.5	2.0
Ilych	31.08.81	12	100	1417.1	4.3	835.9	8.1
Podcherem	16.07-18.07.93	8	100	453.2	2.6	68.8	1.9
Kosju	12.07-22.07.93	25	76	125.5	1.4	42.0	0.7
Vangyr	8.07-9.07.93	10	80	76.9	0.8	32.0	0.7
Vangyr	9.07-12.07.94	12	75	211.3	1.0	74.8	0.4
Kozhym	19.07-20.07.93	10	56	70.0	0.4	79.7	0.9
Kozhym	16.07.95	8	40	29.5	0.4	23.2	0.3
Lemva	23.07.95	8	50	86.1	1.7	141.8	5.4
The Timan tributaries							
Izhma*	26.06-1.07.93	23	63	527.2	1.9	72.4	0.5
Ukhta	26.06-6.07.92	114	51	150.4	0.6	33.9	0.2
Sedju	26.06-29.06.93	21	90	272.3	8.7	17.7	2.9

* Data taken from Shubina (1995)

Table 3. Animal Average for Plecoptera frequencies in the Shugor River in different years, during open-water period.

Years	Total degree-days	Frequency (%)	**Share of total benthis**	
			numbers (%)	biomass (%)
1979	1042	93	4.18	6.6
1983	1222	80	0.60	1.4
1989	1480	64	0.20	1.3

Table 4. Frequency and share of Plecoptera in the food of grayling in the Pechora tributaries

River	Sampling date	Number of fish	Frequency %	Share in the stomach contents	
				By number (%)	By mass (%)
The Urals					
Shugor	07.84	36	50.0	1.9	6.1
Shugor	07.85	64	18.8	0.4	2.4
Kosju	07.93	28	7.1	0.2	0.5
Kozhym	07.81	76	46.1	2.2	19.0
Kozhym	07.84	30	96.7	2.8	4.7
Vangyr	07.93	32	56.3	16.3	1.0
Lemva	07.95	37	45.9	4.5	0.3
Shugor	10.87	26	34.6	47.9	4.9
Shugor	04.91	37	91.9	88.5	72.6
Shugor	04.95	199	94.9	94.5	36.3
Shugor	05.86	39	100.0	83.4	63.5
The Timan					
Myla	07-08.94	19	22.2	3.8	0.3
Suzju	07.94	30	6.7	0.8	0.1
Sedju	06.93	45	15.6	1.2	0.1
Ukhta	06-07.92	39	17.6	0.6	0.7
Kedva	07.95	46	63.0	10.8	0.6

In the Ural tributaries during winter, 11 plecopteran species were recorded in young salmon while 15 were recorded in grayling. Nymphs of *D. nanseni* dominated in mass and sometimes in numbers. Larvae of *A. borealis* were also frequent (one salmon had 170 nymphs in its stomach). In August, young salmon nutrition was dominated by nymphs of *L.fusca*. While grayling nutrition was dominated by *D. nanseni* (both in mass and numbers). Sometimes grayling stomachs had up to 60 nymphs of this species. *A.compacta, I. obscura* and *A. borealis* dominating the benthos of the sub-polar rivers, also had the greatest share in fish nutrition in these rivers. Grayling stomachs also contained imagos of *C. pygmaea*, *I. obscura, A. compacta* and *D. nanseni* (June) and *C. pygmaea, I. grammatica* and *L. digitata* (July) and *L. fusca* (August).

European grayling is the main predator of Plecoptera in the Timan rivers. Plecoptera had the greatest share of grayling diet in June, while in July and August their role was negligible. Grayling nutrition in the Ukhta river was dominated by females of *Nemoura avicularis* Morton 1894 and *L. hippopus*. As well as large females of *R. acuminata*. Species richness was low in grayling stomachs collected in the other Timan rivers in July. Young salmon fed rarely on Plecoptera in the Timan rivers and if so they were usually young nymphs of *Diura* and *A. compacta*, more seldom *A. borealis*.

Analysis of gut species composition revealed considerable similarity in their stonefly predation by young salmon and grayling in summer. Both species have a large coefficient of coincidence (73.8 %) with regard to plecopteran species. However, there was probably little food competition between the species owing to the low fish numbers and rich species diversity of benthos (Sidorov & Shubina 1974).

In the autum, the frequency of Plecoptera in fish stomachs was 20-50 %. In September-October 1987, young larvae of the genera *Capnia* and (very seldom) *Diura* were recorded. In late October, 1993, *T. nebulosa* nymphs were present occasionally with *Diura* nymphs. In 1987 during the same period the nutrition of young salmon was dominated by *A. compacta* and *T. nebulosa,* occasionally *L. fusca*.

During winter grayling nutrition in the Shugor river was dominated by nymphs of *C. pygmaea* (92.1 % of all identifications). Other species present were *D. nanseni* (6.0 %), *A. compacta* (1.2 %), *I. obscura* (0.5 %) and *T. nebulosa* (0.2 %). In stomachs of young salmon, Plecoptera constituted up to 73 % by weight *(C. pygmaea, D. nanseni)*.

Grayling fed on various plecopteran species under the ice in winter. In spite of the domination of the genus *Capnia*, they still played a lesser role than in the Timan rivers. Another species, *T. nebulosa*, had a considerable share, and dominated the stomachs of the Timan graylings by weight.

In May, after ice break, grayling fed mainly on the same species (*C. pygmaea* and *C. atra*) as in April, but mature nymphs and imagos. The nymphs of large-sized Perlodidae were also recorded. Thus, a stomach of one large grayling contained 110 final instar nymphs of *A. compacta* and 12 mature *Diura* nymphs.

Thus, Plecoptera, together with other aquatic insects, serve as a food for young salmon and grayling in the Pechora tributaries in summertime, the main fish feeding period. Plecoptera were also a main nutritional component in winter under the ice.

22 Plecoptera species are recorded in fish stomachs, 21 species in grayling and 11 in young salmon. The most prefered food items in the Pechora tributaries were *A. compacta, D. nanseni, A. borealis* and *C. pygmaea*.

Acknowledgements. Plecoptera nymphs were also collected by V. Shubina. G. Sidorov and V. Ponomarev, ichtiologists of the Laboratory of Aquatic Organisms Ecology, the Institute of Biology, made available collections from 1976-1996 of grayling and young salmon stomach samples containing over 20,000 Plecoptera. Data was also provided on the percentage Plecoptera in fish stomachs. The author is grateful to them and to S.Balina, Institute of Biology, Syktyvkar for translation. The author expresses his acknowledgements to L.A. Zhiltzova, Senior Researcher of Zoological Institute, RAS for advice on Plecoptera identification.

REFERENCES

Brinck, P. 1952. Bäcksländor. *Plecoptera*. Svensk insektfauna. 15. 126 pp. Stockholm.

Chekanovsky-Sorensen, T. 1948. A method of estabilishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biol. Skr. 5, 1-34.

Illies, J. 1955. Steinfliegen oder *Plecoptera*. Die Tierwelt Deutschlands. 43. 150 pp. Jena.

Illies, J.1961.Versuch einer algemeinen biozönotischen Gliederung der Fließgewässer. Int. Rev. Hydrobiol. 46, 2, 205-213.

Illies, J. 1971. Einführung in die Tiergeographie. 92 pp. Stuttgart.

Lillehammer, A. 1988. Stoneflies (*Plecoptera*) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica. 21, 165 pp.

Loskutova, O. A. & Zhiltzova, L .A. 1993. Plecoptera in the ecosystems of the Northern Urals rivers. Pp.168-170 in Kerzhner, I.M. & Pesenko, Yu.A. (ed.), Advances in Entomology in the USSR: ecology and faunistics, smaller orders of insects. St.-Petersburg (in Russian).

Loskutova, O. A. & Zhiltzova, L. A. 1998. Fauna of Plecoptera in the Urals. Pp.12-13 in Problems of Entomology in Russia. 1, 2. St-Petersburg (in Russian).

Methods manual for study of feeding and nutritive relationships of fishes in natural conditions in Borutsky, E.B. (ed.). 1974. Nauka, Moscow. 256 pp. (in Russian).

Nezhikhovsky, R. A. 1988. Floods in rivers and lakes. 184 pp. Hydrometeoizdat, Leningrad (in Russian).

Nikolsky, G. V., Gromchevskaya, I. A., Morozova, G. I. & Pikuleva, V. A. 1947. Fishes of the Upper Pechora basin. 224 pp. Moscow (in Russian).

Rikhter, G. D. 1946. North of the European part of the RSFSR (Physical-geographical characteristics). 190 pp. Moscow (in Russian).

Sedykh, K. F. 1974. Animal world of Komi Autonomous Rebublic. Invertebrates. 191 pp. Komi Publ. Syktyvkar (in Russian).

Sidorov, G. P. & Shubina, V. N. 1974. Autumn feeding of grayling and young salmon. Pp.93-95 in Pota pova, O. I, Smirnov, Yu. A. (ed.), Biological resources of the White Sea and inland water bodies of the European North. Petrozavodsk (in Russian).

Shubina, V. N. 1986. Hydrobiology of a salmon river in the Northern Urals. 157 pp. Nauka, Leningrad (in Russian).

Shubina, V. N. 1995. Benthos of upper stream of the river Izhma (Timan Ridge). Pp. 69-78 in Zakharov,

A. B. (ed.), Biological consequences of economic development of reservoirs of European North. Komi Publ. No. 142, Syktyvkar (in Russian).

Sørensen, T. 1948. A method of estabilishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biol. Skr. 5, 1-34.

Zhiltzova, L. A. 1964. Plecoptera division Pp.177-201 in Bey-Bienko, G.Ja. (ed.), Key for Insects of the European part of the USSR. 1. Nauka, Moscow-Leningrad (in Russian).

Zhiltzova, L. A. 1966. Plecoptera of the European part of the USSR (except the Caucasus) in Stakelberg, A. A. (ed.), Entomological Revue. 45 (3), 525-549 (in Russian).

Zhiltzova, L. A. 1977. Plecoptera division. Pp.303-319 in Kutikova, L.A. & Starobogatov, Ja.I. (ed.), Key for freshwater invertebrates of the Euroepan part of the USSR (plankton and benthos). Hydrometeoizdat, Leningrad (in Russian).

Zhiltzova, L. A. & Loskutova, O. A. 1999. Zoogeographic features of stoneflies (Plecoptera) of Komi Republic. Russian Entomol. J. 8 (3), 155-158 (in English).

Zhiltzova, L. A. & Teslenko, V. A. 1997. Order Plecoptera. Pp.248-264 in Tsalolikhin S.Y. (ed.), A key to freshwater invertebrates of Russia and Adjacent Lands. 3. St.-Petersburg (in Russian).

Received 29 June 2000,
accepted 15 March 2001

Norw. J. Entomol. 48, 199–212. 2001

Distribution, phenology and habitat characteristics of Chironomidae (Diptera) of the northeastern part of European Russia

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Kuzmina, Y. 2001. Distribution, phenology and habitat characteristics of Chironomidae (Diptera) of the northeastern part of European Russia. Norw. J. Entomol. 48, 199-212.

In the territory of the Komi Republic and the Nenets Autonomous District representatives of 6 subfamilies are registered, viz. Podonominae, Tanypodinae, Diamesinae, Prodiamesinae, Orthocladiinae and Chironominae. In the Pechora river basin 161 species and forms were recorded, in the Severnaya Dvina river basin and in the Mezen river basin the numbers were 170 and 87, respectively. In the lakes of the Bolshezemelskaya tundra 127 species were recorded. In addition, seven species of terrestrial chironomids were identified. In the rivers most species belong to the genera *Corynoneura, Cricotopus, Eukiefferiella, Orthocladius, Cladotanytarsus, Tanytarsus,* and *Polypedilum*; in lakes to *Psectrocladius, Orthocladius, Cladotanytarsus,* and *Tanytarsus*. Among the terrestrial chironomids, the most common genera were *Smittia* and *Bryophaenocladius*. In total, the chironomids fauna of the Komi Republic entails 308 species, though this number is steadily increasing. The distribution of species within the dominating complexes in a water body is above all influenced by the character of the biotope. For the studied rivers, two main chironomid complexes were typical, a lytho-phyto-rheophylic and a psammo-rheophylic complex. The lytho-phyto-rheophylic complex is found in the upstream and the middle flow of rivers, while the psammo-rheophylic complex dominates in the downstream of the studied rivers. The lakes, however, mainly include pelophylic complex. In overgrowth of macrophytes, a phytophylic complex is common.

Key words: Chironomidae, species composition, Chironomid complexes.

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INTRODUCTION

Representatives of the family Chironomidae rank as number one both in number and biomass within the benthos fauna of northern rivers (Zvereva 1969, Shubina 1986, Kuzmina 1995). They serve a food supply for most game fish of Northern freshwater reservoirs (Sidorov 1979, Ponomarev & Cherezova 1995, Kuzmina 1999a). Chironomids outnumber all other families of invertebrate by means of species number, constituting 25 % of all freshwater insect species (Shilova 1976). They are adapted to live in both aquatic and terrestrial habitats as the larvae of some species live in humid soil, dung or sphagnum moss.

Zvereva (1947, 1950, 1953a, 1953b, 1962) was the first to publish data on the chironomid fauna of the European North-East of Russia. She performed a fundamental hydrobiological study of water bodies belonging to the Pechora and the Vychegda river basins, and recorded 150 different taxa of chironomids (Zvereva 1969).

This work reviews the data on Chironomid fauna and its distribution over different water bodies and watercourses of the Komi Republic and the Nenets Autonomous District.

STUDY AREA

The study area comprises the territory of the Komi Republic and the Nenets Autonomous District (Figure 1). The chironomid fauna was studied in three river basins: the Pechora basin (the rivers Ukhta, Sedju, Kolva and Podcherem), the Severnaya Dwina basin (the river Vym) and the Mezen basin. In addition, chironomids were studied in tundra water bodies. These were the Bolshoy Kharbey and the Bolshoy Taravey lakes, and small water bodies in the Pechora Delta and adjacent tundra.

Most of the studied rivers have huge populations of salmon. The upstreams are mountainous or semi-mountainous, while the downstream and middle parts are more flat. Accordingly, boulder-pebble soils dominate the upstream, and boulder-pebble, gravel-pebble, gravel-sandy and sandy soils the middle part and the downstreams. The speed of the water current varies between 0.25 and 1.5 m/sec.

The lake Bolshoy Kharbey is 28.5 km^2 with an average depth of 4.6 m and a maximal depth of 18.5 m (Goldina 1972). The sediments consist of different soils: gravel, pebbles and sand in the littoral and silt or silty sand in the central part.

The Bolshoy Taravey is a brackish lake, 20 km^2 wide, and has a depth of 0.5-1.1 m. The bottom substrate consists of silt soils (Loskutova & Fefilova 1996).

The studied smaller lakes are all minor reservoirs situated in the Pechora Delta, on the Barents Sea coastline and on the Nenets Ridge; some of them are flooded by seawaters. Their depth ranges from 0.5 to 1.5 m, and the bottom substrates are made up of sandy and silt soils.

MATERIAL AND METHODS

Most of the material was collected by the author from the rivers Vym, Sedyu and Podcherem. In

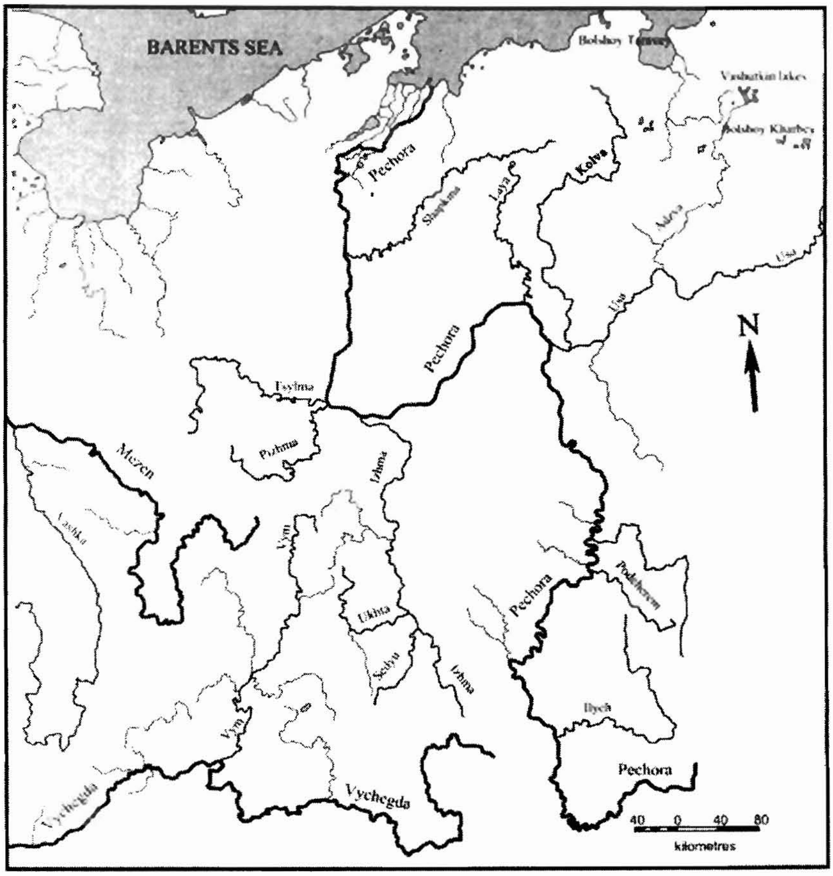

Figure 1. Map of the study area.

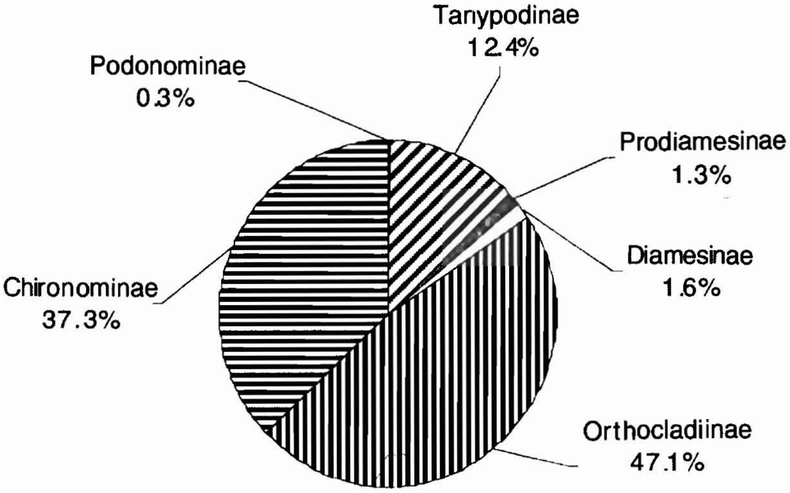

Figure 2. Relation of Chironomid subfamilies in the studied water bodies and watercourses.

addition, larvae, pupae and imagines of chironomids from the rivers Ukhta, Izhma, Mezen and Kolva, and from the lakes Bolshoy Taravey and Bolshoy Kharbey[1] were handed the author for identification by the research staff of the laboratory of Ecology of Water Organisms (Komi SC UrD RAS). The staff also made available data on the general number and biomass of chironomids in these reservoirs. Material from the small lakes of the Pechora Delta[2] and adjacent tundra were delivered by Dr.Ruurd Noordhuis.

Larvae and pupae were sampled by use of Petersen's bottom scraper on sandy soils (grapple square 0.25 m^2), and by hydrobiological scraper on gravel-pebble and pebble-boulder soils (mesh size 0.2 mm). Hydrobiological scoop-net was used in thicket of water plants for qualitative sampling. Pupae exuvia were collected in stagnant or flowing reservoirs near the water level. Both larvae, pupae and exuvia were fixed in 4 % formaldehyde.

Imagines were collected by entomological scoopnet in places with accumulation of midges, e.g. among grass and bushes, and in the air. Midges were fixed by Udemans' liquid (640 parts of 96 % alcohol, 50 parts of glycerin, 230 parts of distilled water and 80 parts of glacial acetic acid).

For identification of pre-imaginal stages, larvae and pupae were reared according to the method described by Shilova (1976). More than 500 rearing experiments were conducted. Chironomids were identified by Pankratova (1970, 1983), Pinder (1978), Widerholm (1983, 1986, 1989), Hirvenoja (1973) and Ashe & Cranston (1990).

In the preparation of larvae, pupae and adults, the methods of Pankratova & Shilova (1976) were applied. For permanent preparations, the Fora-Berleze's liquid was used (proportion: distilled water - 50, chloralhydrate - 200, glycerin - 20, dry gum-arabic - 30 weight parts).

Chironomid complex were distinguished according to the dominance index (d) (Kownacki 1971).

RESULTS AND DISCUSSION

During the study 308 species and forms of chironomids were distinguished, representing 6 subfamilies (Table 1). Of these, most species belonged to the subfamily Orthocladiinae (Figure 2).

The Pechora basin

Ukhta river basin. In this basin, 97 species and forms representing 5 subfamilies were found (Table 2), of which 72 were registered in the river bed. The subfamily Orthocladiinae is most widely represented. The main faunistic complex of the

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[1] Research financed by RFFI grant 98-04-5007

[2] Research performed within Russian-Dutch joint project "Structure and Dynamics of the Pechora Delta Ecosystems"

Ukhta river is lithorheophylic, confined to the boulder-pebble soil, and is typical for chironomid complex of the Ukhta river. This soil has of the highest number of larvae and biomass. On the boulder-pebble ground in the Ukhta river is found an orthocladine complex as 58.9 % of all species found on this biotope belong to Orthocladiinae. This complex was represented by *Orthocladius* gr. *saxicola* Kieffer, *Thienemanniella* gr. *clavicornis* Kieffer and the genus *Eukiefferiella*. Twenty-nine species and forms were found on gravel-pebble soils, and the lithorheophylic complex of these soils consists of *Tanytarsus* sp. and *Polypedilum bicrenatum* Kieffer. Larvae representing 20 species and forms were found on the sandy soils, dominated by *P. bicrenatum, Cladotanytarsus* N 7 (Zvereva) and *Cladotanytarsus* N 3 (Zvereva).

Sedyu river. In the Sedyu river 60 species and forms were found, of which 22 species were characteristic for the pebble-boulder soils overgrown with nardosmia (*Nardosmia* sp.) and water mosses. Most typical were *Thienemanniella* gr. *clavicornis, Corynoneura* sp. and *Nilotanypus dubius* (Meigen). Notwithstanding, the dominating species in the lithorheophylic complex of the Sedyu river is *Rheotanytarsus pentapoda* (Kieffer) (with an average number of 7 100 ind./m^2). The gravel-pebble soils were most rich in species and hosted 34 forms and species. As much as 44.1 % of the species were represented by larvae from the subfamily Orthocladiinae. The dominating chironomid complex consists of *Orthocladius* gr. *saxicola* and *Nilotanypus dubius*. Larvae representing 30 species and forms were found on the gravel-pebble soils, of which 50 % of the species belong to Chironominae; representatives of this subfamily dominated by means of number as well. The dominating chironomid complex was represented by Chironominae: *Polypedilum bicrenatum, Cladotanytarsus* sp. and *Saetheria thylus* (Townes). In the Sedyu river, sandy soils (with accompanying thicket of macrophytes) were confined exclusively to the littoral zone. The psammorheophylic chironomid complex is represented by *Stempellina bausei* Edwards and *Nilotanypus dubius*.

Izhma river. Larvae of 70 species and forms representing 5 subfamilies were identified. In the moss thicket over boulder-pebble soils *Orthocladius* sp., *Orthocladius* gr. *saxicola, Thienemanniella* gr. *clavicornis* and *Eukiefferiella* sp. were found in a huge numbers (more than 2 000 ind./m^2). Larvae from the genus *Cladotanytarsus*, and *Eukiefferiella tshernovskii* Pankratova and *Polypedilum bicrenatum* dominated on the pebble-sandy soils; *Chironomus* sp., *Paralauterborniella nigrohalteralis* (Malloch) and *Tanytarsus* sp. on sandy soils.

Kolva river. Larvae representing 61 species and forms in 5 subfamilies were found, and the average number was 791.4 ind./m^2; biomass 0.103 g/m^2. Altogether 21 species were recorded from boulder-pebble soils, of which 12 belong to Chironominae; dominating are representatives of the genus *Cladotanytarsus, Paracladopelma camptolabis* (Kieffer) and *Parakiefferiella bathophila* (Kieffer). Twenty-four species and forms were found on sandy soils, most of them (62.5%) belonging to Chironominae (62.5%). Nevertheless, Orthocladiinae (*Paracladius inaequalis* (Kieffer) and *Nanocladius bicolor* (Zetterstedt)) were most abundant by means of number.

In the entire Pechora basin, a total of 161 species and forms representing 5 subfamilies were registered (Table 2).

The Severnaya Dwina basin.

In the Vym basin 170 species and forms in 5 subfamilies were identified. In the Vym river bed larvae and pupae of 75 species and forms were distinguished; average number was 5 800 ind./m^2, biomass 0.68 g/m^2. The highest biomass of chironomid larvae was registered on boulder-pebble soils with a moss thicket. The chironomid complex of moss thickets can be characterized as an orthocladine complex, as 66.6% of all registered species belong to this subfamily. The lithorheophylic complex of the Vym river includes *Rheotanytarsus pentapoda, Tanytarsus* sp., *Eukiefferiella claripennis* (Lund.) and *Eukiefferiella calvescens* Edwards. On the gravel-sandy soils 30 species were distinguished. The psammolithorheophylic complex consists of *Cricotopus bicinctus* (Meigen), *Orthocladius* gr. *saxicola, Microtendipes pedellus* (De Geer) and *Rheotanytarsus*

Table 1. Chironomidae recorded from the studied water bodies and watercourses.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
Podonominae				
Boreochlus thinemanni Edwards	-	-	-	X
Tanypodinae				
Ablabesmyia longistyla Fittkau	X	X	-	-
A. phatta (Egger)	-	X	-	X
Ablabesmyia sp.	X	-	-	
Anatopinia plumipes (Fries)	-	-	-	X
Apsectrotanypus trifascipennis (Zetterstedt)	-	X	-	-
Arctopelopia griseipennis (van der Wulp)	X	-	-	-
Arctopelopia sp.	X	X	X	-
Clinotanypus nervosus (Meigen)	-	X	-	-
Conchapelopia melanops (Meigen)	-	X	X	-
C. pallidula (Meigen)	-	-	X	X
Conchapelopia sp.	X	-	-	X
Krenopelopia binotata (Widemann)	X	-	-	-
Larsia sp.	X	-	X	-
Meropelopia flavifrons Roback	-	-	X	-
Meropelopia sp.	X	X	X	X
Monopelopia sp.	X	-	-	-
Nilotanypus dubius Meigen	X	X	X	-
N. fimbricatus (Walker)	X	-	X	-
Nilotanypus sp.	-	-	X	-
Paramerina cingulata (Walker)	X	-	-	-
Procladius choreus (Meigen)	-	-	-	X
Procladius culiciformis (Linne)	-	X	-	-
P. ferrugineus (Kieffer)	X	X	-	X
Psectrotanypus sibiricus (Kruglova & Chernovskij)	X	-	-	X
P. varus (Febricius)	-	-	-	X
Rheopelopia sp.	X	X	X	-
Rheopelopia perda (Roback)	-	-	X	-
Rheotanypus sp.	-	-	X	-
Telmatopelopia nemorum (Goetghebuer)	X	-	-	-
Thienemannimyia fusciceps (Edwards)	-	X	-	X
T. geijskesi (Goetghebuer)	-	-	-	X
T. norena (Roback)	-	X	-	-
T. senata (Walley)	-	-	-	X
Trissopelopia sp.	-	-	X	-
Xenopelopia falcigera (Kieffer)	-	X	-	-
Xenopelopia sp.	X	-	-	-
Zavrelemyia melanura (Meigen)	X	-	-	-
Prodiamesinae				
Monodiamesa bathyphila (Kieffer)	X	X	-	X
M.nitida (Kieffer)	-	-	-	X
Prodiamesa olivacea (Meigen)	X	X	-	-
Odontomesa fulva (Kieffer)	X	X	-	-
Diamesinae				
Diamesa sp.	X	-	-	-

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
Syndiamesa komensis Zvereva	X	-	-	-
Protanypus morio (Zetterstedt)	-	-	-	X
Potthastia longimana (Kieffer)	X	X	X	X
P. gaedi (Meigen)	X	-	X	X
Orthocladiinae				
Acamptocladius submontanus (Edwards)	-	X	-	-
Acricotopus lucens (Zetterstedt)	-	X	-	-
Brillia longifurca Kieffer	X	X	X	
B. modesta (Meigen)	-	X	-	-
Bryophaenocladius nidorum (Edwards)	X	X	-	-
B. tuberculatus (Edwards)	-	X	-	-
B. xanthogyne (Edwards)	-	X	-	-
Camptocladius stercorarius (De Geer)	-	X	-	-
Chaetocladius piger (Goetghebuer)	-	X	-	-
C. vitellinus (Kieffer)	-	X	-	-
Corynoneura arctica Kieffer	-	X	-	-
C. celeripes (Winnertz)	X	X	-	-
C. coronata Edwards	X	-	X	-
C. edwardsi Brundin	X	X	-	-
C. gratias Schlee	-	X	X	-
C. lacustris Edwards	X	X	X	-
C. lobata Edwards	-	X	-	-
C. scutellata Winnertz	X	X	-	X
Corynoneura sp.	X	X	X	X
Cricotopus (Cricotopus) algarum (Kieffer)	-	X	-	X
C. (C.) annulator Goetghebuer.	X	X	-	-
C (C.) bicinctus (Meigen)	X	X	X	-
C.(C.) curtus Hervenoja	-	X	-	-
C. (C.) fuscus (Kieffer)	X	-	X	X
C. (C.) pallidipes Edwards	-	-	X	-
C. (C.) pilosellus Brundin	-	-	-	X
C. (C.) pulchripes Verral	-	-	-	X
C. (C.) similis Goetghebuer	X	-	-	-
C. (C.) tremulus (Linnaeus)	X	-	-	-
C. (C.) triannulatus Macquart	X	-	X	-
C. (C.) trifascia Edwards	X	X	-	-
C. (Isocladius) intersectus (Staeger)	-	-	-	X
C. (I.) laricomalis Edwards.	X	-	-	X
C. latidentatus Chernovskij	X	X	-	-
C. (I.) sylvestris (Fabricius)	X	X	-	-
C. (I.)gr.sylvestris (Fabricius)	X	X	X	X
C. (I.) ticinctus (Meigen)	-	-	-	X
C. (I.) trifasciatus (Meigen)	X	X	-	X
Cricotopus sp.	X	-	X	X
Epoicocladius flavens (Malloch)	X	-	-	-
Eukiefferiella alpestris Goetghebuer	-	-	X	-
E. atrofasciata (Goetghebuer)	-	-	X	-
E. brevicalcar (Kieffer)	X	X	-	-

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
E. claripennis (Lundbeck)	X	X	-	-
E. clypeata (Kieffer)	X	-	-	-
E. coerulescens (Kieffer)	X	-	-	-
E. gracei (Edwards)	X	X	X	X
E. hospita Edwards		X	-	-
E. ilkleyensis (Edwards)	X	-	-	-
E. longipes Chernovskij	X	X	-	-
E. quadridentata Chernovskij	-	-	X	-
E. similis Goetghebuer	-	X	-	-
E. tshernovskii Pankratova	X	X	X	-
Eukieffiriella sp.	X	X	X	X
Eurycnemus crassipes (Panzer)	-	-	X	-
Euryhapsis cilinum Oliver	-	-	X	-
Halocladius variabilis (Staeger)	-	-	-	X
Heterotrissocladius changi Saether	-	-	X	-
Heterotrissocladius maeari Brundin	-	-	-	X
H. marcidus (Walker)	X	X	-	X
Hydrobaenus lugubris Fries	X	-	-	-
Hydrobaenus sp.	-	X	-	-
Krenosmittia camptophleps (Edwards)	X	-	-	-
Limnophyes asquamatus Andersen	X	X	-	-
L. brachitomus Saether	X	-	-	-
L. globifer (Lundström)	X	-	-	X
L. habilis (Walker)	X	-	-	-
L. minimus (Meigen)	X	-	-	-
L. prolongatus (Kieffer)		X	-	-
L. schnelli Saether	X	-	-	-
Limnophyes sp.	X	-	X	-
Lindebergia bothnica Tuiskunen	-	X	-	-
Metriocnemus atratulus (Zetterstedt)	-	-	-	X
M. fuscipes (Meigen)	X	-	-	-
M. gracei Edwards	-	X	-	-
M. hygropetricus Kieffer	-	X	-	-
M. picipes (Meigen)	-	X	-	-
M. tristellus Edwards	-	X	-	-
Nanocladius bicolor (Zetterstedt)	X	X	X	X
N. anderseni Saether	-	X	-	-
Orthocladius (Euorthocladius) rivicola Kieffer	-	-	X	-
O. (E.) thienemanni Kieffer	X	X	X	X
O. (E.) abiskoensis Thienemann	-	-	-	X
O. (Pogonocladius) consobrinus (Holmgren)	-	-	-	X
O. (Orthocladius) dentifer Bundin.	X	X	X	-
O. (O.) frigidus (Zettersted)	-	-	X	-
O. (O.) nigritus Malloch	X	-	-	
O. (O.) oblidens (Walker)	-	X	-	X
O. (O.) obumbratus Johannsen	X	X	X	X
O. (O.) rhyacobius Kieffer	X	-	X	-
O. (O.) rubicundus (Meigen)	X	-	-	-
O. (O.) saxicola Kieffer	-	X	-	-

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
O. (O.) gr.saxicola Kieffer	X	X	X	X
Orthocladius sp.	X	X	X	X
Paracladius conversus (Walker)	X	X	L	X
P. inaequalis (Kieffer)	X	-	-	X
P. inserpens (Walker)	X	-	-	X
P. quadrinodosus Hirvenoja	X	X	X	-
Paracladius sp.	X	-	-	-
Parakiefferiella bathophila (Kieffer)	X	X	X	X
P. coronata (Edwards)	X	X	X	X
P.triquetra (Pankratova)	X	X	X	-
Paratrissocladius excerptus (Walker)	-	X	-	X
Propsilocerus paradoxus (Lundstrom)	-	-	-	X
Psectrocladius (Allopsectrocladius) obvius (Walker)	X	X	-	X
P. (A.) platypus (Edwards)	-	X	-	-
P. (Psectrocladius) brehmi Kieffer	-	X	-	
P. (P.) fennicus Storae	-	-	-	X
P. (P.) limbatellus (Holmgren)	-	X	-	X
P. (P.) psilopterus Kieffer	X	X	X	X
P. (P.) simulans (Johannnsen)	X	X	X	-
P. (P.) sordidellus (Zetterstedt)	-	-	-	X
P. (P.) gr. *sordidellus* (Zetterstedt)	-	-	-	X
P. (Monopsectrocladius) calcaratus (Edwards)	-	-	-	X
Psectrocladius sp.	X	X	-	X
Pseudorthocladius pilosipennis Brundin	-	X	-	-
Pseudismittia forcipata (Goetghebuer)	-	X	-	-
P. nanseni Kieffer	-	X	-	-
P. virgo Strenzke	X	-	X	X
Pseudosmittia sp.	X	X	-	-
Rheocricotopus chalybeatus (Edwards)	-	X	-	-
R. effusus (Walker)	-	X	-	-
Rheocricotopus sp.	X	X	-	X
Rheosmittia languida (Brundin)	X	X	X	-
Smittia aterrima (Meigen)	X	X	-	-
S. edwardsi Goetghebuer	X	-	-	X
S. leucopogon (Meigen)	-	X	-	-
S. nudipennis (Goetghebuer)	X	X	-	-
S. pratopum (Goetghebuer)	-	-	-	-
S. stercoraria De Geer	-	X	-	-
Smittia sp.	X	-	-	-
Synorthocladius semivirens (Kieffer)	X	X	X	-
Thienemanniella acuticornis (Kieffer)	X	X	X	-
T. gr. *clavicornis* (Kieffer)	X	X	X	-
T. flavescens (Edwards)	-	-	X	-
Thienemanniella sp.	X	-	X	-
Trissocladius sp.	X	X	X	X
Tvetenia bavarica (Goetghebuer)	X	X	X	-
T. calvescens (Edwards)	-	X	X	-
T. discoloripes (Goetghebuer)	-	X	X	-

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
T. verralli (Edwards)	-	-	X	-
Tvetenia sp.	X	-	-	X
Zalutschia mucronata (Brundin)	X	-	-	-
Z. tornetraskensis (Edwards)	-	X	-	X
Z. zalutshicola Lipina	-	-	-	X
Chironominae				
Chironomini				
Beckidia zabolotzkyi (Goetghebuer)	-	X	-	-
Chironomus obtusidens Goetghebuer	-	X	-	-
C. gr. *salinarius* Kieffer	-	-	-	X
C. nigrifrons Linevich & Erbaeva	-	X	-	-
Chironomus f.l. *semireductus*	-	-	-	X
Chironomus f.l. *tummi*	X	-	-	X
Chironomus (Lobochironomus) sp.	-	-	-	X
Chironomus sp.	X	X	-	X
Cladopelma viridula (Linnaeus)	-	-	-	X
C. gr.laccophila (Kieffer)	-	-	-	X
Cryptochironomus gr. *defectus* (Kieffer)	X	X	-	X
C. dneprinus (Chernovskij)	-	X	-	-
C. macropodus (Lachov)	-	X	-	-
Cryptochironomus sp.	X	X	X	-
Cryptotendipes holsatus Lenz	X	-	-	-
C. nigronitens (Edwards)	X	-	-	-
C. pseudotener (Goetghebuer)	-	X	-	-
C. usmaensis (Pagast)	X	-	-	-
Cryptotendipes sp.	-	-	-	X
Demicryptochironomus vulneratus (Zetterstedt)	X	X	-	X
Dicrotendipes modestus (Say)	-	-	-	X
D. nervosus (Staeger)	X	X	X	X
D. tritomus (Kieffer)	-	-	-	X
Glyptotendipes baripes (Staeger)	-	-	-	X
G. glaucus (Meigen)	-	-	-	X
G. imbecillis (Walker)	-	X	-	-
G. paripes (Edwards)	-	-	-	X
Glyptotendipes sp.	X	-	-	-
Harnischia curtilamelata (Malloch)	-	X	-	-
H. fuscimana Kieffer	-	X	-	-
Kloosia pusilla (Linne)	-	X	X	-
Lipiniella sp.	X	-	-	X
Microtendipes pedellus (De Geer)	X	X	X	X
M. rydalensis (Edwards)	X	-	-	-
M. tarsalis (Walker)	X	-	-	X
Nilothauma brayi (Goetghebuer)	X	-	-	-
Omisus caledonicus (Edwards)	-	X	-	-
Parachironomus arcuatus (Goetghebuer)	-	-	-	X
P. parilis (Walker)	-	-	-	X
Parachironomus sp.	X	-	-	X
Paracladopelma camptolabis Kieffer	X	X	-	X

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
P. doris (Townes)	X	X	-	-
Paracladopelma sp.	X	-	-	-
Paralauterborniella nigrochalteralis (Malloch)	X	X	-	-
Paratendipes albimanus (Meigen)	-	X	-	-
P. nudisquama (Edwards)	-	X	-	-
Paratendipes «conn.N 3» (Lipina)	-	X	-	-
Phaenopsectra punctipes (Wiedemann)	-	X	-	-
P. (Pentapedilum) exsectum (Kieffer)	X	X	-	X
P. (P.) sordens (van der Wulp)	-	-	-	X
Polypedilum (Polypedilum) acutum Kieffer	-	X	-	-
P. (P.) convictum (Walker)	X	X	-	-
P. (P.) nubeculosum (Meigen)	X	X	-	-
P. (P.) pedestre (Meigen)	X	X	-	X
P. (Tripodura) bicrenatum Kieffer	X	X	X	X
P (T.) scalaenum (Schrank)	X	X	-	X
Polypedilum sp. *(Chironominae* gen .N3*)* (Lipina)	X	X	X	X
Polypedilum sp.	X	-	X	-
Robackia demeijerei (Kruseman)	X	X	X	-
Saetheria thylus (Townes)	X	X	-	-
Saetheria sp.	-	X	-	-
Sergentia coracina (Zetterstedt)	-	-	-	X
Stenochironomus fascipennis (Zetterstedt)	-	X	-	-
S.gibbus (Fabricius)	X	-	-	-
Stictochironomus sticticus (Fabricius)	X	X	-	X
Stictochironomus sp.	X	-	-	X
Synendotendipes impar (Walker)	-	X	-	X
Tanytarsini				
Cladotanytarsus atridorsum Kieffer	-	X	X	X
C. mancus (Walker)	-	X	X	-
C. vandervulpi (Edwards)	-	X	-	-
Cladotanytarsus N 1 (Zvereva)	-	-	X	X
Cladotanytarsus N 2 (Zvereva)	X	-	-	-
Cladotanytarsus N 3 (Zvereva)	X	X	X	-
Cladotanytarsus N 4 (Zvereva)	X	-	-	-
Cladotanytarsus N 5 (Zvereva)	X	-	-	-
Cladotanytarsus N 6 (Zvereva)	X	-	-	-
Cladotanytarsus N 7 (Zvereva)	X	X	-	X
Cladotanytarsus sp.	X	X	X	X
Constempellina brevicosta (Edwards)	-	-	-	X
Corynocera ambigua Zetterstedt	-	-	-	X
Micropsectra apposita (Walker)	X	-	-	X
M. atrofasciata (Kieffer).	X	-	-	-
M. curvicornis Chernovskij	X	X	X	X
M. junici (Meigen)	X	X	-	X
M. radialis Goetghebuer	-	X	-	-
M. recurvata Goetghebuer	X	X	-	X
Micropsectra sp.	-	-	-	-
Paratanytarsus austriacus (Kieffer)	-	-	-	X

Table 1. Continued.

Subfamilies, species	**The Pechora basin**	**The Severnaya Dvina basin**	**The Mezen basin**	**Tundra lakes**
P. confusus Palmen	X	X	X	X
P. hyperboreus Brundin	-	X	-	-
P. natvigi (Goetghebuer)	-	X	-	-
P. quintuplex Kieffer	-	X	-	X
P. penicillatus (Goetghebuer)	-	-	-	X
P. siderophila (Zvereva)	-	X	-	X
Paratanytarsus sp.	-	-	-	X
Rheotanytarsus curtistylus (Goetghebuer)	-	X	-	-
R. pentapoda (Kieffer)	X	X	X	-
R. photophilus (Goetghebuer)		X	-	-
Rheotanytarsus sp.	X	-	-	-
Stempellina almi Brundin	-	X	-	-
S. bausei (Kieffer)	X	-	-	-
Stempellina sp.	-	-	X	-
Stempellinella brevis (Edwards)	-	-	-	X
S. minor (Edwards)	X	X	-	X
Tanytarsus anderseni (Reiss & Fittkau)	-	-	-	X
T. gr.lestagei Goetghebuer	X	X	-	X
T. medius Reiss et Fittkau.	X	X	X	X
T. mendax Kieffer	-	X	X	X
T. norvegicus (Kieffer)	-	-	-	X
T. pseudolestagei Shilova	X	X	X	X
T. usmaensis Pagast	-	-	-	X
T. verralli Goetghebuer	X	X	X	X
T. volgensis Miseiko	X	X	-	-
Tanytarsus sp.	X	X	X	X
Virgatanytarsus arduennensis (Goetghebuer)	X	X	X	-
All species	**161**	**170**	**87**	**127**

pentapoda. Sands constitute 30% of the bottom substrate in the Vym downstream, and larvae of 28 species have been recorded during the survey. Unstable ground provides no conditions for development of stable Chironomid community. The psammorheophylic complex consists of *Paracladopelma doris* (Townes), *Robackia demeijerei* (Kruseman) and *Stictochironomus sticticus* (Fabricius). In the thicket of macrophytes (*Potamogeton gramineus* L.) over the sandy soils, the species composition is more rich both in quantity and quality, and larvae of 43 species were found.

The Mezen river

In all 87 species and forms representing 4 subfamilies were idetified, and the average number of larvae and pupae in the river was 23 466.8 ind./m^2; biomass 2 981.8 mg/m^2. The lithorheophylic complex is the dominant in the Mezen river, and is confined to pebble-boulder soils. This biotope hosts larvae and pupae of 63 species and forms. The fauna on pebble-boulder ground is heterogenous, and one may distinguish between a biotope with silt accretions and a biotope with algae-moss thicket. In the former *Orthocladius* gr. *saxicola* and *Microtendipes pedellus* are dominating; in the latter *Orthocladius* gr. *saxicola* and *Thienemanniella* gr. *clavicornis*. The latter is also characterized by the increased influence of Tanypodinae, represented by 10 species (17.9%). On sandy soils, chironomids are less common. The psammorheophylic complex was represented by *Orthocladius*

Table 2. Percentage of Chironomid subfamilies in studied water bodies and watercourses

Water bodies and water-courses	SUBFAMILIES					
	Podono-minae	Tanypo-dinae	Prodia-mesinae	Diame-sinae	Orthocla-diinae	Chirono-midae
The Pechora Basin						
Ukhta	0	4.1	1.0	3.1	59.8	32.0
Sedyu	0	11.7	0	1.7	48.3	38.3
Izhma	0	11.4	2.9	4.3	35.7	45.7
Kolva	0	11.5	1.6	3.3	36.1	47.5
The Severnaya Dwina Basin						
Vym	0	8.2	1.8	0.6	50.6	38.8
The Mezen Basin						
Mezen	0	13.8	0	3.4	56.3	26.4
Tundra Lakes						
Bolshoy Kharbey	0	8.0	2.0	2.0	41.0	47.0
Small tundra water bodies	1.4	11.6	1.4	4.3	26.1	55.1

obumbratus (Kieffer), *Tanytarsus medius* Reiss & Fittkau and *Cladotanytarsus* N 1 (Zvereva).

Chironomids of tundra lakes

The Bolshoy Kharbey Lake. Altogether 100 species and forms in 5 subfamilies were registered. The fauna is mainly made up by evrybiontic and lymnophylic species. The average number of larvae in the studied lake is 3 084 ind./m^2; biomass 0.96 g/m^2. Most species (47%) belong to the Chironominae. On boulder and gravel soils *Orthocladius* sp., *O. obumbratus* (Kieffer), *Psectrocladius* gr. *psilopterus* Kieffer, *Cricotopus* gr. *sylvestris, Paratanytarsus quantuplex* Kieffer, *P. confusus* Palmen, *Micropsectra curvicornis* Chernovskij dominate. On silt soils the dominating species were *Paratanytarsus confusus* Kieffer, *Stictochironomus sticticus* (Fabricius), *Heterotrissocladius maeari* Brundin, *Polypedilum* spp., *Tanytarsus* sp., and *T.verralli* Goetghebuer; on biomass larvae of the genus *Chironomus* (4 species and forms), *Polypedilum* (2 species), *Procladius* (2 species) and *Monodiamesa bathyphila* Kieffer were dominating.

The Bolshoy Taravey Lake. Five species and forms were found, *Chironomus* gr. *salinarius, Chironomus* sp., *Cladotanytarsus* sp., *Halocladius variabilis* (Staeger) and *Orthocladius consobrinus* (Holmgren). The average number of larvae and pupae was 167.5 ind./m^2; average biomass 0.45 g/m^2.

Small lakes of the Pechora Delta and the adjacent coastline. Larvae and pupae representing 69 species and forms in 6 subfamilies were found in studied reservoirs, of which most belong to Chironominae (55%). The number of chironomids larvae and pupae fluctuated between 540 and 9 076 ind./m^2; biomass between 0.93 and 2.50 g/m^2. Almost all representatives of Chironominae and Tanypodinae are psammopelophylic organisms, a fact determined by the dominance of silt soils in these water bodies. Most frequent were *Procladius choreus* Meigen, *Procladius ferrugineus, Cladopelma gr. laccophila* and the genus *Chironomus* (7 larval forms). In macrophytes overgrowing the banks, species from the genera *Psectrocladius* (4 species), *Orthocladius* (3 species), and *Parakiefferiella coronata* (Edwards) were identified.

A total of 127 Chironomid species and forms have been found in tundra water bodies.

Terrestrial Chironomids

Seven chironomid species with terrestrial larvae were distinguished, *Bryophaenocladius nidorum* Edwards, *Bryophaenocladius tuberculatus* (Edwards), *Camptocladius stercorarius* (De Geer), *Paratrissocladius excerptus* (Walker), *Smittia aterrima* (Meigen), *Smittia leucopogon* (Meigen), *Smittia nudipennis* (Goetghebuer) (Kuzmina 1999b).

Conclusion

In all 308 species and forms in 6 subfamilies were recorded from the study area. They are mainly Palearctic and Holarctic in their distribution, and most of them widely distributed in the territory of Russia. By means of species number, the least common subfamily is Podonominae; one single species, *Boreichlus thinemanni* Edwards, was found in small tundra reservoirs. The subfamilies Prodiamesinae and Diamesinae made up between 0 and 4.3% of the species, and are represented mainly by *Potthasia gaedii* (Meigen), *Potthastia longimana* (Edwards) and *Monodiamesa bathyphila* (Kieffer), recorded from almost all studied water bodies. Another species, *Protanypus morio* (Zettersted), was confined exclusively to the tundra water bodies. Tanypodinae made up between 4.1 and 13.8% of the species, of which most recorded from the Ukhta and the Mezen rivers (14 and 12 accordingly). In the rivers, the most widespread species were *Rheopelopia* sp., *Nilotanypus dubius* and *Conchapelopia melanops* (Wiedemann); in the lakes *Procladius ferrugineus* and *Procladius choreus*. In the rivers Orthocladiinae made up between 36.1 and 59.8 % of the species. The lowest number of Orthocladiinae was registered in the rivers Izhma and Kolva, possibly explained by the dominance of sandy soils in these rivers, by pollution and eutrophication. In the rivers, the most frequent genera were *Cricotopus* (16 species), *Eukiefferiella* (15 species) and *Corynoneura* (9 species). In stagnant reservoirs Orthocladiinae was less common; the highest number of species belonged to the genera *Psectrocladius* (8 species) and *Orthocladius* (10 species). Representatives of Chironominae made up between 26.4 and 47.5% of the species in the rivers and between 47.0 and 55.1% in the lakes. In the rivers most species belonged to the genera *Cladotanytarsus* (11 species), *Tanytarsus* (8 species) and *Polypedilum* (9 species); in the lakes to the genera *Cladotanytarsus* (4 species) and *Tanytarsus* (9 species).

The distribution of species within the dominating complex in a water body is above all influenced by the character of the biotope. For the studied rivers, two main chironomid complexes were typical, a lytho-phyto-rheophylic and a psammo-rheophylic complex. The lytho-phyto-rheophylic complex is found in the upstream and the middle flow of rivers, and is dominated by the tribe Tanytarsini in the subfamily Orthocladiinae. This complex is characterized by a high species diversity, a high number of specimens and biomass. The psammo-rheophylic complex dominates in the downstream of the studied rivers. It has a lower number of specimens and biomass, and is dominated by representatives of Chironominae.

The lakes mainly include pelophylic complex dominated by the genera *Chironomus* and *Procladius*. In overgrowth of macrophytes, the phytophylic Chironomid complex is common (including representatives of the genera *Psectrocladius* and *Orthocladius,* and *Parakiefferiella coronata*).

Acknowledgement. The author thanks Dr. A. Shilova and Dr. N. Zelentsov (Institute of Inland Waters Biology, RAS), Prof. Dr. W.Wuelker (Albert-Ludvig University Freiburg) for advise in the identification of some species. The author is grateful to the researchers of the laboratory of Ecology of Aquatic Organisms, the Institute of Biology KSC UrD RAS – Dr. O. Loskutova., Dr.V. Shubina., M. Baturina, E. Rogovtsova, Dr. G. Sidorov for the material collected, to S. Balina for translation.

REFERENCES

Ashe, P. & Cranston, P. S. 1990. Family Chironomidae. Pp.113-355 in Soos A, Papp (Ed.): Catalogue of Palearctic Diptera. Vol.2.

Wiederholm, T. (Ed.) 1983. Chironomidae of Holarctic region. Keys and diagnoses. Part 1. Larvae . Ent. Scand. 19, 1-457.

Wiederholm, T. (Ed.) 1986. Chironomidae of Holarctic region. Keys and diagnoses. Part 2. Puppae. Ent. Scand. 28, 1-457.

Wiederholm, T. (Ed.) 1989. Chironomidae of Holarctic region. Keys and diagnoses. Part 3. Adult males . Ent. Scand. 34, 1-532.

Hirvenoja, M. 1973. Revision der Gattung *Cricotopus* van der Wulp und ihren Verwandten (Diptera, Chironomidae). Annales Zoologici Fennici. 10, 1, 1-363.

Goldina, L. P. 1972. Hydrography of lakes in the Bolshezemelskaya Tundra. Nauka, Leningrad. 100 pp.

Kownacki, A. 1971. Chironomidae taxa in streams of the Polish High Tatra Mts. Acta hydrobiol. 13, 4, 439-464.

Kuzmina, Y. S. 1995. Chironomid Larvae in the Ukhta river under man impact. Pp.78-90 in Biological Aftereffects of Man Exploration of Water Bodies in the European North. Reports of KSC UrD RAS, N 142. Syktyvkar.

Kuzmina, Y. S 1999a. Chironomidae (Diptera) of the Kharbey lakes and their role in food of fishes. Pp.148-150 in Biological resources of the White sea and inland waters of the European North. Materials of II (XXV) International conference. 22-26 September, 1999. Petrozavodsk.

Kuzmina, Y. S. 1999b. Terrastrial Chironomidae (Diptera) of the Komi Republic. Pp.114-115 in International conference Biodiversity of terrestrial and soil invertebrates in the North. September 15-17, 1999. Abstracts. Syktyvkar.

Loskutova, O. A. & Fefilova, E. B. 1996. Hydrobiological Characteristics of the Northern part of the Bolshezemelskaya Tundra. Pp.125-138 in Some Approaches to Organizing Environmental Monitoring in the Northern Conditions. Proc. Of the Komi SC UrD RAS, N 147. Syktyvkar.

Pankratova, V. Y. 1970. Larvae and pupae of gnats of subfamily Orthocladiinae of the fauna USSR (Diptera, Chironomidae=Tendipedidae). Nauka, Leningrad. 344 pp.

Pankratova, V. Y 1983.Larvae and pupae of gnats of subfamily Chironominae of the fauna USSR (Diptera, Chironomidae=Tendipedidae). Nauka, Leningrad. 296 pp.

Pankratova, V. Y.& Shilova, A. I. 1982. Methods of Collection and Conservation of Larvae, Pupae an Imago of Chironomids. Pp.20-22 in Instruction for Chironomids Study. Dushanbe.

Pinder, L. C. V. 1978. A key to adult males of British Chironomidae (Diptera) the non-biting midges, vol.1, vol.2. Freshwater biological association scienstifig publication. 37, 1 - 169.

Ponomarev, V. I. & Cherezova, M. I. 1995. Some aspects of man impact upon the fish exotrophy. Pp. 38-50 in Biological Aftereffects of Man Exploration of Water Bodies in the European North. Reports of KSC UrD RAS, N 142. Syktyvkar.

Sidorov, G. P. 1979. Feeding of Salmon yearlings. Pp. 135-146 in Pechora Salmon. Reports of the Komi Department of As USSR, N 40. Syktyvkar.

Shilova, A. I. 1976. Chironomids of the Rybinskoye storage reservoir. Nauka, Leningrad. 251pp.

Shubina, V. N. 1986. Hydrobiology of a salmon river in the Northern Urals. Nauka, Leningrad. 158 pp.

Zvereva, O. S. 1947. Animal population of floated logs and benthos of a floating section of a river. Reports of Academy of Sciences of the USSR. 56, 6, 647-650.

Zvereva, O. S. 1950. New forms of Tendipedidae larvae in the Pechora and the Vyshegda rivers. Entomol. Revue 31,1-2, 262-284.

Zvereva, O. S. 1953a. Tendipedidae larvae in the Pechora river. P.194-203 in Fishes and Fishery of the Pechora River. As USSR, Moscow.

Zvereva, O. S. 1953b. Tendipedidae larvae in the plain rivers of the European North of the USSR . Proc. Of All-Union Hydrobiological Society 5, 264-274.

Zvereva, O. S. 1962. Tendipedidae larvae in the water bodies of the Ukhta basin.P. 253-263 in Fishes of the Usa river basin and their feeding resources. As USSR, Moscow-Leningrad.

Zvereva, O. S. 1969. Specific Features of Biology of Principal Rivers of the Komi Republic connected to the History of their Formation. Nauka, Leningrad. 279 pp.

Received 27 June 2000,
accepted 15 March 2001

Norw. J. Entomol. 48, 213–216. 2001

Coleoptera from the Melsomvik area, Norway; collected during 28 June to 2 July 2000

Arvids Barševskis

Barševskis, A. 2001. Coleoptera of the Melsomvik area, Norway; collected during 28 June to 2 July 2000. Norw. J. Entomol. 48, 213-216.

This article provides information about 259 species of beetles that are collected in the Melsomvik area of Vestfold in Norway. *Stenus oscillator* Rye (Staphylinidae) and *Anthonomus brunnipennis* Curt. (Curculionidae) are new to the fauna of Norway.

Key words: Coleoptera, Melsomvik, Norway.

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INTRODUCTION

The 25th Nordic-Baltic Congress of Entomology took place in Melsomvik, Vestfold in Norway during 28 June to 2 July 2000. The congress organization was excellent, and in the evenings the participants had the wonderful possibility to use their free time on the investigation of the insect fauna in this area. Melsomvik area is rich in biologically diverse habitats. The material for the present investigation was collected from meadows, forests, pastures, roadsides, sides of agrocoenosis and along the fjord in an area of approximately 4 km around Melsomvik. A particularly interesting «habitat» was a chicken farm. In the evenings it was possible to observe the rare *Necrobia ruficollis* on the walls of the farm, several Carabidae and many other species. A total of 776 specimens of beetles were collected, representing 259 determined species. In the list of species, number of specimens are give in brackets [ ] behind the name. Two species hitherto not recorded from Norway according to Silfverberg (1992, 1996), Lundberg (1995), or Ødegaard & Ligaard (2000), are marked with an asterix (*). These are *Stenus oscillator* Rye (Staphylinidae) and *Anthonomus brunnipennis* Curt. (Curculionidae). The material is available in the collection of The Baltic Institute of Coleopterology. Nomenclature in this article is basically conformable with Lundberg (1995) on species level and with Lawrence & Newton (1995) on family level. Nomenclature of Carabidae is basically conformable with Lorenz (1998).

THE SPECIES

Carabidae. 57 species. *Nebria brevicollis* (Fabricius) [45]; *Notiophilus aquaticus* (L.) [1]; *N. biguttatus* (Fabricius) [3]; *Carabus granulatus* L. [1]; *C. hortensis* L. [1]; *C. violaceus* L. [1]; *Cychrus carabaoides* (L.) [2]; *Elaphrus riparius* (L.) [1]; *Clivina fossor* (L.) [4]; *Dyschiriodes globosus* (Herbst) [3]; *Patrobus atrorufus* (Ström) [4]; *P. assimilis* Chaudoir [1]; *Epaphius secalis* (Paykull) [2]; *Trechus obtusus* Erichson [4]; *T. quadristriatus* (Schrank) [7]; *Bembidion lampros* (Herbst) [1]; *B. femoratum* Sturm [1]; *B. assimile* Gyllenhal [1]; *B. quadrimaculatum* (L.) [2]; *B. mannerheimi* Sahlberg [1]; *Poecilus cupreus* (L.) [3]; *P. versicolor* (Sturm) [1]; *Pterostichus oblongopunctatus* (Fabricius) [10]; *P. niger* (Schaller) [1]; *P. melanarius* (Illiger) [9]; *P. nigrita* (Paykull) [1]; *P. rhaeticus* Heer [1]; *P. strenuus* (Panzer) [7]; *P. diligens*

(Sturm) [1]; *Calathus fuscipes* (Goeze) [3]; *C. erratus* (Sahlberg) [2]; *C. melanocephalus* (L.) [5]; *C. micropterus* (Duftschmid) [8]; *Synuchus vivalis* (Illiger) [1]; *Anchomenus dorsalis* (Pontoppidan) [5]; *Platynus obscurus* (Herbst) [1]; *P. assimilis* (Paykull) [3]; *Agonum piceum* (L.) [1]; *A. gracile* (Gyllenhal) [2]; *A. fuliginosum* (Panzer) [2]; *A. thoreyi* Dejean [2]; *A. viduum* (Panzer) [1]; *A. afrum* Duftschmid [2]; *Amara similata* (Gyllenhal) [1]; *A. aenea* (De Geer) [1]; *A. lucida* (Duftschmid) [1]; *A. apricaria* (Paykull) [1]; *A. aulica* (Panzer) [2]; *A. gebleri* Dejean [1]; *Ophonus rufibarbis* (Fabricius) [1]; *Harpalus rufipes* (De Geer) [2]; *H. affinis* (Schrank) [4]; *H. latus* (L.) [1]; *H. luteicornis* (Duftschmid) [1]; *H. laevipes* Zetterstedt [8]; *Trichocellus placidus* (Gyllenhal) [2]; *Philorhizus notatus* Stephens [1].

Leiodidae. *Leiodes dubia* (Kugelan) [1].

Silphidae. *Silpha tristis* Illiger [1]; *Phosphuga atrata* (L.) [1].

Staphylinidae. 20 species. *Philonthus decorus* (Gravenhorst) [2]; *Ph. atratus* (Gravenhorst) [1]; *Ph. splendens* (Fabricius) [1]; *Ocypus melanarius* Heer [1]; *Quedius fuliginosus* (Gravenhorst) [1]; *Q. molochinus* (Gravenhorst) [1]; *Xantholinus meyeri* Drugm. [1]; *Stenus lustrator* Erichson [1]; *S. clavicornis* (Scopoli) [1]; *S. intermedius* Rey [1]; **S. oscillator* Rye [2]; *Anthophagus caraboides* (L.) [1]; *Scaphisoma inopinatum* Lobl [1]; *Tachyporus obtusus* (L.) [6]; *T. solutus* Erichson [1]; *T. hypnorum* (Fabricius) [1]; *T. chrysomelinus* (L.) [1]; *Tachynus marginatus* Gyllenhal [1]; *T. laticollis* Gravenhorst [2]; *Drusilla canaliculata* (Fabricius) [2].

Scirtidae. 5 species. *Elodes marginata* (Fabricius) [1]; *Cyphon coarctatus* Paykull [3]; *C. kongsbergensis* Munster [1]; *C. variabilis* (Thunberg) [2]; *C. padi* (L.) [3].

Geotrupidae. *Anoplotrupes stercorosus* (Hartm. in Scriba) [3].

Rutelidae. *Phyllopertha horticola* (L.) [1].

Cetoniidae. *Protaetia cuprea* (Fabricius) [1].

Lucanidae. *Synodendron cylindricum* (L.) [1].

Cantharidae. 16 species. *Cantharis fusca* L. [1]; *C. nigricans* (Müller) [3]; *C. livida* L. (1); *C. figurata* Mannerheim [1]; *C. quadripunctata* (Müller) [1]; *C. rufa* L. [4]; *C. fulvicollis* Fabricius [6]; *C. nigra* De Geer [1]; *Rhagonycha fulva* (Scopoli) [7]; *Rh. testacea* (L.) [4]; *Rh. limbata* Thomson [6]; *Rh. lignosa* (Müller) [1]; *Rh. elongata* (Fallén) [1]; *Malthinus biguttatus* (L.) [2]; *M. punctatus* (Geoffrey) [1]; *Malthodes* sp. [3].

Elateridae. 7 species. *Athous hirtus* (Herbst) [2]; *A. niger* (L.) [11]; *A. haemorrhoidalis* (Fabricius) [2]; *A. subfuscus* (Müller) [5]; *Prosternon tessellatum* (L.) [3]; *Agriotes obscurus* (L.) [1]; *Dalopius marginatus* (L.) [4].

Eucnemidae. *Microrhagus pygmaeus* (Fabricius) [1].

Throscidae. *Trixagus dermestoides* (L) [2].

Buprestidae. *Trachys minutus* (L.) [2].

Byrrhidae. *Byrrhus pilula* (L.) [1].

Dermestidae. *Anthrenus museorum* (L.) [2].

Anobiidae. *Stegobium paniceum* (L.) [1].

Cleridae. *Thanasimus formicarius* (L.) [1]; *Necrobia ruficollis* (Fabricius) [42].

Melyridae: 6 species. *Dasytes cyaneus* (Fabricius) [1]; *D. plumbeus* (Müller) [6]; *D. fusculus* (Illiger) [2]; *Dolichosoma lineare* (Rossi) [9]; *Cordylepherus viridis* (Fabricius) [6]; *Malachius bipustulatus* (L.) [4].

Brachypteridae. 3 species. *Kateretes pedicularius* (L.) [3]; *Brachypterus urticae* (Fabricius) [6]; *Brachypterolus linariae* (Stephens) [6].

Nitidulidae. 13 species. *Epuraea pallescens* (Stephens) [1]; *E. biguttata* (Thunberg) [1]; *E. variegata* (Herbst) [2]; *E. aestiva* (L.) [1]; *Meligethes flavimanus* Stephens [1]; *M. aeneus* (Fabricius) [4]; *M. viridescens* (Fabricius) [9]; *M. umbrosus* Sturm [2]; *M. nigrescens* Stephens [1]; *Omosita discoidea* (Fabricius) [1]; *Thalycra* *fervida* (Olivier) [1]; *Cychramus luteus* (Fabricius) [6]; *Glischrochilus hortensis* (Geoffrey) [1].

Monotomidae. *Rhizophagus ferrugineus* (Paykull) [3].

Cryptophagidae. 5 species. *Cryptophagus pseudodentatus* Bruce [1]; *Antherophagus pallens* (L.) [1]; *Atomaria fuscata* (Schoenh.) [2]; *A. lewisi* Reitter [1]; *A. atricapilla* Stephens [1].

Phalacridae. *Olibrus millefolii* (Paykull) [3]; *O. flavicornis* (Sturm) [4].

Coccinellidae. 8 species. *Cynegetis impunctata* (L.) [5]; *Scymnus suturalis* Thunberg [2]; *Coccinula quatuordecimpustulata* (L.) [1]; *Anisosticta novemdecimpunctata* (L.) [2]; *Propylea quatuordecimpunctata* (L.) [1]; *Psyllobora vigintiduopunctata* (L.) [2]; *Coccinella quinquepunctata* (L.) [1]; *Adalia decempunctata* (L.) [3].

Corticariidae. 9 species. *Latridius minutus* (L.) [2]; *Stephostethus lardarius* (De Geer) [1]; *S. sp.* [1]; *Aridius nodifer* (Westwood) [1]; *Corticaria pubescens* (Gyllenhal) [1]; *C.* sp. [3]; *Corticarina similata* (Gyllenhal) [3]; *C. lambiana* (Sharp) [1]; *C. fuscula* (Gyllenhal) [2].

Byturidae. *Byturus tomentosus* (De Geer) [4].

Mycetophagidae. *Typhaea stercorea* (L.) [1].

Oedemeridae. 4 species. *Chrysanthia viridissima* (L.) [1]; *Ch. nigricornis* (Westh.) [4]; *Oedemera virescens* (L.) [3]; *O. lurida* (Marsh.) [5].

Pyrochroidae. *Pyrochroa coccinea* (L.) [1].

Anthicidae. *Omonadus floralis* (L.) [1].

Tenebrionidae. 3 species. *Eledona agricola* (Herbst) [7]; *Diaperis boleti* (L.) [2]; *Crypticus quisquilius* (L.) [2].

Scraptiidae. 3 species. *Anaspis frontalis* (L.) [5]; *A. thoracica* (L.) [1]; *A. rufilabris* (Gyllenhal) [3].

Mordellidae. *Mordellistena sp.* [3]; *Mordellochroa abdominalis* (Fabricius) [1].

Melandryidae. *Serropalpus barbatus* (Schaller) [1].

Cerambycidae. 8 species. *Alosterna tabacicolor* (De Geer) [1]; *Anoplodera maculicornis* (De Geer) [2]; *A. reyi* (Heyden) [1]; *Leptura maculata* Poda [6]; *L. melanura* L. [6]; *Molorchus minor* (L.) [1]; *Clytus arietis* (L.) [1]; *Phytoecia cylindrica* (L.) [1].

Orsodacnidae. *Orsodacne cerasi* (L.) [4].

Chrysomelidae. 21 species. *Bruchus loti* Paykull [1]; *B. atomarius* (L.) [3]; *Cryptocephalus labiatus* (L.) [1]; *Chrysolina polita* (L.) [2]; *Phratora vitellinae* (L.) [4]; *Ph. atrovirens* (Corn.) [1]; *Galerucella lineola* (Fabricius) [1]; *Lochmaea caprea* (L.) [2]; *Luperus longicornis* (Fabricius) [1]; *Phylotreta nemorum* (L.) [1]; *Aphthona lutescens* (Gyllenhal) [2]; *Longitarsus brunneus* (Duftschmid) [1]; *Altica oleracea* (L.) [2]; *Batophila rubi* (Paykull) [4]; *Asiorestia ferruginea* (Scopoli) [5]; *Crepidodera fulvicornis* (Fabricius) [2]; *C. aurata* (Mrsh.) [2]; *Chaetocnema concinna* (Mrsh.) [1]; *Cassida viridis* L. [1]; *C. nebulosa* L. [1]; *C. denticollis* Sffr. [1].

Attelabidae. *Deporaus betulae* (L.) [1].

Brentidae. 10 species. *Apion hookeri* Kby. [1]; *A. fulvipes* Geoffrey [2]; *A. apricans* Herbst [2]; *A. assimile* Kby. [1]; *A. marchicum* Herbst [1]; *A. rubiginosum* Grill [1]; *A. simile* Kby. [1]; *A. viciae* (Paykull) [3]; *A. ervi* Kby. [1]; *Nanophyes marmoratus* (Goeze) [6].

Curculionidae. 35 species. *Otiorhynchus singularis* (L.) [1]; *O. ligustici* (L.) [1]; *Barypeithes mollicomus* (Ahr.) [2]; *Strophosoma capitatum* (De Geer) [4]; *Barynotus obscurus* (Fabricius) [1]; *Sitona ambiguus* Gyllenhal [3]; *S. hispidulus* (Fabricius) [1]; *Hypera suspiciosa* (Herbst) [1]; *H. postica* (Gyllenhal) [3]; *H. nigrirostris* (Fabricius) [1]; *Dorytomus taeniatus* (Fabricius) [1]; *Cionus tuberculosus* (Scopoli) [12]; *C. scrophulariae* (L.) [9]; *C. hortulanus* (Geoffrey) [11]; *C. longicollis* Br. de Barn. [5]; **Anthonomus brunnipennis* Curt. [1]; *Isochnus foliorum* (Müller) [7]; *Tachyerges stigma* (Germ.) [1]; *Rhampus pulicarius* (Herbst) [1]; *Gymnetron melanarium* (Germ.) [1]; *G. linari-*

ae (Panzer) [14]; *Miarus campanulae* (L.) [2]; *M. graminis* (Gyllenhal) [4]; *M.* sp. [8]; *Hylobius abietis* (L.) [2]; *H. pinastri* (Gyllenhal) [1]; *Rhinoncus castor* (Fabricius) [2]; *Coeliodes rubicundus* (Herbst) [1]; *Ceutorhynchus floralis* (Paykull) [1]; *C. litura* (Fabricius) [1]; *C.* sp.[3]; *Pityogenes bidentatus* (Herbst) [1]; *Ips acuminatus* (Gyllenhal) [1]; *Trypodendron domesticum* (L.) [3]; *T. lineatum* (Ol.) [1].

Acknowledgment. The author wants to thank the congress organization committee for highly professional organization, Norwegian Academy of Science for support to participate in the congress, colleague Mr. R. Cibulskis (Daugavpils Museum of History and Art, Department of Nature, Latvia) for operative determination of Staphylinidae and my family for support.

REFERENCES

Lawrence J.F., Newton, A.F. 1995. Families and subfamilies of *Coleoptera* (with selected genera, notes, references and data on family-group names). Pp. 779 - 1006 in Pakaluk, J. & Slipinski, S.A. (eds): Biology, Phylogeny, and Classification of *Coleoptera*, Papers Celebrating the 80th Birthday of Roy A. Crowson., Vol 2.

Lorenz, W. 1998. A systematic list of extant ground beetles of the World (Insecta Coleoptera «Geadephaga»: Trachypachidae and Carabidae incl. Paussinae, Cicindelinae, Rhysodinae), First Edition, 502 pp. W. Lorenz.

Lundberg, S. 1995. Catalogus Coleopterorum Sueciae. 224 pp. Naturhistoriska Riksmuseet. Entomologiska foreningen, Stockholm.

Silfverberg, H. 1992. Enumeratio Coleopterorum Fennoscandiae, Daniae et Baltiae. 94 pp. Helsingin Hyönteisvaihtoyhdistys - Helsingfors Entomologiska Bytesförening.

Silfverberg, H. 1996. Additions and corrections to Enumeratio Coleopterorum Fennoscandiae, Daniae et Baltiae. Sahlbergia 3, 33-62.

Ødegaard, F. & Ligaard, S. 2000. Contribution to the knowledge of Norvegian Coleoptera. Norw. J. Entomol. 47, 7-19.

Received 18 September 2000,
accepted 30 January 2001 .

Norw. J. Entomol. 48, 217–222. 2001

Collembola from the Baltic Sea coast

Edîte Juceviča

Juceviča, E. 2001. Collembola from the Baltic Sea coast. Norw. J. Entomol. 48, 217-222.

A survey of Latvian Baltic Sea coast Collembola is presented, reporting 84 species along a gradient from the tidal zone to the inland. 19 species were found for the first time in Latvia. A new undescribed species of the genus *Archisotoma* was discovered. The highest number of species was recorded from grey dunes (46) and seashore meadow sites (44).

Key words: Collembola, Baltic Sea, coastline

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INTRODUCTION

Collembola, being one of the most widespread and abundant groups of soil animals (Hopkin 1997) and ubiquitous inhabitants of the most diverse environments, are well investigated in Nordic countries and almost all Europe (Fjellberg 1998). This cannot be said about Latvia and other Baltic States.

Although these insects are abundant and diverse also along the shores of the sea, Latvian coastal dune ecosystems are yet very poorly investigated with respect to collembolan faunistics, mentioned only once in literature until 1994 (Eitminavichute 1976).

The current article reports on a study of collembolan fauna from the Latvian Baltic Sea coast and is based on published papers (Melecis et al. 1994, Paulina & Salmane 1999, Salmane et al. 1999) and subsequent records, covering unsurveyed localities of Latvian coasts as well.

METHODS

The coastline in Latvia is approximately 500 km long, of which 250 km is along the Gulf of Riga seashore, and is relatively straight without distinct promontories, the most distinct being Kolkasrags, Mersrags and Ovishrags in the Kurzeme peninsula. Almost 250 km of the coastline consists of sandy beaches, which are typical for Latvia. In some places beaches exceed even 100-200 m in width. The rest of the Latvian coast consists of sandy-gravely, cobbly and bouldery beaches and coasts overgrown by reeds or seashore meadows (Figure 1). There are mainly low and middle high (2-6 m) coasts along the shoreline, steep slopes (8-15 m) are only present in some places along the coastline. 73 % of all Latvian coastline is dominated by natural or restored coniferous forest landscape. Only 27 % is populated areas with harbours, arable lands, meadows, pastures or partly changed territories. Completely changed coasts cover approximately 2 % (Eberhards & Saltupe 1993).

The Collembolan fauna of the Baltic Sea coast dunes was studied between 1993 and 1998. Investigations were carried out along almost all Latvian seacoast, visiting 16 sites – seashore meadows' reserve Randu Meadows in the northern part of the Gulf of Riga, Salacgriva, Tuja, Saulkrasti, Engure, Mersrags, Roja, Kolka, Mazirbe, Luzna, Ventspils, Pavilosta, Ziemupe, Liepaja, Pape and Nida (Figure 1).

Samples were taken along transects, covering the tidal line, beach, primary, white and grey dunes and pine forest on old dune: beach – mainly unvegetated, primary dunes – mainly with *Ammophila arenaria* vegetation, white dunes – *Ammophila arenaria, Festuca* spp., *Artemisia* sp., *Honckenya peploides, Leymus arenarius, Cakile baltica,* grey dunes – moss, lichen and grass vegetation, *Pinus* *sylvestris, Salix* spp. Detailed description of the reserve Randu Meadows is given by Melecis (Melecis et al. 1997).

At each site sampling was carried out by hand and brought to laboratory in plastic bags and then extracted in open Tullgren funnels.

Nomenclature follows mainly Fjellberg (1980, 1998).

RESULTS AND DISCUSSION

The 84 species of identified coastal Collembola amounts to about 50 % of Collembola on the whole Latvian list. 19 species were found in Latvian fauna for the first time, of which one new species of the genus *Archisotoma* was discovered (Fjellberg & Jucevica 2000). This obviously reflects the scanty information about the Collembola taxocenosis from the Latvian coastal ecosystems.

The number of species from the various localities ranges from 4 to 35. Coastal meadows (Randu Meadows and Mersrags) had the highest number of species. Next three to follow were Saulkrasti and Luzna with 27 species and Liepaja with 23 species.

About 47 % of the species seems to be confined to coastal sand biotopes and seashore meadows, comprising a number of stenoecious species like *Hypogastrura viatica*, all *Archisotoma* species, *Isotoma maritima*, *Onychiurus volinensis*, *Friesea baltica, Pseudostachia populosa*, etc. Only 10 species (*H. viatica, Xenylla maritima, F. baltica, Micranurida pygmaea, Mesaphorura macrochaeta, Folsomia quadrioculata, Archisotoma theae, Cryptopygus thermophilus, Isotoma anglicana* and *Isotoma notabilis*) were generally present along the whole coastline. *M. macrochaeta* and *H. viatica* were the most common species. *X. maritima, Pseudachorutes subcrassus, M. pygmaea, F. quadrioculata, M. macrochaeta* and *I. notabilis* were the only species occurred along the whole transect from the tidal line to the inland (Table 1).

There is a characteristic change in the collembolan community along the coast-inland gradient with marine littoral species close to the sea and species having a wider ecological amplitude in grey dunes and coastal meadows. The particular driftline-beach and primary dune biotopes have a high proportion of habitat specialists (15 of 30 and 13 of 19, respectively). Two typical supralittoral species – *Psammophorura gedanica* and *Proisotoma buddenbrocki* were found only in primary dunes. The species *Jesenikia filiformis, Willemia anophthalma, W. intermedia* and *Axenyllodes echinatus* were present exceptionally in white dunes. 21 species of 33 found in primary and white dunes, are interstitial inhabiting intertidal and supralittoral sand biotopes, most of them being small euedaphic psammobiotic or psammophilic species (Thibaud & Christian 1997).

Surface dwelling Symphypleona, being common mainly on aboveground vegetation and in soils rich in organic material (Hågvar 1982, Hopkin 1997), are absent in primary dunes and rare in other unstable coastal habitats probably due to the high mobility of the surface substrate. There is small species number even in seashore grass meadows and grey dunes, where they could be abundant.

The species richness increases away from the sea responding to the changes in vegetation, diversity of ecological conditions and habitat complexity (McLachlan 1991, Koehler et al. 1995). The collembolan species diversity is highest in grey dunes and seashore meadows. Contrary to primary dunes and white dunes, where typical soil dwellers are found, surface dwellers are numerous in grey dunes and seashore meadows. *Pseudostachia populosa*, found only in grey dunes and supposed to be quite rare, is abundant in Saulkrasti – the only locality of this species in Latvia so far.

The seashore meadows have a mixed collembolan community, consisting of dune species and forest species in addition to the typical grassland species.

Acknowledgements. Author gratefully acknowledges financial support given by Latvian Council of Sciences (grant N 93.140), the Red Data Book of the Baltic Region and the Swedish Threatened Species Unit (Project «Biotopes with high biodiversity of Latvian Baltic Sea coast»). Sincere thanks go to Dr. Arne Fjellberg for his inestimable taxonomic help and Ugis Desmitnieks for technical assistance.

REFERENCES

Eberhards, G. & Saltupe, B. 1993. Sea coast monitoring of Latvia. Environmental monitoring in Latvia

Figure 1. Generalised map showing the distribution of the Latvian sea coast and sampling sites along the Latvian Baltic sea coast between 1993 and 1998 (Modified from Eberhards & Saltupe 1993)

Table 1. List of collembolan species recorded along the Latvian Baltic Sea coast between 1993 and 1998 (RM – Randu Meadows, S – Salacgriva, T – Tuja, Sk – Saulkrasti, E – Engure, Mr – Mersrags, R – Roja, K – Kolka, M – Mazirbe, Lu – Luzna, V – Ventspils, Po – Pavilosta, Z – Ziemupe, L – Liepaja, P – Pape, N – Nida; *new species for fauna of Latvia, **includes species found in pine forest on old dunes).

Family / species	driftline beach	primary dunes	white dunes	grey dunes**	seashore meadows
Hypogastruridae					
Schoettella ununguiculata (Tullberg, 1869)				L	
Hypogastrura viatica (Tullberg, 1872)	S-K,Lu-L	R,V,Po,L	R		RM,Mr
H. manubrialis (Tullberg, 1869)	S				
H. vernalis (Carl, 1901)	S,Sk				RM
H. socialis (Uzel, 1891)				L	
Ceratophysella denticulata (Bagnall, 1941)	E				RM,Mr
Xenylla maritima Tullberg, 1869	L	Sk	T,P,N	T,Sk,K,L,N	
Willemia anophthalma Börner, 1901			V		
* *W. intermedia* Mills, 1934			V,N		
* *W. scandinavica* Stach, 1949	Sk	T		T,Lu	
Brachystomellidae					
Brachystomella parvula (Schäffer, 1896)			Sk	Sk	RM
Neanuridae					
Friesea mirabilis (Tullberg, 1871)				E	RM,Mr
F. truncata Cassagnau, 1958				Sk	RM
* *F. baltica* Szeptycki, 1964	T,Sk,Lu,L	E,R,V,Po,L,P	T,Lu,L		Mr
Pseudachorutella asigillata (Börner, 1901)					RM
Pseudachorutes subcrassus Tullberg, 1871	Sk	Po	T,K,V	Sk,L	
P. parvulus Börner, 1901					RM
Micranurida pygmaea Börner, 1901	E	T,Po,Z	Lu	Sk,V,L,N	Mr
Anurida granaria (Nicolet, 1847)					RM
A. tullbergi Schött, 1891					RM
Neanura muscorum (Templeton, 1835)				M,Lu,L	RM
Odontellidae					
* *Axenyllodes echinatus* Fjellberg, 1988			Lu		
* *Pseudostachia populosa* (Selga, 1963)				Sk	
Onychiuridae					
Micraphorura absoloni (Börner, 1901)	E		V	Sk	
Supraphorura furcifera (Börner, 1901)					RM
Protaphorura armata (Tullberg, 1869)	E	T,R		N	RM,Mr
* *Onychiurus volinensis* Szeptycki, 1964		T,Sk	Sk,Lu	Sk,N	
Stenaphorura quadrispina Börner, 1901					RM
Mesaphorura macrochaeta Rusek, 1976	S	T,R,K,Lu-N	Sk,R,K,V,L-N	T,Sk,Lu,V,L,N	RM,Mr
M. krausbaueri Börner, 1901					Mr
* *M. hylophila* Rusek, 1982			Lu	Sk,K,V	
M. tenuisensillata Rusek, 1974		R,Po	R,V	Sk,K	RM
* *Psammophorura gedanica* Thibaud&Weiner, 1994		Lu			
* *Scaphaphorura arenaria* (Petersen, 1965)		Lu,V,Po,N	Lu,V,L,N	Lu,L	
* *Doutnacia xerophila* Rusek, 1974				T,Sk	

Table 1. Continued.

Family / species	driftline beach	primary dunes	white dunes	grey dunes**	seashore meadows
Isotomidae					
Pseudanurophorus binoculatus Kseneman, 1934			Lu		Mr
* *Jesenikia filiformis* Rusek, 1997			Lu		
Anurophorus laricis Nicolet, 1842	E				
A. septentrionalis Palissa, 1966					RM
Folsomia sp. *bisetosa*-group Gisin					RM
F. diplophthalma (Axelson, 1902)				L	RM,Mr
* *F. dovrensis* Fjellberg, 1976			K		Mr
F. fimetaria (Linnaeus, 1758)	Sk			Sk	RM
* *F. lawrencei* Rusek				L	
F. quadrioculata (Tullberg, 1871)	Sk	T	Lu	Sk,E,K,N	RM,Mr
* *Isotomodes armatus* Naglitsch, 1962				T,L	
Isotomiella minor Schäffer, 1896		Lu		E,L	RM,Mr
* *Archisotoma besselsi* (Packard, 1877)	T,Sk			Sk	
A. theae Fjellberg, 1988	T,S,V,Po,L	K,Lu,P,N	Lu,V		
* *A. martae* Fjellberg & Juceviča, 2000	T,V,Po,N	P			
Cryptopygus thermophilus (Axelson, 1900)	T,Sk,Lu,V	T,E,Z,P	K,N		
Ballistura schoetti (Dalla Torre, 1895)					RM,Mr
Proisotoma minima (Absolon, 1901)			T,Sk		Mr
P. minuta (Tullberg, 1871)				Lu	
* *P. buddenbrocki* Strenzke, 1954		Lu			
Isotomurus palustris (Müller, 1776)	R		K	M,Lu	Mr
Isotoma anglicana Lubbock, 1862			E	T,Sk,K,L,N	RM,Mr
I. maritima Tullberg, 1871	Z				
I. notabilis Schäffer, 1896	L	E,Lu,	R,K,Lu,L	Sk,V,L,N	RM,Mr
I. olivacea Tullberg, 1871	E				
I. tigrina (Nicolet, 1842)					Mr
I. viridis Bourlet, 1839				M,Lu	RM,Mr
Entomobryidae					
Entomobrya marginata (Tullberg, 1871)				N	
* *E. multifasciata* (Tullberg, 1871)	L			N	
* *E. nicoleti* (Lubbock, 1867)				L,N	
E. nivalis (Linnaeus, 1758)				M,Lu	RM
Orchesella cincta (Linnaeus, 1758)				T,M	
Willowsia platani (Nicolet, 1841)	S			M,Lu	
W. nigromaculata (Lubbock, 1873)	K		L		
Lepidocyrtus cyaneus Tullberg, 1871	E			M	
L. lignorum (Fabricius, 1781)	E			Sk,M,Lu,N	RM,Mr
L. violaceus Lubbock, 1873	Sk			Sk	RM
Tomoceridae					
Tomocerus flavescens (Tullberg, 1871)				E,M,Lu	
Sminthurididae					
Sphaeridia pumilis (Krausbauer, 1898)				E,M,Lu,L	RM,Mr

Table 1. Continued.

Family / species	**driftline beach**	**primary dunes**	**white dunes**	**grey dunes****	**seashore meadows**
Sminthurides schoetti (Axelson, 1903)					RM
Katiannidae					
Sminthurinus aureus (Lubbock, 1862)				E	RM,Mr
S. elegans (Fitch, 1863)			T	Sk,N	
Dicyrtomidae					
Dicyrtomina minuta (Fabricius, 1783)				E	
Dicyrtoma fusca (Lucas, 1842)					RM
Sminthuridae					
Sminthurus nigromaculatus (Tullberg, 1872)				L	
S. viridis (Linnaeus, 1758)	E				
Allacma fusca (Linnaeus, 1758)					Mr
Bourletiellidae					
Bourletiellidae sp.juv.					RM
Neelidae					
Megalothorax minimus (Willem, 1900)					RM,Mr
Species richness **Total 84**	**30**	**19**	**27**	**46**	**44**

3. Riga. 46 pp. (in Latvian).

Eitminavichute, I. S. (Ed.) 1976. Soil invertebrate fauna of the coastal area in the east Baltic region. 172 pp. Publ. House «Mokslas», Vilnius (in Russian with English summary).

Fjellberg, A. 1980. Identification keys to Norwegian collembola. 152 pp. Norsk Entomologisk Forening, Ås.

Fjellberg, A. 1998. The Collembola of Fennoscandia and Denmark. Part I: Poduromorpha. 184 pp. Fauna Entomologica Scandinavica. Vol.35.

Fjellberg, A. & Juceviča, E. 2000. A new species of *Archisotoma* Linnaniemi, 1912 from the Baltic coast of Latvia (Collembola, Isotomidae). Norw. J. Entomol. 47, 21-23.

Hågvar, S. 1982. Collembola in Norwegian coniferous forest soils. I. Relations to plant communities and soil fertility. Pedobiologia 24, 255-296.

Hopkin, S.P. 1997. Biology of the Springtails (Insecta: Collembola). 368 pp. Oxford University Press.

Koehler, H., Munderloh, E. & Hofmann, S. 1995. Soil microarthropods (Acari, Collembola) from beach and dune: characteristics and ecosystem context. J. Coastal Cons. 1, 77-86.

McLachlan, A. 1991. Ecology of coastal dune fauna. J. Arid Environ. 21, 229-243.

Melecis, V., Spote, I. & Paulina, E. 1994. Soil microarthropods as potential bioindicators for coastal monitoring. Abstr. Int. Conf. «Coastal conservation and management in the Baltic region». 111-115. Klaipeda (Lithuania).

Melecis, V., Karpa, A., Kabucis, I., Savics, F. & Liepina, L. 1997. Distribution of grassland arthropods along a coenocline of seashore meadow vegetation. Proc. Latvian Acad. Sciences. Section B, 51, No.5/6, 222-233.

Paulina, E. & Salmane, I. 1999. Collembola and gamasin mites of the restricted area Lake Engure, Latvia. Proceedings of the XXIV Nordic Congress of Entomology. Tartu. 145-150.

Salmane, I., Melecis, V. & Paulina, E. 1999. Soil Collembola (Insecta) and Gamasina (Acari) of salty coastal meadows of Latvia. Proceedings of the XXIV Nordic Congress of Entomology. Tartu. 157-162.

Thibaud, J.-M. & Christian, E. 1997. Biodiversity of interstitial Collembola (Insecta) in sand sediments. Eur. J. Soil Biol. 33, 123-127.

Received 28 June 2000,
accepted 15 October 2000.

Norw. J. Entomol. 48, 223–230. 2001

Fauna of soil Gamasina mites (Acari, Mesostigmata) along the Latvian seacoast and the relation to respective habitats

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Salmane, I. 2001. Fauna of soil Gamasina mites (Acari, Mesostigmata) along the Latvian seacoast and the relation to respective habitats. Norw. J. Entomol. 48, 223-230.

Soil free-living Gamasina mites (Acari, Mesostigmata) were analysed in the 13 coastal sites along the Latvian seacoast. Gamasins were collected from the driftline habitats, primary, yellow and grey dunes and determined to the species level. Altogether 76 species from 10 families were found. The investigated habitats yielded 24, 31, 43 and 36 Gamasina species, respectively. Twenty-four species were recorded for the first time in Latvia. Species composition was diverse and specific for each of the investigated habitat types. Rhodacaridae was recorded as a dominant family in the investigated driftline, primary and yellow dune habitats. Parasitidae and Aceosejidae appeared with almost equal number of species in all habitats, while Phytoseiidae and Laelaptidae were restricted to habitats with denser vegetation. Four Gamasina species were common for all habitat types. Thirty-seven species were found in only one habitat type. The most numerous species from the driftline habitats were ubiquitous *Cheiroseius necorniger* and washed ashore inhabitants *Thinoseius spinosus* and *Halolaelaps balticus*; from the primary dunes the ubiquitous *L. halophilus* and *L. bicolor,* and washed ashore species *H. balticus*; from the yellow dune habitats the ubiquitous *Minirhodacarellus minimus* and *L. bicolor,* and forest and dune species *Leioseius insignis* and from the grey dunes mainly common humus and moss species *Zercon carpathicus* and the hygrophilous *Hypoaspis vacua.* Driftline habitats had the smallest number of Gamasina species, but were recognized as the most abundant amongst the seashore habitats investigated. Dune habitats with the relatively variable vegetation and soil humidity conditions had more diverse species composition. Comparatively poorer in nutrients, the primary dune soils had higher number of species than the driftline. About half of the total number of species was typical for respective seashore habitats.

Key words: Acari, Gamasina mites, coastal habitats, dunes, driftline, species' composition

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INTRODUCTION

Coastal dunes are an important factor in the protection of hinterland from floods, as well as in recreation and nature protection. To better understand the ecological processes occurring within the seashore habitats it is important to examine species diversity and composition of various soil organisms living there. Soil microarthropods and in particular soil-dwelling mites have been poorly investigated in coastal habitats. Amongst the soil mites it is important to mention the role of predatory gamasins (Acari, Mesostigmata), which have been observed in coastal processes and discussed by several authors (Purvis 1982, Mallow et al. 1984, Koehler et al. 1992, 1995ab, Salmane & Heldt 2000). These mites have been recognized as an important factor in the nutrient cycling processes in coastal soils and in the regulatory function of various soil organisms' populations in coastal areas.

Before the present study only Kadite from Lithuania had performed some sampling along the Latvian seacoast (Eitminavichute 1976). During the years 1993 – 1998 a large amount of material was collected relating to predatory soil Gamasina mites from the seashore habitats of Latvia. The author (Melecis et al. 1994, Salmane 1996, Salmane 2000, Salmane & Heldt 2001) has partially published the results of these investigations, which mainly cover the western part of the Latvian seacoast.

The current paper combines all data collected from the habitats ranging from the most south-western point to the most north-eastern point of the Latvian seacoast.

MATERIAL AND METHODS

Sampling was performed in 13 sites along the Latvian Baltic Sea Coast and Riga Gulf Coast (Figure 1). Six sampling sites along the Riga Gulf Coast (Salacgriva, Vitrupe, Tuja, Saulkrasti, Roja and Kolkasrags) and seven along the Baltic Sea Coast (Luzna, Mazirbe, Ventspils, Liepaja, Pavilosta, Pape and Nida) were chosen. At each site sampling was carried out by hand or by using a soil corer (23 cm^2 x 10 cm). A single sample included approximately 300-450 g of substrate.

Soil samples were taken from washed ashore material of the driftline or rhizosphere of the respective plants in primary, yellow and grey dunes. Extraction was made using Tullgren funnels, where the samples were exposed for a period of 14 days. Determination and nomenclature of Gamasina species are based upon the keys of Bregetova (1977), Hirshmann (1971), Karg (1993), Kolodochka (1978) and Lapina (1976ab).

The driftline habitats are mostly characterized by fine sand and washed ashore material including fucoid and other algae, decaying vegetable matter of both marine and terrestrial origin, as well as manmade jetsam deposited by the sea. Tidal debris is the main nutrient source for this habitat type. *Cakile maritima, Chenopodium rubrum* or a few specimens of *Salsola calii* were representative of the vegetation found there. The primary dunes are characterized by fine to medium sandy

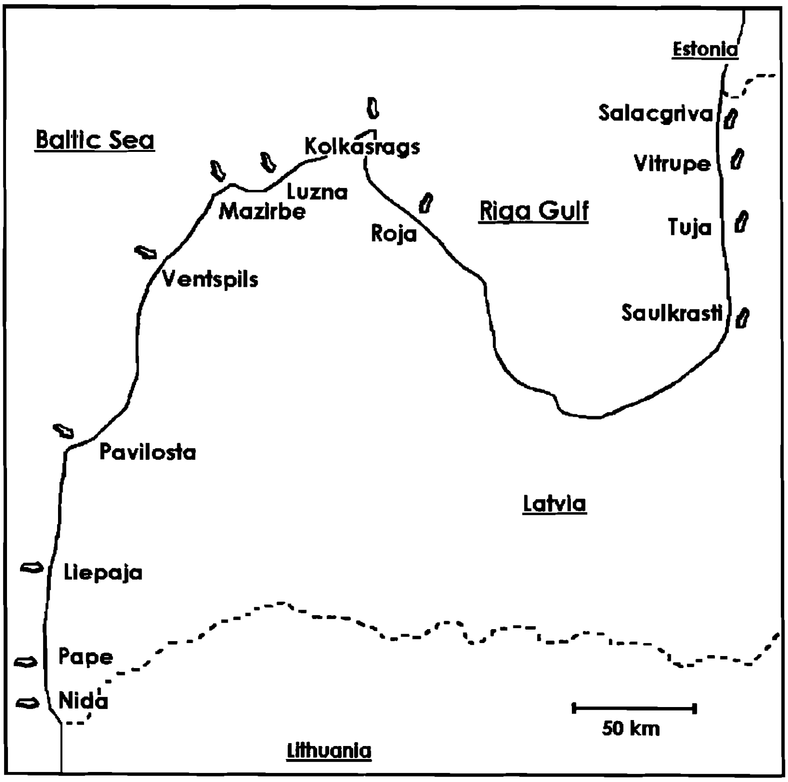

Figure 1. Sampling sites along the Latvian seacoast.

Table 1. Number of Gamasina species in different families from Latvian seashore.

	Driftline	Primary dunes	Yellow dunes	Grey dunes
Rhodacaridae	7	7	10	4
Parasitidae	6	6	6	8
Aceosejidae	6	5	5	4
Phytoseiidae	3	2	9	6
Eviphidae	1	1	1	1
Zerconidae		4	2	4
Laelaptidae		1	6	6
Veigaiaidae		3	1	2
Antennosiidae			1	1
Macrochelidae	1	2		

soils with minimal organic content in the soil. Single specimens of *Calamophila baltica, Ammodenia peploides, Amophila arenaria, Leymus arenarius, Festuca arenaria* and *Juncus balticus* were representative of the vegetation there. The yellow and grey dunes are characterized by medium sandy soils with relatively high organic content and more abundant vegetation including *Calamophila baltica, Amophila arenaria, Festuca arenaria, Hieracium umbellatum, Carex arenarius, Ammodenia peploides, Anthyllis maritima, Lathyrus japonicus* and *Salix* sp. In some cases *Pinus sylvestris* grows on grey dunes.

RESULTS

A total of 10 Gamasina families were found to be represented in the seashore habitats. Among them the most widely distributed were Rhodacaridae, Parasitidae, Phytoseiidae and Aceosejidae (Table 1). In the driftline habitats the most numerous families were Rhodacaridae, Parasitidae, in the primary dunes the most abundant were Rhodacaridae and Parasitidae, in the yellow dunes Rhodacaridae and Phytoseiidae and in the grey dunes Parasitidae, Laelaptidae and Phytoseiidae.

Altogether 76 Gamasina species were recorded in the habitats investigated (Table 2). Twenty-four of them were found for the first time in Latvia. One species was recorded new to science in the driftline of Kolkasrags. The highest diversity of species with 43 Gamasina was found in the yellow dunes, followed by the grey and primary dunes and driftline habitats with 36, 31 and 24 species, respectively.

The highest number of individuals (1960) was found in the driftline's washed ashore material, while the grey dunes had the smallest number.

Four Gamasina species were common for all types of habitats (Table 2), five species for driftline, primary and yellow dunes, four species for primary, yellow and grey dunes and 25 for two types of habitats. Thirty-seven Gamasina species were found only in one of the habitats investigated.

Different species dominated in the seashore habitats. The most numerous species from the driftline were the ubiquitous *Cheiroseius necorniger* and the inhabitants of washed ashore material *Thinoseius spinosus* and *Halolaelaps balticus*, from the primary dunes the ubiquitous *L. halophilus* and *L. bicolor* and the inhabitant of washed ashore material *H. balticus*, from the yellow dune habitats the ubiquitous species *Minirhodacarellus minimus* and *L. bicolour* and the forest and dune species *Leioseius insignis,* from the grey dunes mainly common humus and moss species *Zercon carpathicus,* the hygrophilous *Hypoaspis vacua* and the ubiquitous *Veigaia nemorensis.*

Table 2. List of Gamasina species and their numbers of individuals collected from the Latvian seacoast habitats. 1-driftline, 2-primary dunes, 3-yellow dunes, 4-grey dunes; * - new species for fauna of Latvia.

	Habitats			
	1	2	3	4
Cheiroseius necorniger (Oudemans, 1903)	595			
*_Halolaelaps balticus_ Willmann, 1954	392	65		1
*_Thinoseius spinosus_ (Willmann, 1939)	431	17	8	1
*_Parasitus kempersi_ Oudemans, 1902	177		1	
*_Leioseius insignis_ Hirschmann, 1963	4	26	131	7
*_Halolaelaps incisus_ Hyatt, 1956	150	6		
Leioseius halophilus (Willmann, 1949)	65	67	13	
*_Minirhodacarellus minimus_ (Karg, 1961)			133	
Leioseius bicolor (Berlese, 1918)	1	67	39	3
Zercon carpathicus (Sellnick, 1958)			16	74
*_Dendrolaelaps arenarius_ Karg, 1971		58	14	
*_Dendrolaelaps nostricornutus_ Hir. et Wis., 1982	5	52	3	
*_Parasitus halophilus_ (Sellnick, 1957)	21	26	4	1
Macrocheles glaber (Muller, 1860)	38	2		
Hypoaspis aculeifer (Canestrini, 1883)		3	25	10
Veigaia nemorensis (C.L.Koch, 1839)		11	3	17
Antennoseius bacatosimilis Karg, 1965			31	
*_Gamasodes bispinosus_ (Halbert, 1915)	28			
Hypoaspis vacua (Michael, 1891)			1	27
*_Rhodacarus haarlovi_ Shcherbak, 1977			24	
Amblyseius meridionalis (Berlese, 1914)			5	16
Hypoaspis praesternalis Willmann, 1949			15	6
*_Amblyseius marinus_ (Willman, 1952)	11	3	3	
Arctoseius semisscisus (Berlese, 1892)	9			7
Asca bicornis (Canestrini et Fanzago, 1877)			5	10
*_Hypoaspis sclerotarsa_ Costa, 1968			15	
Pergamasus vagabundus Karg, 1968	1	11	2	
Pergamasus lapponicus Tragardh, 1910				14
Pergamasus crassipes (Linnaeus, 1758)		7	2	3
Amblyseius agrestis (Karg, 1960)	9	1	2	
*_Halolaelaps marinus_ (Brady, 1875)	11			
Parasitus kraepelini Berlese, 1903		8		1
Amblyseius messor Wainstein, 1960			5	4
Prozercon kochi Sellnick, 1943		9		
*_Rhodacarellus silesiacus_ Willman, 1935		2	6	
*_Rhodacarus mandibularis_ Berlese, 1921			7	1
Holoparasitus excipuliger (Berlese, 1905)		2	2	3
Amblyseius andersoni (Chant, 1957)			6	1
Pergamasus teutonicus Willmann, 1956				6

Table 2. Continued.

	Habitats			
	1	**2**	**3**	**4**
Leioseius minutus (Halbert, 1915)			6	
Leioseius montanulus Hirschmann, 1963		6		
Amblyseius obtusus (C.L.Koch, 1839)			3	3
Amblyseius bicaudus Wainstein, 1962	2		4	
Hypoaspis claviger (Berlese, 1883)			3	3
Prozercon trägardhi (Halbert, 1923)		4		3
*[1]*Lasioseius* sp. (subg. *Criniacus* Karg, 1980)	5			
**Hypoaspis similisetae* Karg, 1965			5	
Pergamasus septentrionalis (Oudemans, 1902)		2		2
Pergamasus wasmanni (Oudemans, 1902)			3	1
Rhodacarus reconditus Athias-Henriot, 1961		1	4	
Dendrolaelaps foveolatus Leitner, 1949			2	2
Hypoaspis kargi Costa, 1968			4	
**Zercon fageticola* Halaskova, 1970				4
Veigaia cervus (Kramer, 1876)		1		2
Veigaia kochi (Trägardh, 1901)		3		
Parasitus lunaris Berlese, 1906	2			
Leioseius minusculus (Berlese, 1905)			2	
**Platyseius italicus* (Berlese, 1905)		2		
Antenoseius delicatus Berlese, 1916				2
**Dendrolaelaps tenuipilus* Hirshmann, 1960		2		
Parazercon sarekensis Willmann, 1939		1	1	
**Cheiroseius viduus* C.L. Koch, 1839				1
Amblyseius aurescens Athias-Henriot, 1961			1	
Amblyseius graminis Chant, 1956				1
Amblyseius herbarius Wainstein, 1960				1
Amblyseius bakeri (Huges, 1948)			1	
**Dendrolaelaps cornutus* Vitzthum, 1926	1			
Dendrolaelaspis angulosus Willmann, 1936			1	
**Dendrolaelaps fallax* (Leitner, 1949)	1			
Machroheles tardus (C. L. Koch, 1841)		1		
Hypoaspis karawaiewi (Berlese, 1903)				1
Laelaspis astronomicus Koch, 1839			1	
Hypoaspis austriacus (Sellnick, 1935)				1
Zercon spatulatus (C.L. Koch, 1839)				1
Zercon zelawaiensis Sellnick, 1944		1		
Parasitus celer (C.L. Koch, 1835)	1			
Total number of individuals	1960	467	562	241
Total number of species	**24**	**31**	**43**	**36**

[1] Undescribed species.

DISCUSSION

The families Parasitidae and Aceosejidae were found to be represented with similar numbers of species in all of the investigated habitats (Table 1). Their numbers of species fluctuated only in the range of 2. Many species from these families are known as ubiquitous (Lapina 1988, Salmane 2001). The most variable family was Phytoseiidae from two species in the primary dunes to 9 in the yellow dunes. Mites from this family are known to be plant inhabitants (Kuznetzov & Petrov 1984, Lapina 1988) and therefore they are more common in the yellow and grey dunes. Species of the Laelaptidae family also clearly showed preference to habitats rich in vegetation, as they were more numerous in the yellow and grey dunes. Species of this family are mainly known to be forest and meadow inhabitants.

According to Andre et al. (1994) the plant rooting system plays an important role in the maintenance of more stable moisture conditions and organic matter content in the soil. These are extremely important factors for all soil dwelling microarthropods, including Gamasina mites, particularly in such variable habitats as seashores. Obviously, some groups (Rhodacaridae) are more adapted to the seashore habitats, while some other groups like Laelaptidae are more dependent on the previously mentioned factors and need more stable soil ecological conditions. Rhodacaridae was a dominant family in the driftline, primary and yellow dunes (Table 1). Many species of this family are known as being rather small in size and adapted to living in compact substrates (Scherbak 1980, Karg 1993) like the seashore sandy soils. The highest number of individuals collected from the Latvian coastal habitats appeared in the driftline habitats (Table 2), while Koehler and Weidemann (1997) found the highest numbers of soil arthropods in the yellow dunes of Houstrup Strand (Jutland). This difference probably reflects the varying ecological conditions between the dune habitats in Latvia and Houstrup Strand. Latvian driftline habitats are often rich in washed ashore material, and the highest number of individuals amongst seashore habitats is found here.

The driftline habitats included the smallest number of Gamasina species (24), but eight of them were the most numerous from all seashore habitats (Table 2). Nine species were found only in the driftline habitats. Typical driftline species such as *Thinoseius spinosus* (14.1 % from total of Gamasina), *Halolaelaps balticus* (14.1 %), *Parasitus kempersi* (5.4 %) and *H. incisus* (4.8 %) were the most abundant ones in the washed ashore material. These species make up about 59% of total number of individuals found in the seashore habitats. *Cheiroseius necorniger,* the most numerous species in the Latvian seashore habitats, was found only in the driftline and makes 18.4 % from the total of Gamasina. However, this species is also known as an inhabitant of a very wide range of habitats (mainly soils rich in organics) in Latvia (Salmane 2001) and elsewhere in Europe (Karg 1993). Koehler et al. (1995ab) found this species in the primary dunes of the North-Sea coast of Jutland.

Thirty-one Gamasina species were found in the primary dunes (Table 2). In comparison to other seashore habitats, primary dunes were poorly inhabited by gamasins. Two thirds of all species were found to be represented by less than 10 individuals each, but five species were comparatively abundant here. The species *L. bicolor, D. arenarius* and *D. nostricornutus* reached their maximum abundance in the primary dunes and could be typical for such kind of soil ecological conditions. Among the seven Gamasina species found only in the primary dunes, five are known as widely distributed in various habitats of Latvia (Lapina 1988). *Veigaia kochi* is known as a widely distributed, but not numerous species. *Dendrolaelaps tenuipilus* is known from coastal meadows and dunes and *Platyseius italicus* is the most common for wet habitats of Latvia (Salmane 2001).

The highest number of Gamasina species (43) was found in the yellow dunes. Nine species were the most abundant here, while twelve were found only in the yellow dune habitats. Among them eight species are known as typical for coastal habitats, and *Leioseius minutus, L. minusculus, Hypoaspis kargi* and *Laelaspis astronomicus* are known as inhabitants of diverse biotopes. *Minirhodacarellus minimus* and *Leioseius insignis* were the most abundant species in the yellow dunes. The first one was found only there, while *L. insignis* was found in other seashore habitats as well. These two species can be considered as typical for yellow dunes of Latvian coast.

A total 36 Gamasina species were recorded from the grey dunes. Among them six were found as most numerous and 10 were found only in the grey dunes. The most abundant species in the grey dunes were *Zercon carpathicus, Hypoaspis vacua* and *Veigaia nemorensis. Z. carpathicus* is also known from the forest and dune habitats of Latvia (Lapina 1988). The other two species are inhabitants of a wide range of habitats, but *H. vacua* is more restricted to the wet habitats.

Four Gamasina species were found in all the investigated habitat types (Table 2): *Thinoseius spinosus, Leioseius insignis, L. bicolor* and *Parasitus halophilus. L. bicolor* is known as ubiquitous species and an inhabitant of a very wide range of habitats (Salmane 2001). *Veigaia nemorensis* is the most widely distributed and numerous species in the inland habitats of Latvia (Lapina 1988). In the seashore habitats it was found in comparatively low densities.

Acknowledgements. These studies were partially supported by German project «Biogeography and communities of Collembola (Insecta) and Gamasina (Acari) in coastal dunes of the Southern Baltic» and by Swedish project «Areas with high biodiversity on the Latvian Baltic Sea Coast». The author is very grateful to Dr. Lars Lundquist, Department of Systematic Zoology, Lund University and Dr. Hartmut Koehler, Institute of Ecology and Evolutionary Biology, Bremen University, for given help in determination of some species. The author is also very grateful to Dr. M. Kirrage-de-Hond, England for checking the English.

REFERENCES

Andre, H.M., Noti, M.I. & Lebrun, P. 1994. The soil fauna: the other last biotic frontier. Biodiv. Conserv. 3, 45-56.

Bregetova, N.G. 1977. Identification key for soil inhabiting mites. Mesostigmata. 717 pp. Nauka, Leningrad.

Eitminavichute, I.S. (ed.) 1976. Soil invertebrate fauna of the coastal area in the Eastern Baltic region. 172 pp. Vilnius, Mokslas.

Hirschmann W. 1971. Gangsystematik der Parasitiformes. Acarologie 82-88, 15, 10-42.

Karg, W. 1993. Acari (Acarina), Milben Parasitiformes (Anactinochaeta) Cohors Gamasina Leach. Raubmilben. 2. überarbeitete Auflage, 524 pp. Gustav Fischer Verlag, Jena.

Koehler, H., Hofmann, S. & Munderloh, E. 1992. The soil mesofauna of white-, grey- and brown-dune sites in Jutland (Denmark) with special reference to the Gamasina (Acari, Parasitiformes). Pp. 273-281 in Carter, R.W.G., Curtis, T.G.F. & Sheehy-Skeffington, M.J. (eds.), Coastal dunes. Balkema, Rotterdam.

Koehler, H., Munderloh, E. & Hofmann, S. 1995a. The terrestrial mites of sand dunes from two sites of the North-Sea coast with special reference to the Gamasina. Pp. 217-229 in Kropczynska, D., Boczek, J., & Tomczyk, A. (eds.), The Acari, Physiological and Ecological Aspects of Acari-Host Relationships. Dabor, Warschau.

Koehler, H., Munderloh, E. & Hofmann, S. 1995b. Soil microarthropods (Acari, Collembola) from beach and dune: characteristics and ecosystem context. J. Coastal Conserv. 1, 77-86.

Koehler, H. & Weidemann, G. 1997. On the ecology of the coastal dunes of Houstrup Strand (W-Jutland). Pp. 64-71 in Coastal dunes – management, protection and research. EUCC Dune Seminar, Skagen, Denmark.

Kolodochka L.A. 1978. Handbook on identification of plant-inhabiting phytoseiid mites. 78 pp. Akad. Nauk. SSR, Inst. Zool., Kiev.

Kuznetzov N. & Petrov V. 1984. Predatory mites of the Baltic Region (Parasitiformes: Phytoseiidae, Acariformes: Prostigmata). 144 pp. Zinatne, Riga.

Lapina, I. 1976_. Gamasin mites of the family Aceosejidae Baker et Wharton, 1952 in fauna of the Latvian SSR. Latvijas Entomologs 19, 65-90.

Lapina, I. 1976b. Free-living gamasin mites of the family Laelaptidae Berlese, 1892 in fauna of the Latvian SSR. Latvijas Entomologs 19, 20-64.

Lapina, I. 1988. Gamasina mites of Latvia. 198 pp. Zinatne, Riga.

Mallow, D., Ludwig, D. & Crossley, D.A.Jr. 1984. Microarthropod community structure in a coastal dune ecosystem on Jekyll Island, Georgia U.S.A. Pedobiologia 27, 365-376.

Melecis, V., Spote, I. & Paulina, E. 1994. Soil microarthropods as potential bioindicators for coastal monitoring. Pp. 111-115 in Abstracts Int. Conf. «Coastal conservation and management in the Baltic region», Klaipeda (Lithuania), May 2-8 1994.

Purvis, G. 1982. The soil arthropod fauna (Acari and Collembola) of a coastal locality in Southeast Ireland. J. Life Sci. R. Dublin Soc. 3, 379-396.

Salmane, I. 1996. Gamasin mites (Acari, Gamasina) of Kurzeme coast of the Baltic Sea. Latvijas Entomologs 35, 28-34.

Salmane, I. 2000. Fauna of soil-dwelling predatory Gamasina mites (Acari: Mesostigmata) in seashore habitats of the Kurzeme Coast, Latvia. Ecologia (Bratislava) 19:4, 87-96.

Salmane, I. 2001. (in press). Checklist of the Latvian Gamasina mites (Acari, Mesostigmata) with short notes to their ecology. Latvijas Entomologs, Riga.

Salmane, I. & Heldt, S. 2001 (in press). Soil predatory mites (Acari, Mesostigmata, Gamasina) of the Western Baltic Coast of Latvia. Acarologia.

Scherbak, G.I. 1980. The family Rhodacaridae from the Palearctic region. 216 pp. Naukova Dumka, Kiev.

Received 26 June 2000,
accepted 20 October 2000

Norw. J. Entomol. 48, 231–235. 2001

On the identification of Palaearctic species in the genus *Cordyla* Meigen (Diptera, Mycetophilidae); preliminary results

Olavi Kurina

Kurina, O. 2001. On the identification of Palaearctic species in the genus *Cordyla* Meigen (Diptera, Mycetophilidae); preliminary results. Norw. J. Entomol. 48, 231-235.

The morphology of male specimens of 14 Palaearctic *Cordyla* species is studied. The species can be arranged according to the colour of the swollen segment of palpus, the number of flagellar segments and the structure of male genitalia. On the basis of the colour of the swollen segment of palpi the species can be divided into two groups, the number of flagellar segments into four groups, and the structure of the genitalia into three groups. Morphological differences between the groups are discussed with an emphasise on genital differences.

Key words: Diptera, Mycetophilidae, *Cordyla*.

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INTRODUCTION

The genus *Cordyla* Meigen, 1803 is a well defined monophyletic group in the fungus gnat family Mycetophilidae. The species are small, maximum 5 mm in size. Different authors have classified the genus in tribes Mycetophilini and Exechiini, the latter is more accepted in recent publications (e. g. Tuomikoski 1966, Krivosheina et al. 1986). According to Tuomikoski (1966) the genus is characterized by apomorphies, more significant of them are: 1) short antennae with a reduced number of flagellar segments; 2) swollen antepenultimate segment of palpi; 3) presence of bristles on mesanepisternum (usually typical for Mycetophilini) and 4) m_2 does not reach the wing margin (except in *C. styliforceps* (Bukowski, 1934) and *C. crassicornis* Meigen, 1818). According to Tuomikoski (1966) the genus *Neoallodia* Edwards, 1932 is systematically the closest to *Cordyla*.

So far 19 *Cordyla* species have been recorded from the Palaearctic and 10 species from the Nearctic region (Bechev 1999). Up to now the genus has not been recorded outside the Holarctic but has recently been recorded from the Oriental region (Laos) (Jan Sevcik, pers. comm.). Some palaearctic species lack data else than the initial description and certain problems of synonymity can arise. *C. festiva* (Costa, 1857) has not been found after its original description in Italy (surroundings of Napoli). There are slender data (only female specimens) on *C. vitiosa* Winnertz, 1863, reported mainly in the 19th century and the validity is not confirmed. *C. sixi* (Barendrecht, 1938) and *C. bergensis* (Barendrecht, 1938) are probably not valid species and are possibly synonyms of *C. pusilla* Edwards, 1925 and *C. parvipalpis* Edwards, 1925, respectively (Peter Chandler, pers. comm.). Although, that opinion needs a further investigation. The named four species have been left out of the analysis.

The only special review of the genus is that by Landrock (1926) which obviously is out of time. As only one species (*C. insons* Lastovka et Matile, 1974) has been described since 1940, the genus has been offered less attention than many other genera in the family.

In Europe (Figure 1), *Cordyla* species are most numerous in Germany (14), Estonia (13), Switzerland (12), Czech and Slovak Republics (12). The species numbers in Europe obviously do not reflect the zoogeographical distribution, but different scope and effort of investigations.

The larvae of *Cordyla* are mainly feeding on mushrooms. They are polyphagous, apparently with a preference for genus *Russula*. According to Yakovlev (1994), there are 11 species of fungivorous *Cordyla* species in the Palaearctic. For the rest of species, data on larvae feeding are missing.

MATERIAL AND METHODS

The studied material comprises 430 males representing 14 species. The author has not had a possibility to work with *C. styliforceps*. The species has been put into the described morphological groups according to literature (Bukowski 1934, Chandler & Ribeiro 1995). The material has been gathered by collectors from Estonia, Finland, Sweden, Denmark and Germany.

For each specimen the genitalia were separated from the abdomen and heated in 15 % KOH for identification. This procedure removed soft tis-

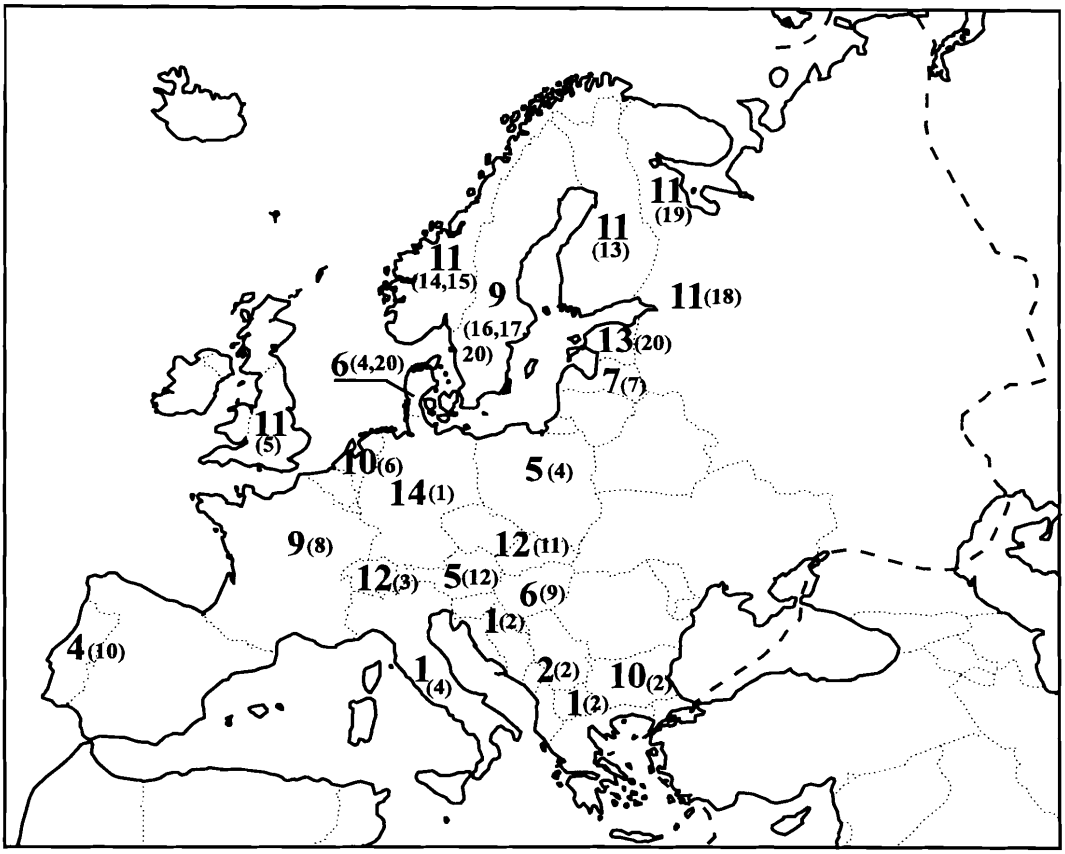

Figure 1. Number of *Cordyla* Meigen, 1803 species recorded in Europe. Numbers in parenthesis indicate references: 1-Kallweit & Plassmann (1999); 2-Bechev (1997); 3-Chandler (1998); 4-Hackman (1988); 5-Edwards (1925); 6-de Meijere (1939); 7-Lackschewitz (1937); 8-Matile (1977); 9-Dely-Draskovitš (1974); 10-Ribeiro (1990); 11-Košel et al. (1997); 12-Plassmann (1996); 13-Hackman (1980); 14-Søli (1994); 15-Økland (1995); 16-Plassmann (1978); 17-Plassmann (1980); 18-Krivosheina et al. (1986); 19-Yakovlev (1994); 20-original data not previously published.

sue which otherwise would have rendered identification difficult. The remaining chitinous parts were washed with destilled water and inserted into glycerin for observation. The genitalia were preserved as glycerin preparations. Antennae were observed without dissection, when possible; or they were removed from the head and treated with the method described for genitalia. Stereomicroscope OLYMPUS SZ4045TR (6.7 - 240 X) and microscope AY-12 (70 - 300 X) were used.

DISCUSSION

For identification of male specimens three sets of characters can be used.

1. The colour of the swollen segment of palpi can be used to distinguish between two species: *C. fasciata* Meigen, 1830 and *C. flaviceps* (Staeger, 1840). All other species have the segment of brownish to blackish colour. Some specimens of *C. flaviceps*, however, have a two-colored swollen segment (yellow and brownish).

2. The number of flagellar segments allows to distinguish 4 groups of species:

those with 10 flagellar segments (3 species, viz. *C. brevicornis* (Staeger, 1840), *C. pusilla* Edwards, 1925, and *C. bicornuta* Landrock, 1926); those with 11 flagellar segments (5 species, viz. *C. fasciata* Meigen, 1830, *C. parvipalpis* Edwards, 1925, *C. fissa* Edwards, 1925, *C. crassicornis* Meigen, 1818, and *C. insons* Lastovka et Matile, 1974); those with 12 flagellar segments (5 species, viz. *C. nitens* Winnertz, 1863, *C. fusca* Meigen, 1804, *C. flaviceps* (Staeger, 1840), *C. styli-*

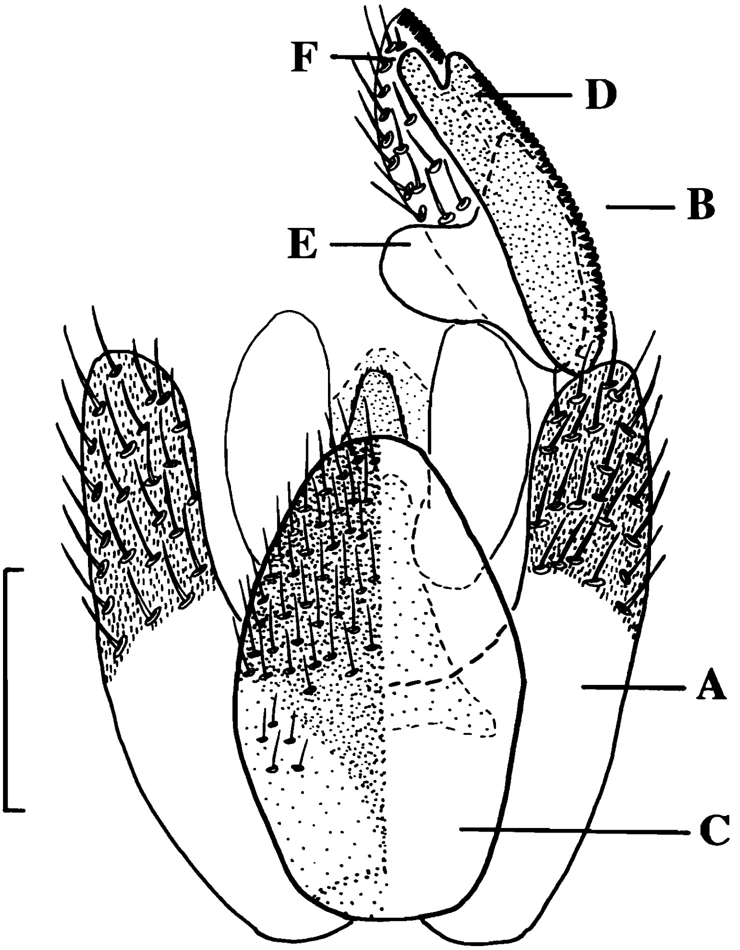

Figure 2. *Cordyla flaviceps* (Staeger, 1840), ventral view of hypopygium; left gonostylus removed. A, gonocoxite. B, gonostylus. C, VIII sternit. D, ventral appendage of gonostylus. E, medial appendage of gonostylus. F, dorsal appendage of gonostylus. Scale bar: 0.1 mm.

forceps (Bukowski, 1934), and *C. murina* Winnertz, 1863); and those with 13 flagellar segments (2 species, viz. *C. semiflava* (Staeger, 1840), and *C. nitidula* Edwards, 1925). The number of flagellar segments is commonly regarded to be a constant characteristic, but some specimens of *C. crassicornis* have 10 flagellar segments, while some *C. murina* have 13.

3. The most important group of characters can be found in the structure of male genitalia, in particular in medial and ventral parts of the gonostylus (Figure 2E,D). For all species the serrated ventral margin of the ventral appendages is typical. Few authors have used the shape of VIII sternit (Figure 2C) as a characteristic for determination, but it is variable and allows to identify only the species *C. semiflava* by its protruding top, distinctly differing from the rest of species.

In most papers only the lateral and ventral views of the gonostylus are presented, thus not showing the shape of the medial appendages. The medial appendages can be observed only after separating the gonostylus (Figure 2B) from the gonocoxites (Figure 2A). The structure of the gonostylus allows to distinguish between three groups, primarily recognized on the outline of the medial parts of the gonostylus.

A. The *semiflava* group comprises five species: *C. semiflava* , *C. murina, C. parvipalpis, C. styliforceps,* and *C. insons.* In these species, the medial part of gonostylus is formed from two ventrally or medially directed appendages. In the group *C. parvipalpis* differs by short ventral appendage. For other species the structure of medial appendages is significant. Male genitalia are most similar in this group.

B. The *crassicornis* group comprises two species: *C. crassicornis* and *C. fissa*. Both species have the dorsal part of gonostylus with protruding appendage. The medial part of gonostylus consists of a large branched appendage and a medially directed two-forked appendage. The gonostylus of *C. fissa* is bigger and the protruding appendage on the dorsal part is clearly outlining. The ventral part of *C. fissa* has a cut on the top.

C. The *fusca* group comprises eight species: *C. fusca, C. nitidula, C. nitens, C. flaviceps, C. fasciata, C. brevicornis, C. pusilla,* and *C. bicornuta.* This is the most variable group with the medial part of gonostylus formed from one or two appendages with various outgrowths. They do also differ in the shape of the ventral part of gonostylus. For example *C. fusca* and *C. nitens* have a semi-hooked ventral appendage; *C flaviceps* has a deep cut on the top (Figure 2 D); *C. fasciata* slender and longer than the tergal appendage, while *C. nitidula* has a ventral appendage, clearly rounded on the top.

It should be observed that the species groups distinguished by the number of flagellar segments and male genitals do not coincide. Some characteristics can be variable, consequently all of them have to be studied in order to identify species. However, the structure of male genitalia is the most important. In destroyed material or material in bad condition the species can be identified only by genitalia.

Acknowledgements. I express my thanks to the Estonian Science Foundation for financial support, Grant No. 3996. I am greatly indebted to Mr. Mart Jüssi for reading the manuscript.

REFERENCES

Bechev, D. N. 1997. Check-list of the fungus gnats (Diptera: Sciaroidea, excluding Sciaridae) of the Balkan peninsula. Trav. Sci. Univ. Plovdiv, Animalia 33 (6), 9-22.

Bechev, D. N. 1999. The zoogeographic classification of the Palaearctic genera of fungus gnats (Diptera: Sciaroidea, excluding Sciaridae). Studia Dipterol. 6 (2), 321-326.

Bukowski, W. 1934. Neue und abweichende Formen von Pilzmücken (Diptera Fungivoridae) aus der Krim. Konowia 13, 184-192.

Chandler, P. J. 1998. Mycetophilidae. Pp. 113-125 in Merz et al. (eds), Fauna Helvetica I. Diptera-Checklist. Schweizerische Entomol. Gesellschaft.

Chandler, P. J. & Ribeiro, E. 1995. The Sciaroidea (Diptera) (excluding Sciaridae) of the Atlantic Islands (Canary Islands, Madeira and the Azores). Bol. Mus. Munic. Fun. (Hist. Nat.) Suppl. 3, 1-170.

Dely-Draskovitš, A. 1974. Systematische und ökologische Untersuchungen an den in Ungarn als Schädlinge der Hutpilze auftretenden Fliegen. Part VI. Mycetophilidae (Diptera). Folia Entomol. Hungarica 27, 29-41.

Edwards, F. W. 1925. British Fungus-Gnats (Diptera, Mycetophilidae). With a revised Generic Classification of the Family. Transactios of the Entomological Society of London 73, 505-670.

Hackman, W. 1980. A check list of the Finnish Diptera I. Nematocera and Brachycera (s. str.). Notulae Entomologicae 60, 17-48.

Hackman, W. 1988. Tribe Exechiini. Pp. 297-325 in Soós, A. & Papp, L. (eds.), Catalogue of Palaearctic Diptera. Vol 3. Ceratopogonidae-Mycetophilidae. Budapest.

Kallweit, U. & Plassmann, E. 1999. Mycetophilidae. Pp. 61-69 in Schumann, H. et al. (eds) Checkliste der Dipteren Deutschlands. Halle (Saale).

Košel, V., Chandler, P. J. & Martinovsky, J. 1997. Mycetophilidae. Pp. 19-23 in Chvála, M. (ed.), Check List of Diptera (Insecta) of the Czech and Slovak Republics. Prague.

Krivosheina, N. P., Zaitzev, A. I. & Yakovlev, E. B. 1986. Insects as decomposers of fungi in the forest of the European part of USSR. 309 pp. Moscow. (in Russian).

Lackschewitz, P. 1937. Die Fungivoriden des Ostbaltischen Gebites. Arb. Naturf.-Ver. Riga. N. F. 21, 1-47.

Landrock, C. 1926. Die palaearktischen Arten der Gattung *Cordyla* Mg. Konowia 5, 64-69; 200-204.

Matile, L. 1977. Catalogue provisoire des Diptères Mycetophilidae de la Faune de France. Bull. Mus. National Hist. Nat. 3, 456, 621-655.

de Meijere, J. C. H. 1939. Naamlijst van Nederlansche Diptera. Tijdschrift Ent. 82, 137-174.

Økland, B. 1995. Diversity patterns of two insect groups within spruce forests of southern Norway. Doctor scientiarium theses 21. 129 pp. Ås.

Plassmann, E. 1978. Pilzmücken aus Messaure in Schweden. I. Barberfallenfänge (Diptera: Mycetophilidae). Senckenbergiana Biol. 58 (3-4), 147-156.

Plassmann, E. 1980. Pilzmücken aus Messaure in Schweden. III. Lichtfallenfänge (Insecta: Diptera: Mycetophilidae). Senckenbergiana Biol. 60 (3-4), 175-189.

Plassmann, E. 1996. Zur Kenntnis der Pilzmückenfauna Österreichs (Diptera: Nematocera: Mycetophiloidea). Mitt. Internat. Entomol. Ver. 21 (3-4), 111-120.

Ribeiro, E. 1990. Contribution to the study of fungus gnats (Diptera: Mycetophiloidea) of Portugal. II-seven new records. Bolm. Soc. Port. Ent. 118, 173-194.

Søli, G. E. E. 1994. Fungus gnats from Jostedalen, West Norway (Diptera; Diadocidiidae and Mycetophilidae). Fauna Norv. Ser. B 41, 1-12.

Tuomikoski, R. 1966. Generic taxonomy of the Exechiini (Dipt., Mycetophilidae). Ann. Ent. Fenn. 32 (2), 159-194.

Yakovlev, E. B. Palaearctic Diptera associated with fungi and myxomycetes. 127 pp. Petrozavodsk. (in Russian, with English summary).

Received 30 June 2000,
accepted 20 October 2000.

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Norw. J. Entomol. 48 (1) 2001

ISSN 1501-8415.

(Continued on inside back cover)

The present journal is a continuation of **Fauna norvegica Series B** (Norwegian Journal of Entomology). With Volume 45 (1998) the publication of this journal by the Foundation for Nature Research and Cultural Heritage Research (NINA-NIKU) has been discontinued. Starting with Volume 46, the journal is published as **Norwegian Journal of Entomology** by the Norwegian Entomological Society. Editor is Professor Lauritz Sømme, University of Oslo.
