Comparison of mosquito (Diptera: Culicidae) populations by wetland type and year in the lower River Dalälven region, Central Sweden

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ABSTRACT: We studied adult mosquito assemblages in six wetlands, representing three types (wet meadow, alder swamp, and bog), in the lower part of the River Dalälven in Central Sweden during three consecutive years (2000-2002) and evaluated the influence of wetland type and year. Mosquito abundance differed significantly between years but not between wetland types. Mosquito species richness showed no significant variation between years or wetland types. Cluster analysis based on percentage of similarity resulted in three clusters, with high similarity between all wetlands in 2000. Ordination analysis showed that mosquito assemblages were mainly correlated with wetland type and water level increase in the previous month. Hydrological conditions varied between the years and between the wetland types, and our collections also included a year (2000) with extreme flood situations. The floodwater mosquito species *Ochlerotatus sticticus* was the predominant species with a strong influence on the whole study due to its long-range dispersal ability. The entire region suffered from enormous numbers of *Oc. sticticus* in 2000. The data from this study provided the basis for the initiation of a mosquito control project in the region. ***Journal of Vector Ecology*** **33 (1): 150-157. 2008.**

Keyword Index: Swamp, bog, wet meadow, *Ochlerotatus sticticus*, mosquito assemblages.

INTRODUCTION

Mosquitoes (Diptera: Culicidae) are a major component of wetland environments (Mitsch et al. 1994). Usually, all kind of wetlands are associated with mosquito annoyance. However, mosquitoes, as any other organisms, show both spatial and temporal variation and an uneven distribution within an environment. Variation can be due to habitat preferences, host preferences, and environmental variation (Zhong et al. 2003). Seasonal variations of mosquito abundance are rather well-studied and can be related to weather and hydrological conditions (Jaenson et al. 1986, Margalit et al. 1987, Merdic and Lovakovic 2001, Zhong et al. 2003). The spatial variation of adult mosquitoes is usually studied for single species that are important disease vectors (Wekesa et al. 1997, Gleiser et al. 2002).

We studied the relation between three common Swedish wetland types (wet meadow, alder swamp, and bog) and adult mosquito faunas. We included temporal variation by studying three consecutive years and also looked at variation between months. Our goal was to evaluate the association between wetland type and mosquito fauna characteristics.

MATERIALS AND METHODS

Study areas

All study areas were located in the lowland of the River Dalälven in Central Sweden (Figure 1). The River Dalälven is regulated by a series of power plants but is nevertheless subject to distinct water level fluctuations, especially in the lowlands of the region "Nedre Dalälven." The river forms a series of lakes in this region. Melting snow in the spring as well as heavy summer rains can cause massive flooding in the lowlands surrounding these lakes. We sampled three wetland types (Keddy 2000): wet meadows (dominated by herbaceous plants rooted in occasionally flooded soil), swamps (dominated by trees rooted in hydric soil), and bogs (dominated by Sphagnum-mosses, Ericaceous shrubs, and evergreen trees rooted in deep peat). We sampled two wet meadows around Lake Hedesundafjärden that are directly influenced by the River Dalälven, two alder swamps that are connected to Lake Färnebofjärden by watercourses and thus influenced by the river, and two bogs that receive all their hydrological input from precipitation. Lake Färnebofjärden is not directly subject to water level regulations while Lake Hedesundafjärden is regulated at its outlet. Water level fluctuations were based on data from a hydrological station in each lake. A normal water level was computed based on data from a digital terrain model and hydrological stations, and positive differences in cm were calculated, using the maximum value for each flood event.

The two wet meadows are located at the edge of Lake Hedesundafjärden at an altitude of 52 m above sea level (a. s. l.). The wet meadow at Sälja (SAL; 60° 16' N; 16° 59' E) covers approximately 94 ha while the wet meadow at Hadeholm (HAD; 60° 17' N; 17° 02' E) is approximately 5 ha. Vegetation is dominated by sedges (*Carex* spp.) with some willows (*Salix* spp.) and aspen (*Populus tremula* L.)

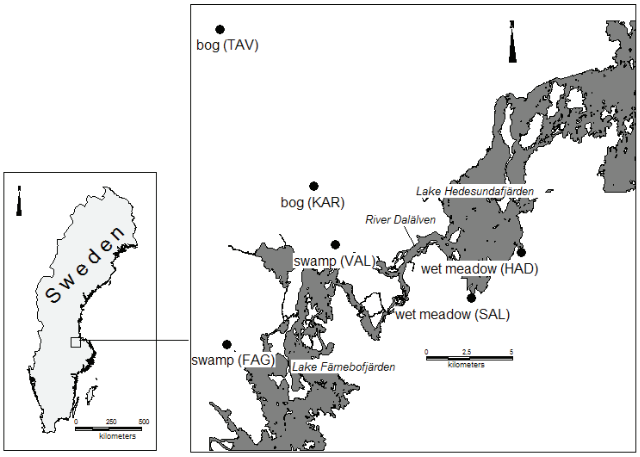

Figure 1. The six study areas, representing three wetland types, from Nedre Dalälven region, Central Sweden, where adult mosquitoes were collected from June to August (2000-2002).

in the shrub layer. The two swamps are connected by creeks to Lake Färnebofjärden and located at an altitude of 56-57 m a. s. l. The swamp Valmbäcken (VAL; 60° 17' N; 16° 50' E) covers approximately 20 ha and the swamp at Fågle (FAG; 60° 14' N; 16° 43' E) covers approximately 2 ha. Both areas are alder (*Alnus glutinosa* (L.)) swamps, dominated by meadowsweet (*Filipendula ulmaria* (L.)) in the herb layer. The two bogs Karinmossen and Tavelmuren are located at an altitude of 60 and 90 m a. s. l., respectively. The bog Karinmossen (KAR; 60° 19' N; 16° 49' E) is an active raised bog that covers a total area of approximately 719 ha. We focused on the western part where peat is no longer mined but many ditches remain. The bog Tavelmuren (TAV; 60° 24' N; 16° 43' E) covers an area of approximately 49 ha. The vegetation of the bogs is dominated by *Sphagnum* spp. mosses and hare's tail cotton grass (*Eriophorum* spp.).

Water level

Water levels of the River Dalälven varied between the three study years and between the two lakes (Figures 2A,B). In Lake Färnebofjärden, flooding occurred each year with variations in the extents. Melting snow caused a spring flood in May during all three years but the water level, and therefore flooded area, was greater in 2000 (79 cm above normal) than in 2001 (35 cm above normal) and 2002 (34 cm above normal). During July 2000, heavy rain in the River Dalälven catchment resulted in a second large flood with a maximum water level of 117 cm above normal at the end of July and beginning of August. In 2001, water levels decreased after a flood in May and remained low. In 2002, two more floods occurred in addition to a spring flood in May within a rather short time period in the beginning of July (3 cm above normal) and end of July (26 cm above normal).

In the regulated Lake Hedesundafjärden, major floods occurred only during 2000, following the same pattern as in Lake Färnebofjärden. The spring flood in May 2000 had a maximum water level of 16 cm above normal while the flood during July/August resulted in 29 cm above normal. During 2001 and 2002, no distinct flood event happened.

Water levels in the bogs were highest in April/May in all study years, remained steady and low in July/August 2000, and declined somewhat in July/August 2001 and 2002.

Sampling methods

Adult female mosquitoes were collected using Centers for Disease Control (CDC) miniature light traps, with carbon dioxide from dry ice as an attractant. Even though all trap collections are biased, this method samples a large variety of mosquito species (Service 1993). The traps were placed in trees approximately 1.5 m above ground. They were activated for 12–14 h from early in the evening until the next morning. Collected mosquitoes were anaesthetized with carbon dioxide, dispensed into plastic ampoules, and immediately killed by freezing on dry ice. They were stored on dry ice and at -70° C until identified. Some collections resulted in high numbers of individuals. In these cases, total number of individuals per trap was estimated by weight, measured on a digital scale (Precisa 620C) with a precision of 0.01 g. At each sampling event, three sets of 100 randomly chosen individuals of mixed species were weighed and the mean was used for estimation of the total catch. Contents were subsampled for identification and the proportion of each species in the identified subsample was used to extrapolate to species abundances in the total sample. Mosquitoes were identified to species with keys by Mohrig (1969), Gutsevich et al. (1974), and Wood et al. (1979), while nomenclature followed Reinert (2000).

In each of the six study areas, we selected three trap sites separated by 35 to 240 m. Trapping was conducted during one period each month from June to August, with two nights per sample period. All 18 traps were operated during the same two nights per month, resulting in 6 trap nights for each trap and year. In 2000 and 2001, additional sampling was conducted during a period each in May and September (not included in analyses). Sampling in 2000 was conducted on 12-15 May, 11-14 June, 10-12 July, 12-15 August, and 18-21 September. Sampling in 2001 was conducted on 14-17 May, 11-14 June, 9-12 July, 6-9 August, and 3-6 September. Sampling in 2002 was conducted on 10-12 June, 8-10 July, and 13-16 August (Schäfer et al. 2006).

Data analysis

We compared mosquito abundance and species richness by wetland types and by year, respectively, with a Kruskal-Wallis test. Calculations were done in Statistica 7.0 (StatSoft Inc. 2005). We compared mosquito faunas of study areas between years using the Sorensen Index for presence-absence data and the Renkonen Index (percentage of similarity) for quantitative data (Krebs 1999, Magurran 2004). Percentage of similarity was chosen because it is relatively unaffected by sample size (Krebs 1999). Both similarity measurements range from 0 (no similarity) to 1 and 100 (complete similarity), respectively. Calculations of similarity indices were done in the software Ecological Methodology 5.1 (Krebs 1998) and Biodiv 5.1 (Baev and

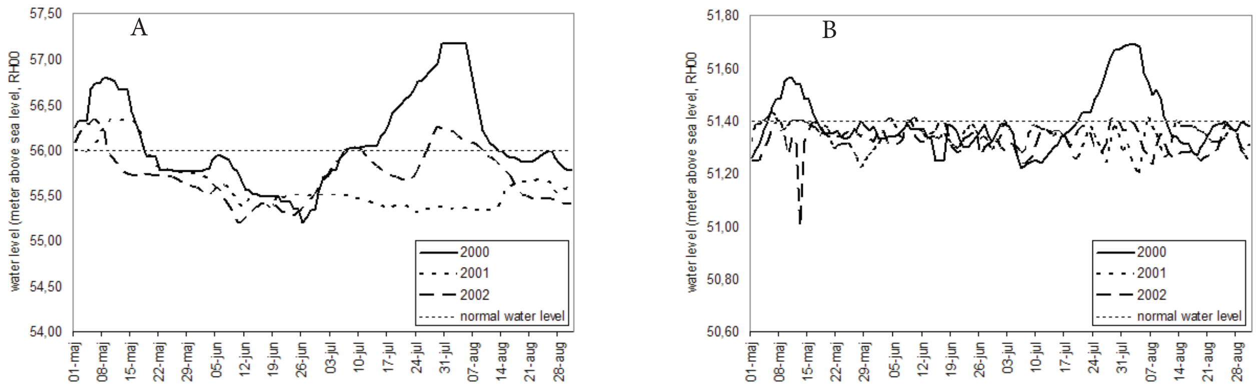

Figure 2. Water level fluctuations from May to August 2000, 2001, and 2002 measured at hydrological stations in Lake Färnebofjärden (A) and Lake Hedesundafjärden (B).

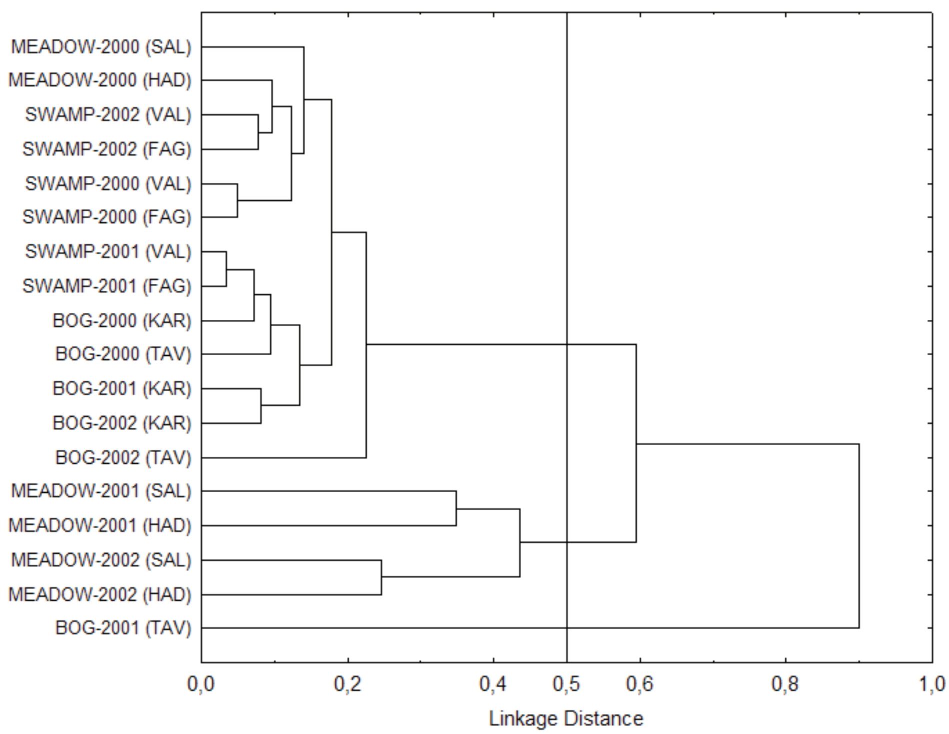

Figure 3. A cluster analysis of mosquito assemblages from six wetlands, representing three wetland types from Nedre Dalälven region, Central Sweden, and from three years, based on percentage of similarity and with UPGMA as the cluster technique.

Penev 1995). Dendrograms were constructed using UPGMA (unweighted pair-group method using arithmetic averages) as the cluster technique (StatSoft Inc. 2005).

We used Redundancy Analysis (RDA) to evaluate the association of mosquito assemblages with wetland type, month of sampling, year, and water level increase in the previous month. Wetland type (wet meadow, swamp, bog) and year (2000, 2001, 2002) were nominal variables, while month (6-8) and water level increase in the previous month (cm above normal water level) were quantitative variables. Species data was based on individual trap collections and log (x+1) transformed and rare species were down-weighted. Significance of relationship among species and environmental data were tested by Monte-Carlo permutation test with 1,000 permutations under the reduced model. Forward selection of environmental variables was chosen to rank the importance of explanatory variables for determining the species data. RDA was performed in the software Canoco 4.5 (ter Braak and Smilauer 2002).

RESULTS

Mosquito abundance pooled by study area and year differed significantly between years (Kruskal-Wallis H=8.667, p=0.013), with highest numbers sampled in 2000 (total 893,223 individuals), followed by 2001 (total 256,158 individuals) and 2002 (total 106,837 individuals). Mosquito abundance did not differ significantly between wetland types (Kruskal-Wallis H=5.345, p=0.07).

Twenty-three mosquito species were collected in this study (Table 1). Mosquito species richness pooled by study area and year did neither differ significantly between wetland types (Kruskal-Wallis H=1.615, p=0.446) nor between years (Kruskal-Wallis H=2.421, p=0.298), ranging from 8-17 species in each wetland.

Species composition (presence/absence) was similar between years in the two wet meadows (Sörensen Indices between 0.88 and 0.97), and also in the two alder swamps (Sörensen Indices between 0.81 and 0.90). In the bogs, species composition varied more between the years than in the other wetlands (Sörensen Indices between 0.58 and 0.90). A cluster analysis based on the Sörensen Index (data not shown) resulted in mixed clusters of different wetland types and different years.

The mosquito assemblages (quantitative data) showed much more variation between years than species composition, especially in the bogs (percentage of similarity between 2 and 92%) and in the wet meadows (percentage of similarity between 30 and 90%). In the alder swamps, mosquito assemblages were similar between years (percentage of similarity between 84 and 97%). Cluster analysis resulted in three clusters at a linkage distance of 0.5 (Figure 3). One large cluster consisted of both wet meadows in 2000, both swamps during all three years, both bogs in 2000 and 2002, and one bog (KAR) in 2001. Similarity between the mosquito assemblages of these wetlands was rather high. The wet meadows in 2001 and 2002 formed a separate cluster and a third cluster was formed by one bog (TAV) in 2001.

Ordination analysis by RDA (Figure 4) showed that wetland type explained 54% of the variation explained by all variables. Together with water level increase in the previous month, these variables accounted for 74% of all variation. The results show a correlation of the floodwater species *Ochlerotatus sticticus* (Meigen), *Aedes rossicus* D. G. M., and *Ae. cinereus* Meigen with the wetland type swamp, the year 2000, and water level increase in the previous month. The snowmelt mosquito species (e.g., *Oc. communis* (de Geer), *Oc. cantans* (Meigen), *Oc. punctor* (Kirby), *Oc. intrudens* Dyar) were placed between the wetland types wet meadow and swamp.

The differences between the wetland types and the years show up clearly when looking at the seasonal variation and the percentage of the dominant species *Oc. sticticus* (Figures 5A-D). The swamps, most subject to flooding, were dominated by *Oc. sticticus,* which accounted for between 70 to 87% of the total catch in each year. Mean mosquito numbers per trap night were very high in June and August 2000 with a maximum number of 57,000 individuals in one trap and night, but also in June 2001 (maximum 30,000 mosquitoes in one trap and night). Beside *Oc. sticticus*, the swamps produced mostly *Ae. rossicus* and *Oc. intrudens*. In the two wet meadows, mosquito numbers also peaked in June and August 2000, with *Oc. sticticus* dominating in the latter collection and a maximum of 62,100 mosquitoes in one trap and night. In 2001, mosquito abundance was low, with *Ae. cinereus* as the dominating species. In 2002, mean number of mosquitoes per trap night was also low, but *Oc. sticticus* dominated the August samples. The wet meadows

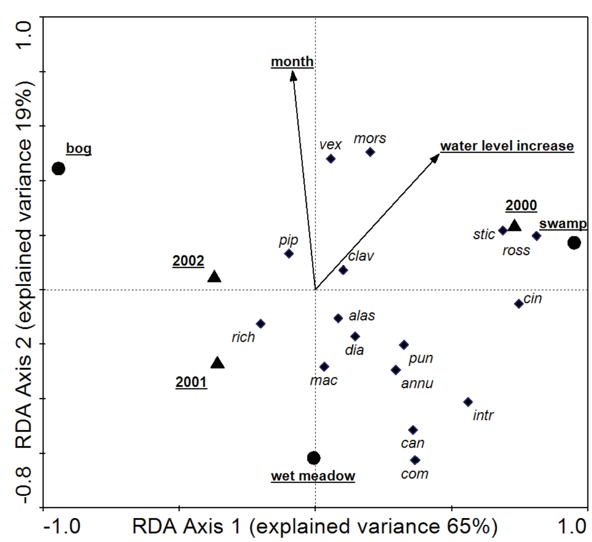

Figure 4. Ordination biplot of mosquito species and explanatory variables based on a Redundancy Analysis (RDA). Species abbreviations are explained in Table 1. Species with fewer than 100 individuals in total are not included.

Table 1. Number of mosquitoes per species collected during June, July, and August 2000-2002 in six wetlands in the Nedre Dalälven region, Central Sweden. Abbreviations are given for the common species (>100 individuals) included in the RDA diagram.

		Wet meadows			Swamps			Bogs			
Species	Abbrev	2000	2001	2002	2000	2001	2002	2000	2001	2002	Total
Ae. cinereus Meigen	cin	33,242	7,505	3,799	25,051	7,141	3,880	1,446	15	147	82,226
Ae. rossicus D.G.M.	ross	16,606	51	2,605	60,240	7,618	3,479	3,190	1	32	93,822
Ae. vexans (Meigen)	vex	230	42	137	97	181	840	137	4	542	2,210
Oc. annulipes (Meigen)	annu	364	77	18	247	247	63	31	24	14	1,084
Oc. cantans (Meigen)	can	12,464	2,377	616	1,068	1,057	1,185	33	15	8	18,823
Oc. cataphylla Dyar		0	0	0	0	0	1	0	10	2	13
Oc. communis (DeGeer)	com	3,898	3,650	2,650	4,897	5,279	3,849	830	2,173	596	27,822
Oc. detritus (Haliday)		0	1	0	0	2	0	0	0	0	3
Oc. diantaeus HD & K	dia	12	37	32	19	249	1,585	2	15	12	1,964
Oc. excrucians (Walker)		7	0	0	7	1	0	0	0	0	14
Oc. intrudens Dyar	intr	11,352	1,285	247	20,296	8,573	4,767	2,056	1,035	252	49,864
Oc. pullatus (Coquillett)		0	0	0	0	0	0	3	0	0	3
Oc. punctor (Kirby)	pun	5,870	1,586	427	1,333	805	496	2,251	1043	233	14,044
Oc. sticticus (Meigen)	stic	192,195	2,325	7,883	367,240	187,555	54,275	124,357	11,403	9,407	956,639
An. claviger (Meigen)	clav	13	3	21	20	7	53	0	0	14	131
An. maculipennis Meigen s.l.	mac	68	12	44	0	4	9	0	0	0	138
Cq. richiardii (Ficalbi)	rich	536	1,790	1,309	18	252	615	335	493	418	5,766
Cs. alaskaensis (Ludlow)	alas	22	4	2	5	8	0	2	1	0	44
Cs. bergrothi (Edwards)		0	0	1	0	0	2	2	5	4	14
Cs. morsitans (Theobald)	mors	320	28	61	407	35	40	314	21	42	1,268
Cs. ochroptera Peus		3	0	0	0	0	4	0	5	1	12
*Cx. pipiens/torrentium**	pip	21	28	52	36	54	21	29	27	45	312
Total		276,240	18,937	18,414	480,495	218,708	74,420	134,338	15,736	11,245	1,248,533

* Females of *Cx. pipiens pipiens* L. and *Cx. torrentium* Martini are not distinguishable to species based on morphology and are therefore reported as *Cx. pipiens/torrentium*.

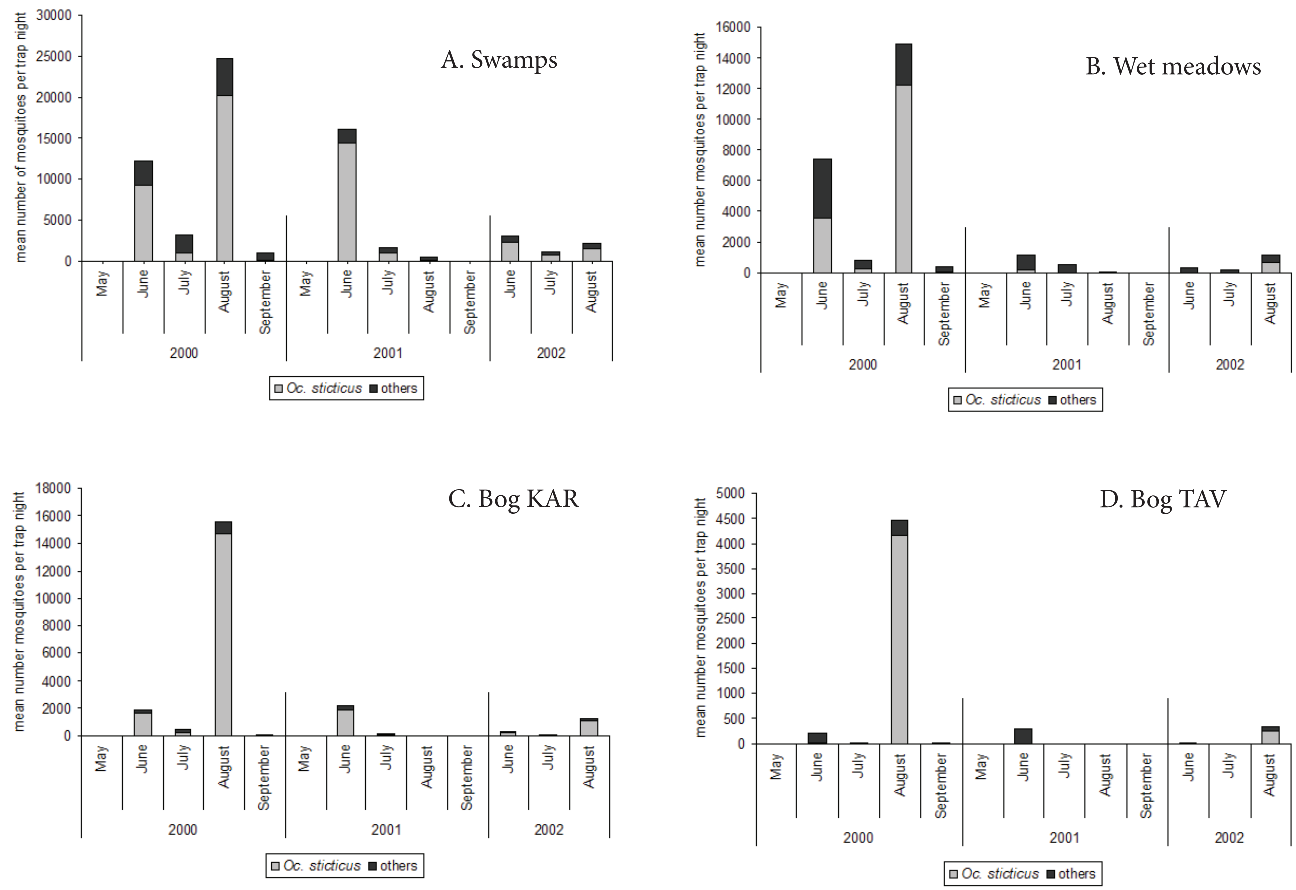

Figure 5. Seasonal variation of mean mosquito numbers per trap night and percentage of *Ochlerotatus sticticus* during three years per wetland type. The results for the two bogs are shown separately.

produced, beside *Oc. sticticus* and *Ae. cinereus,* mostly *Oc. communis*. The two bogs are shown separately since they did not cluster together for all years. Both bogs had high numbers of mosquitoes in August 2000 dominated by *Oc. sticticus* (94 and 93%, respectively). The bog KAR was dominated by *Oc. sticticus* in all years with peaks in June and August 2000, June 2001, and August 2002. The bog TAV at greater distance from Lake Färnebofjärden had rather low numbers of mosquitoes except in August 2000. This bog was dominated by *Oc. communis* and *Oc. punctor.*

In 2000 and 2001, additional sampling was conducted in May and September. Mosquito numbers were low during these months. These samples added up to three species for each wetland type in comparison with sampling from June to August. In 2000, two species could be added to the species list for all wetlands when including samples from May and September, *Ochlerotatus cataphylla* Dyar (one individual) and *Oc. hexodontus* Dyar (two individuals). In 2001, 21 species were recorded in total for both scenarios. Among the species most likely to be missed when sampling from June to August were *Culiseta bergrothi* (Edwards), *Cs. ochroptera* Peus, and *Anopheles maculipennis* s.l.

DISCUSSION

The number of mosquito species and the species composition of a wetland type were similar in the three years of our study, whereas mosquito populations showed large differences between years. This indicates that there is a certain species pool available in a wetland, but that the final mosquito assemblage depends on the local hydrological conditions, together with other factors like flooding in adjacent areas and input of species from such areas. In a study in Florida, Hribar (2005) also found stable species compositions with seasonal variation in relative abundances.

Our results showed a correlation of mosquito assemblages with wetland type together with an annual variation, reflecting variations in flooding. Hydrological conditions varied both between the years and between the wetland types. The swamps adjacent to Lake Färnebofjärden were subject to most flooding events in comparison with the other wetlands. Mosquito production was influenced by the extent of flooding and previous precipitation. Our sampling years included the year 2000 with extreme flood situations. In 2000, there were two large floods affecting both Lake

Färnebofjärden and Lake Hedesundafjärden. In this year, large numbers of mosquitoes were sampled in all wetlands including the bogs located at some distance (approximately four and 14 km, respectively) from Lake Färnebofjärden and not subject to floods.

The seasonal variation of mosquito abundance was rather similar during the three study years, with mosquito peaks in June and/or August. This pattern followed the occurrence of flood events, as could be expected (Merdic and Lovakovic 2001).

The predominant species, *Oc. sticticus,* had a strong influence on the entire study. *Oc. sticticus* is known for its long-range dispersal ability and has been shown to disperse at least 10 km from larval sites (Brust 1980). In our study, the population of *Oc. sticticus* was extremely high in 2000 and as a result, the whole region experienced enormous numbers of *Oc. sticticus,* with even the bogs being invaded by this species. This unforeseen mass production of *Oc. sticticus* had great impact on our data. Mosquito assemblages were rather similar in all wetland types in 2000. In 2001, the wet meadows were less flooded and thus less dominated by *Oc. sticticus*. The bog Tavelmuren, approximately 14 km from the river, had a mosquito species composition in 2001 dominated by snow melt mosquito species. In bog pools, mainly larvae of *Oc. communis* and *Oc. punctor* would be expected (Brummer-Korvenkontio et al. 1971). The bog, at a distance of 4 km from the River Dalälven, had a species composition influenced by that proximity.

Collections restricted to the core of the mosquito season (June to August) in northern climates gave representative samples of the mosquito fauna but missed some early or rare species. However, it is rarely cost effective to record every species in an assemblage, especially in situations with high dominance of single species (Magurran 2004), which is often the case with mosquitoes (Schäfer and Lundström 2001).

Mosquito faunas are often influenced by large rivers with adjacent lowlands that flood regularly, with *Oc. sticticus* or *Ae. vexans* as the dominant species in Europe (Becker and Ludwig 1981, Merdic and Lovakovic 2001, Minar et al. 2001). Large numbers of *Oc. sticticus* in the swamps or wet meadows adjacent to the River Dalälven were thus not surprising, although no previous record of the high numbers of this species in this area existed. In a study by Jaenson (1986) during September 1985, *Ae. rossicus* was the most abundant and annoying species, followed by *Oc. sticticus.* Blackmore and Dahl (2002) sampled in July and August 1998 and their collections in CDC traps were dominated by *Coquillettidia richiardii* (21%) and *Oc. sticticus* (20%) but mosquito numbers were low (mean number of 160 mosquitoes per trap night) compared to our collections (mean number of 17,945 mosquitoes per trap night in a swamp in 2000). According to local residents, severe mosquito nuisance has occurred irregularly during decades. The study documented tremendously high mosquito abundances with up to 62,100 mosquitoes in one trap and night and identified the major nuisance species. These data provided the basis for the initiation of a mosquito control project in the region.

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REFERENCES CITED

Baev, P.V. and L.D. Penev. 1995. BIODIV. Program for calculating biological diversity parameters, similarity, niche overlap, and cluster analysis. Exeter Software. Setauket, NY.

Becker, N. and H.W. Ludwig. 1981. Untersuchungen zur Faunistik und Ökologie der Stechmücken (Culicinae) und ihrer Pathogene im Oberrheingebiet. Mitt. Dtsch. Ges. Allg. Angew. Entomol. 2: 186-194.

Blackmore, M.S. and C. Dahl. 2002. Field evaluation of a new surveillance trap in Sweden. J. Am. Mosq. Contr. Assoc. 18: 152-157.

Brummer-Korvenkontio, M., P. Korhonen, and R. Hämeen-Anttila. 1971. Ecology and phenology of mosquitoes (Dipt, Culicidae) inhabiting small pools in Finland. Acta Ent. Fenn. 28: 51-73.

Brust, R.A. 1980. Dispersal behavior of adult *Aedes sticticus* and *Aedes vexans* (Diptera: Culicidae) in Manitoba. Can. Entomol. 112: 31-42.

Gleiser, R.M., G. Schelotto, and D.E. Gorla. 2002. Spatial pattern of abundance of the mosquito, *Ochlerotatus albifasciatus*, in relation to habitat characteristics. Med. Vet. Entomol. 16: 364-371.

Gutsevich, A.V., A.S. Monchadskii, and A.A. Shtakel'berg. 1974. Diptera. Mosquitoes, Family Culicidae. Keter Press, Jerusalem. 408 pp.

Hribar, L.J. 2005. Relative abundance of mosquito species (Diptera: Culicidae) on Big Pine Key, Florida, U.S.A. J. Vector Ecol. 30: 322-327.

Jaenson, T.G.T. 1986. Massförekomst av *Aedes rossicu*s och andra stickmyggor vid Dalälven hösten 1985. Ent. Tidskr. 107: 51-52.

Jaenson, T.G.T., B. Niklasson, and B. Henriksson. 1986. Seasonal activity of mosquitoes in an Ockelbo disease endemic area in central Sweden. J. Am. Mosq. Contr. Assoc. 2: 18-28.

Keddy, P.A. 2000. *Wetland Ecology. Principles and Conservation.* Cambridge University Press, Cambridge. 614 pp.

Krebs, C.J. 1998. Ecological methodology, Exeter Software, New York.

Krebs, C.J. 1999. *Ecological Methodology.* Benjamin/ Cummings, Menlo Park. 620 pp.

Magurran, A.E. 2004. *Measuring Biological Diversity.* Blackwell Publishing, Malden. 256 pp.

Margalit, J., C. Dimentman, and J. Danon. 1987. Distribution patterns and population dynamics of adult mosquitoes (Diptera: Culicidae) in southern Israel. Bull. Entomol. Res. 77: 477-486.

Merdic, E. and T. Lovakovic. 2001. Population dynamic of *Aedes vexans* and *Ochlerotatus sticticus* in flooded areas of the River Drava in Osijek, Croatia. J. Am. Mosq. Contr. Assoc. 17: 275-280.

Minar, J., I. Gelbic, and J. Olejnicek. 2001. The effect of floods on the development of mosquito populations in the middle and lower river Morava Regions. Acta Universitatis Carolinae Biologica 45: 139-146.

Mitsch, W.J., R.H. Mitsch, and R.E. Turner. 1994. Wetlands of the old and new worlds: ecology and management. In: W.J. Mitsch, (ed.) *Global Wetlands: Old World and New*. pp. 3-56. Elsevier Science, Amsterdam.

Mohrig, W. 1969. Die Culiciden Deutschlands. Untersuchungen zur Taxonomie, Biologie und Ökologie der einheimischen Stechmücken. VEB G. Fischer Verlag, Jena. 258 pp.

Reinert, J.F. 2000. New classification for the composite genus *Aedes* (Diptera: Culicidae: Aedini), elevation of subgenus *Ochlerotatus* to generic rank, reclassification of the other subgenera, and notes on certain subgenera and species. J. Am. Mosq. Contr. Assoc. 16: 175-188.

Schäfer, M. and J.O. Lundström. 2001. Comparison of mosquito (Diptera: Culicidae) fauna characteristics of forested wetlands in Sweden. Ann. Entomol. Soc. Am. 94: 576-582.

Schäfer, M.L., E. Lundkvist, J. Landin, T.Z. Persson, and J.O. Lundström. 2006. Influence of landscape structure on mosquitoes (Diptera: Culicidae) and dytiscids (Coleoptera: Dytiscidae) at five spatial scales in Swedish wetlands. Wetlands 26: 57-68.

Service, M.W. 1993. Mosquito ecology: Field sampling methods. Chapman & Hall, London.

StatSoft Inc. 2005. STATISTICA (data analysis software system). Tulsa.

ter Braak, C.J.F. and P. Smilauer. 2002. CANOCO Reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY. 499 pp.

Wekesa, J.W., B. Yuval, R.K. Washino, and A.M. d. Vasquez. 1997. Blood feeding patterns of *Anopheles freeborni* and *Culex tarsalis* (Diptera: Culicidae): effects of habitat and host abundance. Bull. Entomol. Res. 87: 633-641.

Wood, D.M., P.T. Dang, and R.A. Ellis. 1979. *The Mosquitoes of Canada. Diptera: Culicidae.* Can. Dep. Agric. Publ., Ottawa. 390 pp.

Zhong, H., Z. Yan, F. Jones, and C. Brock. 2003. Ecological analysis of mosquito light trap collections from West Central Florida. Environ. Entomol. 32: 807-815.