# SEASONAL ACTIVITY OF MOSQUITOES IN AN OCKELBO DISEASE ENDEMIC AREA IN CENTRAL SWEDEN

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ABSTRACT. In the Sässman area, province of Hälsingland, Sweden, mosquitoes were sampled in 1983 from aquatic habitats, overwintering sites, cattle sheds, human bait, with UV-light traps, rabbit-, guinea-pig-, hen-, dove- and unbaited suction traps and similarly baited net traps.

*Anopheles beklemishevi, An. messeae, Aedes cantans, Ae. cataphylla, Ae. cinereus, Ae. communis, Ae. diantaeus, Ae. excrucians, Ae. hexodontus, Ae. intrudens, Ae. leucomelas, Ae. pionips, Ae. punctor, Ae. vexans, Culex pipiens, Cx. torrentium, Cx. territans, Culiseta alaskaensis, Cs. bergrothi, Cs. morsitans, Cs. ochroptera* and *Mansonia richiardii* were recorded as new to the province. Data are presented on the ecology including seasonal abundance and seasonal blood-feeding activity of each species.

Ockelbo disease, caused by a virus indistinguishable from Sindbis virus, is prevalent amongst humans in the study area. The ecological and behavioral potential of species of *Culex, Culiseta* and *Aedes* to transmit the virus is discussed.

## INTRODUCTION

Human cases of Ockelbo disease were first recognized in Sweden about two decades ago. Since then the disease has been prevalent, particularly in the southern and coastal provinces of North Sweden (Norrland). The syndrome (arthralgia, myalgia and exanthema) is usually benign and of short duration. A disease with similar symptoms has been described from Finland and the western USSR. Nearly all clinical cases have appeared during August and September. Epidemiological data suggested that the infection is caused by a mosquito-borne virus (Skogh and Espmark 1982, Espmark and Niklasson 1984, Lvov et al. 1984).

A virus closely related to or identical with Sindbis virus (*Alphavirus,* Togaviridae) was isolated by Niklasson et al. (1984) from a pool of *Culiseta* mosquitoes collected in August 1982 in the Sässman area, province of Hälsingland, Sweden (Fig. 1). Virological data indicated that this virus isolate, designated Edsbyn 5/82, is the causative agent of Ockelbo disease.

The Sässman area was chosen as a study site because several cases of Ockelbo disease had occurred there in 1981–82. Also, the area has a rich mosquito and bird fauna. The primary aims of the entomological investigations were to obtain information on the ecology and feeding behavior of the potential mosquito vectors of Sindbis virus and to determine when the mosquitoes contain this virus.

Data on the ecology of mosquitoes in Sweden are sparse. The purpose of this paper is to present information on the seasonal occurrence, seasonal blood-feeding activity and relative abundance of adult mosquitoes found in the Sässman area. This information will form a basis for a better understanding of the ecology of Ockelbo disease, and perhaps other mosquito-borne infections, in Sweden. Results on the host-feeding patterns of the mosquitoes and from the virological studies will be presented in subsequent papers.

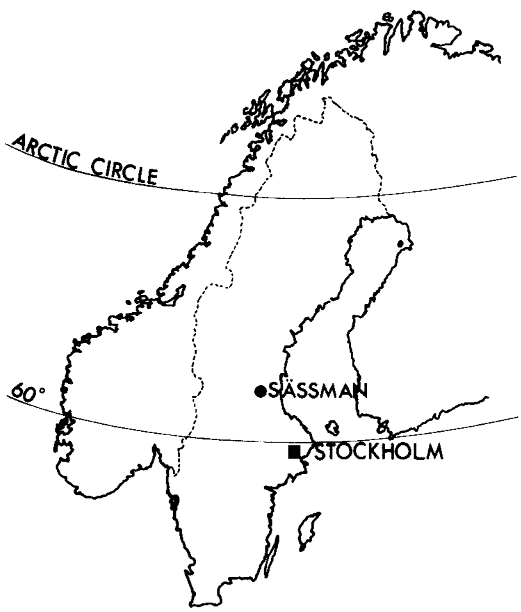

Fig. 1. Map showing location of the Sässman area at Edsbyn, province of Hälsingland, Sweden.

## MATERIALS AND METHODS

Study area. Investigations were carried out from March to October 1983 in the Sässman area 1 km east of Edsbyn village, province of Hälsingland, Sweden. The Sässman area is about 4 km² and is traversed by the Voxnan River, which meanders through a flood plain with small lakes, marshland, mixed stands of

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coniferous and deciduous forests, and agricultural lands. The area is situated in the South Taiga vegetation region. It is part of the coniferous region of northern and central Sweden and is a continuation westwards of the extensive boreal coniferous areas in Finland and the Soviet Union.

Vegetation communities in the study area were, in general, subclimax communities extensively modified (directly or indirectly) by man. Forest vegetation at the main trap site consisted of 3 layers and was dominated by trees (*Betula verrucosa*, silver birch; *Populus tremula*, aspen; *Alnus incana*, grey alder; and *Salix* spp., willow), shrubs or small trees (*Prunus padus*, bird-cherry; *Populus tremula*; and *Sorbus aucuparia*, mountain ash) and large herbs (*Urtica dioeca*, stinging nettle; *Dryopteris spinulosa*, narrow buckler-fern; *Filipendula ulmaria*, meadow-sweet; *Rubus idaeus*, raspberry; *Rosa canina*, dogrose; and *Chamaenerion angustifolium*, fireweed). Dominant plants on the marshy ground near the main trap site included *Salix* spp., *Carex rostrata* (bottle sedge), *Potentilla palustris* (marsh cinquefoil) and *Hippuris vulgaris* (mare's-tail). Vegetation at the edges of the small lake Fällbergstjärn, 200 m south of the main trap site, was dominated by *Scirpus lacustris* (bulrush), *Equisetum fluviatile* (water horsetail) and *Potamogeton* sp. (pondweed). During the study period the pH of the permanent and semipermanent water bodies near the main trap site fluctuated between 4.0–5.5.

More than 170 species of birds have been recorded in the area. About 60 species breed here regularly. Large mammals including cattle (*Bos taurus* L.), roe deer (*Capreolus capreolus* L.) and moose (*Alces alces* L.) are abundant.

Temperature and rainfall data were received from The Swedish Meteorological and Hydrological Institute at Edsbyn.

SAMPLING STRATEGY. To obtain material for the virological studies we attempted to collect large numbers of as many mosquito species as possible. From these collections we also wanted to obtain data on host-feeding patterns, potential host preferences, seasonal abundance and seasonal blood-feeding activity of each species. Several different sampling methods were therefore used. These included: sampling of aquatic stages (to obtain both sexes of species which may not be present in sufficient numbers in other samples, and to study if these specimens had been vertically infected with Sindbis virus); collection of overwintering females (to determine if Sindbis virus survives the winter in adult mosquitoes); collection from cattle sheds (to obtain endophilic, zoophagous mosquitoes); human-bait catches (to obtain anthropophagous species); animal-baited trap collections (to study host-feeding patterns, potential host preferences, seasonal abundance and blood-feeding activity); and UV-light trap collections (to obtain both sexes for virus studies and data on seasonal occurrence). Nearly all non-engorged mosquitoes were processed for virus isolation while all trap-collected, engorged females were processed for host blood meal identification.

One of 2 UV-light traps used was in operation continuously between April 14 and September 28, 1983. Based on the catch-levels in this trap we could estimate when to begin and end the main sampling period using animal-baited traps and a second UV-light trap. These traps were in operation on the same 2–3 days every week between April 26 and September 28. Overwintering females were only sampled before and after the mosquito season. During this season sampling of aquatic stages and from cattle sheds usually took place at 2 week intervals. Standardized human-bait catches were carried out at least once every month from June to September during evenings selected because of favorable weather conditions.

MOSQUITO TRAPS AND HUMAN-BAIT CATCHES. All mosquito trapping (except 1 UV-light trap) and human-bait catches were carried out about 400 m N of the Voxnan River (61° 23'N, 15° 51'E) at an altitude of 150 m above sea level. This site is located about 300 m N of the trap site where a pool of *Culiseta* females, infected with Sindbis virus (isolate Edsbyn 5/82), was collected in 1982 (Niklasson et al. 1984).

Two types of animal-baited traps were used: suction traps (S-traps; Emord and Morris 1982) and net traps (N-traps; Jupp and McIntosh 1967).

The 5 S-traps included one unbaited control trap and 4 baited traps. Baited traps contained either a domestic rabbit, a guinea pig, a dwarf hen (Japanese bantam, *Gallus domesticus* L.) or a domestic dove (*Columba livia* Gmelin). Traps were positioned in a stand of birch trees in a line 1.3 m between each other and 1 m above ground. Trap positions were interchanged each sampling day according to a randomization procedure.

The 6 N-traps were made of white netting (marquisette) and measured 1.5$^3$ m. The net was supported on poles and had a zipper at 1 end to permit access. When set, the sides were rolled up to provide a 0.2 m opening all around the bottom to allow entry of insects (Jupp and McIntosh 1967). Four traps were baited with the same kind of animals as the S-traps while 2 of the N-traps were unbaited. In subsequent calculations only data for one of the 2 unbaited N-traps were used (randomly chosen). The traps were placed in a circle 1 m apart in open woods about 10 m from the nearest S-trap. Every morning each animal with its respective cage was randomly allocated to the N-traps. Every Monday the animals in the S-traps were placed into the N-traps and vice versa.

A UV-light trap (Miniature Black Light Trap, J. W. Hock Co.) was hung 1.8 m above the ground in the forest 7 m from the nearest S-trap.

All the traps were in operation from Monday-Thursday, i.e., three 24-hr periods per week from April 26 to September 28 (except on the first and last week when there were 2 sampling days per week).

A second UV-light trap was positioned in a garden on the southern shore of the Voxnan River 1.3 km SW from the main study site. This trap was operated continuously between April 14 and September 28. All 13 traps were emptied in the mornings.

A human collector was positioned in the forest about 25 m from the main trap site. Mosquitoes were collected from the clothing and exposed parts of the body with plastic tubes. Generally, the females were not allowed to engorge. Mosquitoes were collected during a 3-hr (June 7) or 4-hr (July 10, August 4, August 22 and September 28) period ending at sunset. Additionally, mosquitoes attracted to man were captured with a killing jar or hand net for 15–30 min between 1500 and 2030 hr on other occasions (see Table 1).

Mosquitoes in cattle sheds. Mosquitoes were collected with a battery-powered aspirator from 2 cattle sheds in the Sässman area during the afternoons (5–7 hours before sunset) on March 15, March 29, April 20 and at 2 week intervals from April 27 to September 14. The final collection was on October 22.

Overwintering females. Mosquito females were collected by aspirator from cellars, basements, out-houses and protected shelters under cattle barns in the Sässman area in March, April and October.

Aquatic stages. Mosquito larvae and pupae were sampled with a hand net from 3 water bodies near the main trap site. Sampling was carried out at 2 week intervals from April to August, each time for 15 min from each habitat. Two of the 3 sampling sites dried up in July. Most of the larvae and pupae were reared to adults. A smaller number of 4th instar larvae and larval skins were preserved in 70% ethanol.

Identification of mosquitoes. Because most captured mosquitoes were used for virus isolation, the mosquitoes were frozen alive, stored in air-tight vials at −20°C for a maximum of 2 weeks and then stored at −80°C. Species identification was done on a chill table (+1°–+3°C) using 14 −80x magnification, 1–6 months after collection. Damaged *Aedes* females that could not be identified to species were pooled as unidentified *Aedes* spp. They consisted mainly of black-legged *Aedes*, presumably mainly *Ae. communis* (DeGeer) and *Ae. intrudens* Dyar. The genitalia of males of *Culex* and *Culiseta* were mounted for identification of species. A few individuals from each species collected were pinned for reference use. A small number of females were dissected to determine if they had been inseminated and if they had oviposited. Identification of species of *Anopheles maculipennis* Meigen s.l. was based on the morphology of the eggs (Jaenson et al. 1986).

## RESULTS

Aquatic stages. *Aedes communis* was the most abundant species in the larval stage. This mosquito was present in early May with *Ae. cataphylla* Dyar and *Ae. cinereus* Meigen; in late May and early June with *Ae. cantans* (Meigen),

Table 1. Species composition and dates of occurrence of female mosquitoes attracted to man in the Sässman area in 1983.

| Species | Sampling date: Apr 26 | May 24 | Jun 7 | Jun 8 | Jun 22 | Jul 6 | Jul 10 | Jul 20 | Aug 3 | Aug 4 | Aug 17 | Aug 22 | Aug 31 | Sept 28 | No. | Percent of total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | B | A | B | B | B | A | B | B | A | B | B | B | A | | |
| *An. maculipennis* s.l. | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 |
| *Ae. cantans* | 0 | 0 | 0 | 0 | 1 | 6 | 27 | 2 | 11 | 34 | 4 | 6 | 2 | 0 | 93 | 8.6 |
| *Ae. cinereus* | 0 | 0 | 0 | 0 | 0 | 7 | 123 | 1 | 2 | 20 | 1 | 5 | 2 | 0 | 161 | 14.8 |
| *Ae. communis* | 0 | 0 | 115 | 13 | 0 | 5 | 63 | 0 | 4 | 21 | 0 | 4 | 1 | 0 | 226 | 20.8 |
| *Ae. diantaeus* | 0 | 0 | 0 | 0 | 0 | 3 | 23 | 0 | 1 | 7 | 0 | 2 | 0 | 0 | 36 | 3.3 |
| *Ae. excrucians* s.l. | 0 | 0 | 0 | 0 | 5 | 37 | 114 | 1 | 13 | 34 | 9 | 6 | 0 | 0 | 219 | 20.2 |
| *Ae. intrudens* | 0 | 0 | 242 | 0 | 35 | 15 | 16 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 312 | 28.7 |
| *Ae. punctor* s.l. | 0 | 0 | 3 | 1 | 1 | 1 | 21 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 33 | 3.0 |
| *Cs. alaskaensis* | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.5 |

A Standardized method with continuous sampling for 3 or 4 hours up to sunset, of mosquitoes sitting on the collector.

B Not standardized sampling method. Collection for 15–30 min between 1500 and 2030 hrs by net-catching mosquitoes flying around or sitting on the collector.

*Ae. cinereus, Ae. diantaeus* Howard, Dyar and Knab, *Ae. intrudens,* and *Ae. punctor* (Kirby) s.l.; and in late June with *Ae. cantans, Ae. diantaeus, Ae. excrucians* (Walker) s.l., and *Ae. punctor* s.l. (Table 2).

Table 2. Mosquitoes collected as larvae and/or pupae at 3 sites in the Sässman area during biweekly sampling from April to August 1983.

| Species | Sampling date | Total number emerged |
|---|---|---|
| *Ae. cantans* | May 24–June 21 | 123 |
| *Ae. cataphylla* | May 10–24 | 26 |
| *Ae. cinereus* | May 10–June 8 | 6 |
| *Ae. communis* | May 10–June 21 | 1,245 |
| *Ae. diantaeus* | June 8–21 | 13 |
| *Ae. excrucians* s.l. | May 24–June 21 | 6 |
| *Ae. intrudens* | May 24–June 8 | 36 |
| *Ae. pionips* | June 8–21 | 4 |
| *Ae. punctor* s.l. | May 24–June 21 | 23 |
| *Cx. territans* | July 5 | 5 |
| *Cs. alaskaensis* | June 21–July 20 | 5 |
| *Cs. bergrothi* | August 3 | 4 |
| *Cs. morsitans* | April 20–June 21 | 60 |

Larvae of *Culiseta morsitans* (Theob.) were found during a relatively long period (April-June). *Culex territans* Walker, *Cs. alaskaensis* (Ludlow) and *Cs. bergrothi* (Edwards) were only collected after June 20 in restricted numbers (Table 2). No larvae could be found after August 3.

OVERWINTERING FEMALES. Relatively large numbers (N=351) of inseminated, nulliparous females of *An. maculipennis* s.l. were collected from most of the potential overwintering sites investigated.

One female of *Cs. alaskaensis* was found in a basement on March 15 and one female of *Cx. territans* was found in a cellar on March 16.

Four other species that hibernate as adults, *Cx. pipiens* L., *Cx. torrentium* Martini, *Cs. bergrothi* and *Cs. ochroptera* (Peus) were collected in the study area as adults during the warmer part of the year. Despite intensive searches of potential sites, we were unable to find overwintering females of these species.

MOSQUITOES IN CATTLE SHEDS. Six species or species groups were collected in the cattle sheds between April 27 and September 14 (Table 3).

Females of the *An. maculipennis* complex dominated the mosquito fauna. They appeared in late April and increased in numbers during May. The summer generation started to emerge in the latter part of June. The last 2 gonoactive females were collected on September 14. Both females were engorged with blood and developed their follicles beyond stage 2. On the same day non-gonoactive females were caught in the cattle sheds.

Seventy-seven egg batches were obtained from the *An. maculipennis* s.l. females collected between April 27 and July 6 (Table 3). The egg morphology revealed that 10% were *An. beklemishevi* Steg. & Kab. and 90% were *An. messeae* Falleroni. Eggs of *beklemishevi* were obtained from females collected between April 27 and June 8. These females produced 32 egg batches, 8 of which were identified as *beklemishevi* and the remaining as *messeae*.

Although *An. beklemishevi/messeae* generally dominated the mosquito fauna in the cattle sheds, a large number of *Aedes* females, especially *Ae. intrudens,* were also present in June (Table 3).

MOSQUITOES ATTRACTED TO MAN. Table 1 lists the mosquitoes that were attracted to man. In April and May low numbers of *An. maculipennis* s.l. and *Cs. alaskaensis* were collected. In early June large numbers of *Ae. intrudens* and *Ae. communis* were captured. In early July the composition of the samples had changed with a high prevalence of *Ae. excrucians* s.l., *Ae. cinereus* and *Ae. communis* and a lower prevalence of *Ae. cantans, Ae. intrudens, Ae. diantaeus* and *Ae. punctor* s.l. In August the most abundant species attracted to man were *Ae. excrucians* s.l. and *Ae. cantans* followed by *Ae. communis, Ae. cinereus, Ae. diantaeus, Ae. punctor* s.l. and *Ae. intrudens,* All species listed in Table 1, except *An.*

Table 3. Female mosquitoes collected in 2 cattle sheds in the Sässman area between April 27 and September 14, 1983.

| | Sampling date | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Apr 27 | May 11 | May 24 | Jun 8 | Jun 21 | Jul 6 | Jul 20 | Aug 3 | Aug 17 | Aug 31 | Sept 14 | No. | Percent of total |
| *An. maculipennis* s.l. | 40 | 134 | 266 | 58 | 69 | 197 | 17 | 4 | 5 | 1 | 6 | 797 | 85.9 |
| *Ae. communis* | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0.9 |
| *Ae. excrucians* s.l. | 0 | 0 | 0 | 0 | 10 | 5 | 1 | 0 | 0 | 0 | 0 | 16 | 1.7 |
| *Ae. intrudens* | 0 | 0 | 0 | 65 | 32 | 5 | 0 | 0 | 0 | 0 | 0 | 102 | 11.0 |
| *Ae. punctor* s.l. | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.4 |
| *Cs. bergrothi* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 |

*maculipennis* s.l., were observed to ingest human blood.

MOSQUITO FEMALES IN TRAPS. The monthly occurrence and relative abundance of species captured in each of the 3 types of traps are shown in Table 4. All species listed are new records for the province of Hälsingland (Dahl 1977). The S-traps collected the largest total number of both species and specimens. All species or species groups captured with any other sampling method were, except *Ae. cataphylla*, also caught with the S-traps. Species captured by S-traps but not by N-traps included *An. maculipennis* s.l., *Ae. vexans* Meigen and *Cs. alaskaensis*.

Due to mechanical failures with the S-traps, data for June 8, July 13–14 and September 21 were excluded from the calculations. Unidentified *Aedes* females numbered 27 in N-traps and 288 in S-traps; these were omitted from all calculations except Fig. 2.

Comparatively few mosquitoes were captured with UV-light traps. Four species, *Ae. leucomelas* (Meig.), *Ae. vexans*, *Cs. ochroptera* and *Mansonia richiardii* Ficalbi, were captured in low numbers with at least one type of animal-baited trap but not with UV-light traps. *Aedes cinereus*, which was abundant in the animal-baited trap samples, was also absent from light trap samples.

Figure 2 shows the seasonal succession and

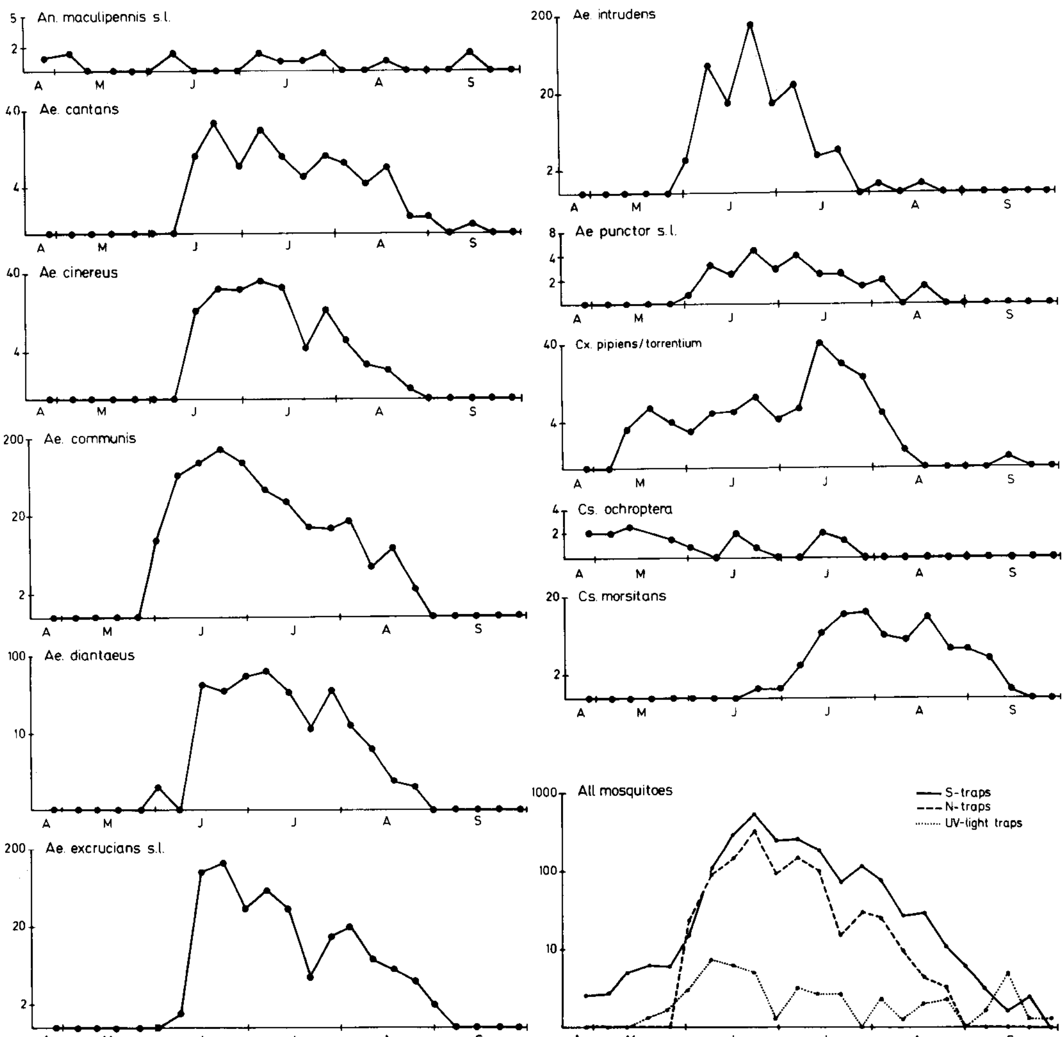


Fig. 2. Relative abundance of mosquito females caught in S-traps between April and September 1983 in the Sässman area. The number of females (y-axis) captured in each 2–3-day period was transformed to Williams' mean. The three curves for all species combined (bottom right) include unidentified *Aedes* spp. Total numbers of mosquitoes collected are shown in Table 4.

Table 4. Species composition and monthly occurrence of mosquito females in 3 different types of traps set in the Sässman area from April to September (AMJJAS) 1983.

| Species | S-traps[1] | | | | | | (N=5,296 ♀♀) | N-traps[2] | | | | | | (N=3,050 ♀♀) | UV-light traps[3] | | | | | | (N=142 ♀♀) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | M | J | J | A | S | % of N | A | M | J | J | A | S | % of N | A | M | J | J | A | S | % of N |
| *An. maculipennis* s.l. | + | + | + | + | + | + | 0.2 | – | – | – | – | – | – | 0 | – | + | + | + | + | + | 12.0 |
| *Ae. cantans* | – | – | + | + | + | + | 5.2 | – | – | + | + | + | – | 3.8 | – | – | + | + | – | + | 2.8 |
| *Ae. cinereus* | – | – | + | + | + | – | 7.0 | – | – | + | + | + | – | 6.5 | – | – | – | – | – | – | 0 |
| *Ae. communis* | – | – | + | + | + | – | 27.0 | – | – | + | + | + | – | 29.7 | – | – | + | + | + | – | 29.6 |
| *Ae. diantaeus* | – | – | + | + | + | – | 15.5 | – | – | + | + | + | – | 6.9 | – | – | + | – | + | – | 2.1 |
| *Ae. excrucians* s.l. | – | – | + | + | + | – | 21.7 | – | – | + | + | + | – | 25.8 | – | – | + | + | + | + | 19.7 |
| *Ae. intrudens* | – | – | + | + | + | – | 13.1 | – | – | + | + | + | – | 20.5 | – | – | + | – | – | – | 8.5 |
| *Ae. leucomelas* | – | – | + | – | – | – | 0.04 | – | – | + | + | – | – | 0.2 | – | – | – | – | – | – | 0 |
| *Ae. punctor* s.l. | – | – | + | + | + | – | 0.9 | – | – | + | + | + | – | 6.4 | – | – | + | + | – | – | 4.2 |
| *Ae. vexans* | – | – | + | – | – | – | 0.02 | – | – | – | – | – | – | 0 | – | – | – | – | – | – | 0 |
| *Cx. pipiens/torrentium* | – | + | + | + | + | + | 4.9 | – | – | + | + | – | – | 0.1 | – | – | + | + | + | + | 4.2 |
| *Cx. territans* | – | – | + | + | – | – | 0.04 | – | – | + | – | – | – | 0.07 | – | – | + | – | – | – | 0.7 |
| *Cs. alaskaensis* | – | + | + | + | – | – | 0.15 | – | – | – | – | – | – | 0 | – | + | + | – | + | + | 6.3 |
| *Cs. bergrothi* | – | + | + | + | – | – | 0.08 | – | – | + | – | – | – | 0.03 | – | – | – | – | + | – | 1.4 |
| *Cs. morsitans* | – | – | + | + | + | + | 3.2 | – | – | – | – | + | – | 0.03 | – | – | – | + | + | + | 8.5 |
| *Cs. ochroptera* | + | + | + | + | – | – | 0.4 | – | – | + | – | – | – | 0.03 | – | – | – | – | – | – | 0 |
| *Ma. richiardii* | – | – | – | + | + | – | 0.4 | – | – | – | + | – | – | 0.03 | – | – | – | – | – | – | 0 |

[1] Four animal-baited and 1 unbaited suction trap. (288 unidentified, badly rubbed *Aedes* spp. not included in the data).
[2] Four animal-baited and 1 unbaited net trap. (27 unidentified, badly rubbed *Aedes* spp. not included in the data).
[3] Two black light traps.

relative abundance of the more abundant female mosquitoes captured with the S-traps. Similar information is also given for all species combined with respect to trapping method. Both types of animal-baited traps captured the greatest number of mosquitoes, mainly *Ae. communis, Ae. excrucians* s.l. and *Ae. intrudens*, during the period June 21–23 (Fig. 2). During the last week of June and first week of July, rainy and relatively cool weather prevailed. Adverse weather conditions may explain the drop in catch levels for all 3 types of traps during the period June 28–30. A similar drop in catch levels around July 20 may be explained by the low air temperatures and prevailing strong winds.

## DISCUSSION

GENERAL. This study is the first where the mosquito fauna at a locality in Scandinavia has been sampled regularly throughout the mosquito season. No previous records exist of Culicidae from Hälsingland (Dahl 1977). The following species found in the study area are the northernmost records for Sweden: *Ae. cataphylla, Ae. leucomelas, Cx. territans,* and *Cx. torrentium.* The record of *Ae. pionips* is the southernmost one for Sweden, the record of *Mansonia richiardii* is the northernmost one for Fennoscandia, and the record of *Culiseta ochroptera* is the first one for the Scandinavian peninsula.

The relatively high number of species recorded in this study is presumably a reflection of the use of many sampling methods and the varied ecology of the Sässman area. Similar localities in this part of Sweden may thus have an equally high number of mosquito species.

The data should not be used for generalizations on seasonal abundance of mosquitoes to other years, because the weather in 1983 was exceptional. March to June and September had a rainfall much higher than average whereas July and August were very dry. Therefore, almost no hatching of *Aedes* eggs could take place in July and August. It is likely that the mortality rates in the adult populations during these months were higher than normal.

All the species captured in the human-bait catches (Table 1) have previously been recorded as man-biting in Fennoscandia (Natvig 1948, Utrio 1979, Mehl et al. 1983). Only about half of the species caught in the traps were present in the human-bait samples. All the species listed in Table 3 are known to feed on domestic animals (see Mehl et al. 1983 for references).

Different trapping techniques usually sample different segments of a population. Light traps are highly selective for species, which is confirmed by our results (Table 4), and also for physiological state and age of females (Service 1976).

In central and northern Sweden around midsummer the scotophase is very short. This may explain why peak catch-level with the UV-light traps was not attained around midsummer as was the case with the S- and N-traps (Fig. 2).

ECOLOGY OF MOSQUITO SPECIES. Data obtained on the ecology of each species are compared here with previously published data, with emphasis on seasonal occurrence (Fig. 2) and seasonal blood-feeding activity of the females.

*Anopheles maculipennis* s.l.—Large numbers of blood-fed, gonoactive females were present in the cattle sheds between late April and mid-September. The low numbers captured in the field (April 27–September 28) are presumably a reflection of the endophagous habits of the females. Males were caught between June 29 and September 21 mainly with light traps but also in the cattle sheds, S-traps and N-traps. Both species hibernate as inseminated, nulliparous females. Our data suggested that in 1983 the species had one overwintering and one summer generation. The presence of *An. beklemishevi* in Sweden has only recently been confirmed (Jaenson et al. 1986).

*Aedes cantans*—The species was abundant. Females and males were captured in all 3 types of traps (females: June 14–September 15, males: June 9–July 26). Engorged females were present in the samples between June 16 and August 16. Blood-seeking females were relatively abundant in the human-bait catches in July and August.

Our data suggest that *Ae. cantans* was univoltine in the study area, which supports the conclusions of Mohrig (1969) and Service (1977). A univoltine breeding pattern seemed to be typical for most or all of the *Aedes* species in the study area. In any case the dry weather in July and August drastically reduced the likelihood for a second generation to appear.

*Aedes cataphylla*—This species appeared to be rare in the area and was only found in the larval stage (in May). It is considered to be an early spring species with one annual generation, although hatching sometimes may take place, to a small extent, in autumn (Brummer-Korvenkontio et al. 1971).

*Aedes cinereus*—Females were captured in the animal-baited traps between June 14 and August 24. This species was very abundant in the human-bait catches but was absent from collections with light traps and in cattle sheds.

Among the more abundant species of *Aedes, cinereus* was the last one to appear in the summer. This agrees with the results of

Brummer-Korvenkontio et al. (1971). Many authors consider this species to be multivoltine (Detinova 1968, Mohrig 1969, Gutsevitch et al. 1974, Wood et al. 1979) whereas Service (1969) concluded that in England the species is univoltine. The varying results may, partly, be due to the fact that in England only *Ae. cinereus* s.str. occurs while in continental Europe and the USSR at least two other species, very closely related to *cinereus*, are also present. It may be possible that the seasonal activity patterns differ between these species. In North America, however, it has been shown that about half the eggs laid by *Ae. cinereus* were nondiapausing eggs that hatched without cold conditioning (Wood et al. 1979). Our results do not show whether *cinereus* had a second generation.

The flight and biting behavior of *Ae. cinereus* is different from those of other species of *Aedes* in the study area. The females mainly attack the lower extremities and usually fly very close to the ground (Mohrig 1969), at least during daytime (Natvig 1948). The fact that no males were captured in any of the traps and that no females were caught in the light traps may be further reflections of the peculiar behavior of *cinereus*.

*Aedes communis*—Amongst all of the female mosquitoes caught in traps, this was the most numerous species. Females and males were present between May 31–August 25 and May 26–July 13, respectively. Trap-caught, engorged females were present between June 2 and August 11. *Aedes communis* was the second most numerous species in the human-bait catches in early June. It was still biting man in late August. In wet summers *communis* may have a second population peak due to a second generation (Gutsevitch et al. 1974) or delayed hatch (Detinova 1968).

Lvov et al. (1984) recently isolated an agent, possibly identical with the Okelbo disease agent, from a pool of *Aedes* mosquitoes collected in central Karelia in 1983. About 80% of the mosquitoes were *Ae. communis*. They concluded that *Ae. communis* probably is the vector of the Karelia fever.

*Aedes diantaeus*—Adult females and males were collected in all 3 trap-types (females: June 2–August 23, males: June 8–July 19). Large numbers of both sexes were captured in the S-traps. Blood-filled females were present in the trap samples between June 15 and August 3.

*Aedes diantaeus* is considered to be relatively rare in Denmark and Sweden (Natvig 1948). It had previously only been recorded from 5 Swedish provinces from Scania in the south, to Lapland in the north (Dahl 1977). This suggests that *Ae. diantaeus* may have a scattered distribution throughout Sweden, as in Finland (Utrio 1979). There is usually one annual generation with flight starting later than many other species of *Aedes* (Gutsevitch et al. 1974) which agrees with our data.

*Aedes excrucians* s.l., *Ae. excrucians* s.str. and a similar but apparently different species were present in the samples. No regular attempts were made to distinguish between the two species. They are, therefore, treated together as *excrucians* s.l. In the animal-baited traps both sexes were captured in large numbers, whereas in the light-traps both sexes were present only in low numbers. In the traps, females and males were caught during June 9–September 13 and June 9–July 19, respectively. In the trap samples blood-fed females were present from June 14 to August 18. *Aedes excrucians* s.str. has normally only one generation per year (Gutsevitch et al. 1974).

*Aedes intrudens*-Both sexes were captured with all 3 types of traps (females: May 31–August 17, males: June 1–22). Blood-filled females were trap-caught between June 7 and August 4. *Aedes intrudens* was the most abundant species in the human-bait catches in June. It was also the most numerous culicine species in the cattle sheds in June. In agreement with other observations (Mohrig 1969, Gutsevitch et al. 1974, Wood et al. 1979), *Ae. intrudens* had only one generation and the adults appeared to be short-lived. The endophilic habit of *intrudens* (Natvig 1948, Wood et al. 1979) is confirmed by the present records of large numbers of *intrudens* in the cattle sheds.

*Aedes leucomelas*—This species is considered rare in Sweden (Natvig 1948, Dahl 1977) as was noted in the Sässman area. Only 7 females were caught in the S-traps and N-traps between June 2 and July 19. It is regarded as one of the earlier species of *Aedes* to appear and the flight of the single annual generation ends in the middle of the summer (Mohrig 1969, Gutsevitch et al. 1974). This agrees with our data.

*Aedes pionips*—Only 4 larvae were found (in June).

*Aedes punctor* s.l.—Apart from typical specimens of *punctor* s.str., females with an extensively scaled probasisternum, a large patch of white scales at the base of the costal vein and apically white-scaled abdominal sterna were found. These females were identified as *Ae. hexodontus* Dyar. However, intermediate forms were seen and no regular attempts were made to distinguish between the two species. They are, therefore, treated together as *Ae. punctor* s.l. Aquatic stages of *punctor* s.str. were found in May and June. Females occurred in the trap-samples between May 31 and August 16. In these samples, blood-fed females were present between June 14 and July 14. However, the species was present in the human-bait samples between June 7 and August 4. In the Sässman area there seemed to be only one generation of *punctor* s.l. although a second population peak, possibly due to delayed hatching of eggs, may occur in some areas (Brummer-Korvenkontio et al. 1971, Gutsevitch et al. 1974).

*Aedes vexans*—Only one specimen was captured, this being a female caught in the rabbit-baited S-trap on June 21. There are only a few previous records of this species from Fennoscandia (Finland and Scandinavia) (Natvig 1948, Dahl 1977, Utrio 1979).

*Culex pipiens* and *Cx. torrentium*—Examination of male terminalia revealed that both *Cx. pipiens* and *Cx. torrentium* occurred in the area. Since it is not possible morphologically to distinguish with certainty individual females of the two species, they are treated together. Females and males were caught in the traps from May 10 to September 15 and July 13 to September 15, respectively. Blood-fed females were only found from May 17 to July 28.

Like other *Culex* species the non-blood fed females overwinter (Wood et al. 1979). After overwintering they feed mainly on birds (Service 1971). Man-biting females of *Cx. pipiens* have not been found in the Sässman area. *Culex pipiens* may have more than one generation annually (Brummer-Korvenkontio et al. 1971). Sindbis virus was isolated from one pool of 50 nonengorged females of *Cx. pipiens* collected with the traps between July 20 and August 3 1983.

*Culex territans*—Females were collected in the traps between June 8 and July 19. One male was caught in a N-trap on July 14. The species appeared to be rare in the study area as in other parts of Sweden.

*Culiseta alaskaensis*—Man-biting females were captured in April and May. Unengorged females were caught in the animal-baited traps between May 10 and July 28. Larvae were found in June and July, and 4 newly emerged females, presumably non-gonoactive and destined to overwinter, were caught in an UV-light trap on September 15. There is only one annual generation (Wood et al. 1979), which conforms to our data. Thus, the females that emerged from the larval samples were destined for hibernation. Our observations, that *Cs. alaskaensis* ingests human blood, appear to be the first ones for the Scandinavian peninsula (Natvig 1948, Mehl et al. 1983).

*Culiseta bergrothi*—Females, presumably blood-seeking, were caught in the animal-baited traps between May 24 and July 13. One female was caught in a cattle shed on June 21. A few larvae were sampled on August 3. Two newly emerged females, presumably destined to overwinter, were caught in August in an UV-light trap.

In the northern part of its geographic range *Cs. bergrothi* has one generation annually. The hibernated females feed mainly on cattle, and sometimes enter cattle sheds (Gutsevitch et al. 1974). These statements conform to the data here obtained. Although *Cs. bergrothi* was not present in the human-bait catches, we have observed this species to ingest human blood in the Uppsala area, central Sweden. The females from the larval samples collected in early August as well as the females captured in August with the light traps were, presumably, nongonoactive females destined to overwinter.

*Culiseta morsitans*—Late instar larvae were sampled between April 20 and June 21. Adult females and males were trap-caught between June 22–September 13 and June 23–September 15, respectively. Blood-fed females were present only during the period 26 July–6 September. The species was caught neither in the cattle sheds nor off human bait.

In contrast to the other species of *Culiseta* in the study area *Cs. morsitans* apparently overwinters in the larval stage. This agrees with other observations on *Cs. morsitans* in northern Europe and Russia (Natvig 1948, Brummer-Korvenkontio et al. 1971, Gutsevitch et al. 1974). In most of Canada, however, *Cs. morsitans* overwinters in the egg stage (Wood et al. 1979). One generation per year seems to be the rule for *Cs. morsitans*. In agreement with our data, Service (1969) and Morris (1984) showed that there was a delay of 5–6 weeks between adult emergence and blood feeding. The females are long lived and capable of producing several egg batches (Wood et al. 1979). Although there are records of *Cs. morsitans* biting domestic mammals and man, this mosquito is essentially a night-biting, avian feeder (Service 1969, 1971; Wood et al. 1979).

The late appearance in the summer of blood feeding *Cs. morsitans* females, their feeding habits and long average life-span may be of considerable importance to the epidemiology of Sindbis virus and other arboviruses. There have been several isolations of Eastern equine encephalitis, which is related to Sindbis virus, from *Cs. morsitans* in the eastern USA. Sindbis virus was isolated from one pool of 24 nonengorged females of *Cs. morsitans* collected in the traps between July 24 and August 3, 1983.

*Culiseta ochroptera*—This species was found to be ornithophilic and probably hibernates in the adult stage as inseminated, nulliparous females (Jaenson et al. 1984). Twenty females were captured in the S- and N-traps between April 28 and July 19. They are the first records of *Cs.*

*ochroptera* from the Scandinavian peninsula. The species was not found in cattle sheds nor in human-bait samples.

According to Gutsevitch et al. (1974) *Cs. ochroptera* prefers birds as host but sometimes bites man. Because *Cs. ochroptera* probably does not feed on blood until after overwintering, i.e. in spring and summer, and due to its relatively low abundance and ornithophagous habits this species may be disregarded as an important link vector of Sindbis virus. However, in view of its ornithophagous habits, *Cs. ochroptera* may be of some importance as a primary (sylvatic) vector of Sindbis virus. The apparently close taxonomic relationship between *Cs. ochroptera* and the Nearctic *Cs. minnesotae* Barr needs further study.

*Mansonia richiardii*—This was a relatively rare species and found only during the period July 12–August 23 as non-engorged females in the S-traps and an N-trap. Near Uppsala, central Sweden we have found this species in horse stables and in human-bait collections.

Apparently *Ma. richiardii* had only one annual generation which conforms to other investigations (Natvig 1948, Service 1969, Gutsevitch et al. 1974). Hibernation occurs in the larval stage and a first batch of eggs may be produced autogenously (Service 1969). Elsewhere in Sweden *Ma. richiardii* sometimes occurs in very large numbers attacking man and domestic animals (Jaenson, unpublished data).

EPIDEMIOLOGICAL IMPLICATIONS. Various ecological factors determine the geographic distribution of Ockelbo disease in humans. On the *a priori* assumption that birds are natural vertebrate hosts of Sindbis virus in Sweden, as they are for other strains of Sindbis virus, ornithophagous mosquitoes are likely to be primary vectors. It may then be assumed that, in spring and early summer, the virus is transmitted in bird populations mainly by *Cx. pipiens/torrentium* and *Cs. ochroptera.* Later in the summer and autumn it is likely that *Cs. morsitans* may be the main vector among birds. This hypothesis is supported by the isolation of Sindbis virus from 2, possibly 3, (single species) pools of nonengorged females of *Cs. morsitans* and *Cx. pipiens* as well as the record of Sindbis virus neutralizing antibodies during August-September in one of the doves used as bait (Niklasson, Jaenson and Espmark unpublished data, Niklasson et al. 1984). The possibility that *Cs. morsitans* transmits Sindbis virus to at least some humans should however, not be dismissed. But the majority of the human infections are probably caused by abundant link vectors, which feed on both birds and man. In late summer *Ae. communis* (Lvov et al. 1984) and other abundant *Aedes* species may be potentially important link vectors. Species of *Aedes* may also be included among potentially important mechanical vectors of tularemia to man in this part of Sweden.

In order to give a concise picture of the epidemiology of Ockelbo disease, results of virological and serological investigations and data on host-feeding patterns of the mosquitoes will be presented in subsequent papers and experiments on the vector competence of the suspected vectors are being planned.

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