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THE MOSQUITO FAUNA OF THE HULEH RESERVE IN NORTHERN ISRAEL: SPECIES COMPOSITION, SEASONAL PATTERNS, AND HABITAT PREFERENCES

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ABSTRACT

The Huleh nature reserve in northern Israel was surveyed, and samples of mosquito larvae were collected at least once a month between April 1984 and May 1985. Larvae of 12 species, representing 5 genera were collected. The species list included species with a wide geographical distribution (e.g. (*Cx. pipiens*), as well as more northern Palearctic species (e.g. *Cx. territans*) and southern Ethiopian species (e.g. *Cx. antennatus*), which reach the limit of their distribution in the area. Breeding activity was highest in the spring and fall, and lowest in the winter. Species diversity, highest in the winter and lowest in the summer, was significantly correlated with air temperature, and was probably limited by high maximum water temperature in the summer. The distribution and association of the species appear to be related to seasonal patterns more than to habitat preferences.

INTRODUCTION

The Huleh Nature Reserve, located in the north of the Jordan Valley and consisting of an area of 3.2 km^2, is all that remains today of the former Huleh lake and swamps. The lake and the swamps, covering an area of 62 km^2 at the beginning of the present century (Paz, 1976), were drained between 1951 and 1959. The area designated as a nature reserve in the northwest corner of the lake (Fig. 1) served as the study area for this research project.

The Huleh area, due to its sealed-off situation, demonstrates a climate which is continental in nature, with both annual and daily temperatures showing large fluctuations (Karmon, 1956). Phytogeographically, the Huleh area is the meeting point of Holarctic species with Paleotropic species, many of which reached here their furthermost point of distribution — south or north, respectively (Zohary & Orshansky, 1947). The unique complex of aquatic and animal life which flourished in the past on clean water, originating from the Jordan river and from local springs feeding the Huleh basin, was severely damaged by the melioration works and by the draining of land for agricultural use. The water level in the reserve is maintained at about 6 m above that in the rest of the valley, and fluctuates by about 50 cm between winter-spring and summer-fall.

The reserve contains 4 major habitats (Fig. 1): open-water areas which include a lake, canals, and a settling pool which acts as a purifier for the water coming in from the adjacent fish-ponds; papyrus (*Cyperus papyrus*) thickets which grow in the shallows of the lake; meadows which are flooded in the winter and become swamps covered with low marsh vegetation, and which mostly dry out during the summer; and a small area of reed (*Phragmites australis*) habitat, serving as a grazing area for a herd of water buffaloes, large parts of which also dry out during the summer (Paz, 1976; Ashkenazi, 1983).

Until the 1940's, the Huleh area was a hyper-endemic malaria area (Kliger, 1930; Palestine Department of Health, 1941; Saliternik, 1964). Several malaria vectors,mostly *An. sacharovi* Favre and *An. sergentii* (Theobald) were abundant in the area (Buxton, 1924; Saliternik, 1955, 1957; Barkai & Saliternik, 1968). Historical information on the mosquito fauna of the area, especially the *Anopheles* species, is relatively abundant in consequence. The present study reports the species composition, abundance and associations of the mosquito fauna in the Huleh reserve in 1984-1985.

This paper is dedicated to Prof. J. Kugler, on the occasion of his 70th birthday, in recognition of his numerous contributions to the study of the entomofauna of Israel.

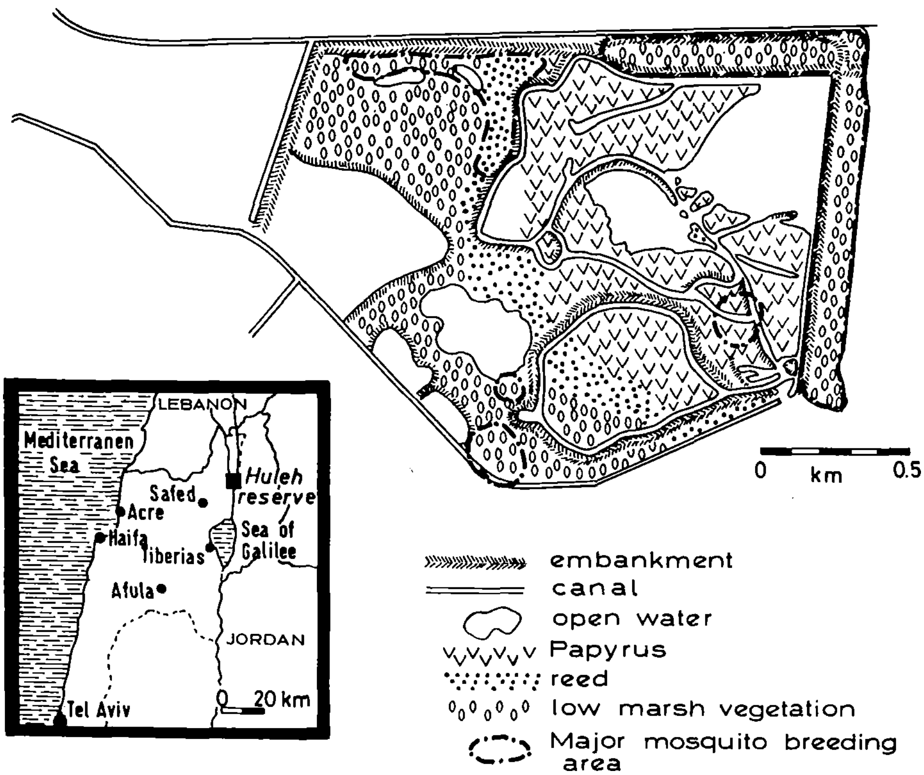

Fig. 1. The Huleh Nature Reserve (after Paz, 1976).

MATERIALS AND METHODS

The study area was visited and sampled at least once a month from April 1984 to May 1985. The whole area of the reserve was surveyed. During each visit samples of mosquito larvae from all habitat types were collected using mosquito dippers. In the open water areas and in some parts of the papyrus thickets samples were collected both on foot and by boat (the papyrus thickets were partially impenetrable by either method). In the other two habitat types all collections were made on foot. From each of the habitat types, at least 100 dips were taken during each visit, with the exception of the meadows in July-September, when they dried out and a smaller number of samples could be taken. Whenever mosquito larvae were found in a dip sample, at least 5 samples per 1 m^2 were taken in the surrounding 10 m^2 (or in the whole flooded area, if smaller). If the area in which larvae were found was too large to be sampled by this method, at least 1 dip per 10 m^2 were taken. Samples were transferred live to the laboratory in plastic bags (Whirl Pak bags), and the larvae were reared to either 4th instar or to adults, and then identified. Adult mosquitoes were collected with CDC miniature light traps and identified in the laboratory.

The occurrence of predatory aquatic insects was recorded and several groups of predators were transferred to the laboratory, where their ability to feed on mosquito larvae was verified.

Data on temperature and precipitation is collected routinely by the meteorological station in Ayelet Hashahar, 12 km south of the reserve. Water temperature and pH measurements in the various sampling locations in the reserve were taken, but due to large daily fluctuations in temperature in the shallow flooded areas where most larvae were found, they supplied only limited information.

RESULTS

Species found

Larvae of 12 mosquito species were found in the reserve during the study period, including 7 *Culex* species, 2 *Anopheles* species, and one representative of each of the following 3 genera: *Aedes, Culiseta* and *Uranotaenia*. The species found were: *Culex pipiens* complex (identification within this complex remains problematic), *Culex univittatus* Theobald (also referred to as *Culex perexiguus* Theobald), *Culex antennatus* (Becker), *Culex theileri* Theobald, *Culex hortensis* Ficalbi, *Culex territans* Walker (formerly referred to as *Culex apicalis* Adams which is a new world species), *Culex martinii* Medschid (which was not formerly recognized as a separate species), *Culiseta annulata* (Schrank), *Uranotaenia unguiculata* Edwards, *Aedes caspius* (Pallas), *Anopheles tenebrosus* Donitz (formerly referred to as *Anopheles coustani* Laveran), and *Anopheles claviger* (Meigen), of which only single larvae were found in some of the winter months.

Habitat

No mosquitoes were found breeding in the open water areas, where water level remained high throughout the year. In these areas vegetation is absent and fish are present. Even along the edges, due to steep embankments, no apparent refuges occur.

In the papyrus thickets, the water level is high between November and May, and practically no mosquito larvae were found. During the summer, the water level becomes low, especially in one location where larvae were common (Fig. 1) between June and October. In fact, this was the only habitat type where large numbers of larvae were found during the hot summer months (June-September), when the meadows either dry up or reach very high water temperatures during the day. The papyrus thicket habitat, which is largely shaded, and where the water is somewhat deeper, remained cooler during the hot summer days.

Excluding the summer, most larvae were found in the flooded meadows and the reed habitats, especially in the former where all species were encountered at some time or the other. Thus, larvae were found mostly in the flooded meadows in November-May, in the papyrus thickets in June-September and in the reed habitat in October-November. At times, especially in the late spring and early fall, vast numbers of larvae of *Cx. pipiens* and *Cx. univittatus* were found in these shallow pools. *Cx. antennatus* was the most common mosquito in the reed habitat (during the fall). The papyrus thickets served as the main habitat for *An. tenebrosus*, which was the only mosquito to commonly breed in this habitat. It appears that the distribution of larvae among habitats is more a function of habitat availability and seasonal changes rather than a function of habitat preference of most species.

Monthly changes in larvae abundance and species diversity

A peak in number of mosquito larvae, as estimated by number of dips in which larvae were found, maximum number of larvae in a dip ($\geqslant 10$) and average number of larvae per dip in areas were larvae were found (> 2), occurred in the spring (May-June) and the fall (October-November). In the summer, large numbers of *An. tenebrosus* adults and larvae were found, but the species diversity was very low (1-2 species in July-September, Fig. 2). The peak number of species was found in the late fall-early winter (November-January, Fig. 2), when 9-11 species were found, up to 8 species in single pool. During this period the total number of larvae found was very small (rarely more than 1 per dip, with average number per dip close to 0). Between February and May the number of species remained constant (6-7), while the number of larvae gradually increased.

Both the number of larvae found and the species diversity were highly correlated with weather conditions (Fig. 2). The highest number of larvae was found in the spring and fall when the average temperatures are in the range of 16-23°C. In the summer when the average temperature rises to 25-28°C the number of larvae found declined, possibly due to the high water temperature during the day, which often rises to 40°C or more in the shallow pools. In the winter, when the temperature averages 10-12°C and when water temperature does not exceed 12°C only very few larvae were found. The correlation between monthly average air temperature and number of species found is highly significant ($r = 0.796$, $P < 0.001$), while the correlation with monthly rainfall is not significant ($r = +0.508$, $P > 0.05$). When both the average maximum temperature and the average minimum temperature are correlated with number of species, the correlation is higher with the monthly average maximum temperature ($r = -0.780$, $P < 0.001$), than with the monthly average minimum temperature ($r = -0.689$, $P < 0.01$). Water level, which reaches a peak in March and a minimum in September did not show significant linear correlation with species diversity. However, in the

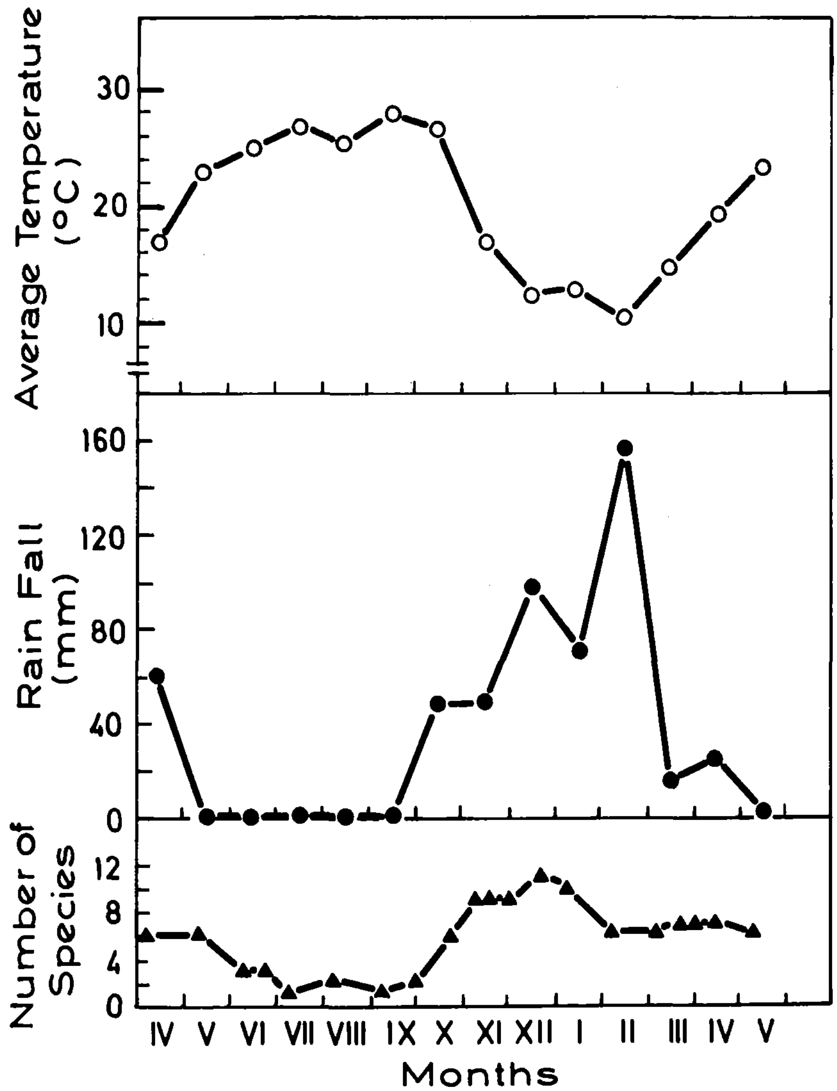

Fig. 2. Monthly changes in number of species, rainfall and average temperature.

summer the vast decrease in area of flooded meadows and reed habitat where most larvae are found, limits the amount of habitat available for breeding.

Monthly occurrence of different species

Monthly changes in species composition and abundance are summarized in Table 1. In the summer months only one species (*An. tenebrosus*) was found breeding in large numbers. *An. tenebrosus* was the main human biter and the only mosquito caught in large numbers in light traps between June and September. In the fall months of October-November the most common mosquito was *Cx. antennatus*, a southern

TABLE 1. MONTHLY OCCURENCE OF MOSQUITO LARVAE IN THE HULEH NATURE RESERVE

	1984									1985				
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Cx. pipiens	+++	+					++	+++	++	+	++	+	++	+
Cx. univittatus	++	+++	++		+		++	++	++	+	+	++	+++	+++
Cx. antennatus						+++	+++	+						
Cx. theileri		+					+	++	++	+	+	++	+++	+++
Cx. hortensis								+	+	+		+++	++	+
Cx. territans	++	++							+	+	++	++	+	++
Cx. martinii	+							+	++	+	++			
Cx. annulata	+	+						++	++	+++	+++	+++	++	
Ur. unguiculata	+	++					+	+				+	++	+
Ae. caspius	+							+	++	+		+		
An. tenebrosus		+	+++	+++	+++	+++	++	++	+	+				
An. claviger									+		+	+		

+ = <10 larvae found in ≤2 locations
++ = ≥10 larvae found in >2 locations
+++ = ≥50 larvae found in >3 locations

species which was supposed to be rare in Israel. It was not found in any other season. The two most common species in Israel, *Cx. pipiens* and *Cx. univittatus* (Kitron & Pener, in press) were also abundant in the fall as well as in the spring (April-May). *An. tenebrosus* (the summer mosquito), *Cx. antennatus* (the fall mosquito), *Ur. unguiculata* and *Ae. caspius* were the only species whose larvae were not found at least in small numbers throughout the winter. *Ur. unguiculata* has two distinct breeding periods, and *Ae. caspius* appears to breed in very restricted locations, and thus may have been missed during some sampling dates. It was also caught biting in April and May of 1985. Only a single larva of *An. claviger* was found on 3 occasions in the winter. *Cs. annulata* was the most common mosquito in the winter. *Cx. hortensis* and Cx. territans which are colder climate mosquitoes were found only between November and May, both being most common in the late winter-early spring (March-May). *Cx. martinii*, which is also a more northern species, was found in the same months, but was never very common.

Species associations

Nearly all possible species associations were found at least once (except for the very rare species). Most associations were found in frequencies that were not significantly different from those accepted based on the relative frequencies of the different species. Species which were found together more often than expected (positive associations significant on the basis of the χ contingency test) were: *Cx. univittatus* with *Cx. theileri* and with *Cx. antennatus* ($P < 0.01$), *Cx. hortensis* with *Cx. theileri* ($P < 0.01$), and *Cx. pipiens* with *Ur. unguiculata* ($P < 0.05$). The only significant negative association was between *Cx. antennatus*, a fall mosquito, and *Cx. territans*, a late winter-early spring mosquito, ($P < 0.05$). As 24 associations were tested, even the significant associations (especially those significant on the 0.05 level) have to be viewed with caution.

Predators

Several predators of mosquito larvae were encountered. Mosquitoes are practically absent from the open-water areas of the reserve at least partially due to the abundance of fish including *Gambusia affinis* and *Tilapia* species, which are well-known mosquito predators. Tadpoles are common in the spring and summer in the shallow pools and meadow areas. Among the insects, species of *Notonecta*, Dytiscid beetles and *Odonata* larvae are common and have been shown to be voracious feeders on mosquito larvae in the laboratory. In several cases spiders spun webs on light traps and were found in the morning to have caught several adult mosquitoes.

DISCUSSION

All species reported in this study have been reported in the Huleh area before, except for *Cx. martinii* which was not recognized as a separate species (Kitron & Pener, in press). *Anopheles claviger*, though not reported in the literature as occuring in the Huleh area, was found in the reserve a few times during the last decade by the Israeli Ministry of Health antimalaria inspectors. The rarity of this species and its occurrence in the winter when little sampling was conducted explain it not being reported.

Among the species that used to be common in the Huleh area the most noteworthy for their absence are the malaria carrying anophelines, foremostly *An. sacharovi* and *An. sergentii*. Their absence, and especially that of *An. sacharovi* can be related to the drainage of the swamps and the decline in water quality (Saliternik, 1974). *Anopheles hyrcanus* (Pallas), which was not a malaria vector also disappeared, and in fact has not been found in the country since the drainage of the large swamps (Margalit & Tahori, 1970, 1974; Pener & Kitron, 1985). Several other culicines which have been reported in the area in earlier studies, were also not encountered during the study period. Two *mansonia* species which have been reported in the Huleh before drainage, *Mansonia buxtoni* (Edwards) which is considered extinct and *Mansonia richiardii* (Ficalbi) which was found once after the drainage (Margalit & Tahori, 1970, 1974), have not been reported since 1970. Antimalaria inspectors of the Israeli Ministry of Health collected larvae of the following species between 1974-1983 (in addition to larvae of species encountered in this study): *An. algeriensis* in 1974 and 1982, *An. sergentii* in 1976, *Cx. laticinctus* in 1981, *Cx. tritaeniorhynchus* in 1980, and *Cs. longiareolata* in 1974 and in 1978-80 (Pener & Kitron, 1985; Kitron & Pener, in press; Ministry of Health, unpublished data).

In spite of the drainage of the Huleh area, the small remaining reserve serves as a breeding habitat for a large number of species. Some of the species have a widespread distribution not only in the Mediterranean basin but also in the Palearctic and the Ethiopian regions (*Cx. pipiens, Cx. theileri, Ur. unguiculata, Ae. caspius*); 2 southern species, *An. tenebrosus* and *Cx. antennatus* reach the northern limit of their distribution in northern Israel; several more northern species, such as *An. claviger, Cx. territans* and *Cx. martinii* are also encountered (information on species distribution from Gutsevich et al., 1971; Kirkpatrick, 1925; Knight & Stone, 1977). Thus, in spite of the vast reduction in area and deterioration of water quality of the Huleh, the reserve is still a meeting point for a diverse mosquito fauna including both northern and southern species.

The presence of the largest number of species in the winter, when the total number of larvae is low, and when no dominant species occurs, may indicate the importance of competitive interactions (direct or indirect) among the different species and the relation of high species diversity to release from competitive interactions. During the winter, only 3rd and 4th instars were found in the water, and no adult activity (light trap catches) was encountered. Thus, it appears that several species can overwinter as larvae in the study area. Diapausing adults were not encountered during searches in buildings and trees in the reserve. However, field experiments in the area showed that at least *Cx. pipiens* does enter reproductive diapause (Nudelman, 1984).

The presence of only a few species in the summer, and the high negative correlation of number of species with average monthly temperature, especially with average maximum monthly temperature, indicate the importance of high water temperatures as a limiting factor for the breeding of many species. Indeed, the only larvae which are found in large numbers during the summer belong to *An tenebrosus*, which due to its preference for the shaded and relatively deep water habitat of the papyrus thickets, can avoid the high water temperature encountered during the summer days in the shallow open pools. In fact, several species are found breeding in the region during the summer months in deeper or more shaded pools (Pener & Kitron, 1985; Kitron & Pener, in press).

Water level per se is not significantly correlated with number of larvae or with species diversity, but fluctuations in water level play an important role in breeding patterns. Species diversity is highest when water level is on the rise (late fall and early winter), as the breeding habitat becomes more extensive. The species diversity, which reaches a minimum in the late summer, does not begin to rise until water level also rises (October). The numbers of larvae found are highest in the spring when the water level begins to fall (April-May), and in the fall (October-November) when water level starts to rise. In both cases, new breeding areas become available.

The few significant associations among species can be related to their seasonal patterns. As most species are found in one type of habitat (shallow temporary pools), habitat preference does not appear to play a major role in the species occurrence and distribution, except possibly *An. tenebrosus* with its preference for the papyrus thickets, and *Ae. caspius* with its patchy distribution. Seasonal patterns of species occurrence are also related to the geographic distribution of a species. The southern species, *An. tenebrosus* and *Cx. antennatus* are found in the summer and fall, while the more northern species such as *An. claviger, Cx. territans* and *Cx. martinii* are found in the winter and early fall.

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