

THE ECOLOGY OF MARSH MOSQUITOES AND THEIR ATTRACTION TO
MALLARD DUCKS, DOMESTIC CHICKENS AND YELLOW-HEADED
BLACKBIRDS AT OAK HAMMOCK MARSH, MANITOBA

A Thesis
Submitted to the Faculty
of
Graduate Studies
The University of Manitoba

by
Robert Gene Anthony Fortney

In Partial Fulfillment of the
Requirements for the Degree
of
Master of Science

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ROBERT GENE ANTHONY FORTNEY

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of the University of Manitoba in partial fulfillment of the
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MASTER OF SCIENCE

(c)

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DEDICATION

I dedicate this thesis to my late father Paul Bernard, who provided an inner strength, and to my mother Eileen Dorteia who was always there when I needed her.

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ABSTRACT

During the years of 1985 to 1987 a survey was carried out to determine the species of mosquitoes that were breeding and host seeking in Oak Hammock Marsh. The abundance of adult female mosquitoes in the marsh was monitored with Solid State Army Miniature (SSAM) light traps, which were used to trap host seeking adults. The abundance of raft laying species was also monitored in 1985 and 1986, using ovipools known to be attractive to Cx. tarsalis Coquillett, Cx. restuans Theobald and Cs. inornata (Williston). Larval breeding was monitored by regular sampling of 20 sampling sites within the marsh, to determine the species of mosquitoes breeding there during two summer seasons.

Species abundance, as determined by trap collections of adult females, varied each year. In 1985 the abundance of only the most common species, Cx. tarsalis, Cx. restuans, Ms. perturbans (Walker), An. earlei Vargas, Cs. inornata, was monitored. In 1986 and 1987, all mosquitoes were identified and Ae. vexans (Meigen) and Ae. flavescens (Muller) were the most numerous species in the collections. In 1987 the numbers of Ms. perturbans and An. walkeri Theobald were noticeably greater than in 1986.

Fourteen species were found to breed in the marsh during the 2 years of larval sampling; Cs. inornata, Ae. flavescens and Ae. vexans were the dominant species.

Cx. tarsalis egg rafts dominated, with a mean/weekly count of 16 egg rafts. Cs. inornata and Cx. restuans followed with mean/week counts of 4.4 and 3.7 respectively.

Ovarian parity was studied in females of several species collected in SSAM traps during 1984-1986, to determine the physiological age of the population. A maximum of 30 live adult female mosquitoes/week were removed from the collections. Cx. tarsalis probably completed 3 generations in 1984 and 1986 while in 1985 it appeared to complete only 2 generations. One-parous individuals were collected during the second week of June, 1985 and 1986, and in the second week in July in 1984. Tri-parous females were observed in August of 1984 and July of 1986. Ms. perturbans had single generations during both years, and nullipars were collected from June or July until August. One-parous individuals were collected in the third week of July in 1985, and the last week of June in 1986. One-parous individuals of An. walkeri were collected in June, 1987. There was an increase in nullipars in the third week in July, suggesting it may complete two generations in Manitoba.

A mosquito attraction study was conducted in 1986 and 1987. In 1986 two bait animals, the domestic chicken and the mallard duck, were used. A fan assisted box trap, the 'Fortney Fan Trap', was used to contain the bait and trap attracted mosquitoes. In 1987 the experiment was expanded to include an additional trap (Ehrenberg) and an additional bait species,

viz, the yellow headed blackbird. Blackbirds were used in pairs while the other species were used as single animals/trap. Trapping was conducted 3 times weekly for 6 weeks in 1986 and for 10 weeks in 1987. In the 1986 study, fifteen species of mosquitoes were attracted to each bait species, totalling 943 mosquitoes. Three species, Cx. tarsalis, Ms. perturbans and Ae. vexans, accounted for 80% of the catch. The majority of Cx. tarsalis were attracted during the first week of August. The duck and chicken baits attracted 53% and 42% of the catch respectively. The duck bait was more attractive to Cx. tarsalis and Ms. perturbans, and several minor species, while chickens were more attractive to Ae. vexans. In 1987, 3319 mosquitoes were attracted comprising 14 species. An. walkeri was collected in large numbers in 1987. In 1986 four species accounted for 74% of the catch. The blackbirds attracted 48% of the catch, and were most attractive to Cx. tarsalis. The duck and chicken baits attracted 35% and 11% of the catch respectively.

Two flock cages, containing 7 - 10 birds of each bait species, were located in the vicinity of the single/paired attraction study. A mosquito flock trap was attached to each bird flock cage. The species of the mosquitoes attracted and whether they had bloodfed was recorded.

The flock traps attracted the same dominant species as the single/pair baited traps, however, the ranking of species attracted was reversed on the baits. Chickens were the most

attractive bait, and Ae. flavescens was the most abundant species.

GENERAL INTRODUCTION

Mosquitoes are fairly ubiquitous in their distribution throughout the world and have long been linked with the distribution of pathogenic organisms causing disease to human populations. Mosquito biology and the relationships between mosquitoes and arboviruses, have been the subjects of research for more than a century. For example, the transmission of Yellow Fever virus in Cuba by mosquitoes was reported by Carlos Finlay in 1886 (Sosa 1989).

The association of the mosquito with other members of the animal community in which it is found has been considered as an important mechanism necessary in the maintenance of disease cycles involving humans. Population dynamics, host-seeking behaviour, arbovirus research and overwintering biology of Cx. tarsalis have been examined in great detail since Hammon and Reeves (1943) demonstrated the interrelationship between Cx. tarsalis and the Western Equine Encephalitis (WEE) virus. Since that time, many other species have been linked to this cycle.

WEE is an arbovirus affecting humans and horses, that is distributed across western Canada and the United States. The cycle that maintains this disease in nature involves a bird reservoir and a mosquito vector. Little is known about the overwintering biology of the disease, but Reisen and Monath (1987) suggested 3 possibilities: '(i) long term survival of

infected overwintering life stages of primary or secondary vectors, (ii) chronically infected or hibernating vertebrates, and (iii) regional autumnal extinction followed by annual vernal re-introduction'. The principal vector in Manitoba is Culex tarsalis (Sekla et al. 1980) although many other species of mosquitoes may play a role in the transmission of this virus.

Oak Hammock Marsh is a remnant of a larger natural marsh known as St. Andrews Bog which in the 1800s was one of Manitoba's largest marshes, encompassing 47,000 ha. Presently the marsh is a Wildlife Management Area under provincial jurisdiction, that encompasses 3450 ha, of which 1,984 ha is marshland, 1296 ha is grassland and 243 ha are seeded in lure crops. The Oak Hammock Marsh Wildlife Management Area is located in the midst of an important farming area, 30 km north of the city of Winnipeg. The marsh was designed to act as a staging area, and provide nesting sites for migrating waterfowl. It also provides access to the marshland ecosystem for the tourist or the naturalist. This marsh provides a habitat for a wide variety of flora and fauna, including many types of aquatic and terrestrial insects.

Little research has been done to examine the potential of Oak Hammock Marsh with respect to mosquito production (Brust, pers. comm.). Sentinel chicken flocks have been used for several years to monitor levels of WEE virus. Antibodies to the virus have been isolated from chickens kept at Oak Hammock

Marsh from 1976 - 1985 (Brust, pers. comm.) and virus has been isolated from mosquitoes collected there (Sekla et al. 1980). The role of ducks, blackbirds or other marsh birds in the annual cycle of WEE has not been studied. It is not known if a marsh ecosystem is conducive to transmission of WEE virus, since vector species may not be attracted to aquatic waterfowl. If they are attracted, it would also be important to know if they feed on waterfowl or on other bird species that nest in the marsh.

The objectives of my research were: (i) to determine which mosquitoes breed in the marsh and their seasonal abundance, (ii) to examine the host preference of marsh mosquitoes, when several birds species native to the marsh are presented as potential hosts, and (iii) to examine the physiological age structure of the host-seeking adults, for several bird feeding species.

II. LITERATURE REVIEW

LITERATURE REVIEW

This literature review is the background on some of the major concerns regarding mosquitoes in Manitoba. The overwintering strategies for three important species [Cx. tarsalis Coquillett, Cs. inornata (Williston) and Ms. perturbans (Walker)] will be discussed and the bloodseeking behaviours and host preferences for these species will be briefly reviewed. The life histories and basic biology for Cx. tarsalis and Cs. inornata have been discussed by previous authors (Gallaway 1983, Buth 1983), and will not be discussed here. Marshes and wetlands in general have been described by Rubec and Pollett (1979), eliminating the need for any further discussion in this thesis.

In Manitoba, there are 45 species of mosquitoes (Wood et al. 1979). Many of these are not important as pest species, or as vectors of disease pathogens. Gadawaski (1990) lists 38 mosquito species collected as larvae or adults by the Insect Control Branch in the Winnipeg area. Ellis (1987) reported that Ae. vexans (Meigen) was regularly the most important pest species in Winnipeg. The major concern for the public is the annoyance of this species, when females feed, or attempt to feed, on humans.

There have been several outbreaks of Western Equine Encephalitis (WEE) in Manitoba in recent years, and a number of mosquito species may be infected with the virus. Some of

our common species transmit the WEE virus to both humans and animals (Sekla 1976, 1982, Sekla et al. 1980, Artsob 1983). WEE is a viral infection affecting the central nervous system of humans and horses and has been responsible for infection rates of epidemic and epizootic proportions (Monath 1984). Culex tarsalis is the primary vector of WEE in Manitoba and elsewhere. Culexeta inornata may act as a secondary vector, involved in the amplification of the WEE virus in nature (McLintock and Rempel 1963). The first isolation of WEE from Ms. perturbans was made from a pool of live mosquitoes collected in 1977 in Manitoba (Sekla et al. 1980). The role that this mosquito species may play in the dissemination among human and animal populations is unknown at this time (Brust pers. comm.).

The role of mosquitoes as human pests or as vectors of disease and subsequent methods of control will be better understood when the population dynamics and host-seeking behaviours of mosquitoes are understood. Knowledge of the age structure of the population as well as the natural factors affecting survival, fecundity and dispersal are essential to the understanding of the factors that affect mosquito abundance and pathogen transmission (WHO 1967).

Overwintering

The survivorship of any mosquito species depends on the ability of that species to survive during periods when adverse

conditions prevail. These periods may be related to weather, climate or availability of a food resource. This period may be survived by entering a dormant state. Dormancy, that is initiated in response to low temperatures (northern climates), is termed hibernation. If it results from exposure to high temperatures (southern climates) it is termed aestivation. At the northern latitudes, there may be a complete suspension of reproductive activity, as well as both sugar and blood feeding. In the southern latitudes, reproductive activity may continue with or without the suspension of carbohydrate feeding (Reisen 1987).

Reisen (1987) suggested 4 strategies of overwintering: (i) univoltine species that overwinter as diapausing eggs, (ii) multivoltine species that overwinter as diapausing, drought resistant eggs, (iii) as hibernating larvae, (iv) as hibernating adult females. Reproductive or ovarian diapause normally occurs for mosquitoes that overwinter as inseminated adult females. In Canada, most species overwinter in the egg stage (Lewis 1987).

Culiseta inornata

Culeseta inornata exhibits the type (iv) strategy for overwintering, according to Reisen (1987). At northern latitudes, Cs. inornata females hibernate during winter, while at southern latitudes, females aestivate in summer and are active during winter. In Alberta, near Edmonton, few bloodfed,

gravid and parous individuals were collected after the end of August, although, Cs. inornata may continue to fly until late October (Hudson 1977). Female Cs. inornata that had been transferred as new fourth instar, from 16 h daylength at 20°C, to 12 h daylength, 10°C, developed ovarian follicles characteristic of diapause (Hudson 1977), which is characterized by the absence of yolk granules in the oocyte (Barr 1974).

Mammal burrows may be used as shelters during the overwintering period (Hayles et al. 1979). According to Barr (1958), hibernation may begin in October in Minnesota. Shemanchuk (1965) stressed the importance of snow cover for survival of hibernating females. He also correlated emergence with the spring soil temperature inversion, as well as 50°F air temperature. Adult females were first observed to emerge from mammal burrows during April, May and June of 1964 in southern Alberta.

Culex tarsalis

In Canada, Culex tarsalis overwinters as a fertilized hibernating female (Wood et al. 1979). Field collected Cx. tarsalis entered diapause when larvae or early pupae were transferred from summer (25°C, 16:8 [L:D] photoperiod) to winter (18°C, 10:14 [L:D] photoperiod) in Kern County, California. It was suggested that the older fourth instar larvae or young pupae are the immature stages that are

sensitive to diapause induction cues (Reisen 1986). The 'diapause induced' larval stage does not hibernate, but adult females enter diapause. However, in California, larvae have been observed during the winter period. In Kern County, California, numerous larvae and pupae were found in 'duck club' ponds, during November and December of 1959 - 1960 (Washino and Bellamy 1963).

Overwintering Cx. tarsalis have been observed in a variety of different sites. Cellars and mines have been utilized (Bennington et al. 1958) as well as subterranean tunnels (Arntfield et al. 1982), and mammal burrows (Shemanchuk 1965). In Alberta, Cx. tarsalis began to enter mammal burrows in late August of (Shemanchuk 1965), while in Boulder, Colorado, overwintering females have been collected from mine tunnels in late September (Mitchell 1981). In Manitoba, the overwintering female that emerges in the spring is difficult to collect, possibly due to low survival rates (Brust pers. comm.). In 1987 Cx. tarsalis was collected in Winnipeg on May 13th (Ellis 1987), while in other years first collections of females are usually in June (Gadawaski 1990).

Mansonia perturbans

Mansonia perturbans overwinters as larvae, attached to the roots of aquatic plants, in the second, third or fourth larval stage. The larvae are not in a true diapause state and obtain their oxygen supply from the plant, while feeding on the

detritus in the area of their attachment (Wood et al. 1979). In Minnesota, overwintering larvae have survived the winter period frozen solidly into the substrate of a permanent marsh (Rademacher 1979).

Bloodseeking and Host Preference

The host preference and bloodseeking behaviour of mosquitoes suspected as vectors of an arbovirus, is necessary information in epidemiological research. Adult females feed on plant sugars as a carbohydrate source, but require a blood meal for ovarian development (O'Meara and Evans 1973). The blood-feeding pattern of a mosquito species becomes important when a susceptible human population coexists with a mosquito population infected with a human disease-causing pathogen (Reisen and Monath 1987).

Culiseta inornata

Culiseta inornata, due to its feeding habits, is considered to play a minor role in the spread of WEE. Culiseta inornata has been considered primarily as a mammal feeder (Tempelis et al. 1967) and has been found to be infected with WEE (Sekla et al. 1980). At southern latitudes, Cs. inornata is actively hostseeking during the winter period and undergoes aestivation during the summer (Reisen 1987). The reverse occurs at northern latitudes, where this species hibernates during the winter (Hudson 1977). During a study on feeding behaviour in

the Sacramento Valley in California, Tempelis and Washino (1967) determined that Cs. inornata fed exclusively on mammals. Cattle were the main source of large, single blood meals however, birds were involved in 25% of the cases where multiple feedings were required to complete a blood meal (Edman and Downe 1964). Passeriform birds are considered as a principal component of the summer transmission cycle of WEE (Reisen and Monath 1987), and the habit of multiple feedings to complete a bloodmeal increases the opportunity to disseminate the virus among human and animal populations. Because of its preference for large mammals, Cs. inornata is an unlikely vector of WEE.

Culex tarsalis

Culex tarsalis is the principal vector of WEE in western North America and in Manitoba (Sekla et al. 1980), and the feeding behaviour of this species during years of high virus prevalence may be a determining factor in the degree of dissemination of this disease.

Culex tarsalis appears to have a variable host-feeding pattern, as shown by a three year study in the rural areas of Kern County, California by Tempelis et al. (1965). This species prefers passerine birds, especially in the winter, while in the summer, doves and mammals (primarily cattle) are preferred. They concluded that host preference was related to relative abundance of the host in this area. Host preference

in Cx. tarsalis may be related to size of host, in addition to whether it is mammalian or avian (McIver 1968). In McIver's study, Cx. tarsalis preferred chicks to mice only when the bird's weight was twice that of mice. Engorgement rates varied according to different bird species and attraction rate. The biting attacks of Cx. tarsalis on birds were influenced by a combination of the host's attractiveness and acceptability, while increased numbers of mosquitoes were believed to cause a depression on the degree of engorgement when the hosts were chickens (Dow et al. 1957).

The highly variable feeding behaviour of Cx. tarsalis, especially its periodic tendency to feed on passerine birds, would confirm its role as a major vector of WEE.

Mansonia perturbans

In New York State, the host preference of Ms. perturbans, in order, are birds, mammals, amphibians and reptiles (Means 1967). Downe (1962) performed experimental trials to determine the host preference of this species. He used pigs and rabbits as mammal hosts and chickens, and domestic ducks as avian hosts. From his results, Ms. perturbans was attracted to mammal hosts, but in the majority of cases did not feed on them. He suggested that the preferred hosts were birds. This species may require several feedings to complete a blood meal, possibly due to its painful bite, which elicits a defense response from the host.

In southern Ontario, Ms. perturbans exhibited a daily pattern of movement between the forest canopy and ground level, and a shift in feeding behaviour. During the day, Ms. perturbans was at ground level and fed on the mammals which were in close proximity. At dusk, this species began its ascent through the canopy. Females were able to feed on roosting birds at the top of the canopy by midnight (Downe 1962).

Mansonia perturbans is known as a persistent and painful biter (Steward and McWade 1961) and is an important pest species throughout its range. There is a need for a detailed study of the host preference of this species because of its abundance at Oak Hammock Marsh (the likely breeding site for larvae), its possible involvement in WEE infections at the marsh (Sekla et al. 1980), and its preference for avian hosts. Considering that this species is primarily univoltine in Canada (Wood et al. 1979), and few females appear to obtain more than one blood meal in Manitoba (pers. obs.) or in southern Ontario (Trueman and McIver 1983), it is unlikely to be an important vector of WEE.

III. MOSQUITO COLLECTIONS FROM OAK HAMMOCK MARSH, MANITOBA

INTRODUCTION

Population studies of mosquitoes are necessary in epidemiological research to determine the age structure of a population, as well as changes in abundance over time. To do this, the egg, larval and adult stages must be sampled. Sampling of larval as well as adult populations is important in monitoring outbreaks of mosquito-borne pathogens (Utrio 1985). Monitoring of egg, larval and adult stages is necessary to show the seasonal characteristics of mosquito populations (Beck 1961).

The population dynamics of the principal and potential vectors of WEE in Manitoba are poorly understood (Buth et al. 1990). Adult populations in the Winnipeg area have been surveyed on a regular basis since 1957 (Smith 1959); however, the first intensive larval survey within Winnipeg was carried out in 1967 and 1968 by Dixon and Brust (1972). A thorough study has never been undertaken on the mosquito population of Oak Hammock Marsh; however, mosquito species that are known as vectors, or suspected to play a role in the maintenance of Western Equine Encephalitis (WEE), have been collected at the Marsh since 1976 (Brust pers. comm.). Culex tarsalis Coquillett is the main vector of WEE in western Canada. WEE virus has also been isolated from Ae. vexans (Meigen), Cs. inornata (Williston), Ms. perturbans (Walker) and An. earlei Vargas, and all of these species are known to frequent the Oak

Hammock Marsh (Sekla et al. 1980).

The objectives of this study were: (i) to determine the mosquito species breeding in the marsh and their relative seasonal abundance and (ii) to determine the seasonality of the adult mosquito population actively involved in host-seeking at the marsh.

MATERIALS AND METHODS

Oviposition Pool Study 1985-1986

During the summers of 1985 and 1986, egg production of Cx. tarsalis, Cs. inornata and Cx. restuans Theobald was monitored using three oviposition pools. The location of the pools is illustrated in Fig. 1. In 1985, the pools were lined with sod and filled with water from 10 May until 22 August, while in 1986 the study period started 12 May and ended 19 August. The oviposition pools were one meter square wooden frames constructed of 5 x 15 cm. lumber. The frames were lined with black plastic and filled with water. A piece of lawn sod approximately 70 x 70 x 20 cm was placed into the pool to provide the oviposition attractant. The water level was maintained at 10 cm. Egg rafts were removed from the pools two times per week and returned to the laboratory. The egg rafts were hatched individually in 500 ml. polystyrene cups at 24°C. A drop of a liver powder slurry was added as food for the larvae. First instar larvae from two collections/week were identified to species, using Dodge (1966). The temperature of the water in the oviposition pools was monitored using maximum/minimum thermometers. The SAS Inc. statistical package was used to determine the mean number of rafts/pool collected per week and the results are expressed graphically.

Larval Sampling Study 1986 and 1987

Dipper Sampling 1986 and 1987

A larval sampling area was selected in the marsh, and 20 sampling stations were monitored weekly, using a 500 ml dipper sampler. Each sampling effort consisted of 3 dips (1500 ml.) per site, until water was no longer present. Larvae were reared to the fourth instar in the laboratory, and then stored in Kahles' solution (Martin 1977). The pupae were placed in polystyrene cups containing dechlorinated water, and the adults were identified to species.

Carbon Dioxide Trap Collections 1985

Host-seeking mosquitoes were monitored at Oak Hammock Marsh from 1985 to 1987, using the Solid State Army Miniature (SSAM) light traps, Model 2112 (J.W. Hock Company, Gainesville, Fl.) (Focks 1986). The trap site was surrounded by 2 to 8 m. high willows (Salix spp.) and the marsh was dominated by sedge (Carex spp.), cane grass (Phragmites spp.), bulrushes (Scirpus spp.) and cattail (Typha spp.). Trap locations are shown in Figure 1.

During 1985, a SSAM trap was located at each of sites 1, 2 and 3, and these were operated 4 nights/week from 4 June to 23 August. At dusk, a photocell activated the small 6 volt pea bulb and motor driven fan, starting the daily collecting cycle. The light was inactivated by the photocell at dawn, and

the fan prevented the escape of trapped mosquitoes. The collecting nets were removed from the traps every morning, and returned to the laboratory where the most abundant species were identified and examined for mites. The SAS Inc. statistical package was used to determine and display graphically the mean weekly catch for the most abundant species. Specimens of live Cx. tarsalis and Ms. perturbans were frozen and kept for later dissection for the parity study.

Carbon Dioxide Trap Collections 1986

Adult mosquitoes were monitored from 14 May until 30 August, using 4 traps (sites 1, 2, 3 and 4). The traps were operated three nights/week. During the months of July and August, the light bulbs were removed from traps, 3 and 4. All mosquitoes collected were identified (Table 5), and the mean weekly catch was compared for the lighted and the non-lighted traps.

Carbon Dioxide Trap Collections 1987

Adult host-seeking mosquitoes were monitored as in previous years, using 3 traps located at sites 1, 2 and 3. All traps remained lighted throughout the study period and all mosquitoes collected were identified to species.

Mean weekly air temperatures (Winnipeg Airport, Environment Canada Station) were determined for 1985, 1986 and 1987. Since

the daily period of trap operation was determined by the photocell, the trap functioned only from dusk to dawn. Therefore only the hourly temperatures from 2000 to 0800 h. each day were used to calculate the weekly mean temperatures.

RESULTS

Oviposition Study 1985 and 1986

The dominant species for the combined years was Cx. tarsalis (66%), while Cs. inornata and Cx. restuans accounted for 18% and 15% respectively (Table 1).

In 1985, 234 egg rafts were collected. Culex tarsalis accounted for 43%, while Cs. inornata and Cx. restuans made up 31% and 26% respectively (Table 1). During the summer the number of Cx. tarsalis egg rafts collected peaked on week 32, when 43 egg rafts were collected. The peak collection of Cs. inornata egg rafts occurred on week 35. Cx. restuans egg rafts were collected on only 7 of the 11 weeks of the study, and numbers were low throughout the summer. The peak occurred on week 28, with a collection of 18 egg rafts (Fig. 5).

In 1986, 397 egg rafts were collected. Culex tarsalis accounted for 80% of the entire collection. There were two peaks in the numbers of Cx. tarsalis egg rafts. The largest peak occurred on week 27, with 91 egg rafts while 68 were collected on week 31. Culex restuans egg rafts were less abundant in the ovipools in 1986, with peak numbers of egg rafts collected (21) on week 30. Numbers of Cs. inornata egg rafts collected were substantially lower in 1986 with only 43 egg rafts collected. The peak collection was 13 on week 21 (Fig. 6).

Larval Sampling

Dipper Sampling 1986

The main larval development period occurred during July, 1986. Of the 280 larvae collected and identified, Cs. inornata was most abundant, followed by Ae. dorsalis (Meigen), Ae. flavescens (Muller), Cx. tarsalis, Cx. territans Walker and Ae. vexans (Meigen) (Table 2, Figs. 7, 8).

Dipper Sampling 1987

Larval sampling was begun much earlier than in 1986, and 3095 larvae were collected. Out of 14 species identified, Ae. vexans made up 54% while Cs. inornata, Ae. flavescens, and Ae. dorsalis made up 23%, 12% and 7% of the collection. The numbers of all 14 species are given in Table 13. Aedes flavescens was taken in large numbers during the last two weeks of April, and the numbers decreased after that; Cx. tarsalis did not appear until the last three weeks in August (Fig. 9). Aedes vexans was most abundant during week 31 and Cs. inornata during weeks 20 and 34 (Fig. 10). Aedes dorsalis was collected throughout the summer, but Cx. restuans was collected only during the final 3 weeks (Fig. 11).

Effect of Sites

During the two years of regular sampling of the 19 sites, larval productivity differed according to site. The numbers of

larvae collected/site varied from 1 to 940 larvae, and the species collected also varied according to site. Site number 17 produced 940 larvae but only 6 species; Sites 8 and 11 produced 109 and 262 larvae, and 9 different species were collected at each of these sites. Culiseta inornata and Ae. flavescens were most widely distributed, indicating a preference for a variety of habitats (Table 4) and were taken from 17 out of 19 sites. Aedes dorsalis was collected from 10 sites, but it was concentrated mostly at sites 10 and 13. Both pools 10 and 13 were transient in nature, and vegetated with sedge (Carex spp.). Aedes vexans was collected in large numbers from sites 2 and 17. Site 2 was shaded by willows and Phragmites spp., and was quite different from site 17 which was an open, unshaded site. Minor species, i.e. those taken in low numbers, were found in sites 3 to 11 (Table 3).

Carbon Dioxide Trap Collections

1985 Collection

The numbers of adult mosquitoes and the species coming to CO₂ (SSAM) traps are shown in Figures 12,13 and 14. The most numerous species was Cx. tarsalis, (32%), followed by Ms. perturbans and An. earlei, making up 31% and 27% of the collection respectively (Table 5).

Culex tarsalis and Ms. perturbans were both collected every week from week 25 until the end of the study. Numbers of Ms. perturbans continued to build from week 25 until week 30, when

a peak catch of 158 mosquitoes occurred. A lesser peak followed on week 32. The numbers of Cx. tarsalis increased after week 27, to a peak of 97 on week 29, and a larger peak of 176 on week 32. After week 32, the numbers declined rapidly (Fig. 12).

Anopheles earlei adults peaked at a mean of 200 individuals/trap on week 32. Culex restuans was rarely collected, and only after week 31 (Fig. 13).

Culiseta inornata accounted for 8% of the collection, and was most numerous during weeks 25, 32 and 33, suggesting 2 major generations (Fig. 14).

1986 Collection

In 1986, collections were started earlier than 1985, and continued for 16 weeks. Four traps, operating three nights/week (192 trap nights), collected 34,657 mosquitoes. Aedes vexans dominated the collection, and accounted for 55% of the catch. Mansonia perturbans, Cx. tarsalis and Ae. flavescens followed and accounted for 11%, 9% and 9% respectively. The remainder of the collection (16%) was comprised of 15 species (Table 5).

Culex tarsalis was collected in low numbers from week 20 until week 26; the numbers then increased to 263 on week 31, marking the peak catch for the summer. The numbers of Ms. perturbans increased quickly after week 25, reaching 310 by week 27, and dropped off rapidly after week 30 (Fig. 15).

Aedes vexans was the most abundant species in 1986. There was a large increase in the collection on week 31, when the mean trap catch reached 1019 individuals. The numbers remained high until week 35, when 92 were trapped (Fig 16).

The largest numbers of Cs. inornata were collected in 1986, when the weekly mean trap catch was 5 to 56 individuals (Fig. 17).

The largest numbers of Ae. flavescens were collected on week 25, and decreased steadily thereafter; An. walkeri numbers increased gradually throughout the summer, with the peak occurring on week 35.

There were three peaks of An. earlei Vargas, corresponding to weeks 25, 30 and 32 respectively. Culex restuans was a minor species throughout the summer (Fig. 19).

1987 Collection

In 1987, three traps were operated three nights/week for 17 weeks (153 trap nights) and these captured 29,896 mosquitoes and 21 species. Aedes vexans was the most abundant species accounting for 37% of the collection. Mansonia perturbans and An. walkeri were next in abundance, accounting for 31% and 8% respectively. Aedes dorsalis, Ae. flavescens and Cx. tarsalis followed, with 6%, 5% and 5% respectively (Table 5).

Mansonia perturbans dominated the catches from week 24 until week 30, and its numbers peaked during week 27 when the mean weekly trap collection was 1022 mosquitoes. The numbers

dropped rapidly, and adults disappeared from the catch after week 32. The seasonal abundance of Cx. tarsalis was much lower than Ms. perturbans, with peaks on weeks 27 and 30 reaching 80 and 96 respectively (Fig. 20).

Culiseta inornata adults were collected from week 18 until week 34. There were two distinct peaks in the collection over the summer, suggesting 2 generations (Fig. 21).

Aedes vexans was collected every week from week 22 until week 34. The main peak occurred on weeks 32 and 33, with weekly mean/trap of 1063 and 1073 mosquitoes respectively (Fig. 22).

Aedes flavescens was more numerous from weeks 22 to 26, and An. walkeri between weeks 27 to 34. The numbers of Ae. flavescens peaked on week 23 with 246 individuals, An. walkeri peaked on weeks 22, 28 and 32 when this species reached 38, 145 and 110 mosquitoes respectively (Fig. 23). Anopheles earlei was collected throughout the summer beginning on the last week in April, and peaking on week 28. Culex restuans was caught in the latter half of the summer, with a single peak on the last week of the study period, when the mean number/trap reached 16 (Fig. 24).

Effect of Trap Site and Trap Type

During 1985 and 1987, the trap at site 1 captured more mosquitoes than those at sites 2 and 3 (Tables 6 and 7). In 1985, site 1 trap captured 140% and 129% more mosquitoes than

the traps at sites 2 and 3 respectively; in 1987, the site 1 trap captured 206% and 279% more than the traps at sites 2 and 3 respectively.

When 2 SSAM traps with light, were compared to 2 with CO₂ only, the total mosquitoes trapped was 284% greater (Table 8). The greatest difference in numbers trapped was seen in Ae. vexans, where 5 times as many were collected in the CO₂ traps with lights. The reverse occurred with Cs. minnesotae Barr, where 4 times as many were collected in traps without light.

Hydracarina Parasitism of Mosquitoes at Oak Hammock Marsh

Mansonia perturbans was the species most commonly parasitized by water mites during the course of this study. In 1987, mites were found from weeks 26 to week 30, corresponding to the period during which Ms. perturbans was most abundant (Fig. 25).

Table 1. Numbers of egg rafts collected from May to August
(11 weeks in 1985 and 15 weeks in 1986).

<u>Mosquito</u>	<u>POOL NUMBER</u>							
<u>Species</u>	<u>1</u>		<u>2</u>		<u>3</u>		<u>Total</u>	
	<u>1985</u>	<u>1986</u>	<u>1985</u>	<u>1986</u>	<u>1985</u>	<u>1986</u>	<u>1985</u>	<u>1986</u>
<u>Cx. tarsalis</u>	34	108	42	89	25	120	101	317
<u>Cx. restuans</u>	32	3	16	20	12	14	60	37
<u>Cs. inornata</u>	45	8	24	6	4	29	73	43
<u>Sub Total</u>	<u>111</u>	<u>119</u>	<u>82</u>	<u>115</u>	<u>41</u>	<u>163</u>	<u>234</u>	<u>397</u>
<u>Combined Total</u>	<u>230</u>		<u>197</u>		<u>204</u>		<u>631</u>	

Table 2. Mean numbers/week of larvae collected at sites 1 through 19 during weeks 27, 30 and 31, of 1986 and weeks 17 through 21, and 31 through 34, in 1987.

<u>Mosquito</u> <u>Species</u>	<u>1986</u>	<u>1987</u>
<u>Cx. tarsalis</u>	3.7	4.2
<u>Cx. restuans</u>	0	1.8
<u>Cx. territans</u>	5.7	2.2
<u>Ae. vexans</u>	1.7	174.7
<u>Ae. flavescens</u>	5.7	40.0
<u>Ae. dorsalis</u>	3.7	25.8
<u>Ae. fitchii</u>	0	1.9
<u>An. earlei</u>	.1	.3
<u>Cs. minnesotae</u>	0	1.3
<u>Cs. inornata</u>	71.3	78.4
<u>Ae. riparius</u>	0	.4
<u>Ae. excrucians</u>	0	1.4
<u>Ae. euedes</u>	0	.2
<u>Ae. canadensis</u>	0	.2

Table 3. Numbers of mosquito larvae/3 dipper samples at sites 1 through 10 during weeks 27, 30 and 31, 1986 and weeks 17 - 21 and 31 - 34, 1987.

<u>Mosquito</u> <u>Species</u>	<u>Site Number</u>									
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
<u>Cx. tarsalis</u>	0	0	0	0	1	6	3	2	1	1
<u>Cx. restuans</u>	0	0	4	0	0	3	1	4	0	1
<u>Cx. territans</u>	0	1	4	4	9	0	4	3	1	0
<u>Ae. vexans</u>	10	101	429	39	0	46	40	24	2	52
<u>Ae. flavescens</u>	12	4	36	28	24	5	0	1	1	57
<u>Ae. dorsalis</u>	0	0	9	0	0	17	9	11	1	36
<u>Ae. fitchii</u>	0	0	2	2	0	0	0	2	0	2
<u>An. earlei</u>	0	0	0	0	0	0	0	1	0	0
<u>Cs. minnesotae</u>	0	1	1	3	3	2	0	0	1	0
<u>Cs. inornata</u>	9	25	12	58	16	28	53	61	78	244
<u>Ae. riparius</u>	0	0	0	0	0	0	1	0	0	0
<u>Ae. excrucians</u>	0	0	8	0	1	0	0	0	1	0
<u>Ae. euedes</u>	0	0	0	0	0	0	0	0	0	0
<u>Total</u>	<u>31</u>	<u>132</u>	<u>505</u>	<u>134</u>	<u>54</u>	<u>107</u>	<u>111</u>	<u>109</u>	<u>85</u>	<u>393</u>

Table 3. (cont'd) Numbers of mosquito larvae/3 dipper samples at sites 11 through 19 during weeks 27, 30 and 31, of years 1986 and weeks 17 - 21 and 31 - 34, in 1987.

<u>Mosquito Species</u>	<u>Site Number</u>								
	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>
<u>Cx. tarsalis</u>	33	1	0	0	0	1	0	0	0
<u>Cx. restuans</u>	3	2	0	0	0	0	2	0	0
<u>Cx. territans</u>	3	0	0	5	1	1	1	0	0
<u>Ae. vexans</u>	15	1	0	2	22	40	854	0	0
<u>Ae. flavescens</u>	56	11	55	14	27	16	29	0	1
<u>Ae. dorsalis</u>	0	6	26	0	1	1	10	0	0
<u>Ae. fitchii</u>	3	0	3	0	1	1	0	0	0
<u>An. earlei</u>	0	0	0	0	0	0	0	1	0
<u>Cs. minnesotae</u>	1	0	0	0	0	0	0	0	0
<u>Cs. inornata</u>	147	14	29	78	8	16	44	0	0
<u>Ae. riparius</u>	0	2	1	0	0	0	0	0	0
<u>Ae. excrucians</u>	1	1	0	0	0	0	0	0	0
<u>Ae. euedes</u>	0	0	1	0	1	0	0	0	0
<u>Total</u>	<u>262</u>	<u>37</u>	<u>110</u>	<u>99</u>	<u>61</u>	<u>60</u>	<u>940</u>	<u>1</u>	<u>1</u>

Table 4. Characteristics of natural pools (sites 1-10) sampled for larvae in 1986 and 1987.

<u>Characteristic of Pool</u>	<u>Site Number</u>									
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Very temporary*	0	0	x	0	0	0	0	0	0	x
Temporary**	0	x	0	x	0	x	0	x	x	0
Permanent	x	0	0	0	x	0	x	0	0	0
Shaded	0	x	0	0	0	0	0	x	x	0
<u>Carex</u> spp.	x	0	x	x	0	x	0	0	0	x
<u>Typha</u> spp.	0	0	0	0	0	0	0	x	0	0
<u>Phragmites</u> spp.	0	x	0	0	0	0	0	0	x	0
<u>Scirpus</u> spp.	0	0	0	0	x	x	x	0	0	0
<u>Salix</u> spp.	x	x	0	0	0	0	x	0	0	0

* Pool suitable for larval development 7-10 days

**Pool suitable for larval development 2-3 weeks

Table 4 (cont.). Characteristics of natural pools (sites 11 - 19) sampled for larvae in 1986 and 1987.

<u>Characteristic of Pool</u>	<u>Site Number</u>								
	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>
Very Temporary*	x	x	x	0	0	0	x	0	0
Temporary**	0	0	0	x	0	x	0	0	0
Permanent	0	0	0	0	x	0	x	x	x
Shaded	0	0	0	x	0	0	0	0	0
<u>Carex</u> spp.	x	x	x	0	0	x	x	0	0
<u>Typha</u> spp.	0	x	0	x	x	0	0	0	x
<u>Phragmites</u> spp.	0	x	0	x	0	0	0	0	0
<u>Scirpus</u> spp.	0	0	0	x	x	0	0	0	x
<u>Salix</u> spp.	0	0	0	x	0	0	0	0	x

* Pool suitable for larval development 7-10 days

**Pool suitable for larval development 2-3 weeks

Table 5. Mean numbers of mosquitoes attracted to the SSAM light traps, per trap/year, during 1985, 1986 and 1987.

<u>Mosquito</u> <u>Species</u>	<u>1985</u>	<u>YEAR</u> <u>1986</u>	<u>1987</u>
<u>Cx. tarsalis</u>	633	783	482
<u>Cx. restuans</u>	27	48	34
<u>Cx. territans</u>	0	1	5
<u>Ms. perturbans</u>	612	982	3090
<u>Ae. vexans</u>	0	4745	3669
<u>Ae. dorsalis</u>	0	330	574
<u>Ae. flavescens</u>	0	801	524
<u>Ae. intrudens</u>	0	0	128
<u>Ae. euedes</u>	0	0	21
<u>Ae. excrucians</u>	0	66	21
<u>Ae. cinereus</u>	0	16	41
<u>Ae. fitchii</u>	0	5	24
<u>Ae. spencerei</u>	0	31	24
<u>Ae. sticticus</u>	0	29	40
<u>Ae. provocans</u>	0	0	2
<u>An. earlei</u>	534	207	203
<u>An. walkeri</u>	0	263	826
<u>An. punctipennis</u>	0	0	.3
<u>Cs. minnesotae</u>	0	42	125
<u>Cs. inornata</u>	167	283	129
<u>Cs. morsitans</u>	0	35	4
<u>Total</u>	<u>1,973</u>	<u>8,668</u>	<u>9,966.3</u>

Table 6. Numbers of mosquitoes attracted to the SSAM light traps/site, during 1985.

<u>Mosquito</u> <u>Species</u>	<u>SITE NUMBER</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>Cx. tarsalis</u>	733	584	583
<u>Cx. restuans</u>	31	26	24
<u>Ms. perturbans</u>	651	595	590
<u>An. earlei</u>	722	337	544
<u>Cs. inornata</u>	241	161	99
<u>Total</u>	<u>2,378</u>	<u>1,703</u>	<u>1,840</u>
<u>Mean/species</u>	<u>476</u>	<u>568</u>	<u>368</u>

Table 7. Numbers of mosquitoes attracted to the SSAM light traps/site, during 1987.

<u>Mosquito</u> <u>Species</u>	<u>SITE NUMBER</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>Cx. tarsalis</u>	577	568	302
<u>Cx. restuans</u>	35	36	32
<u>Cx. territans</u>	2	9	3
<u>Ms. perturbans</u>	4509	2382	2378
<u>Ae. vexans</u>	6373	2829	1804
<u>Ae. dorsalis</u>	1163	518	43
<u>Ae. flavescens</u>	960	299	314
<u>Ae. intrudens</u>	80	60	243
<u>Ae. euedes</u>	31	10	23
<u>Ae. excrucians</u>	20	7	28
<u>Ae. cinereus</u>	57	19	46
<u>Ae. fitchii</u>	28	16	29
<u>Ae. spencerei</u>	36	12	25
<u>Ae. sticticus</u>	59	34	28
<u>Ae. provocans</u>	3	1	2
<u>An. earlei</u>	242	179	189
<u>An. walkeri</u>	1457	631	391
<u>An. punctipennis</u>	0	1	0
<u>Cs. minnesotae</u>	149	105	120
<u>Cs. inornata</u>	277	79	32
<u>Cs. morsitans</u>	4	6	1
<u>Total</u>	<u>16,062</u>	<u>7,801</u>	<u>5,763</u>

Table 8. The total numbers of mosquitoes attracted to the SSAM trap, lighted vs nonlighted, during weeks 27 to 34 of 1986.

<u>Mosquito Species</u>	<u>Trap type</u>			
	<u>Lighted</u>		<u>Nonlighted</u>	
	Site 1	Site 2	Site 3	Site 4
<u>Cx. tarsalis</u>	985	774	565	624
<u>Cx. restuans</u>	65	54	22	20
<u>Cx. territans</u>	4	1	0	0
<u>Ms. perturbans</u>	1081	982	602	1025
<u>Ae. vexans</u>	7729	7591	1733	1413
<u>Ae. dorsalis</u>	600	426	111	123
<u>Ae. flavescens</u>	788	427	242	250
<u>Ae. excrucians</u>	45	43	44	60
<u>Ae. cinereus</u>	24	11	9	11
<u>Ae. fitchii</u>	4	0	3	1
<u>Ae. spenceri</u>	37	45	17	16
<u>Ae. sticticus</u>	17	16	20	25
<u>Ae. communis</u>	18	11	7	4
<u>Ae. canadensis</u>	1	0	2	0
<u>An. earlei</u>	170	115	180	160
<u>An. walkeri</u>	291	126	249	212
<u>Cs. minnesotae</u>	13	21	55	71
<u>Cs. morsitans</u>	22	28	31	57
<u>Cs. inornata</u>	222	189	16	17
<u>Total per site</u>	<u>22,116</u>	<u>10,860</u>	<u>3,908</u>	<u>4,089</u>
<u>Total per treatment</u>	<u>22974</u>		<u>8097</u>	

Fig. 1. Site where SSAM traps, artificial ovipools
and larval study were located 1985 - 1987.
S - location of SSAM traps
L - location of larval sampling sites
O.P. - location of artificial ovipools

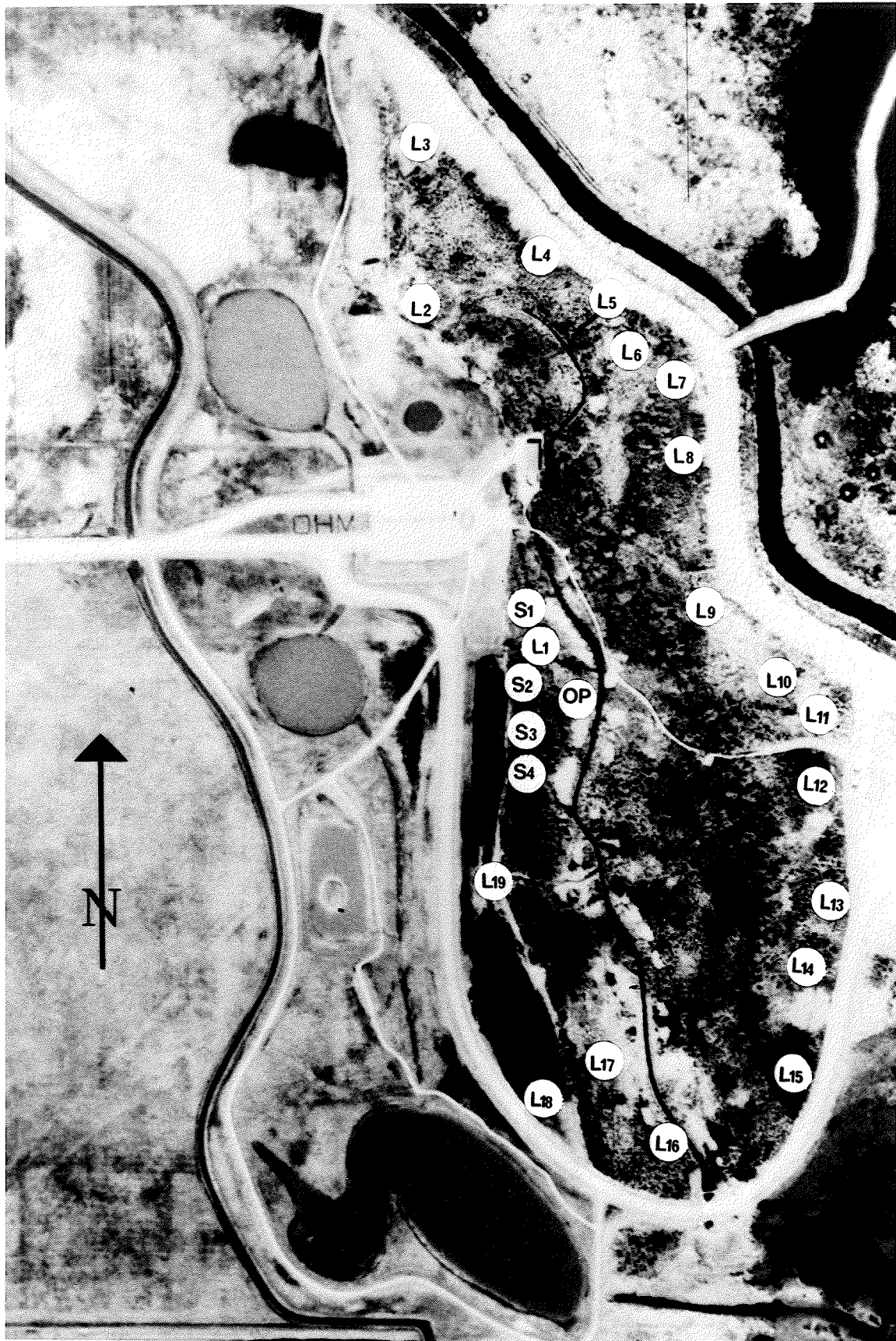


Fig. 2. Mean weekly temperatures, in 1985.

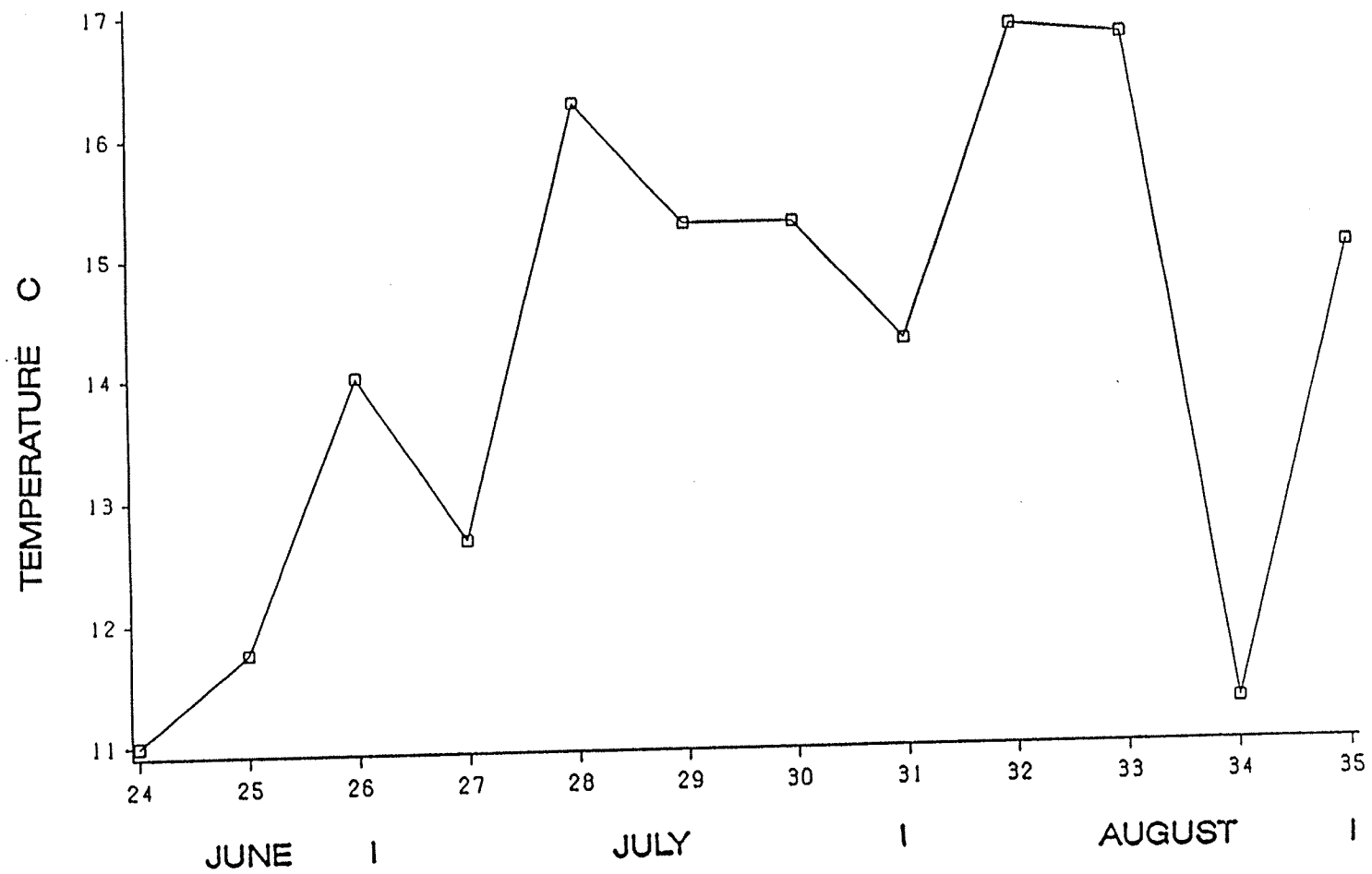


Fig. 3. Mean weekly temperatures, in 1986.

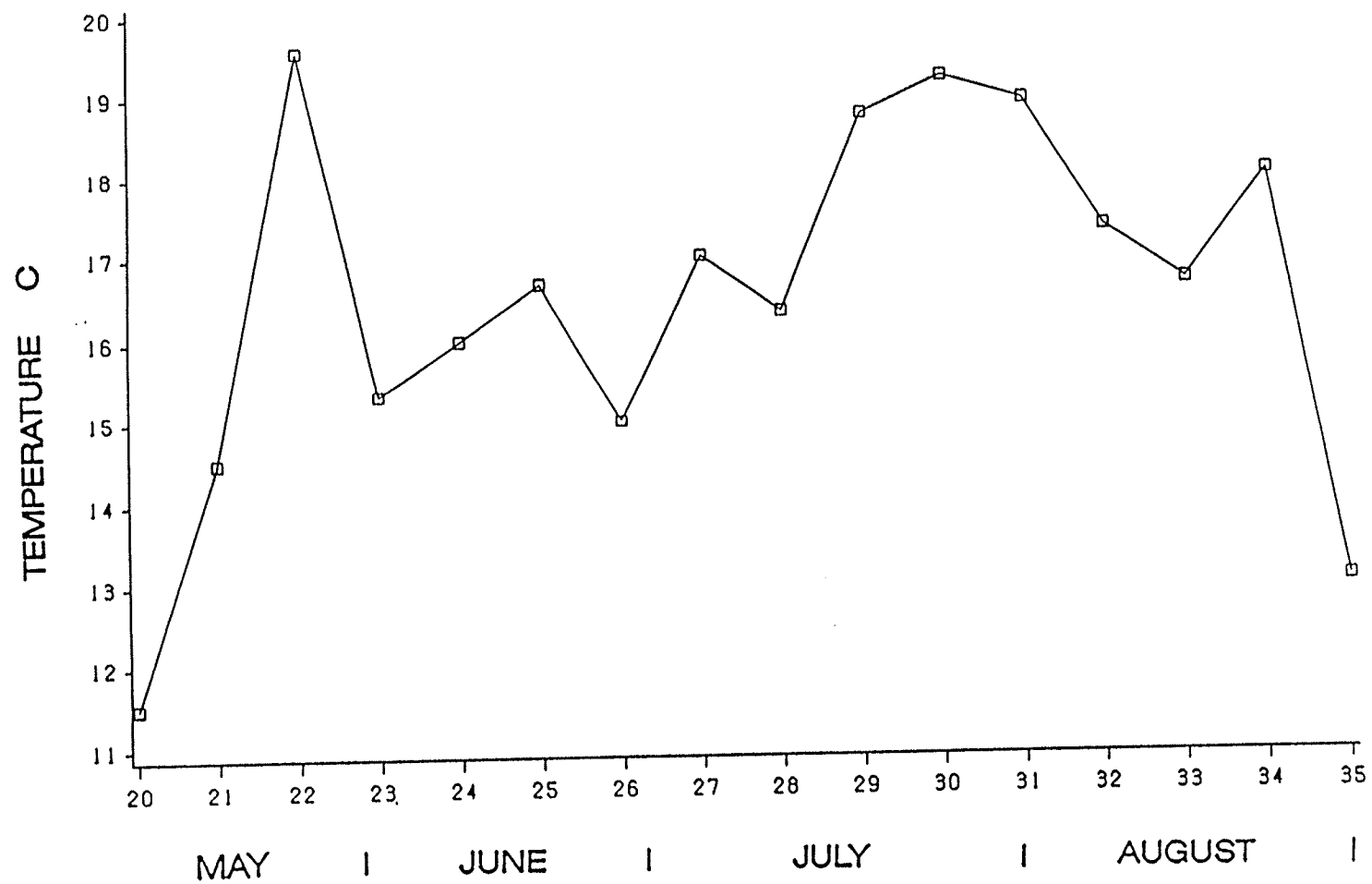


Fig. 4. Mean weekly temperatures, in 1987.

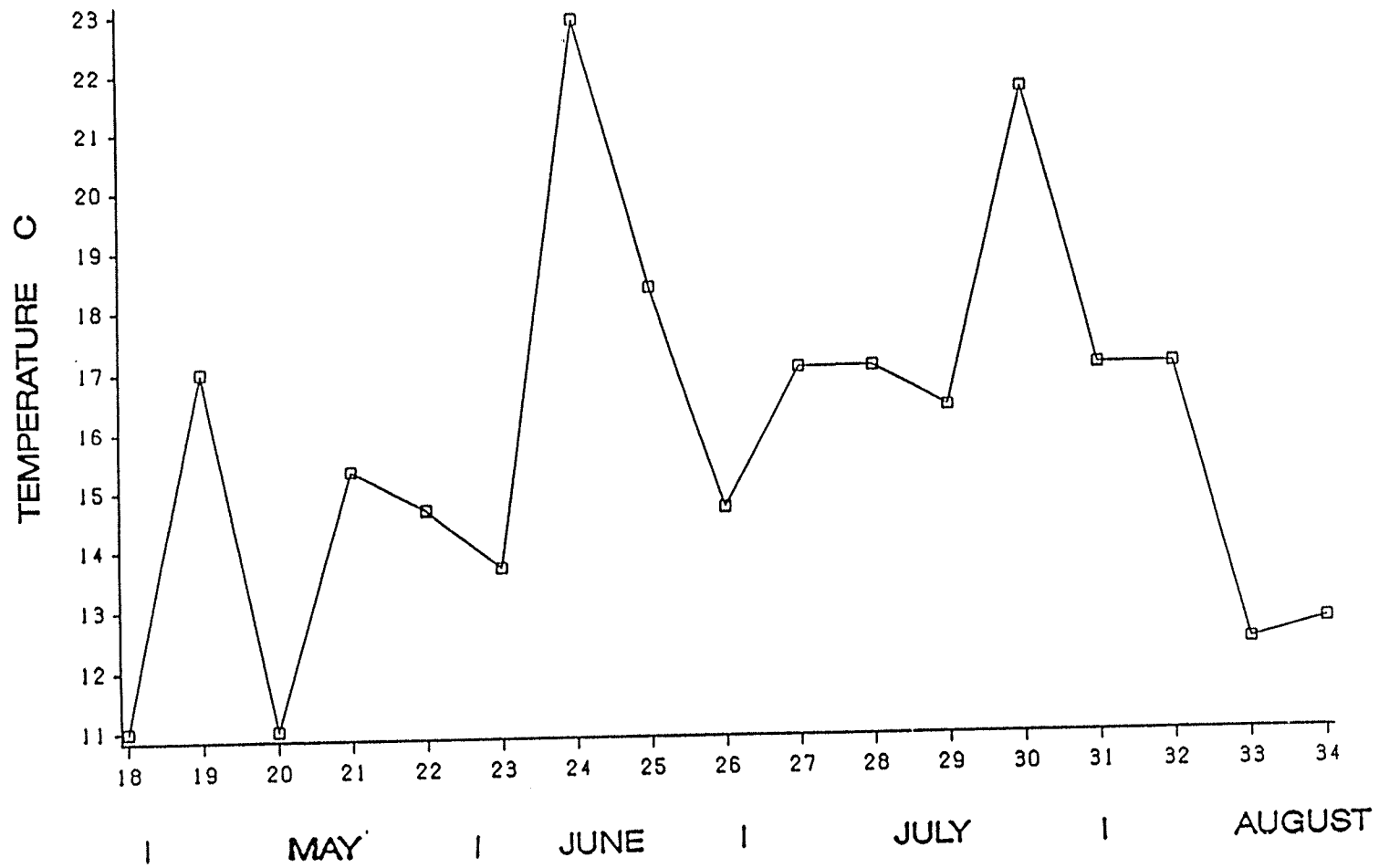


Fig. 5. Total numbers of egg rafts/week, 1985.

<u>CULEX RESTUANS</u>	
<u>CULISETA INORNATA</u>	
<u>CULEX TARSALIS</u>	

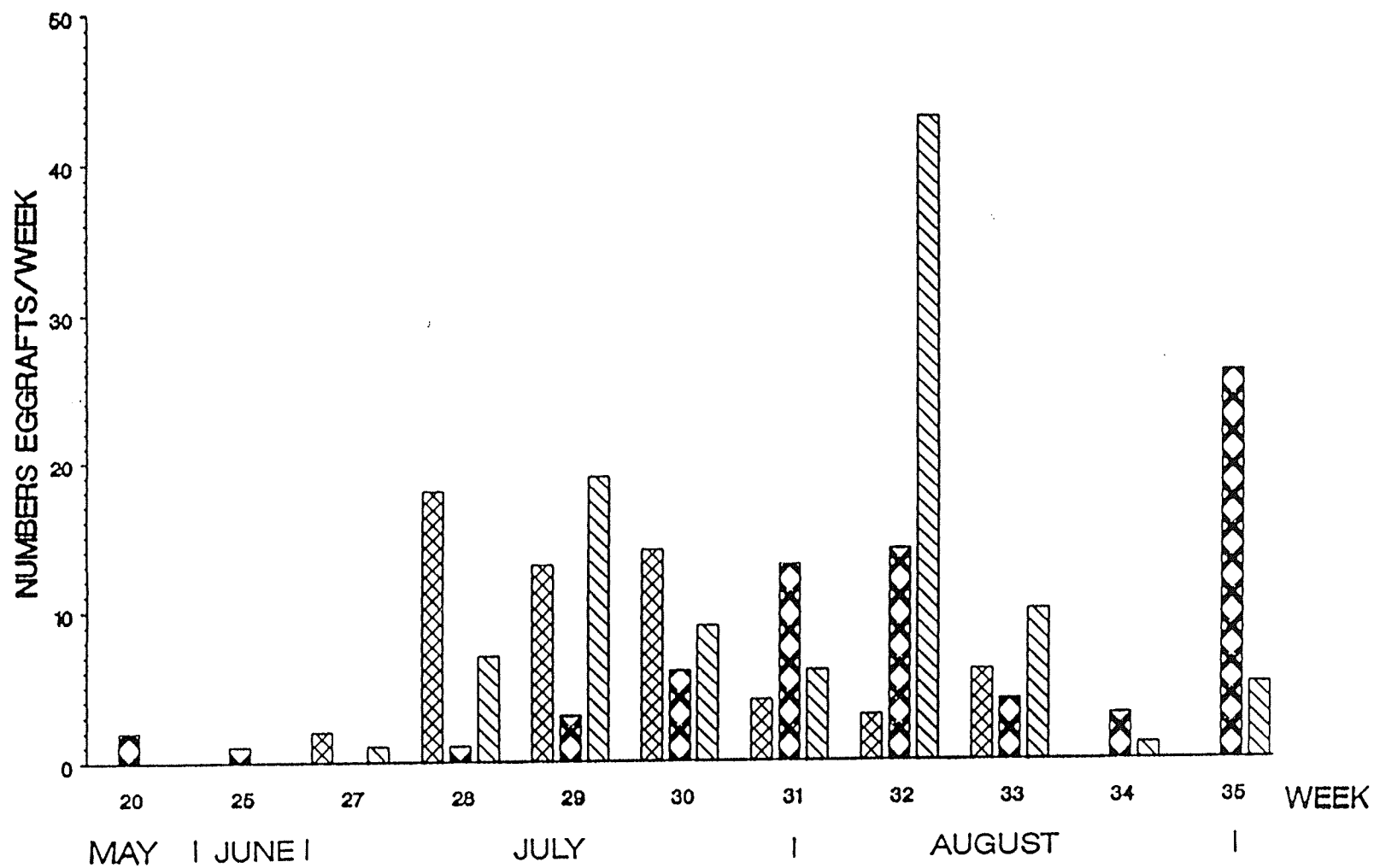


Fig. 6. Total numbers of egg rafts/week, 1986.

<u>CULEX RESTUANS</u>	
<u>CULISETA INORNATA</u>	
<u>CULEX TARSALIS</u>	

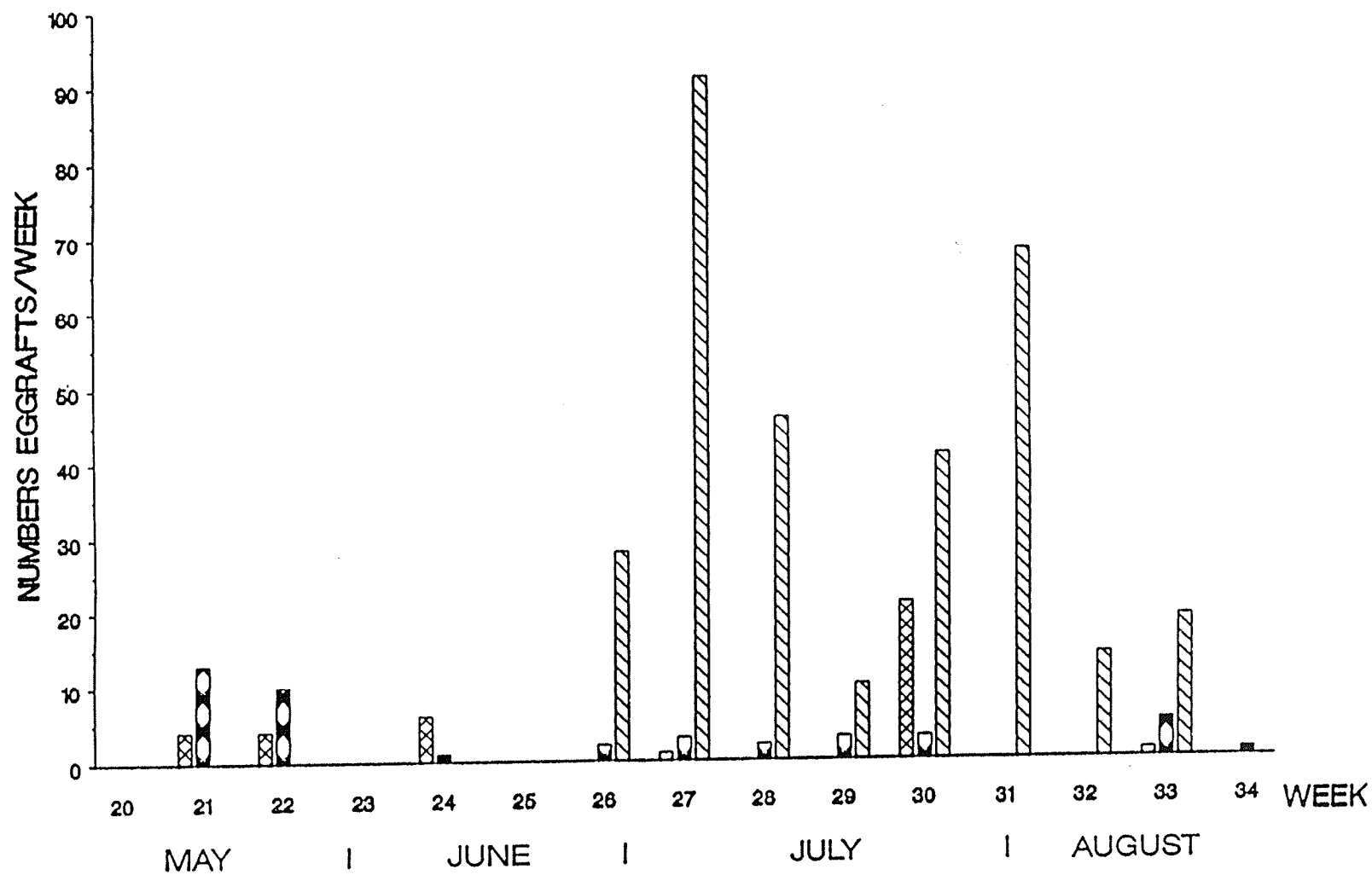


Fig. 7. Weekly abundance of immatures of Ae. flavescens and Cx. tarsalis, 1986.

AEDES FLAVESCENS 

CULEX TARSALIS 

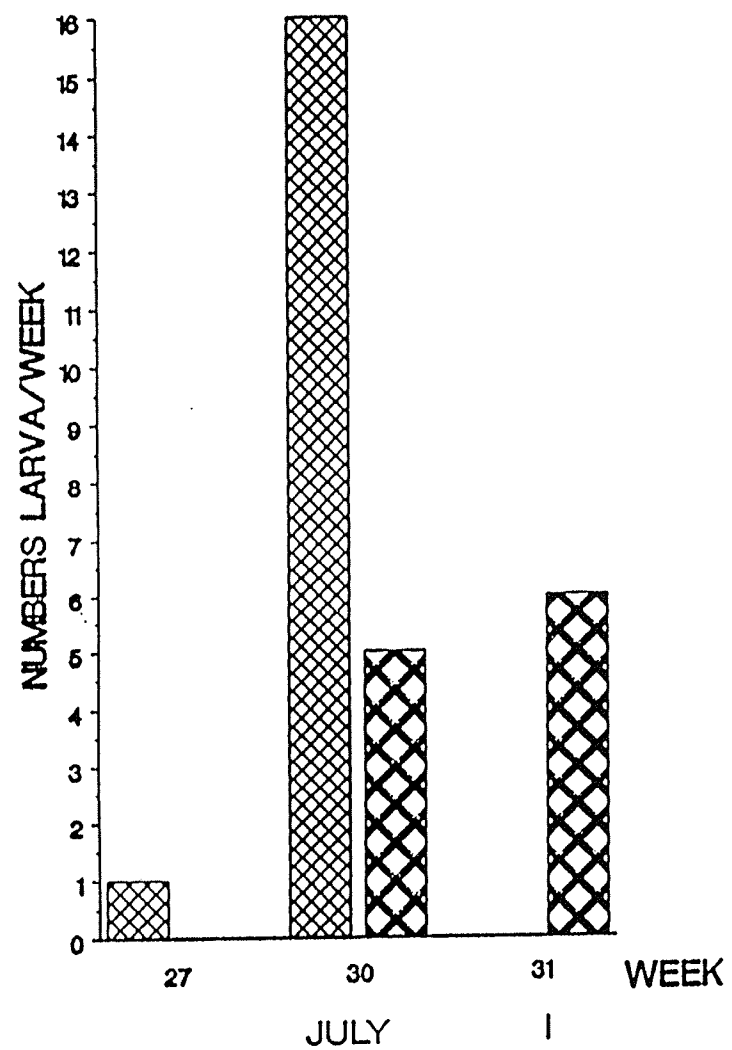


Fig. 8. Weekly abundance of immatures of Ae. vexans and Cs. inornata, 1986.

AEDES VEXANS 

CULISETA INORNATA 

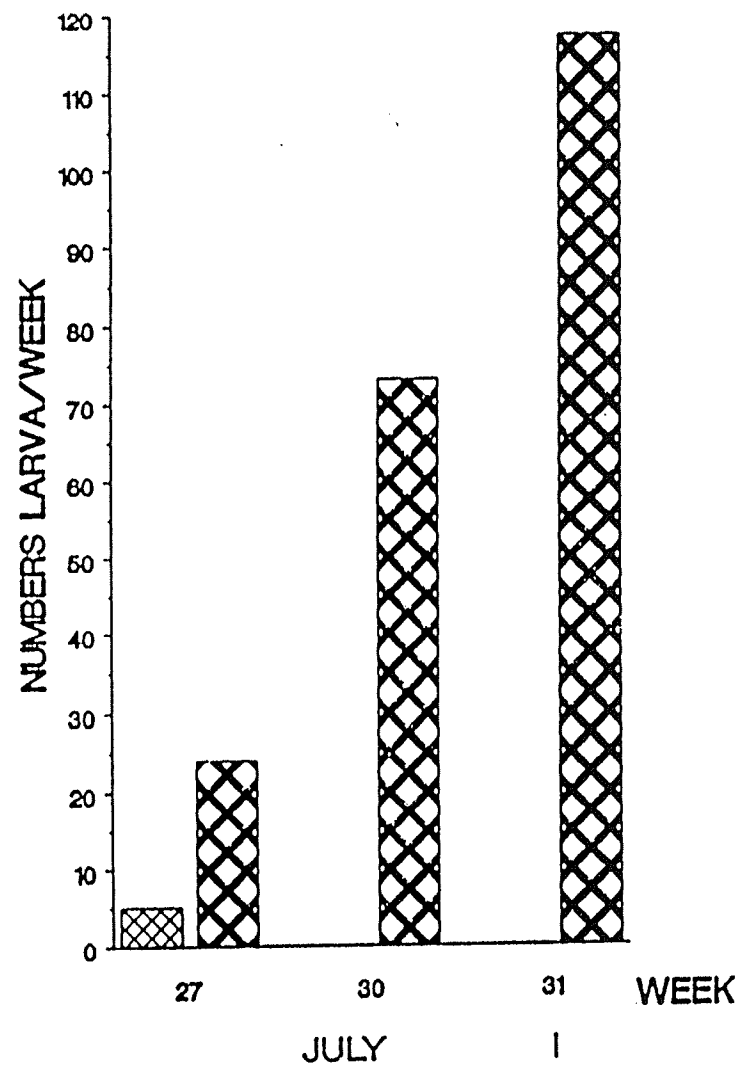


Fig. 9. Weekly abundance of immatures of Ae. flavescens and Cx. tarsalis, 1987.

AEDES FLAVESCENS 

CULEX TARSALIS 

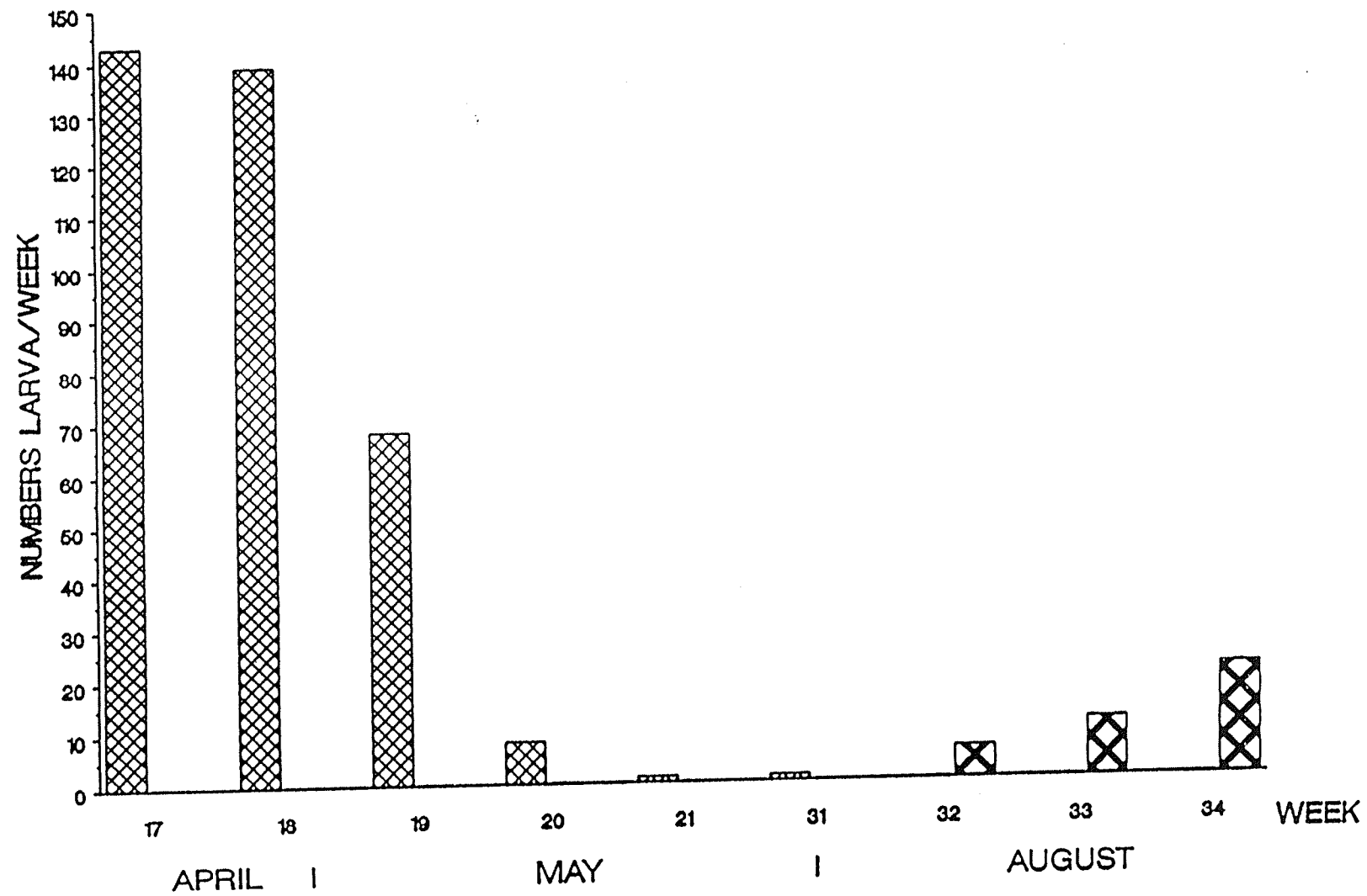


Fig. 10. Weekly abundance of immatures of Ae. vexans and Cs. inornata, 1987.

AEDES VEXANS 

CULISETA INORNATA 

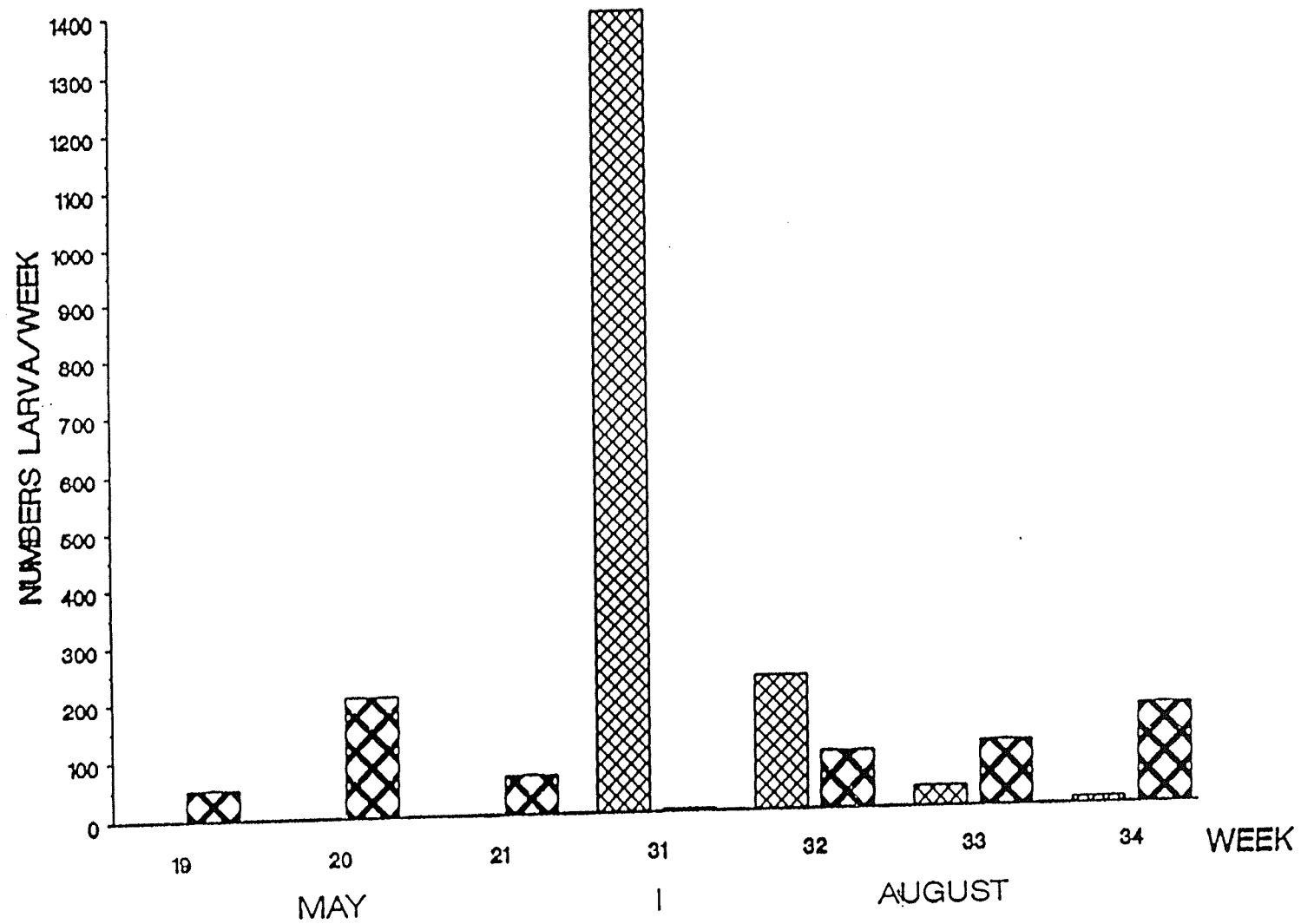


Fig. 11. Weekly abundance of immatures of Ae. dorsalis and Cx. restuans, 1987.

AEDES DORSALIS 
CULEX RESTUANS 

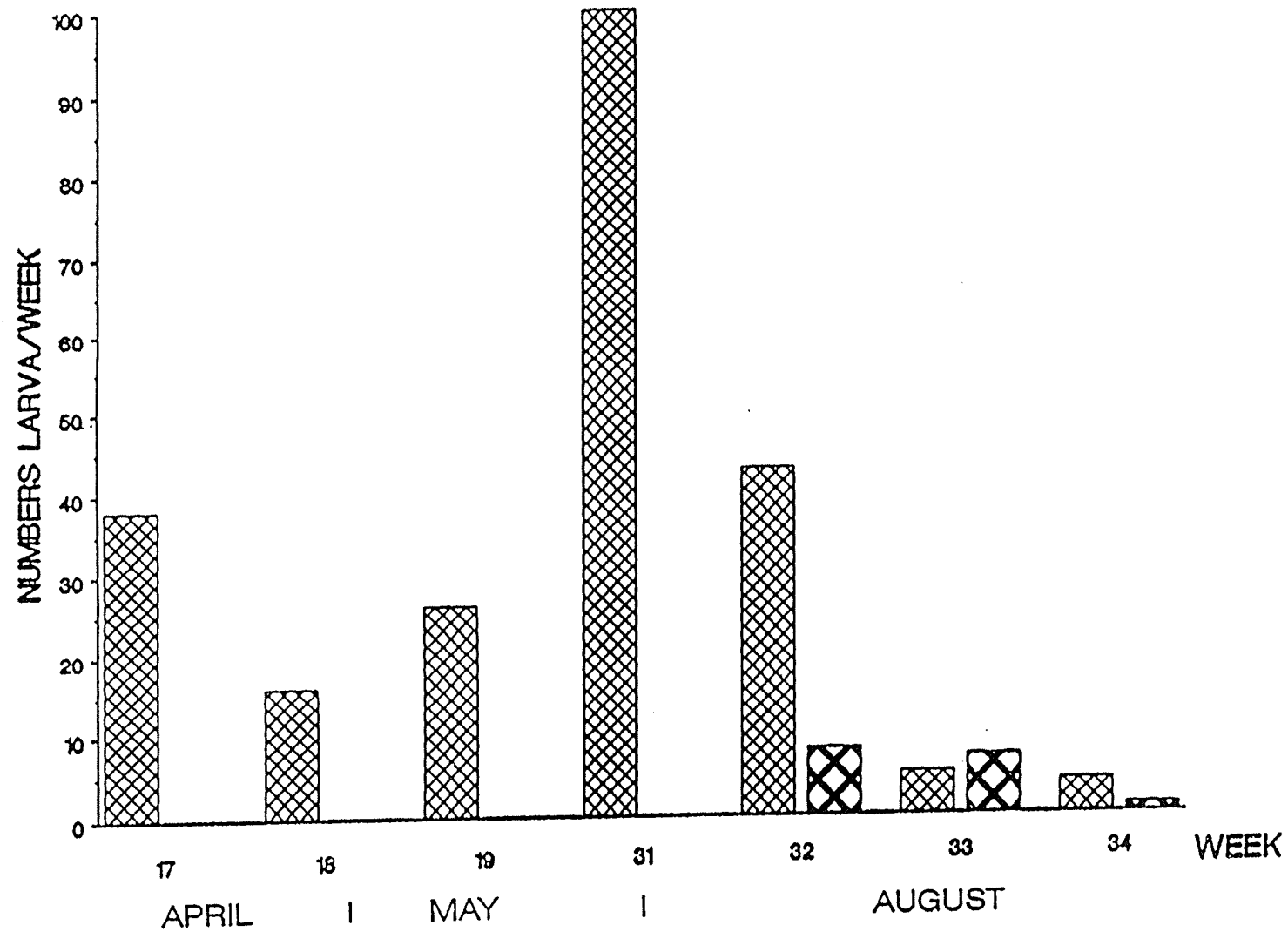


Fig. 12. Number of adult Culex tarsalis and Mansonia perturbans captured per trap/week in CO₂ baited SSAM light traps in 1985.

CULEX TARSALIS 
MANSONIA PERTURBANS 

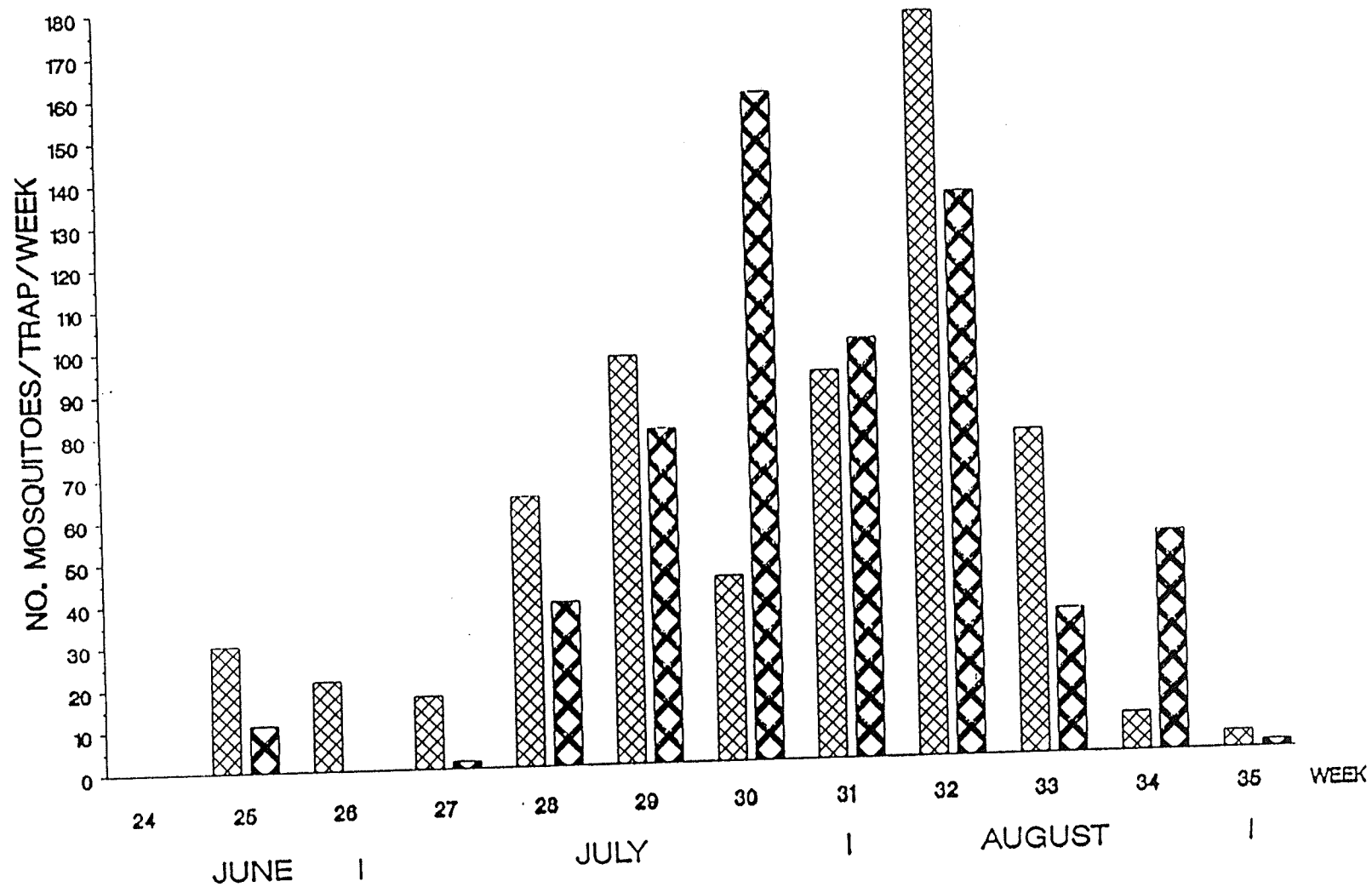


Fig. 13. Number of adult Anopheles earlei and Culex restuans captured per trap/week in CO₂ baited SSAM light traps in 1985.

ANOPHELES EARLEI 

CULEX RESTUANS 

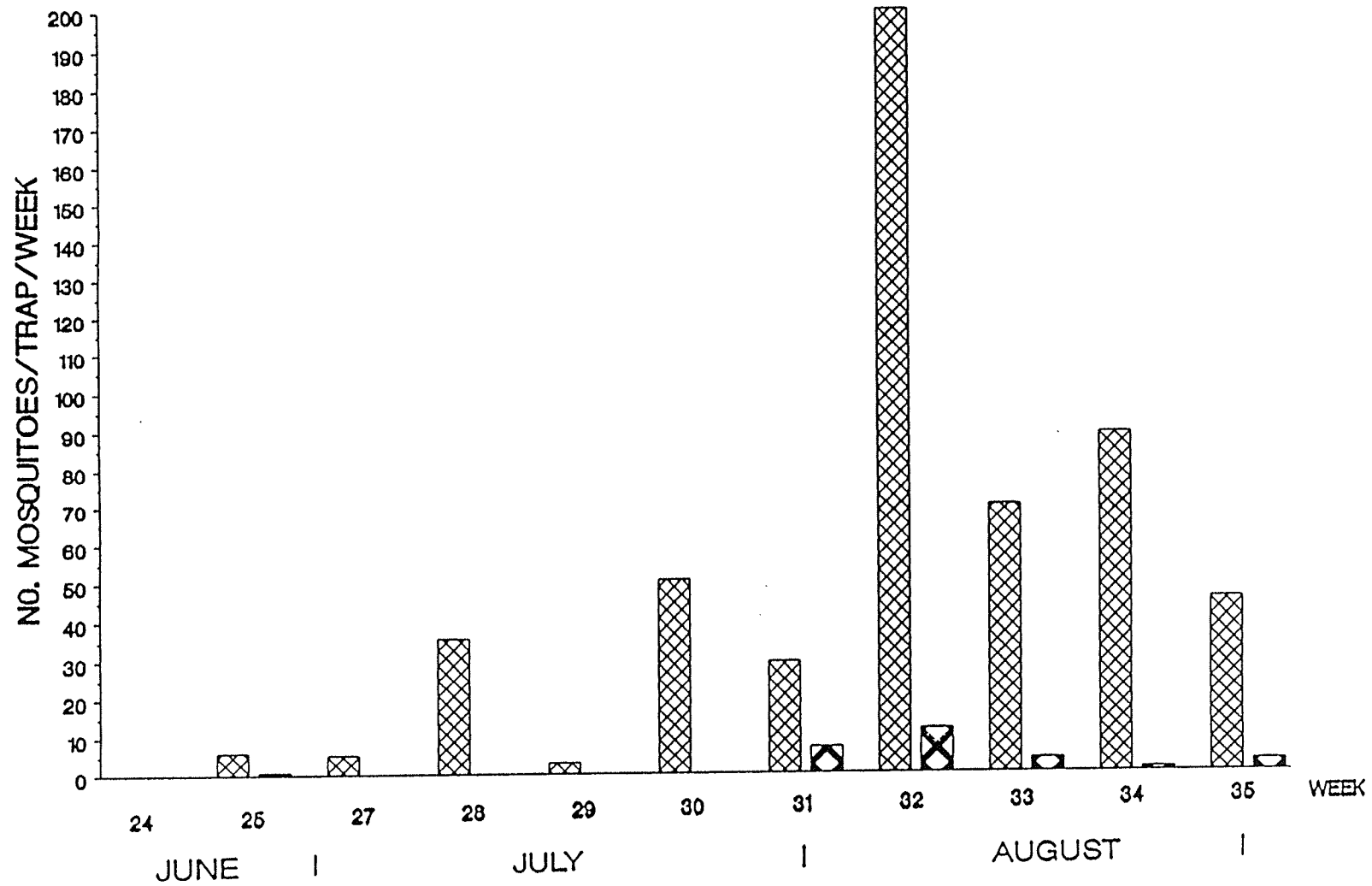


Fig. 14. Number of adult Culiseta inornata captured per trap/week in CO₂ baited SSAM light traps in 1985.

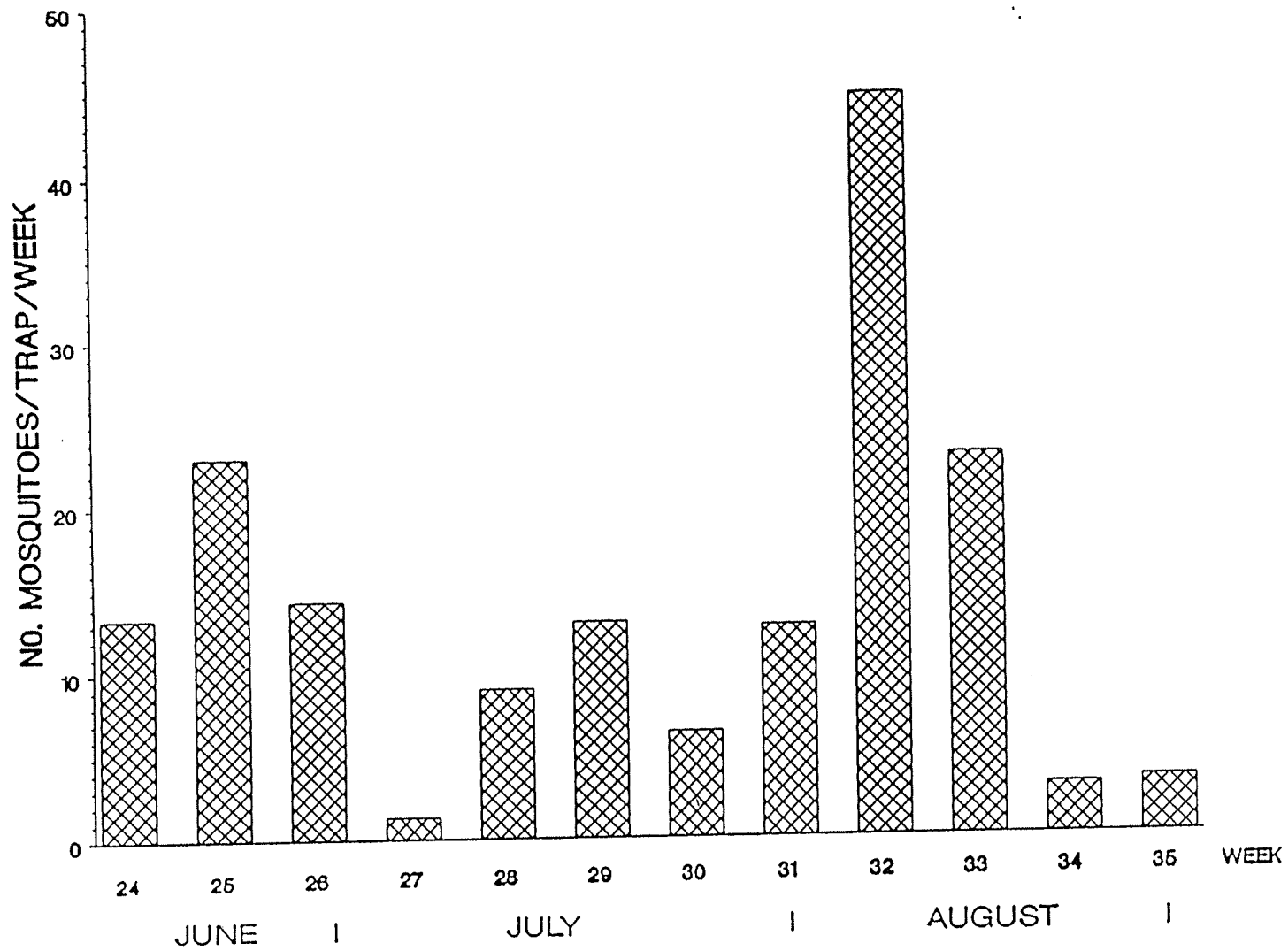


Fig. 15. Number of adult Culex tarsalis and Mansonia perturbans captured per trap/week in CO₂ baited SSAM light traps in 1986.

CULEX TARSALIS 

MANSONIA PERTURBANS 

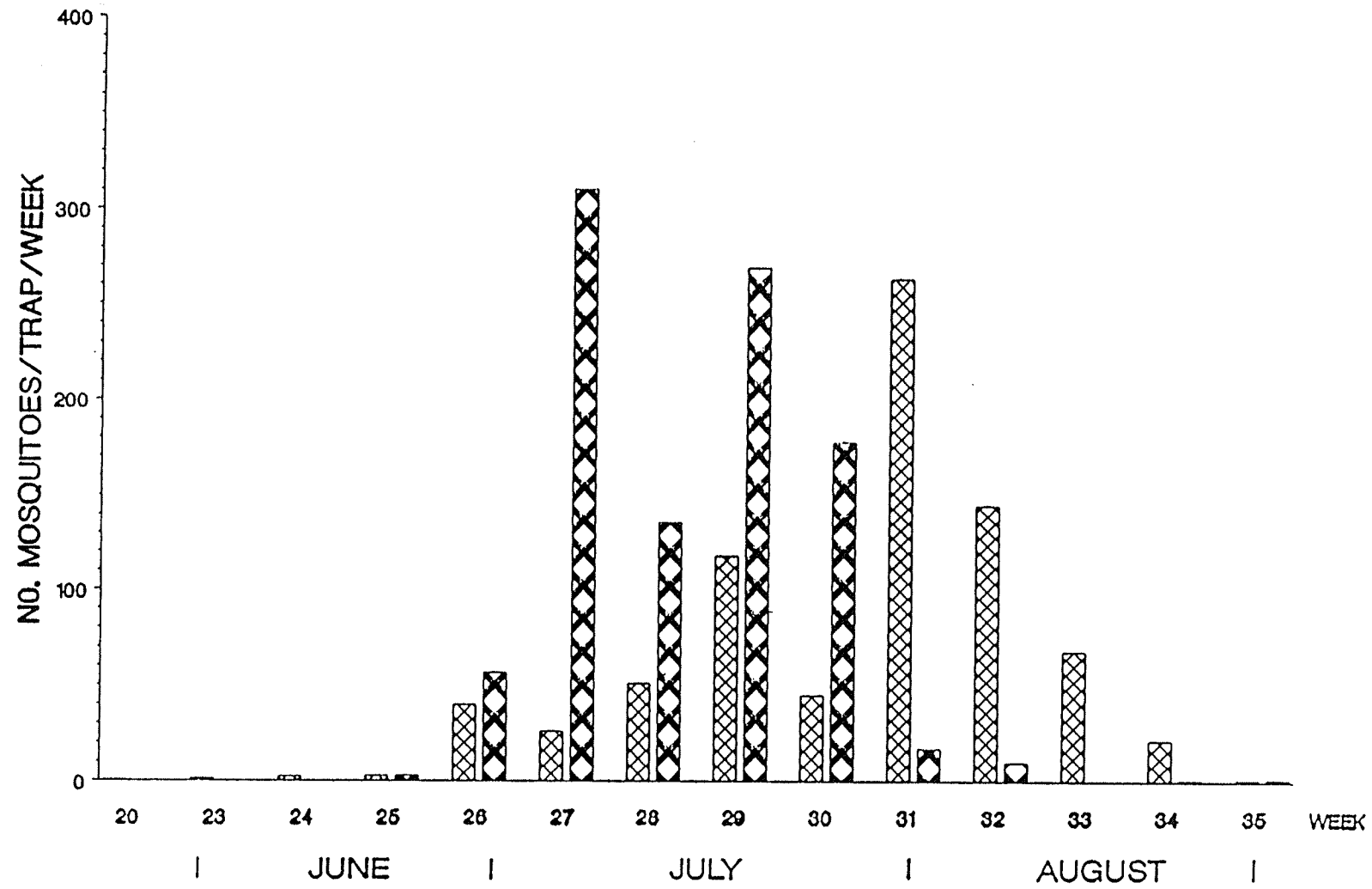


Fig. 16. Number of adult Aedes vexans captured per trap/week in CO₂ baited SSAM light traps in 1986.

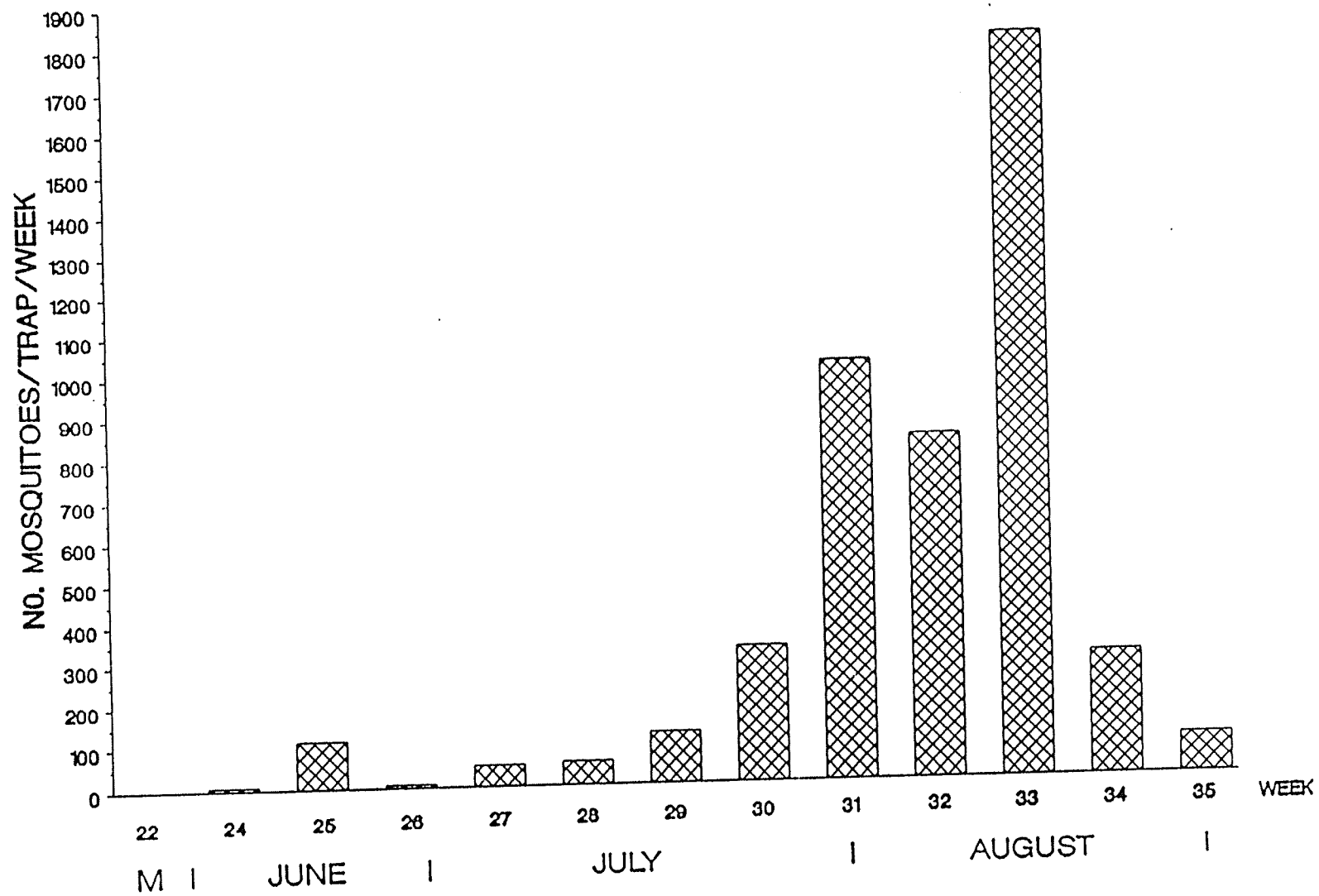


Fig. 17. Number of adult Culiseta inornata captured per trap/week in CO₂ baited SSAM light traps in 1986.

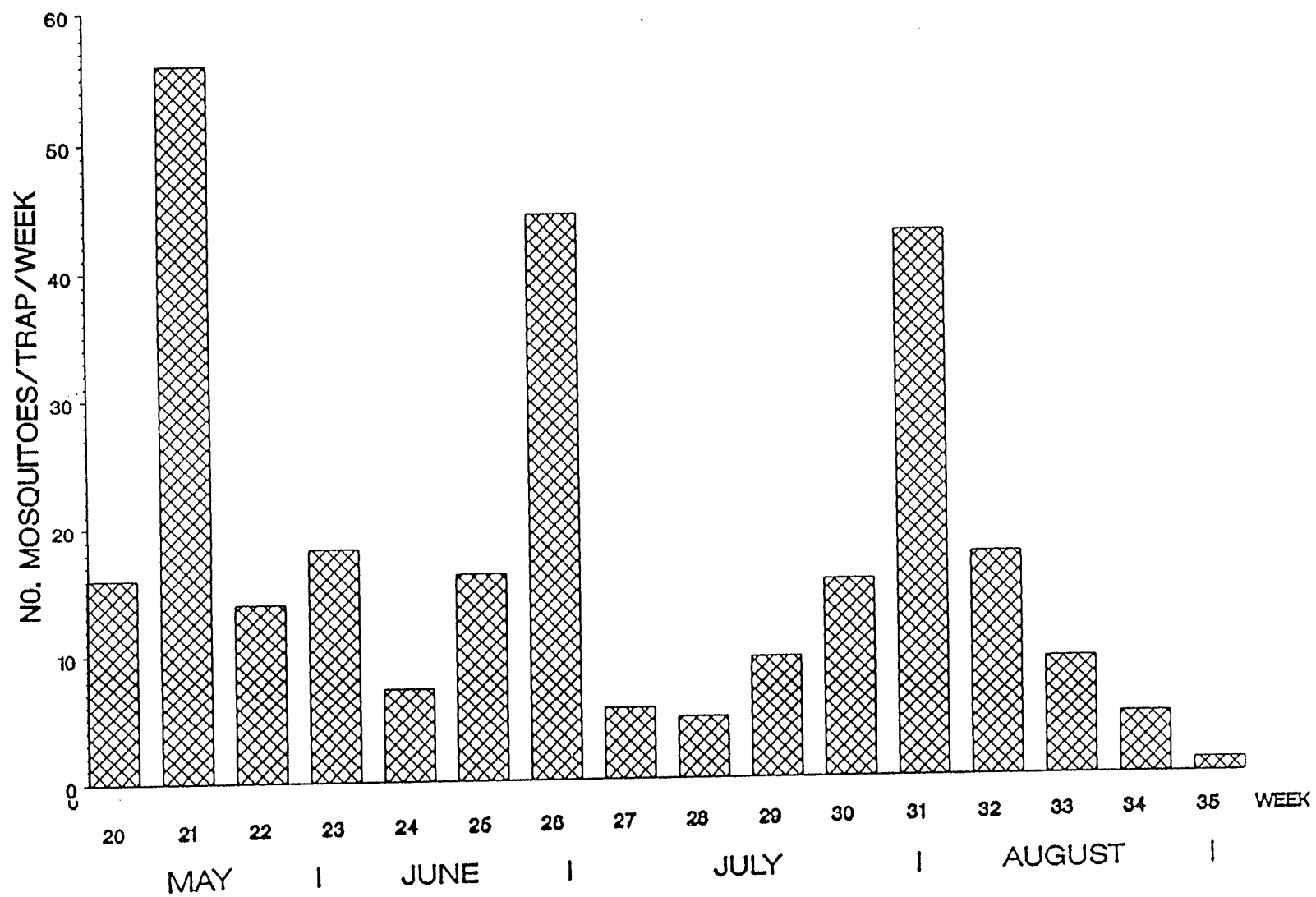


Fig. 18. Number of adult Aedes flavescens and Anopheles walkeri captured per trap/week in CO₂ baited SSAM light traps in 1986.

AEDES FLAVESCENS 

ANOPHELES WALKERI 

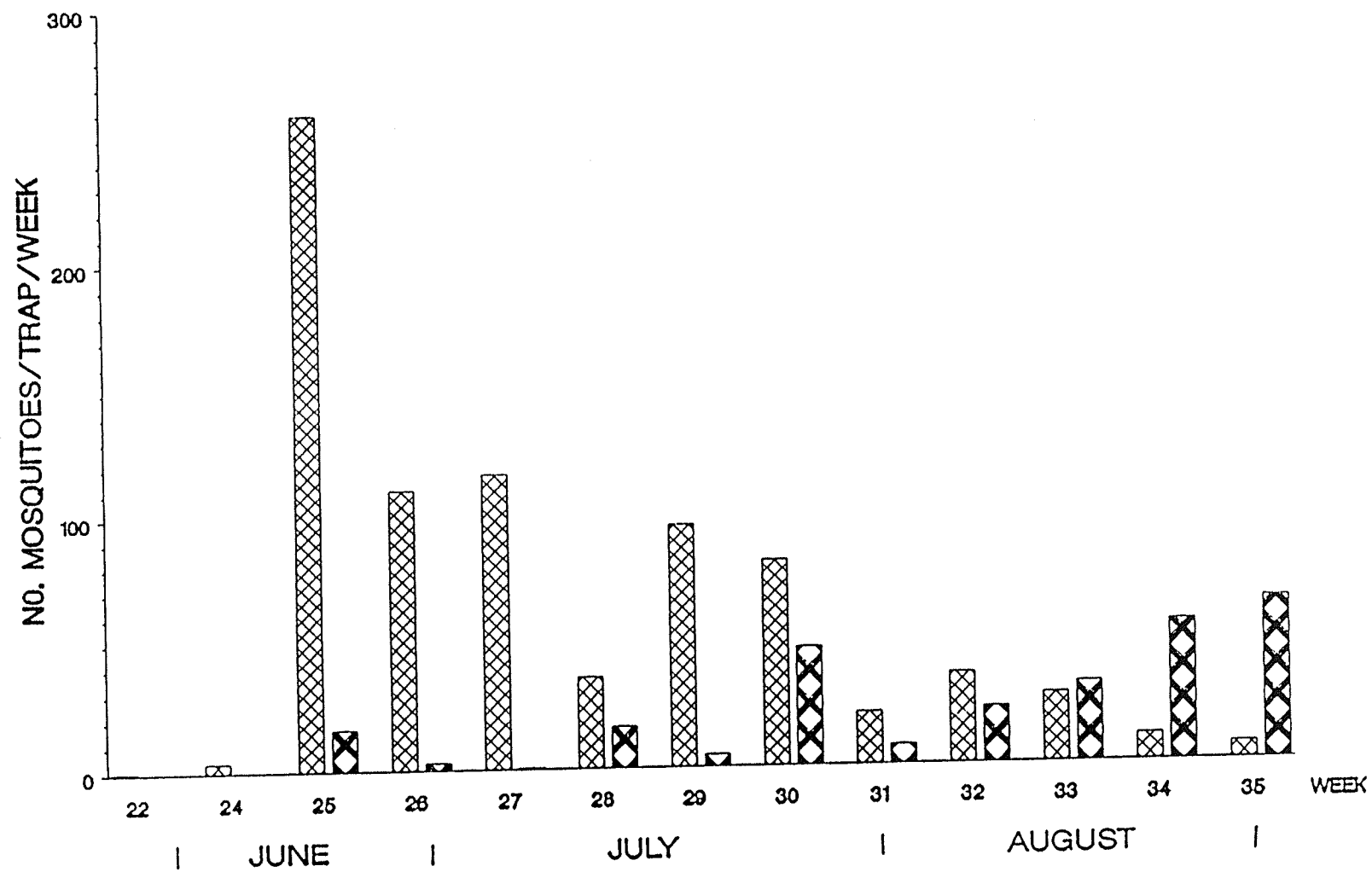


Fig. 19. Number of adult Anopheles earlei and Culex restuans captured per trap/week in CO₂ baited SSAM light traps in 1986.

ANOPHELES EARLEI 

CULEX RESTUANS 

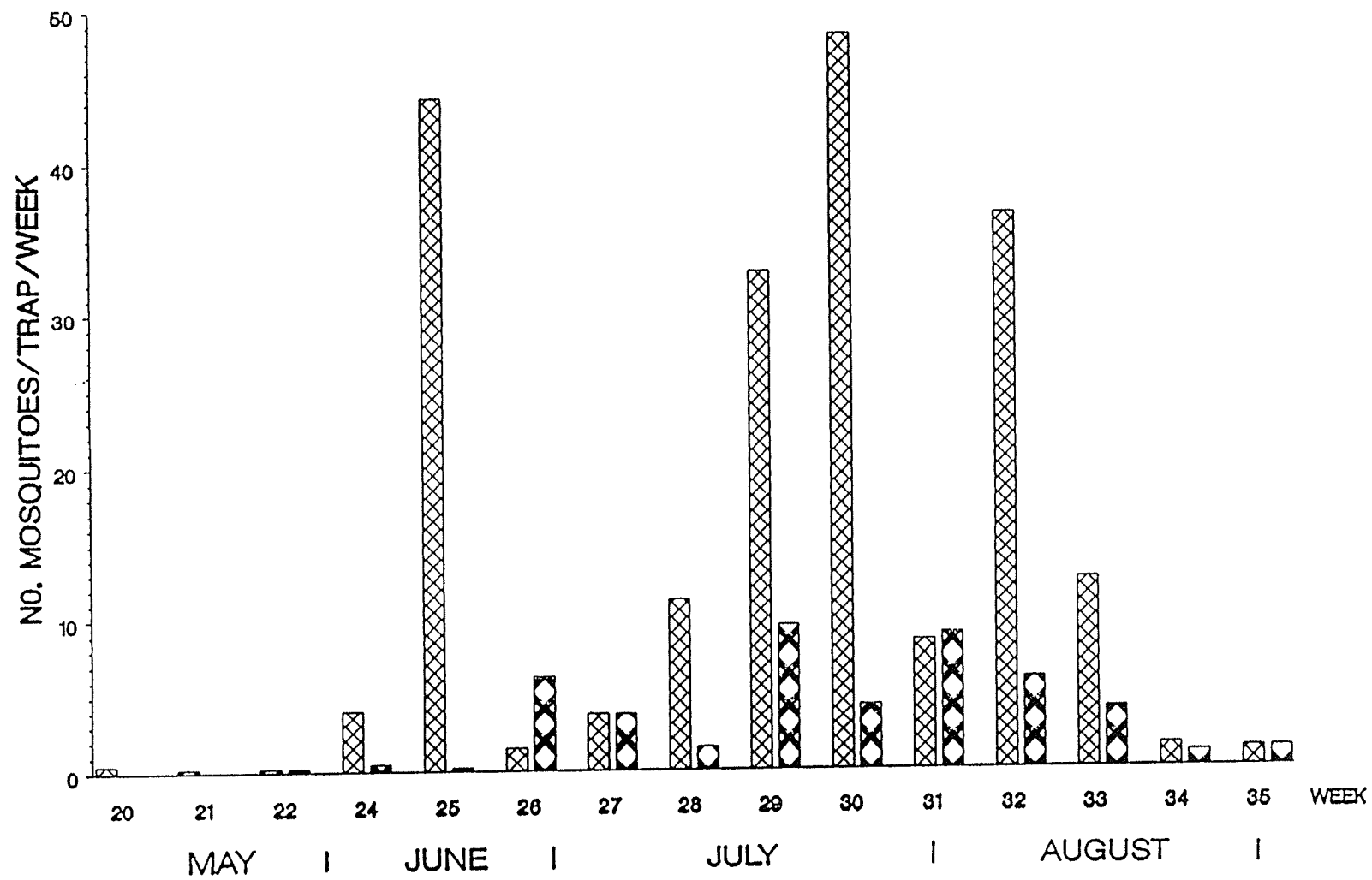


Fig. 20. Number of adult Culex tarsalis and Mansonia perturbans captured per trap/week in CO₂ baited SSAM light traps in 1987.

CULEX TARSALIS 

MANSONIA PERTURBANS 

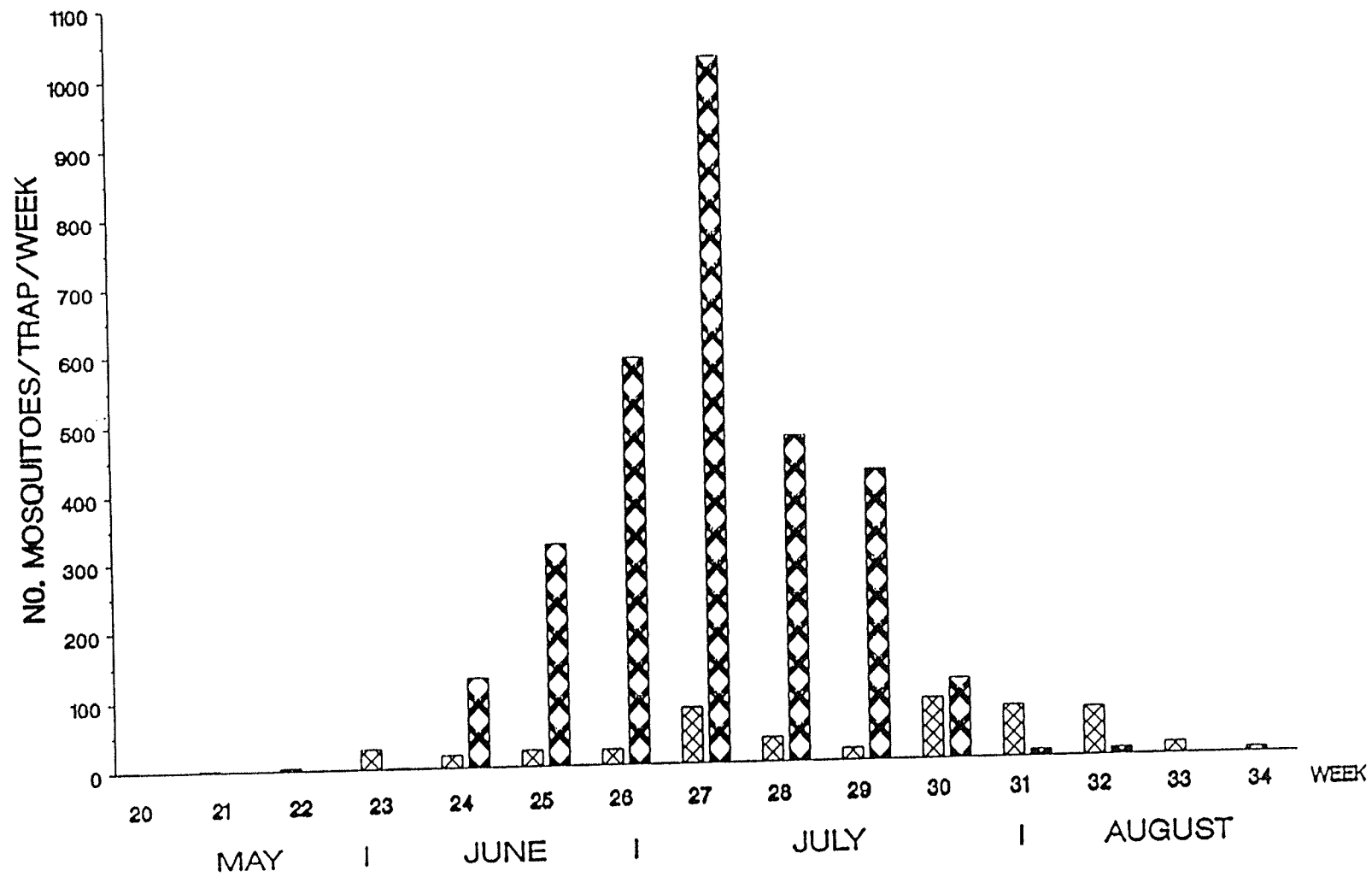


Fig. 21. Number of adult Culiseta inornata captured per trap/week in CO₂ baited SSAM light traps in 1987.

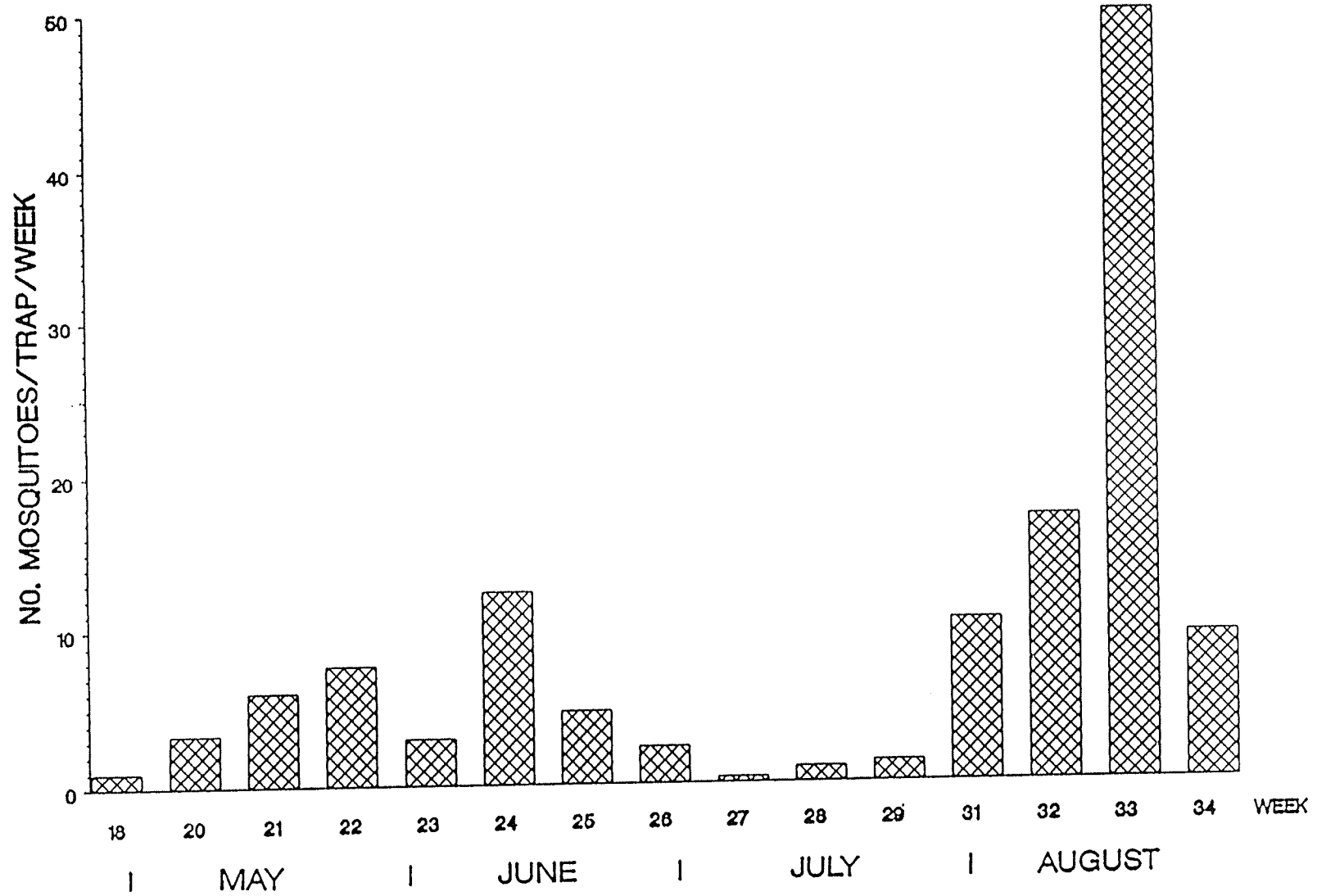


Fig. 22. Number of adult Aedes vexans captured per trap/week in CO₂ baited SSAM light traps in 1987.

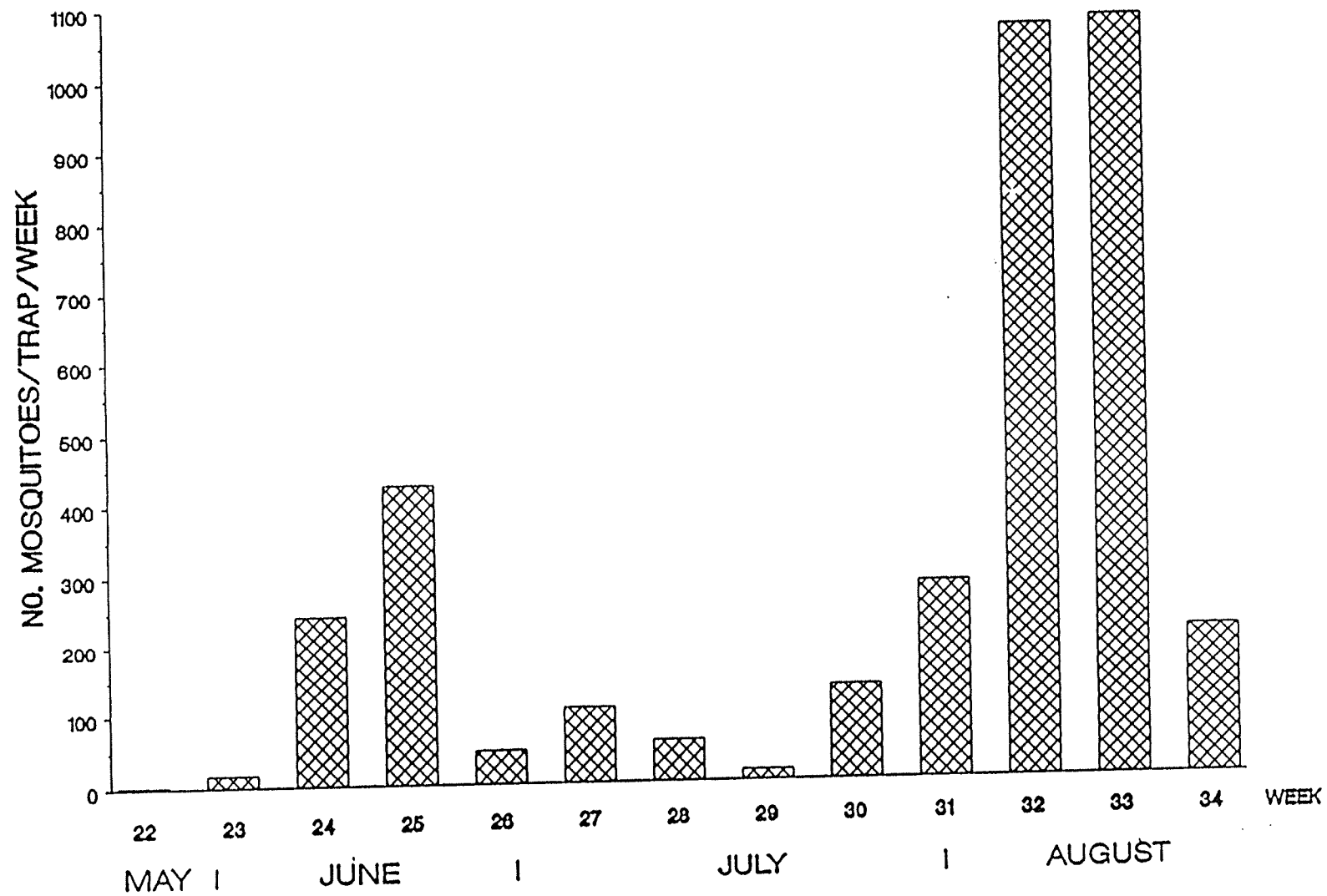


Fig. 23. Number of adult Aedes flavescens and Anopheles walkeri captured per trap/week in CO₂ baited SSAM light traps in 1987.

AEDES FLAVESCENS 

ANOPHELES WALKERI 

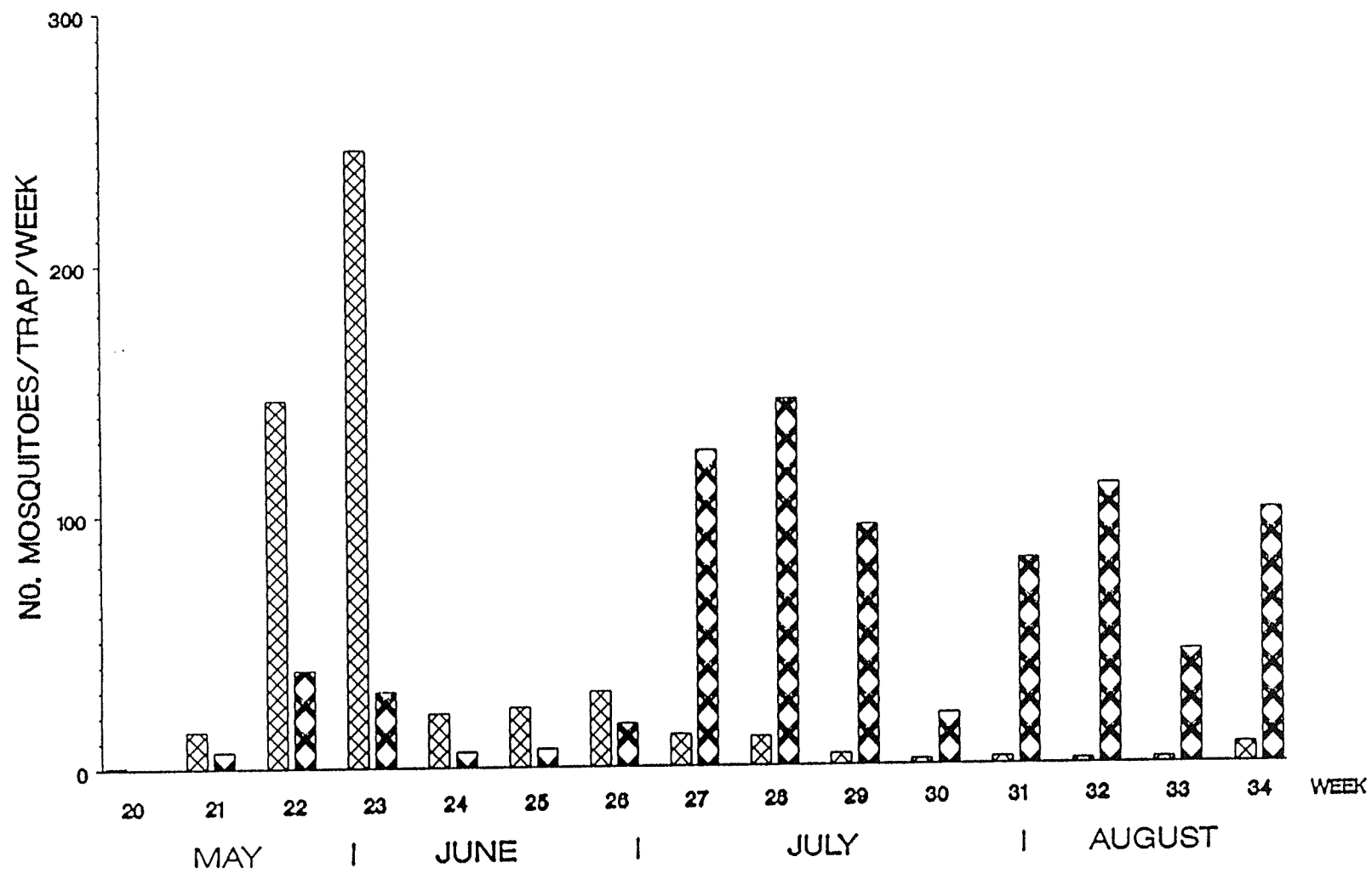


Fig. 24. Number of adult Anopheles earlei and Culex restuans captured per trap/week in CO2 baited SSAM light traps in 1987.

ANOPHELES EARLEI 

CULEX RESTUANS 

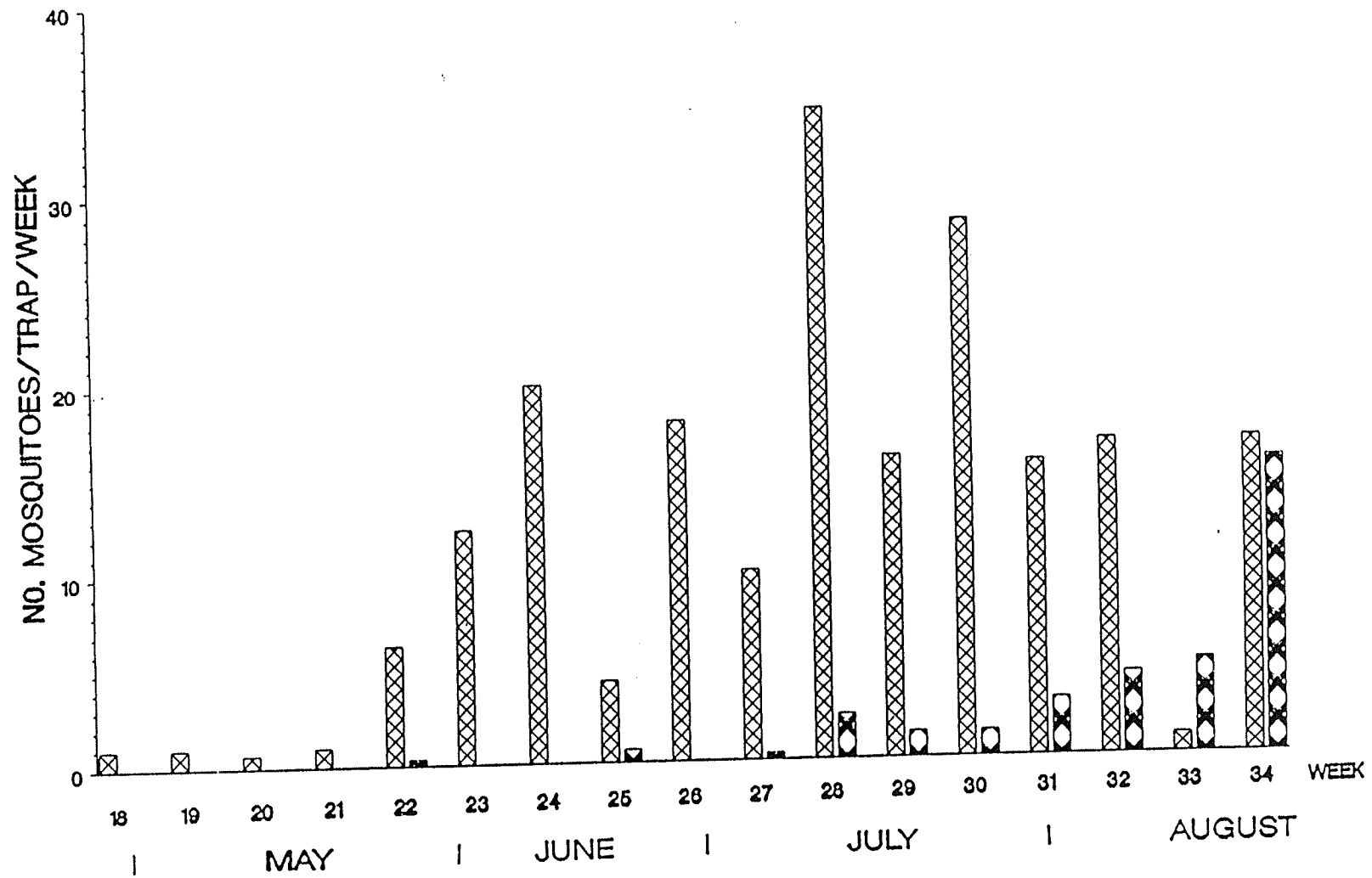
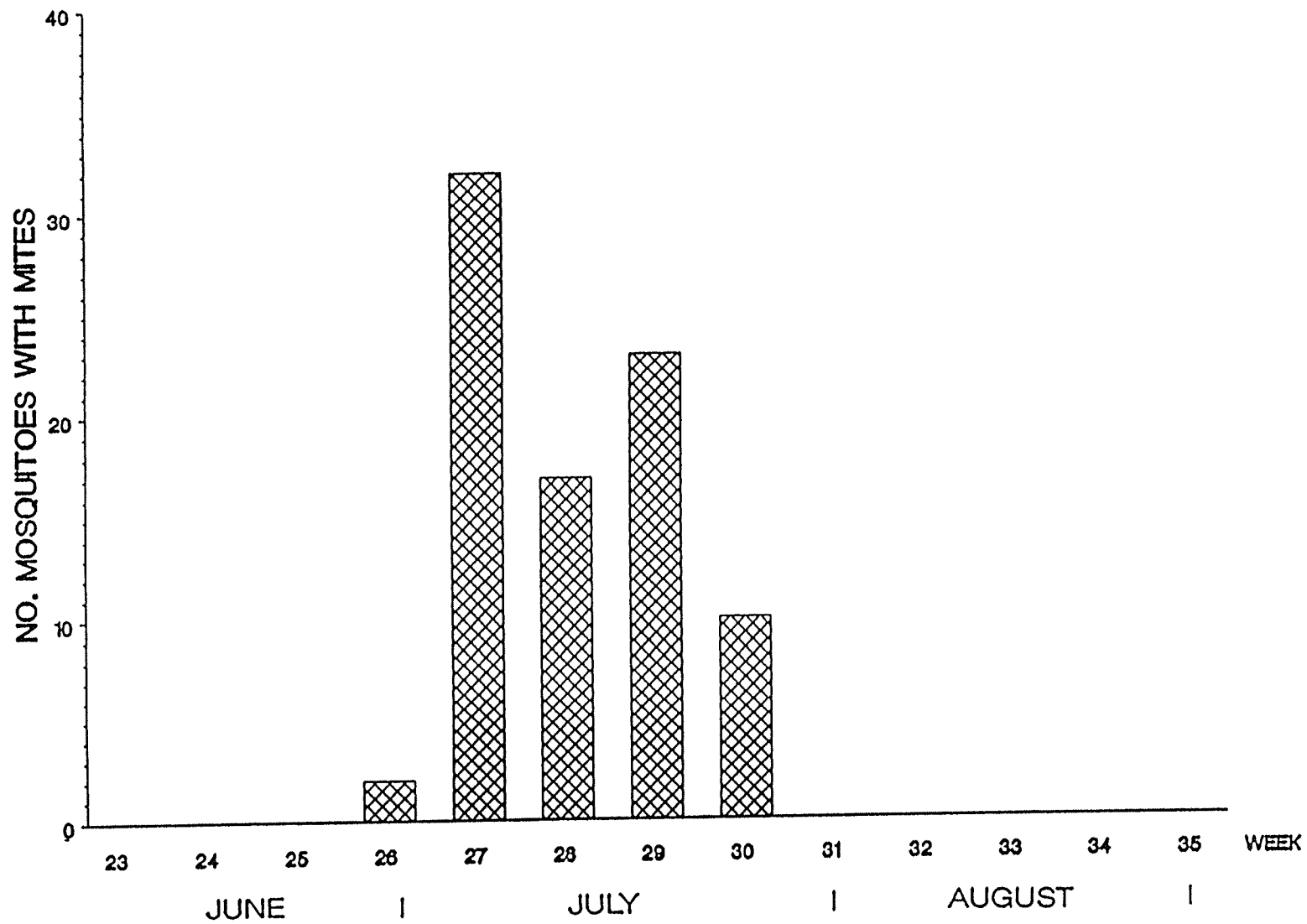


Fig. 25. Number of adult Mansonia perturbans infested with mites/trap/week in CO2 baited SSAM light traps in 1987.



DISCUSSION

Oviposition in Artificial Pools

The number of egg rafts collected in artificial pools at Oak Hammock Marsh was much lower than expected. During the same years, 1985 and 1986, Brust (1990) obtained a mean of 12 and 30 Cx. tarsalis and 9 and 15 Cx. restuans egg rafts/pool/week respectively, at the Glenlea Research Station, Glenlea, MB. This was about 4x as many Cx. tarsalis and about 5x as many Cx. restuans rafts/pool in 1985, and about 20x as many Cx. restuans rafts/pool in 1986, as I collected at Oak Hammock Marsh (Table 1).

There are several possibilities for the differences observed in egg raft collections at the Glenlea Research Station and at Oak Hammock. First of all, at Glenlea, there are few natural oviposition sites. The ovipools provide the only suitable oviposition site within a radius of at least a km. around the ovipools, while at Oak Hammock Marsh the ovipools were surrounded by ample natural oviposition sites. Secondly, the sod was changed biweekly at Oak Hammock Marsh while at Glenlea, Brust (1990) changed the sod at different intervals (weekly, biweekly and no change). Brust (1990) found that bi-weekly changes were preferred by ovipositing Cx. tarsalis, and weekly changes were preferred by Cx. restuans. Thirdly, the ovipools at Oak Hammock Marsh were covered in duck weed (Lemna minor L.) after mid-summer each year. The source of the duck

weed was the nearby creek, which I used as a source of water for the ovipools. Duck weed has been reported to be repellent to ovipositing females and reduces the survival of Aedes aegypti L. (Angerilli 1980; Angerilli and Beirne 1974), and may have repelled Culex and Culiseta species at Oak Hammock.

Larval Sampling

Oak Hammock appears to provide suitable breeding sites for at least 14 species of mosquitoes (Table 3). The dominant species during 1986 and 1987 were Cs. inornata and Ae. vexans respectively (Tables 2 and 3). Aedes vexans is a temporary pool mosquito, and in 1987 dormant eggs hatched after the large rainfall (140 mm.) which occurred in July; Cs. inornata is a permanent pool mosquito, and similar numbers would be expected each year, as occurred in 1986 and 1987 (Table 2).

Habitat Suitability of Natural Breeding Sites

Aedes species and An. walkeri lay eggs that may remain dormant for months or years, and hatch in response to inundation from melting snow or rainfall. The oviposition site does not need to be wet, but only damp, at the time the eggs are laid. Hence, the larval breeding site is determined by the ovipositing females. The most attractive oviposition sites for Ae. vexans are ones with an abundant growth of water-tolerant-grasses (Carex spp.) and shrubs (Salix spp.) (Bodman and

Gannon 1950; Brust pers. comm.) Moist soil and a heavy layer of decaying, water-tolerant-grasses are 2 characteristics that are necessary to attract ovipositing Ae. vexans (Brust pers. comm.). Eggs of all Aedes species and An. walkeri hatch during the spring and summer, in response to flooding. The abundance of larvae of these species in sites 1 - 19, reflect the suitability of oviposition sites.

Culiseta and Culex spp. and An. earlei lay egg rafts in standing water only (permanent pools). The abundance of larvae of these species in pools 1 - 19 would reflect the attractiveness of the site at the time of oviposition, and the abundance of gravid females of each species. Culiseta inornata larvae occurred at every site, except 18 and 19 (Table 3). The latter sites were permanent with little vegetation and were unsuitable for all species, since only 1 larva was found all summer (Table 3).

CO₂ Trap Survey

Seasonal abundance of adult mosquitoes generally varies each year, and the Oak Hammock area fits this pattern as well. Mansonia perturbans numbers were greatest in 1987, Cx. tarsalis, Cx. restuans and Cs. inornata were most abundant in 1985 (Table 5).

At Oak Hammock, although Ae. vexans larvae were twice as abundant in 1987 compared to 1986 (Table 2), the numbers of Ae. vexans adults trapped in 1986 were greater (Table 5). This

suggests that Ae. vexans adults migrate to the marsh from more distant breeding sources.

Mansonia perturbans is an abundant adult at Oak Hammock, but no larvae were found during 1985, 1986 or 1987. The entire summer of 1985 was spent searching for larvae among cattail and bulrush roots. Forty, one-meter-square adult emergence cages were placed over cattail and bulrush sites, and sampled weekly for the entire summer. If larvae breed in the marsh, it appears they are so widely scattered that one is unlikely to locate them. Considering the square kms of possible habitat in the marsh system, it would be difficult to locate isolated or scattered populations. Two egg rafts were found in 1986 (McElligott pers. comm.), but again no larvae were recovered from the marsh. Adults may be flying in from other breeding sites. Evidence for this is that adults emerged from a Glenlea, MB., farm dugout in 1986, where 10, one-meter-square cages were placed during July (Brust, pers. comm.). There are farm dugouts around Oak Hammock Marsh, and these could supply some of the adults trapped at the marsh.

IV. PAROUS RATES OF MANSONIA PERTURBANS, CULEX TARSALIS AND
ANOPHELES WALKERI FROM OAK HAMMOCK MARSH IN MANITOBA

INTRODUCTION

The ability of vector mosquitoes to transmit disease organisms is directly related to their ability to survive (Hoc and Charlwood 1990). Studies on the age-composition of mosquito populations, and consequently their epidemiological importance has gone hand-in-hand for many years (Detinova and Gillies 1964, Gillies and Wilkes 1965, Charlwood and Wilkes 1979). The greater number of gonotrophic cycles completed by a vector, the greater the potential for that individual to encounter a host carrying a pathogen, for example WEE virus, ingest the virus during the blood meal, and subsequently pass the virus on to a host during the next blood meal.

Culex tarsalis Coquillett, Ms. perturbans (Walker) and An. walkeri Theobald are common to Oak Hammock Marsh. Culex tarsalis is the principal vector of Western Equine Encephalitis (WEE) in Manitoba and the WEE virus has been isolated from Ms. perturbans (Sekla et al. 1980). The role of An. walkeri in the maintenance and/or transmission of the WEE virus is unknown; however, the abundance of this species is known to vary from year to year and can account for a large proportion of the collection in Solid State Army Miniature Light Trap (SSAM) and bird-baited traps.

The objectives of this study were to determine the survivorship or parity status of populations of Cx. tarsalis, Ms. perturbans and An. walkeri attracted to SSAM traps at Oak

Hammock Marsh.

MATERIALS AND METHODS

Parous Rates of Cx. tarsalis, Ms. perturbans and An. walkeri 1984 - 1986

Solid State Army Miniature Light Traps (SSAM) were set up at Oak Hammock Marsh during the summers of 1984-1986. The traps were operated 3 nights/week for 12 weeks of 1984 and 1985, and 16 weeks in 1986. The traps were emptied between 0800 and 0900 each morning, following the overnight sampling period. The mosquitoes were placed in coolers chilled with freeze packs, and transported to the laboratory where they were anaesthetized with dry ice, sorted, and stored in a freezer at -20°C until later dissection. In 1984, Cx. tarsalis females, in 1985 Cx. tarsalis and Ms. perturbans females, and in 1986 Cx. tarsalis, Ms. perturbans and An. walkeri females were frozen for later dissection.

Approximately 30 mosquitoes per week were examined for gonotrophic stage. In 1984 and 1985, both ovaries were removed for examination. One ovary was dried on a glass slide and observed for changes in ovarian tracheation. The presence of uncoiled tracheoles was assessed to represent a parous individual and the presence of coiled tracheoles, a nonparous (nullipar) individual. The other ovary was teased apart in Hayes' saline solution under a dissecting microscope, and individual ovarioles were examined for the presence of dilatations and follicular relicts. The number of ovarian

cycles (gonotrophic age) was determined by the numbers of dilatations present, according to methods described by Detinova (1962). In 1986, the examination of the ovarian tracheation was curtailed and replaced by a more detailed examination of the ovary in saline. All ovarioles were examined, and the details recorded regarding the physiological condition of the ovariole and the gonotrophic age of the individual. The difference between the percentages reported in both categories (parous and nulliparous) and 100%, results from females that could not be categorized with regard to parity.

RESULTS

Seasonal Parity Profiles for Cx. tarsalis, Ms. perturbans and An. walkeri

Parity Rates of Cx. tarsalis 1984-1986

The first parous individuals appeared on week 27 in 1984 which coincided with the first peak in the nullipars (Fig. 26). In 1985 and 1986, the first parous individuals appeared on week 24 for both years (Fig. 27 and 28). Nulliparous individuals were present throughout the seasons of all three years, and may represent newly emerged adults entering the population. Since very few of the females survive the winter (Brust pers. comm.) the nulliparous individuals appearing early in the summers for these three years probably represent the first summer generation. The per cent nullipars peaked on week 27 in 1984, week 28 in 1985 and in weeks 23 and 25 in 1986. In 1984, 1985 and 1986, peak numbers of uniparous individuals were observed on weeks 31, weeks 27 and 28, and week 28 for the three years respectively. In 1984, week 31 also marked the peak in the per cent biparous and the first incidence of triparous individuals. Triparous individuals were again present on week 33. There were no triparous individuals found in 1985, but they were present on week 28 in 1986. In 1985 and 1986, biparous individuals peaked on week 26, and weeks 27 and 34 respectively.

Parous Rates of Ms. perturbans 1985-1986

In 1985 and 1986 the first parous individuals appeared on weeks 30 and 28, respectively (Fig. 29 and 30). The per cent unipars increased throughout the summer until the end of the study (week 35). Biparous individuals were present on weeks 31 and 32, and weeks 29 and 31 for 1985 and 1986 respectively.

Parous Rates of An. walkeri 1986

The percentage nulliparous was high throughout the summer of 1986 (Fig. 31). The first parous (uniparous) individuals were recorded on week 26. Biparous and triparous individuals were not observed.

Fig. 26. The seasonal parity profile for Cx. tarsalis dissected in 1984. The bars represent the percentage of females in each category.

NULLIPAROUS	
UNIPAROUS	
BIPAROUS	
TRIPAROUS	

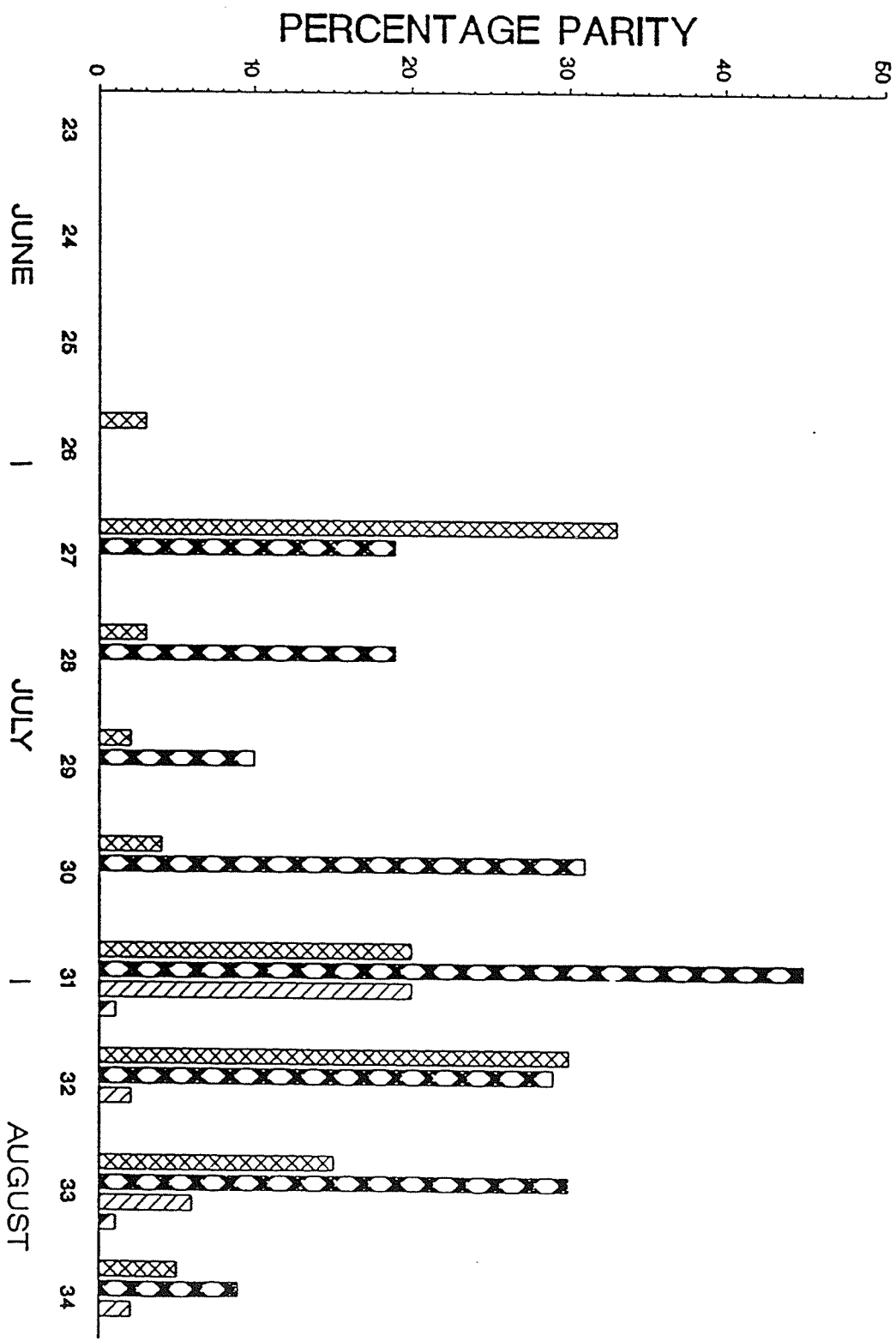


Fig. 27. The seasonal parity profile for Cx. tarsalis dissected in 1985. The bars represent the percentage of females in each category.

NULLIPAROUS	
UNIPAROUS	
BIPAROUS	
TRIPAROUS	

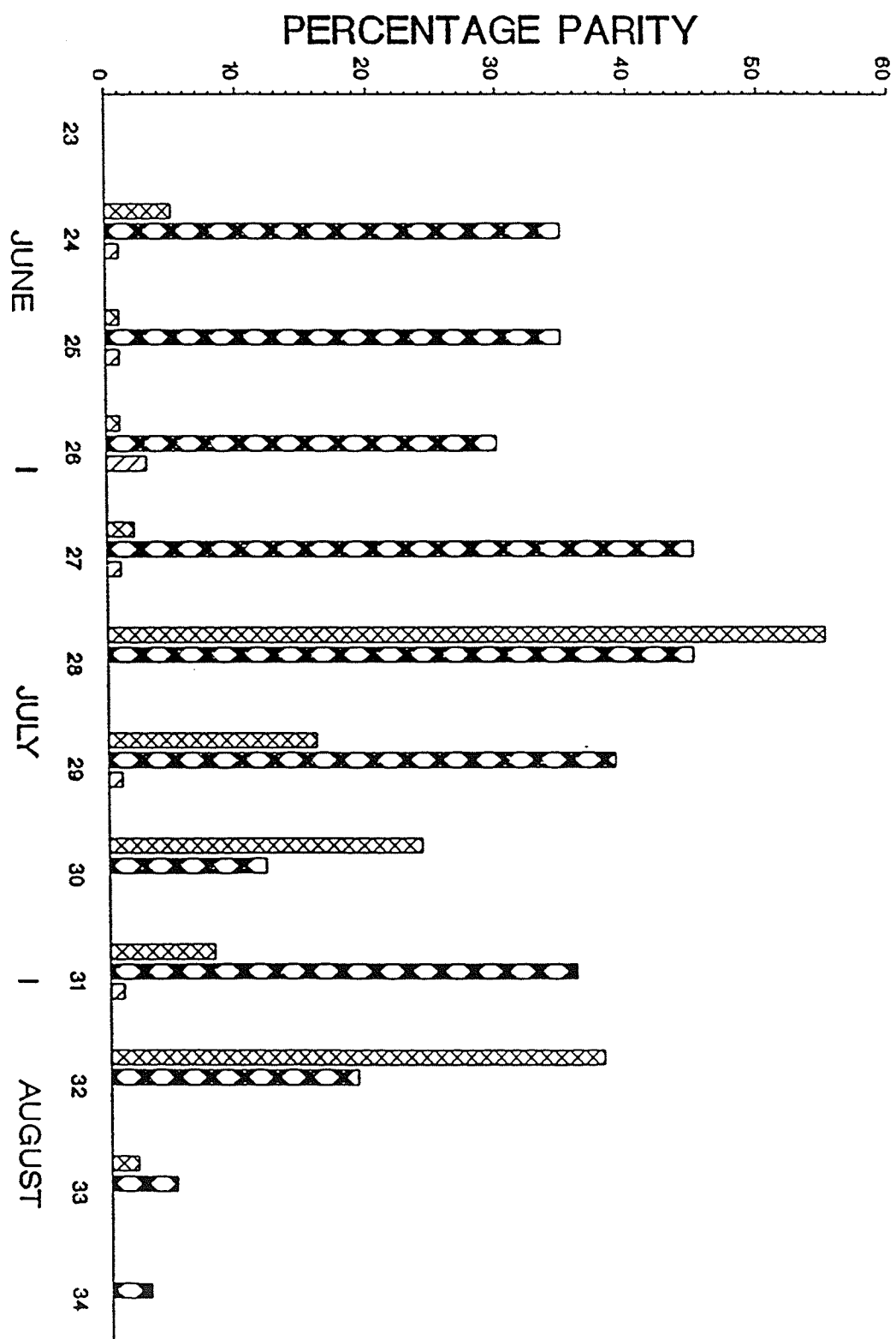


Fig. 28. The seasonal parity profile for Cx. tarsalis dissected in 1986. The bars represent the percentage of females in each category.

NULLIPAROUS	
UNIPAROUS	
BIPAROUS	
TRIPAROUS	

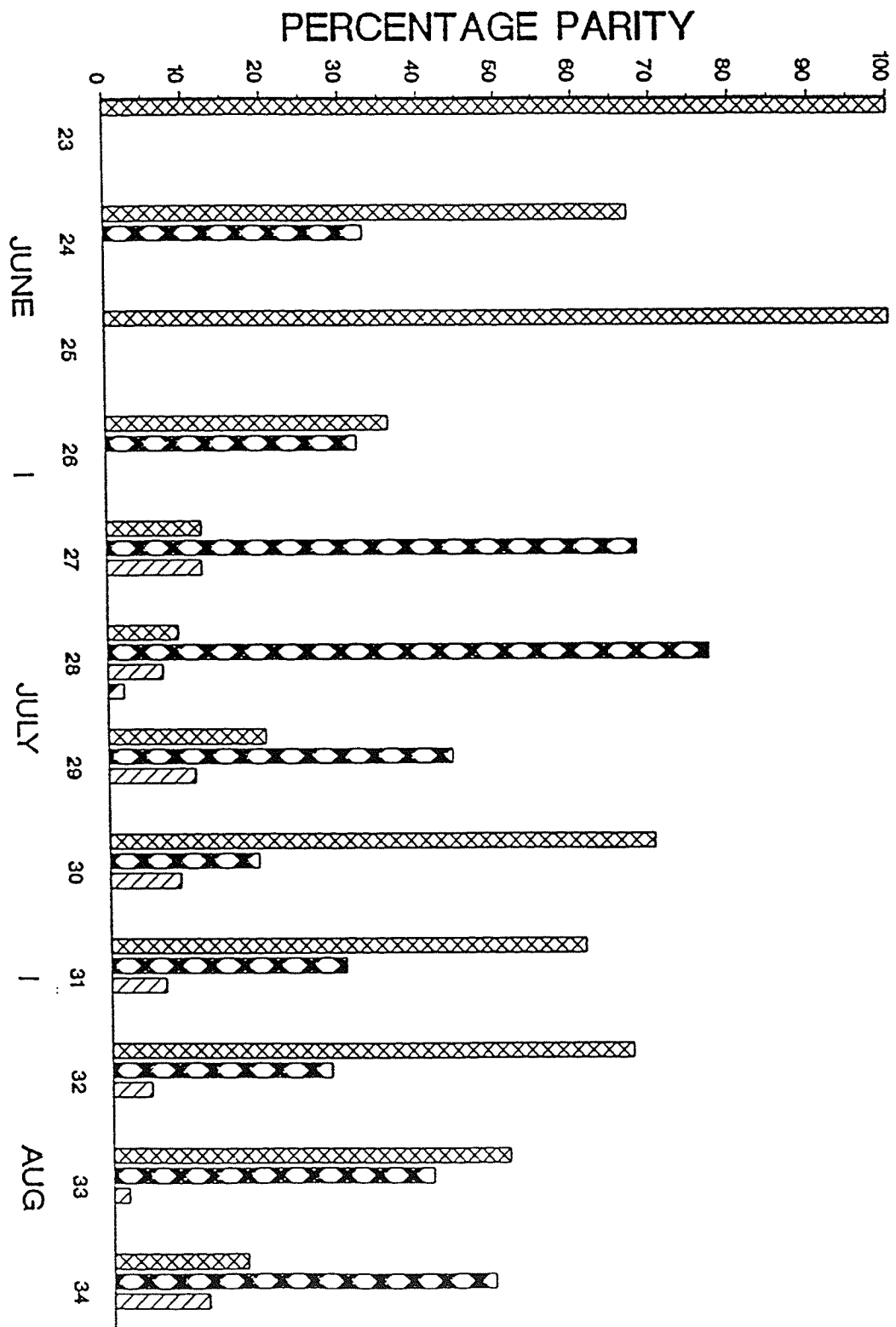


Fig. 29. The seasonal parity profile for Ms. perturbans dissected in 1985. The bars represent the percentage of females in each category.

NULLIPAROUS 

UNIPAROUS 

BIPAROUS 

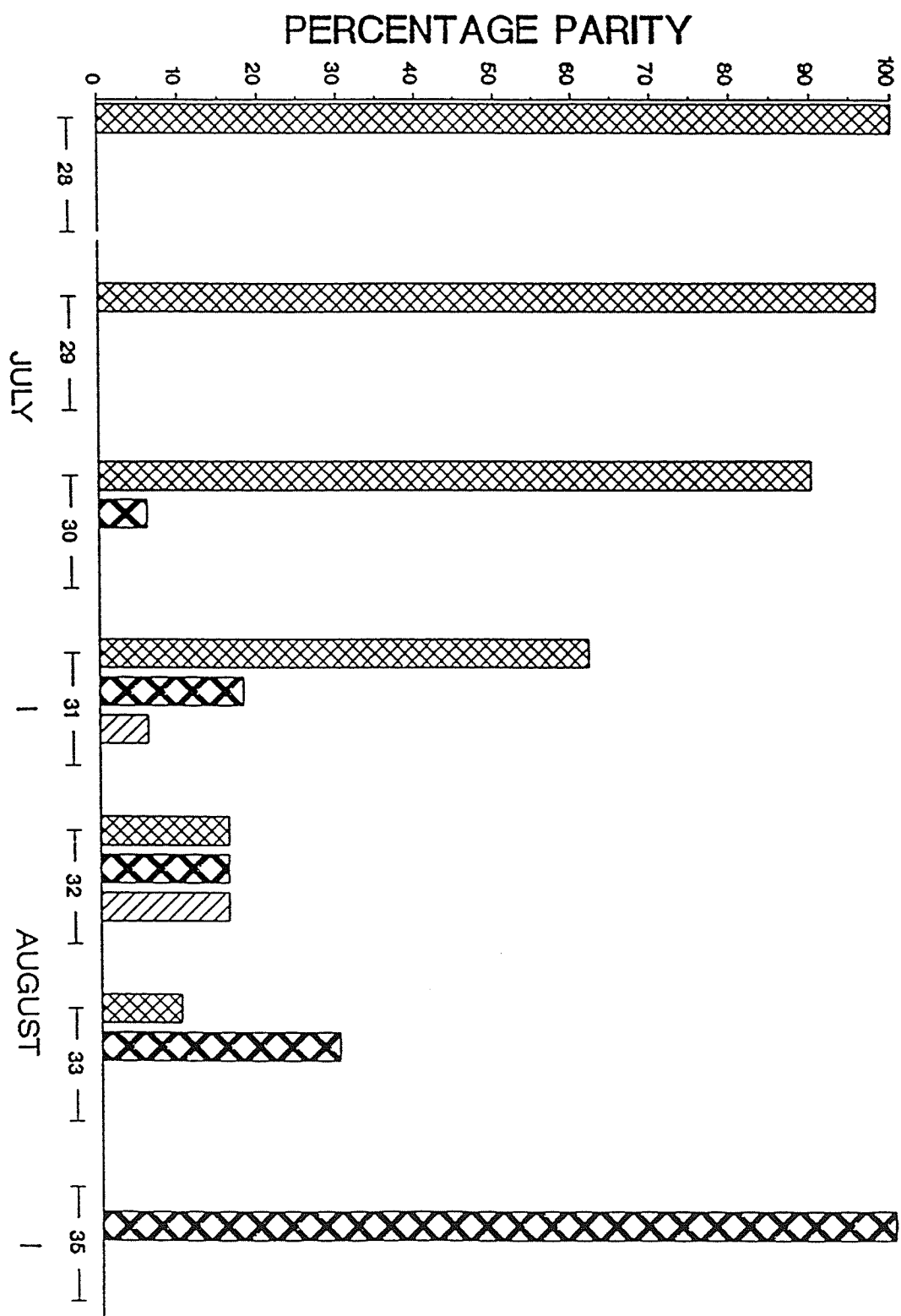


Fig. 30. The seasonal parity profile for Ms. perturbans dissected in 1986. The bars represent the percentage of females in each category.

NULLIPAROUS 

UNIPAROUS 

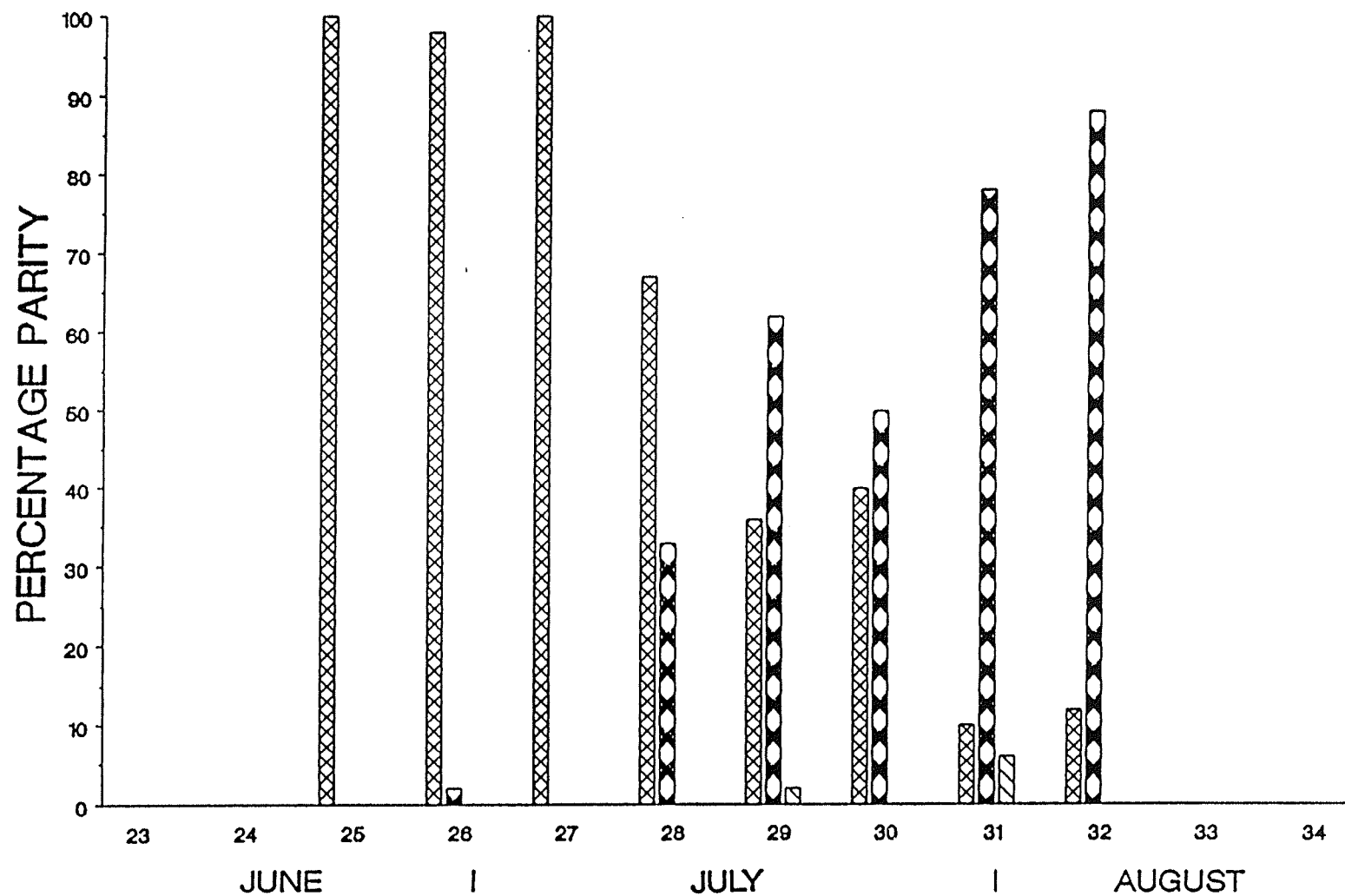
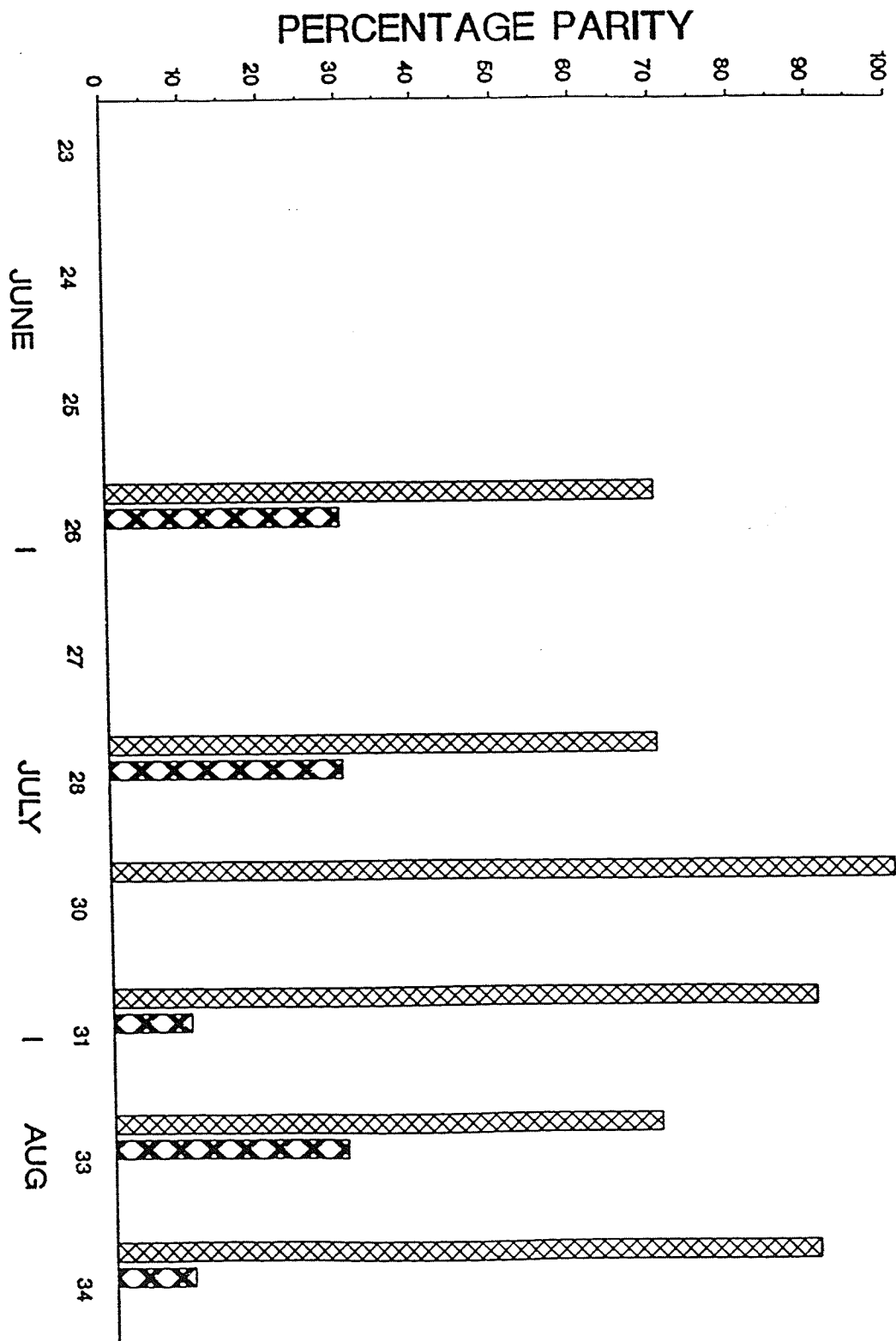


Fig. 31. The seasonal parity profile for An. walkeri dissected in 1986. The bars represent the percentage of females in each category.

NULLIPAROUS 

UNIPAROUS 

BIPAROUS 



DISCUSSION

Seasonality Studies on Parity in Cx. tarsalis 1984 - 1986

In 1984 and 1986 there were three generations while in 1985 there were only 2 generations (Figs. 49, 50 and 51). This conclusion is in agreement with the findings of Buth et al. (1990), who concluded that Cx. tarsalis had 2.6-2.9 generations in 1980 and 1981 at Winnipeg, Manitoba.

In 1984 and 1985, uniparous individuals dominated the seasonal parity profile, while in 1986 the per cent nulliparous females dominated (Figs. 49, 50 and 51). Charlwood et al. (1985) stated that sampling location may be more important than sampling method in causing a bias in the age groups sampled. For example, traps located near breeding sites may collect younger age classes in larger proportion than older age classes. The presence of nullipars throughout the entire season during every year of my research suggests a fairly continual inflow of newly emerged adults into the population (Fig. 51). The presence of the younger age class in relatively high proportions in the sample suggests that the traps were located near the breeding site. This is not as apparent for the other two years and may suggest alternate breeding areas. Management policies include water level manipulation which could change the locations of suitable breeding sites.

Buth et al. (1990) believed that each generation of Cx.

tarsalis requires 35-40 days for development. In Oak Hammock, the appearance of a peak in numbers of unipars 3 to 5 weeks following a peak in nullipars suggests that they may be the same generation following a period of oviposition (Fig. 49). With the abundant bird life at the marsh, it is not unlikely that the mosquitoes found hosts in the vicinity of the traps.

Seasonality Studies on Parity in Ms. perturbans 1985 - 1986

Mansonia perturbans has a single generation in Canada (Wood et al. 1979), and as expected, had single generations at Oak Hammock Marsh during 1985 and 1986. There was little overlap between the parous and nulliparous individuals during both years. Newly emerged adults were recruited into the population during late June and July (Figs. 52 and 53). In southwestern Ontario, Allan et al. (1981) observed this species to emerge from 13 June until 24 August. The first parous individuals in Oak Hammock Marsh occurred in late July in 1985 and late June, 1986 (Figs. 52 and 53), while in southwestern Ontario, Trueman and McIver (1983) observed the first parous Ms. perturbans on 8 July in 1981. In 1968, in Wisconsin, Morris and DeFoliart (1971) found the maximum parous rate to coincide with the population peak, on 17 July.

The seasonal profile of this population of Ms. perturbans is similar to a population in southern Ontario where the first biparous individual was recorded on 30 July, and a triparous

mosquito was collected on 12 August (Trueman and McIver 1983). The presence of biparous females in the collection in late July and early August in this study suggests that females were able to readily obtain blood meals and oviposit a second time.

Seasonality Studies on Parity in An. walkeri 1986

An. walkeri probably has two generations in Manitoba. The presence of both age groups until week 28 (mid-July) and the presence of nullipars throughout the summer (Fig. 54) suggests that the traps were located near the breeding site of this species (Charlwood et al. 1985). The presence of unipars during all but one week (week 30) suggests that the adults were able to readily locate a host, possibly in the vicinity of the breeding site.

V. THE ATTRACTION OF MARSH MOSQUITOES TO MALLARD DUCKS,
DOMESTIC CHICKENS AND YELLOW-HEADED BLACKBIRDS AT OAK
HAMMOCK MARSH, MANITOBA

INTRODUCTION

Western Equine Encephalitis (WEE) is an arbovirus that is maintained in nature within a cycle between a mosquito vector and a suitable vertebrate reservoir. Reeves et al. (1963), and coworkers in California, have shown that the principal mosquito vector is Culex tarsalis Coquillett, and wild birds are believed to play an important role as the reservoir host (Hardy 1987). The association between wild ducks and WEE has been established in Saskatchewan (Burton et al. 1961). Oak Hammock Marsh provides habitats for both the vector and the potential reservoir hosts. Several other mosquito species have been linked to WEE virus and may have a role in its transmission. WEE virus has been isolated from Culesita inornata (Williston), Aedes vexans (Meigen), Coquillettidia perturbans (Walker) and Anopheles walkeri Theobald in Manitoba (Sekla et al. 1980), and these species are known to occur in Oak Hammock Marsh (Sekla et al. 1980).

Research on the mosquitoes of Oak Hammock Marsh is extremely limited and the vast majority of host preference studies has been limited to tropical or semi-tropical regions of the world (Muirhead-Thompson 1982). The usual technique for host preference is to determine the blood meal source of recently fed mosquitoes (Reeves et al. 1963, Hayes et al. 1973, Tempelis and Galindo 1975, Williams and Meisch 1981, Mitchell 1983, Anderson and Gallaway 1988). A different approach is to

provide a choice of host types to a natural mosquito population, and to capture the bloodseeking mosquitoes while in the vicinity of this host. The host types provided would be species normally found in the location of the study site. There are few studies where bird-baited traps were used, but in most cases, the bird bait species were domestic varieties held in a flock rather than individuals of a wild species (Rainey et al. 1962, Gillies and Wilkes 1974 and Crans 1986). The usual trap type used for single/paired bird (e.g. chicken, Japanese quail or small mammal) baits is the 'Lard Can' type trap (Bellamy and Reeves 1952), or the similarly constructed Eherenberg pigeon trap (Eherenberg 1966, Mitchell and Millian 1981).

Oak Hammock Marsh provides a habitat for both the vector and potential reservoir hosts for Western Equine Encephalitis. In order to test the interaction between marsh breeding mosquitoes and birds common to Oak Hammock, single, paired and/or flocks of three bird bait species were used to determine the relative numbers of mosquitoes attracted to the three bait types. Two trap types were tested: the Ehrenberg, and the newly designed fan assisted box trap, or 'Fortney Fan Trap'.

MATERIALS AND METHODS

INDIVIDUAL BIRD ATTRACTION STUDY 1986

Mosquito attraction to potential avian hosts was monitored during the summers of 1986 and 1987 at Oak Hammock Marsh. In 1986 a study site was selected in the ecotone between marshland and grassland interspersed with willow (Salix spp.) on the southwest side of the marsh. The grassland on the west side of the marsh had been replaced by a cultivated lure crop several years prior to the study.

Nine trap positions (site numbers 1 - 9) were located within the principal study site in 1986 (Fig. 32). The entrance of each trap was positioned in one of four directions. The orientation was varied for each position, in order to evaluate the effect of wind. A fan assisted box trap (FORTNEY FAN TRAP) was designed and used specifically for this study. Single chickens (mean weight 2.21 kg) or adult mallard duck (mean weight 1.2 kg) were placed within the restraining cage, and the latter placed within the main body of the trap (Figure 33A). Three replicates of each bait species and three replicates for controls (empty boxes), made up the experimental units. The domestic chicken (Cornish Giant - Gallus domesticus, Guenter pers. comm.) and a wild strain of mallard duck, Anas platyrhynchos, were utilized as the bait animals. A random number table was used to determine at which site a particular trap would be located each week. The

experiment was active for three consecutive nights/week for six weeks, from 17 July to 21 August (corresponding to week 29 to 34). The traps were returned to the laboratory at the end of each three night period, and the mosquitoes were removed and identified. Blood-fed mosquitoes were separated from the rest, and sorted according to species. Additional categories under each species included male identifications and both males and females infested with parasitic larvae of water mites. Temperatures were averaged from 2000 hours to 0800 hours each day of the three day experiment, each week, and plotted (Figs. 35 and 36). Temperature, windspeed and wind direction records were taken from Environment Canada's Monthly Meteorological Summary (Winnipeg Airport). The mean numbers of mosquitoes/bait/week were determined for the most abundant mosquito species using SAS Institute Inc. statistical package. Species that were successful in obtaining bloodmeals, as well as the total numbers attracted, were compared.

SINGLE/PAIRED BIRD ATTRACTION STUDY 1987

In 1987 the size of the experiment was increased to accomodate an additional bait species as well as the modified Eherenberg trap (Ehrenberg 1966). Two yellow-headed blackbirds were used in each Ehrenberg and Fortney Fan trap (Fig. 33B). Six additional sites (10 - 15) were established within the principal study site (Fig. 1). Three replicates of the Eherenberg trap, and three replicates of the Fortney Fan Trap

were used for blackbirds. Three Fortney Fan Traps were used for mallard ducks and three for domestic chicken bait. Blackbirds were paired in all traps, but chickens and mallard ducks were single. Due to the absence of mosquitoes in the 3 non-baited controls in 1986, the number of control replicates was reduced to two. The experiment was run from 26 June to 27 August for ducks and chickens, and from 9 July to 27 August for blackbirds. The collection of mosquito data was the same as in 1986, and the results were analysed in the same manner as the previous year.

SENTINAL FLOCK ATTRACTION STUDY 1986+1987

One sentinel flock cage holding ducks and one holding chickens, were set up at locations adjacent to the single attraction study site (Fig. 34). Both flock cages were located at the marsh throughout the summers of 1986 and 1987 (Fig. 1). In 1986, the traps were maintained from 24 June to 27 August weeks (26 to 36), while in 1987 the study period commenced on 23 June and ended on 30 August. The numbers of birds in the cages varied from 7 to 10 birds, depending on the number needed for the single bird attraction study.

A mosquito collection trap was located on the end of the flock cage (Fig. 34). The mosquitoes were removed from the trap daily, and taken to the laboratory for identification and for recording the presence or absence of a bloodmeal. The

seasonality of the three most abundant mosquito species and their bloodfeeding behaviour were determined. Mosquito species are compared using numbers attracted per week. Numbers of mosquitoes are also compared with mean weekly temperatures.

RESULTS

Fortney Fan and Ehrenberg Trap Collections

1986 BAIT TRAP COLLECTIONS

In 1986, a total of 943 mosquitoes and fifteen species were collected. A single trap type and 2 bait species were used over the 6 week study period. Culex tarsalis, Ms. perturbans and Ae. vexans accounted for 80% of the total catch. The seasonal distributions for these three species and An. walkeri are presented in Figures 37 to 40.

The mallard duck bait attracted 15 species and 53% of all mosquitoes attracted to baited traps, while the domestic chicken bait attracted 15 species and 42% of the total collection. Nine species obtained blood meals from chickens and 8 species obtained blood meals from mallard ducks (Table 9). The number of mosquitoes attracted to the three controls amounted to 5% of the total catch. The principal mosquito species attracted to both bait species was Cx. tarsalis, which made up 59% of those attracted to the duck bait and 50% of those attracted to the chicken bait. Aedes vexans was the principal species attracted to the non-baited controls, amounting to 60% of the catch, while Cx. tarsalis accounted for 12% (Table 9).

Culex tarsalis was present in the collections from both bait species during every week throughout the summer. There was a gradual increase in numbers caught from weeks 29 to 31, with the peak catch for both baits occurring during week 31, when collections from ducks contained 240 mosquitoes/trap, while collections from chickens contained 130 mosquitoes/trap (Fig. 37). Sixty five per cent of the mosquitoes in the chicken traps and 15% of the mosquitoes from duck traps obtained at least a partial blood meal (Table 9). The numbers of mosquitoes from both bait traps remained low for the rest of the summer, with a small peak occurring on week 34, when the chicken traps collected about 30 mosquitoes/week, while the duck traps collected about 20 mosquitoes/week (Fig. 37).

Mansonia perturbans adults were attracted to both bait types during the first three weeks of the study. The largest peak in the catch occurred on week 30, when the duck traps captured 29 mosquitoes/week (Fig. 38). Traps using chickens as bait were less attractive, with a mean/bait/week catch of 0.8 mosquitoes, resulting in 25% being bloodfed while the traps using duck bait averaged 9 mosquitoes per trap during the same time period and resulted in only 8% of the catch being bloodfed (Table 9).

Aedes vexans was caught during every week of the study. This mosquito species was attracted to both bait species in similar proportions most of the summer. The numbers caught

were generally low throughout the summer except for weeks 30 and 31 when chicken traps collected 41 and 71 mosquitoes respectively and the numbers collected in duck traps was 31 and 23 mosquitoes for the same two weeks (Fig. 39). Five per cent of those collected in the chicken traps had bloodfed while 2% of those collected in the duck traps had fed (Table 9).

Anopheles walkeri was collected in the duck-baited traps during the last 4 weeks of the study with the peak catch occurring on week 30 (Fig. 40). This mosquito species had a bloodfeeding success rate of 9% on ducks and 40% on chickens (Table 9). Ducks were much more attractive than chickens over the 4 week period (Fig. 40).

1987 BAIT TRAP COLLECTIONS

In 1987, a total of 3319 mosquitoes including 15 species, was attracted to three bait species and two non-baited controls over a 10 week study period (Table 10). Culex tarsalis, Ms. perturbans and An. walkeri accounted for 74% of the total catch. Anopheles walkeri, at 14%, replaced Ae. vexans as the third most abundant species for the year. The blackbird bait attracted 48% of the catch and 14 species of mosquitoes, but only 3 of these species took blood. The dominant species attracted to this bait was Cx. tarsalis, which amounted to 37% of the catch, followed by Ms. perturbans and An. walkeri accounting for 21% and 12%

respectively. The duck bait attracted 35% of the total catch, out of 13 species, with Mansonia perturbans, An. walkeri and Cx. tarsalis accounting for 22%, 18% and 9% respectively, attracted to this bait. Only 5 species obtained a bloodmeal from ducks. The chicken bait attracted 15% of the total catch, out of 11 species, and 6 species were able to bloodfeed. Ms. perturbans, Ae. vexans and Cx. tarsalis represented 33%, 27% and 19% of the mosquitoes attracted to chickens (Table 10).

Culex tarsalis was collected in traps of all three bait species throughout the summer of 1987. The three peak catches for ducks, chickens and blackbirds corresponded to weeks 27, 29, and 30 respectively. The largest peak occurred in the trap with blackbirds on week 30, with a catch of 115 mosquitoes (Fig. 41). Thirty-nine per cent, 6% and 1% of those attracted obtained bloodmeals from chickens, ducks and blackbirds respectively (Table 10).

Mansonia perturbans was attracted primarily to ducks. The adult population disappeared at the end of July. A single peak was observed during week 27, when duck traps collected 350 mosquitoes. A smaller peak (100 mosquitoes) occurred in the collections from the chicken-baited traps on week 29. The peak in the blackbird catch occurred on the same week, when about 80 mosquitoes were caught (Fig. 42). Bloodfeeding success for Ms. perturbans on the different bait types was

24% for chickens, 8% for ducks and, 1% for blackbirds (Table 10).

Aedes vexans occurred in relatively low numbers until the beginning of August. The largest number was collected from chicken-baited traps on week 32. Smaller peaks occurred in the collections from duck and blackbird baited traps on week 33, with none caught during the last week (26) of June (Fig. 43). Blood feeding occurred on chickens (1%) but not on ducks or blackbirds (Table 10).

Anopheles walkeri was attracted to all three baits throughout the summer. In 1987 there was a tenfold increase in the catch over the catch of 1986. Peak catches occurred on weeks 27, 29 and 31, with the duck bait traps collecting 58, 51 and 33 mosquitoes respectively on these weeks. Five per cent obtained blood meals from ducks (Table 10). The peak catch from chicken baited traps occurred on weeks 29 and 34, when the trap catch averaged 33 and 27 mosquitoes respectively. The bloodfed portion was 9%. An. walkeri was not as readily attracted to the blackbird bait, with the highest number collected on week 28. None obtained a blood meal (Table 9 and 10, Figure 42).

EFFECT OF TEMPERATURE

Mean weekly air temperatures during the night (2000 to 0800 h.) ranged from 12°C to 21°C, during the two years of study (Figs. 35 and 36). The mean weekly temperatures at

which the largest number and variety of mosquitoes were attracted was 17°C. The next largest peaks occurred at 16°C and 18°C. The attraction profile was not the same for all species. The peak catch for Ae. vexans and Cs. minnesotae Barr occurred at 15°C and 12°C respectively, and for Ae. dorsalis (Meigen) and Cx. tarsalis it was 18°C (Table 11).

EFFECTS OF WIND

Average windspeed varied from calm to 30 kilometers per hour (kph) during study periods over the two years. Calm air or very low windspeed (0-5 kph) occurred at the time of the highest collection rate (13.6 mosquitoes per week). High windspeed (>10kph) followed by medium windspeed (5-10kph) occurred at times when the numbers attracted declined from 9.9 to 5.9 mosquitoes per week respectively (Table 12).

EFFECTS OF SITE

The numbers of mosquitoes attracted varied from 0.5 to 3.1 per week, depending on the site. The lowest attraction rate occurred at site number 4 (Table 13). If the sites are grouped into three groups (3 sites each), according to location within the overall study site (Fig. 32), the results are easier to illustrate. The sites where the traps were located during periods of the highest catch were the northern group (sites 7, 8 and 9). The location of the traps accounting for the intermediate catching rate was the

southern group (sites 1,2 and 3). The smallest catch occurred at the central group (sites 4,5 and 6) (Table 13).

EFFECTS OF TRAP

The more successful trap was the blackbird-baited Ehrenberg trap, which collected an average weekly catch of 8.1 mosquitoes. The Fortney Fan trap, also with 2 blackbirds/trap, collected 69% fewer mosquitoes. However, the Ehrenberg failed to collect An. earlei Vargas, which was taken in the Fortney Fan trap (Table 14).

FLOCK ATTRACTION STUDY

1986 TRAP COLLECTIONS

In 1986 one flock cage containing ducks, and the other chickens, attracted 15,258 mosquitoes into the mosquito trap over a 12 week period. Twelve out of the 14 species fed on chickens while only 5 of the 13 species fed on ducks (Table 15). Five of the 16 species represented 95% of the total catch. Seasonal abundance per bait species for the five most abundant mosquito species is shown in Figures 45 to 49, and is similar to the seasonal profiles for the single baited traps. However, the most attractive bait species was usually different. The most numerous species (65%) collected from both baits was Ae. flavescens (Muller). The next two most abundant species were C. tarsalis and Ae. vexans, each

representing 13% of the catch. Ms. perturbans was attracted in low numbers and represented 1.1% of the catch (Table 15)

Eighty per cent of all mosquitoes were collected in the chicken flock trap. The three dominant species were Ae. flavescens, C. tarsalis and Ae. vexans, representing 72%, 14% and 6% of all mosquito species attracted. Bloodfeeding success rates were 4%, 10% and 6% respectively (Table 15).

Twenty per cent of the mosquitoes were collected in the mallard duck trap. Aedes vexans, Ae. flavescens and Cx. tarsalis represented 42%, 39% and 10% respectively of all mosquitoes attracted to this bait. Bloodfeeding success for these three species was <1%, <1% and 14% respectively (Table 15).

Culex tarsalis was collected mainly from the chicken flock from weeks 26 to 35, with a peak of 950 on week 31 (Fig. 45). Over the summer a mean of 10% took blood meals from chickens (Table 15). The number of Cx. tarsalis collected in the mallard duck trap was quite low throughout the summer (Fig. 45). The mean number obtaining a blood meal was also smaller; however, the percentage obtaining blood (14%) was similar to that for chickens (Table 15).

Mansonia perturbans was collected from the chicken flock trap during weeks 20 to 26, at a mean weekly rate of 13.3 mosquitoes and a bloodfeeding success rate of 42% (Table 15). This species was less abundant in the duck flock trap,

and no blood meals were obtained from mallards (Fig. 46, Table 15).

Aedes vexans females were collected from chickens and mallard duck traps from weeks 29 to 35. Both flock traps collected similar numbers with the exception of week 31, when the duck flock trap collected more than twice as many as the chicken flock trap (Fig. 47). Bloodfeeding success for this species was 6% on the chicken bait, and <1% on the duck bait (Table 15).

Aedes flavescens was collected from the chicken flock trap in large numbers during the weeks of 25 to 32, with a bloodfeeding success rate of 4% (Table 15). The peak occurred on week 29, when the mosquito trap collected 2700 mosquitoes. This species was less abundant in the duck flock trap (Fig. 17), and <1% obtained blood meals from mallard ducks (Table 15).

1987 FLOCK TRAP COLLECTIONS

In 1987, the duck and chicken bait traps collected 16 species over a 11 week period, totalling 5096 mosquitoes. Thirteen of the 16 species obtained at least partial blood meals on chickens while only 5 of the 16 species fed on ducks (Table 16). Seventy-three per cent of the total mosquito collection was taken from the chicken flock trap. The 3 most abundant mosquito species collected from the chicken flock trap and the duck flock trap were: An. walkeri

32% vs 22%, Ms. perturbans 25% vs 31% and Ae. flavescens 14% vs 18% respectively. Culex tarsalis made up 10% of the collection in the chicken trap compared to 5% of the catch in the duck trap. Aedes vexans accounted for 10% of the catch on the chicken trap and 18% of those mosquitoes collected in the duck flock trap (Table 16).

Culex tarsalis was collected in greater numbers from the chicken flock trap (33.9) than from the duck flock trap (6.9) (Table 10). The seasonal peak in the catch for both bait species occurred during week 30 (Fig. 50). This species had obtained blood 8% and 14% of the time from chickens and ducks respectively (Table 16).

Mansonia perturbans was collected in greater numbers from the chicken flock throughout the season (Fig. 51). A similar ratio of females was able to obtain blood from mallard ducks (27%) and chickens (22%) (Table 16).

Aedes vexans was collected in the chicken and duck flock trap at a weekly rate of 34.4 and 24.7 mosquitoes respectively (Fig. 52); five per cent of the females from the chicken flock trap had obtained blood, but only 0.4% of the females from the duck flock trap had obtained blood (Table 16).

Aedes flavescens females were collected from the chicken flock trap every week, from week 25 to week 35 (Fig. 53). The mean weekly rate was 47.5 mosquitoes with 4% of the females having obtained a blood meal (Table 16). The duck

flock trap collected a mean of 25.2 mosquitoes/week; <1% of those had bloodfed (Table 16).

Anopheles walkeri females were collected in the chicken flock trap at a mean weekly rate of 108.5 mosquitoes, while the weekly mean in the duck flock trap was 30.5. Bloodfeeding success rates for this species were 7% and 12% for the chicken and duck respectively (Table 16). More females were collected each week from the chicken flock trap with the population peaking during weeks 28-30 (Fig. 54).

EFFECTS OF TEMPERATURE

Mosquito collection data are presented for 16 different temperatures, ranging from 7°C to 23°C (Table 17). The temperature at which the greatest number of mosquitoes was trapped was 18°C. At this temperature the largest numbers of 4 of the 16 species were collected. These include Cx. tarsalis, Cx. restuans Theobald, Ae. vexans and Ae. flavescens. Peak numbers of Ms. perturbans and An. walkeri were trapped at 16°C (Table 17). Lower numbers were trapped at temperatures of <14°C (Table 17) and at temperatures >21°C (Table 17).

Table 9. Mean numbers per week of mosquitoes attracted to the two bait species (3 traps per bait) and the corresponding mean numbers per week of mosquitoes that obtained at least a partial blood meal during 1986.

<u>Mosquito Species</u>	<u>Chicken</u>		<u>Duck</u>		<u>Control</u>	
	A	B	A	B	A	B
<u>Cx. tarsalis</u>	33.2	21.6	49.0	7.2	.8	.3
<u>Ms. perturbans</u>	.8	.2	9.0	.8	.2	0
<u>Ae. vexans</u>	21.5	1.2	11.2	.2	4.2	0
<u>An. walkeri</u>	.5	.2	2.2	.2	0	0
<u>Cs. minnesotae</u>	.5	0	1.0	.3	0	0
<u>Cx. restuans</u>	2.3	.3	2.7	.8	.5	0
<u>Cs. inornata</u>	.8	.7	.8	.3	.3	.2
<u>Cs. morsitans</u>	.5	.5	.2	0	0	0
Other species*	5.8	.7	6.7	.7	1.0	0
<u>Mean/species</u>	<u>4.4</u>	<u>1.7</u>	<u>5.5</u>	<u>.7</u>	<u>.5</u>	<u>.06</u>

A - Numbers of mosquitoes attracted

B - Numbers of mosquitoes with at least a partial blood meal

* An. earlei, Cx. territans, Ae. dorsalis, Ae. cinereus, Ae. flavescens, Ae. sticticus, Ae. canadensis

Table 10. Mean numbers per week of mosquitoes attracted to the chicken, duck (3 traps each) and blackbird bait (6 traps) and the corresponding mean numbers per week of mosquitoes that obtained a blood meal during 1987.

<u>Mosquito Species</u>	<u>Chicken</u>		<u>Duck</u>		<u>Control</u>		<u>YHBB</u>	
	A	B	A	B	A	B	A	B
<u>Cx. tarsalis</u>	9.3	3.6	10.9	.7	1.6	0	57.8	.5
<u>Ms. perturbans</u>	16.1	3.9	73.1	6.2	1.6	.1	32.6	.2
<u>Ae. vexans</u>	13.0	.1	4.0	0	2.3	0	9.4	0
<u>An. walkeri</u>	6.9	.6	21.2	1.0	1.0	0	18.5	0
<u>Cs. minnesotae</u>	.4	.3	3.8	.3	.3	0	17.4	.1
<u>Cx. restuans</u>	.6	0	1.3	0	.3	0	13.6	0
<u>Cs. inornata</u>	.2	0	.4	.1	.1	0	1.6	0
<u>Cs. morsitans</u>	0	0	.3	0	.2	0	1.0	0
Other species*	1.8	.2	1.7	0	.6	0	6.0	0
<u>Mean/species</u>	<u>2.3</u>	<u>.5</u>	<u>7.7</u>	<u>.5</u>	<u>.5</u>	<u>0</u>	<u>10.5</u>	<u>.06</u>

YHBB - Yellow-headed blackbirds

A - Numbers attracted

B - Numbers with at least a partial blood meal

* An. earlei, Cx. territans, Ae. dorsalis, Ae. cinereus,
Ae. flavescens, Ae. sticticus, Ae. canadensis

Table 11. Mean numbers of mosquitoes attracted to all bait species per week at different mean weekly temperatures (2000-0800 h/day, 3 nights/week) during 1986 and 1987.

<u>Mosquito</u> <u>Species</u>	<u>Temperature °C</u>								
	<u>12</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>	<u>21</u>
<u>Cx. tarsalis</u>	.5	.4	3.3	14.6	18.8	24.9	2.9	.4	15.6
<u>Cx. restuans</u>	.3	.1	1.9	2.8	4.4	1.3	.3	.5	.5
<u>Ms. perturbans</u>	0	2.9	0	20.8	48.6	.4	1.9	1.4	4.1
<u>Ae. vexans</u>	5.1	.1	6.3	5.8	1.1	7.2	5.5	.6	.3
<u>Ae. dorsalis</u>	1.2	0	1.0	.4	0	.7	.4	0	.1
<u>Ae. flavescens</u>	.2	.1	.1	.6	1.0	.3	.8	.5	.4
<u>An. walkeri</u>	2.3	.3	2.2	8.2	13.5	.4	.4	0	3.2
<u>An. earlei</u>	.2	0	0	.9	.1	.4	.3	0	.1
<u>Cs. minnesotae</u>	0	0	4.1	2.8	1.8	.3	.1	.2	5.1
<u>Cs. inornata</u>	0	.1	.1	.5	.6	.2	.4	0	.2
<u>Cs. morsitans</u>	.1	0	0	.3	.4	.3	0	0	.1
Other Species*	.5	0	.2	.1	.3	.4	0	.1	.2
<u>Mean/species</u>	<u>.6</u>	<u>.4</u>	<u>1.6</u>	<u>4.8</u>	<u>7.5</u>	<u>3.1</u>	<u>1.1</u>	<u>.3</u>	<u>2.5</u>

*Cx. territans, Ae. cinereus, Ae. sticticus, Ae. canadensis,
Ae. spenceri

Table 12. Mean numbers of mosquitoes attracted to all bait species per week at different mean windspeeds (2000-0800 h/day) during 1986 and 1987.

<u>Mosquito Species</u>	<u>WINDSPEED*</u>		
	<u>Low</u>	<u>Medium</u>	<u>High</u>
<u>Cx. tarsalis</u>	41.8	18.4	21.4
<u>Cx. restuans</u>	8.8	.9	2.3
<u>Ms. perturbans</u>	18.6	13.3	47.4
<u>Ae. vexans</u>	25.1	5.1	1.7
<u>An. walkeri</u>	14.0	6.0	10.8
<u>Cs. minnesotae</u>	6.4	5.8	2.1
<u>Cs. inornata</u>	1.1	.4	.8
<u>Cs. morsitans</u>	.6	.4	.2
Other Species**	6.1	2.9	2.3
<u>Mean/species</u>	<u>13.6</u>	<u>5.9</u>	<u>9.9</u>

*Low 0-5 kmph, Medium 5-10 kmph, High +10kmph

** An. earlei, Cx. territans, Ae. dorsalis, Ae. cinereus, Ae. flavescens, Ae. sticticus, Ae. canadensis, Ae. spenceri

Table 13. Mean number of mosquitoes per week attracted to the control, chicken and duck baited Fortney Fan traps located at sites 1 through 9 during weeks 29 through 34, 1986 and 1987.

<u>Mosquito</u> <u>Species</u>	<u>Site Number</u>								
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
<u>Cx. tarsalis</u>	9.3	10.0	12.8	1.2	6.2	8.9	12.3	14.6	10.7
<u>Cx. restuans</u>	1.1	.6	.9	1.3	.6	3.2	1.9	3.6	.8
<u>Ms. perturbans</u>	3.9	4.0	.3	.4	6.0	.8	4.1	6.0	9.0
<u>Ae. vexans</u>	1.8	4.3	3.8	.5	2.1	1.6	1.3	2.3	7.8
<u>Ae. flavescens</u>	1.0	0	.1	.2	.4	0	.7	.3	.8
<u>Ae. dorsalis</u>	.1	.2	0	0	0	.3	1.8	.7	.8
<u>An. walkeri</u>	2.2	1.0	.3	.4	3.5	.9	2.0	3.5	4.8
<u>An. earlei</u>	0	.8	0	.2	.2	.4	.5	.3	.2
<u>Cs. minnesotae</u>	.9	.1	.1	1.8	.7	1.1	4.1	3.4	.8
<u>Cs. inornata</u>	0	.2	.3	0	.1	.3	.7	.1	.8
<u>Cs. morsitans</u>	.3	.3	0	.3	.1	.2	.1	0	0
Other Species*	.2	.1	.1	.1	.1	.3	.3	.2	.4
<u>Mean/species</u>	<u>1.7</u>	<u>1.8</u>	<u>1.6</u>	<u>.5</u>	<u>1.6</u>	<u>1.5</u>	<u>2.5</u>	<u>2.9</u>	<u>3.1</u>

*Cx. territans, Ae. cinereus, Ae. sticticus, Ae. spenceri

Table 14. Mean numbers of mosquitoes attracted per week to the blackbird bait held in two trap types at Oak Hammock Marsh during weeks 25 to 35, 1987.

<u>Mosquito</u> <u>Species</u>	<u>Trap type</u>	
	<u>Fortney Fan</u>	<u>Ehrenberg</u>
<u>Cx. tarsalis</u>	4.2	43.0
<u>Cx. restuans</u>	1.1	12.5
<u>Ms. perturbans</u>	5.8	14.6
<u>Ae. vexans</u>	7.7	1.4
<u>Ae. dorsalis</u>	2.9	.4
<u>Ae. flavescens</u>	.4	.7
<u>An. walkeri</u>	4.8	8.7
<u>An. earlei</u>	.2	0
<u>Cs. minnesotae</u>	1.5	14.0
<u>Cs. inornata</u>	.2	1.3
<u>Cs. morsitans</u>	.1	.6
Other Species*	.9	.1
<u>Mean/species</u>	<u>2.5</u>	<u>8.1</u>

*Cx. territans, Ae. cinereus, Ae. spenceri

Table 15. Mean numbers per week of mosquitoes attracted to the two bait species (held in flocks of 7-10 birds) and the corresponding mean numbers per week of mosquitoes that obtained at least a partial blood meal during 1986.

<u>Mosquito Species</u>	<u>Chicken</u>		<u>Duck</u>	
	A	B	A	B
<u>Cx. tarsalis</u>	138.2	13.2	31.3	4.3
<u>Ms. perturbans</u>	13.3	5.6	.9	0
<u>Ae. vexans</u>	32.6	2.1	125.2	.3
<u>Ae. flavescens</u>	732.0	30.8	116.9	.7
<u>Ae. spencerei</u>	30.7	.3	8.9	.2
<u>An. walkeri</u>	6.2	.9	1.6	.6
<u>Cs. minnesotae</u>	.7	0	.3	0
<u>Cx. restuans</u>	3.8	.1	.5	0
<u>Cs. inornata</u>	28.3	.7	9.8	0
<u>Cs. morsitans</u>	.3	0	.1	0
Other species*	8.5	.4	3.6	0
<u>Mean/species</u>	<u>90.4</u>	<u>4.9</u>	<u>27.2</u>	<u>.6</u>

A - Numbers of mosquitoes attracted

B - Numbers of mosquitoes with at least a partial blood meal

* An. earlei, Ae. dorsalis, Ae. sticticus (chickens only),
Ae. excrucians

Table 16. Mean numbers per week of mosquitoes attracted to the two bait species (held in flocks of 7-10 birds) and the corresponding mean numbers per week of mosquitoes that obtained at least a partial blood meal during 1987.

<u>Mosquito Species</u>	<u>Chicken</u>		<u>Duck</u>	
	A	B	A	B
<u>Cx. tarsalis</u>	33.9	2.6	6.9	.3
<u>Ms. perturbans</u>	86.4	18.8	42.1	11.3
<u>Ae. vexans</u>	34.4	1.8	24.7	.1
<u>Ae. flavescens</u>	47.5	1.9	25.2	.2
<u>Ae. spencerei</u>	5.5	0	.9	0
<u>An. walkeri</u>	108.5	7.6	30.5	3.7
<u>Cs. minnesotae</u>	1.8	.2	1.4	0
<u>Cx. restuans</u>	.7	0	0	0
<u>Cs. inornata</u>	14.1	.2	3.7	0
<u>Cs. morsitans</u>	0	0	0	0
Other species*	6.5	.5	.8	0
<u>Mean/species</u>	<u>30.8</u>	<u>3.1</u>	<u>12.4</u>	<u>1.4</u>

A - Numbers of mosquitoes attracted

B - Numbers of mosquitoes with at least a partial blood meal

* An. earlei, Ae. dorsalis, Ae. excrucians, Ae. cinereus,
Ae. fitchii and Ae. sticticus (chickens only)

Table 17. Mean numbers of mosquitoes attracted per week to both chicken and duck-baited flock traps at different temperatures during 1986 and 1987.

<u>Mosquito</u> <u>Species</u>	<u>Temperature °C</u>					
	<u>7</u>	<u>8</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>
<u>Cx. tarsalis</u>	.5	0	0	1.3	2.3	1.1
<u>Cx. restuans</u>	.1	0	0	0	.1	.1
<u>Ms. perturbans</u>	0	0	0	0	3.3	.7
<u>Ae. vexans</u>	.7	0	0	2.4	4.4	6.2
<u>Ae. dorsalis</u>	.1	0	.1	0	.3	.2
<u>Ae. flavescens</u>	3.3	.3	.3	2.3	9.1	2.3
<u>Ae. spencerei</u>	.2	0	0	.3	0	.1
<u>An. walkeri</u>	.9	0	0	3.3	6.4	5.9
<u>An. earlei</u>	.2	0	.1	.1	0	.1
<u>Cs. minnesotae</u>	.1	0	0	.3	.1	.1
<u>Cs. inornata</u>	.3	.3	.5	5.1	3.0	.4
<u>Cs. morsitans</u>	0	0	0	0	0	0
Other Species*	.1	0	0	0	.3	0
<u>Mean/species</u>	<u>.5</u>	<u>.1</u>	<u>.1</u>	<u>1.2</u>	<u>2.3</u>	<u>1.3</u>

*Ae. excrucians, Ae. cinereus, Ae. sticticus, Ae. fitchii

Table 17(cont.). Mean numbers of mosquitoes attracted to both chicken and duck-baited flock traps per week at different temperatures at Oak Hammock Marsh during 1986 and 1987.

<u>Mosquito</u> <u>Species</u>	<u>Temperature °C</u>				
	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>
<u>Cx. tarsalis</u>	5.6	28.0	9.6	3.0	18.8
<u>Cx. restuans</u>	.1	.4	.3	.1	1.3
<u>Ms. perturbans</u>	2.7	.2	28.4	1.2	1.2
<u>Ae. vexans</u>	.7	15.8	1.5	3.8	41.7
<u>Ae. dorsalis</u>	.4	1.9	.1	.5	.7
<u>Ae. flavescens</u>	46.2	26.6	99.0	31.0	156.7
<u>Ae. spencerei</u>	2.3	3.3	.7	2.3	5.2
<u>An. walkeri</u>	2.1	8.9	16.9	.4	1.8
<u>An. earlei</u>	.7	.4	.6	.1	.7
<u>Cs. minnesotae</u>	.1	.1	.5	.1	0
<u>Cs. inornata</u>	.5	6.1	1.4	.3	3.7
<u>Cs. morsitans</u>	0	0	.1	0	0
Other Species*	.3	0	0	.1	.2
<u>Mean/species</u>	<u>4.7</u>	<u>7.1</u>	<u>12.2</u>	<u>3.3</u>	<u>17.8</u>

*Ae. sticticus, Ae. excrucians, Ae. spenceri, Ae. fitchii

Table 17(cont.). Mean numbers of mosquitoes attracted to both chicken and duck-baited flock traps per week at different temperatures during 1986 and 1987.

<u>Mosquito Species</u>	<u>Temperature °C</u>				
	<u>19</u>	<u>20</u>	<u>21</u>	<u>22</u>	<u>23</u>
<u>Cx. tarsalis</u>	13.7	9.3	9.3	1.4	.9
<u>Cx. restuans</u>	.2	.1	.1	0	0
<u>Ms. perturbans</u>	23.5	.3	3.2	.9	4.8
<u>Ae. vexans</u>	24.4	7.9	2.1	.2	.3
<u>Ae. dorsalis</u>	.6	.1	.1	0	0
<u>Ae. flavescens</u>	21.0	39.3	24.5	.9	2.2
<u>Ae. spencerei</u>	2.2	1.5	4.6	0	0
<u>An. walkeri</u>	12.5	.4	4.8	3.1	1.6
<u>An. earlei</u>	.3	.2	.3	.1	0
<u>Cs. minnesotae</u>	.1	.1	.1	.4	0
<u>Cs. inornata</u>	2.1	1.2	.9	0	0
<u>Cs. morsitans</u>	.1	0	.1	0	0
Other Species*	.1	.1	.1	0	0
<u>Mean/species</u>	<u>7.8</u>	<u>4.7</u>	<u>3.9</u>	<u>.5</u>	<u>.8</u>

*Ae. excrucians, Ae. sticticus, Ae. fitchii

Fig. 32. Trap sites 1-15 at Oak Hammock Marsh 1986-1987.
(The duck flock was located 150 meters north of
site number 9 and the chicken flock was located
60 meters south-east of site number 13).

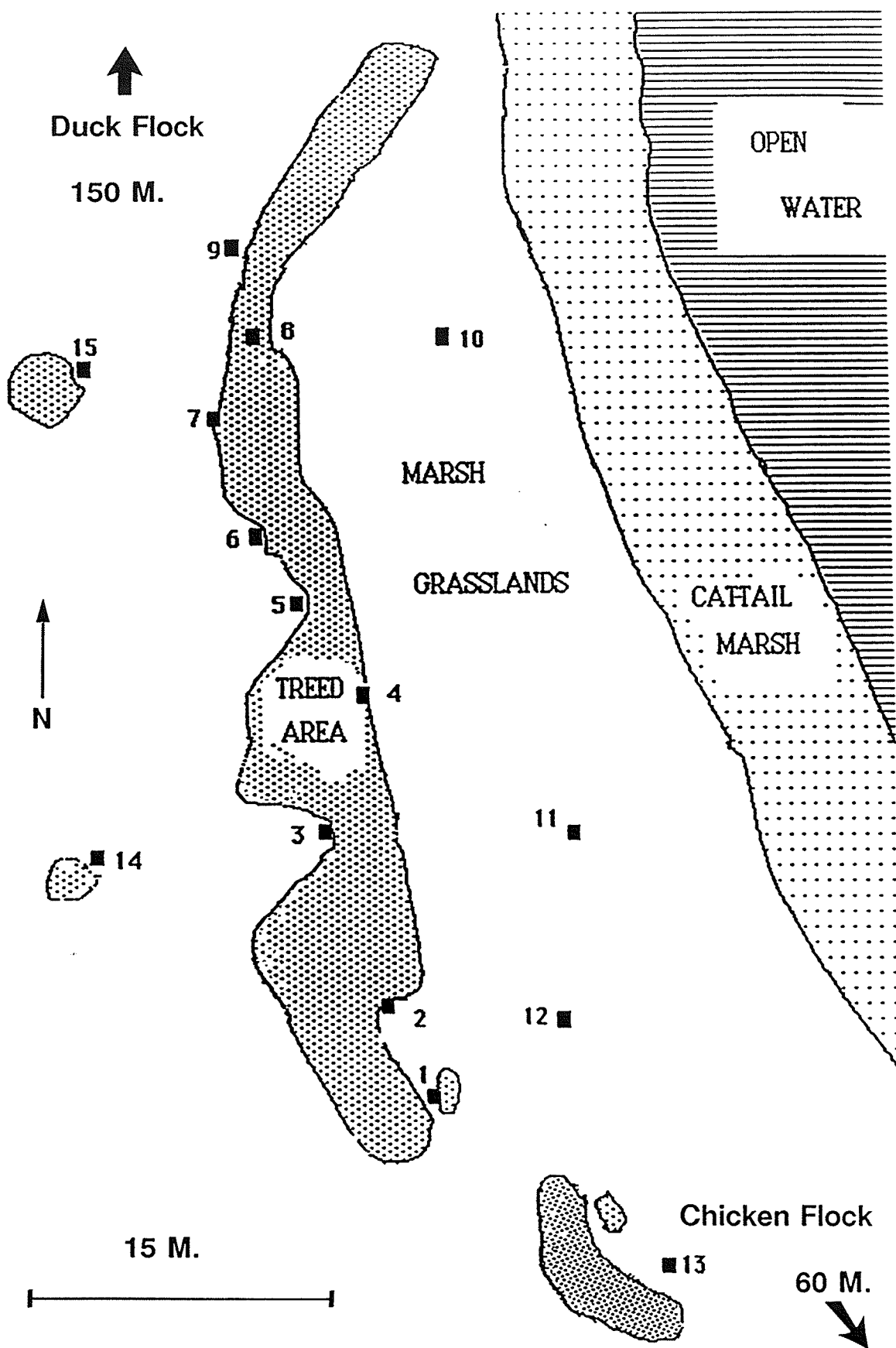


Fig. 33A. Fortney Fan trap. Procedure for setting up the trap: (i) bait is placed in the restraining cage, (ii) the cage is placed within the main body of the trap, and the door is inserted, (iii) the mosquito catch net is placed within the fan housing, (v) the fan housing is bolted to the side of the main body of the trap.

Fig. 33B. Modified Ehrenberg trap. The bait restraining cage is inserted, and the mosquito catch nets are then bolted to each end.

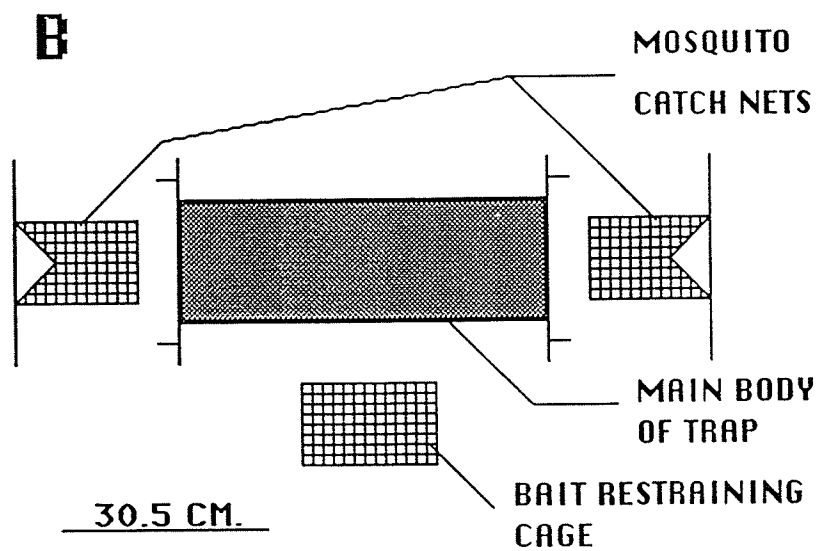
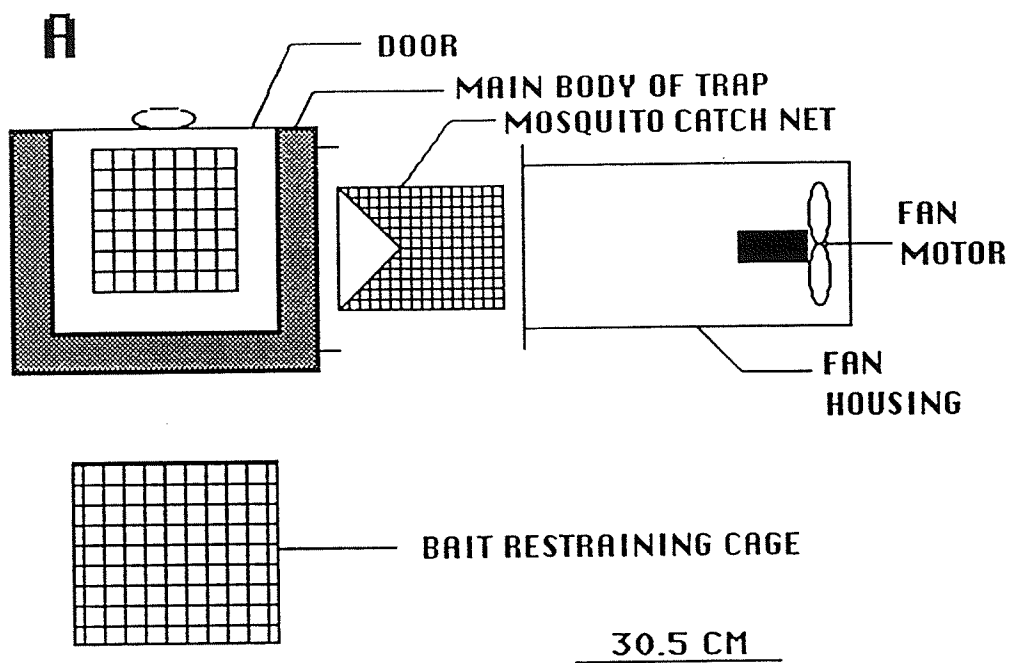


Fig. 34. Flock Cage. The top of the cage opens for placement and removal of birds. Mosquitoes enter the trap from inside the cage.

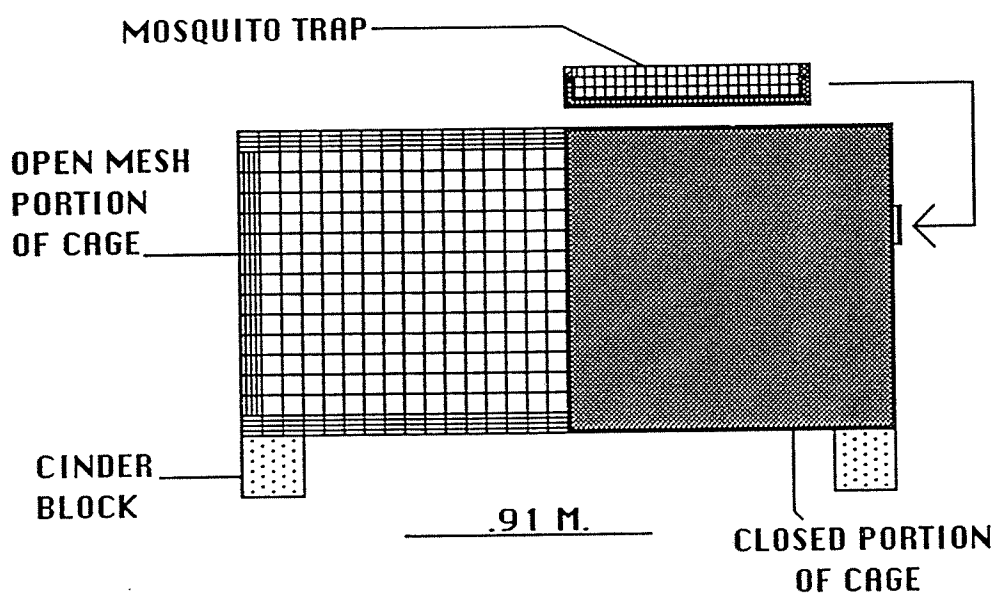


Fig. 35. Mean weekly temperatures during six weeks of study in 1986. The temperatures were from Environment Canada's station at the Winnipeg airport. Weekly means are based on hourly temperatures from 2000 to 0800 each day.

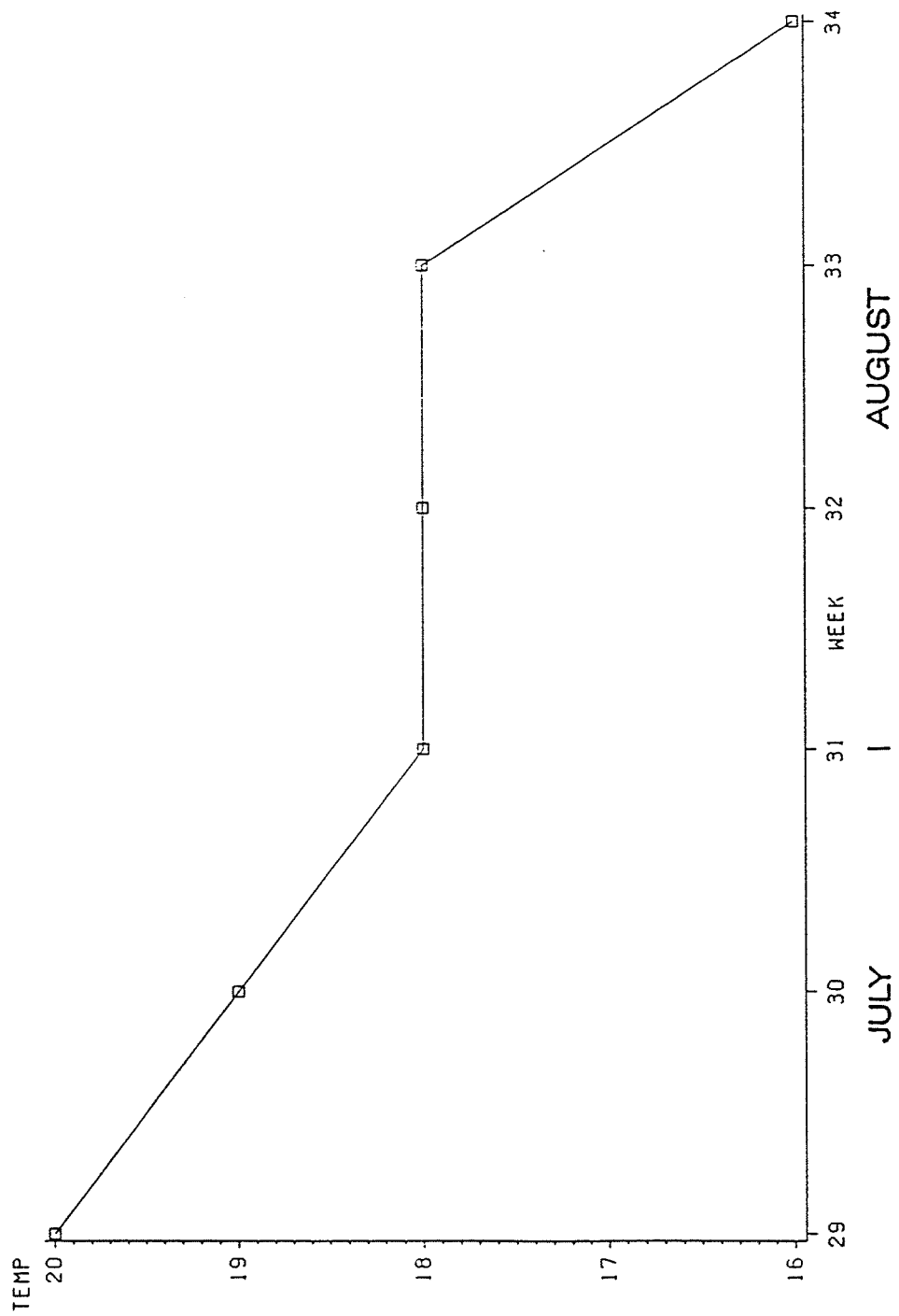


Fig. 36. Mean weekly temperatures during ten weeks of study in 1987.

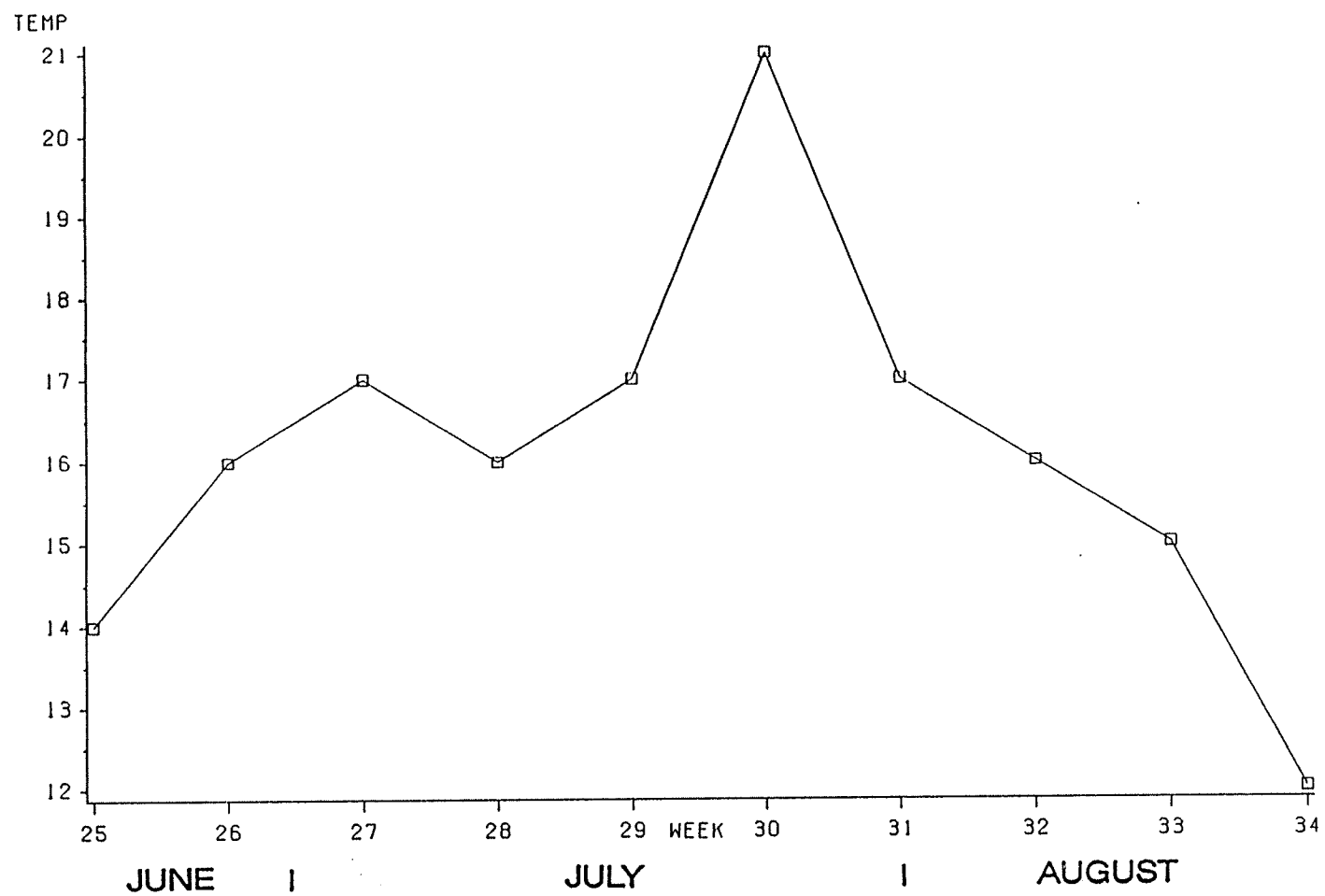


Fig. 37. Number of adult Culex tarsalis captured per week in 1986 in traps baited with C - Domestic Chicken and D - Mallard duck.

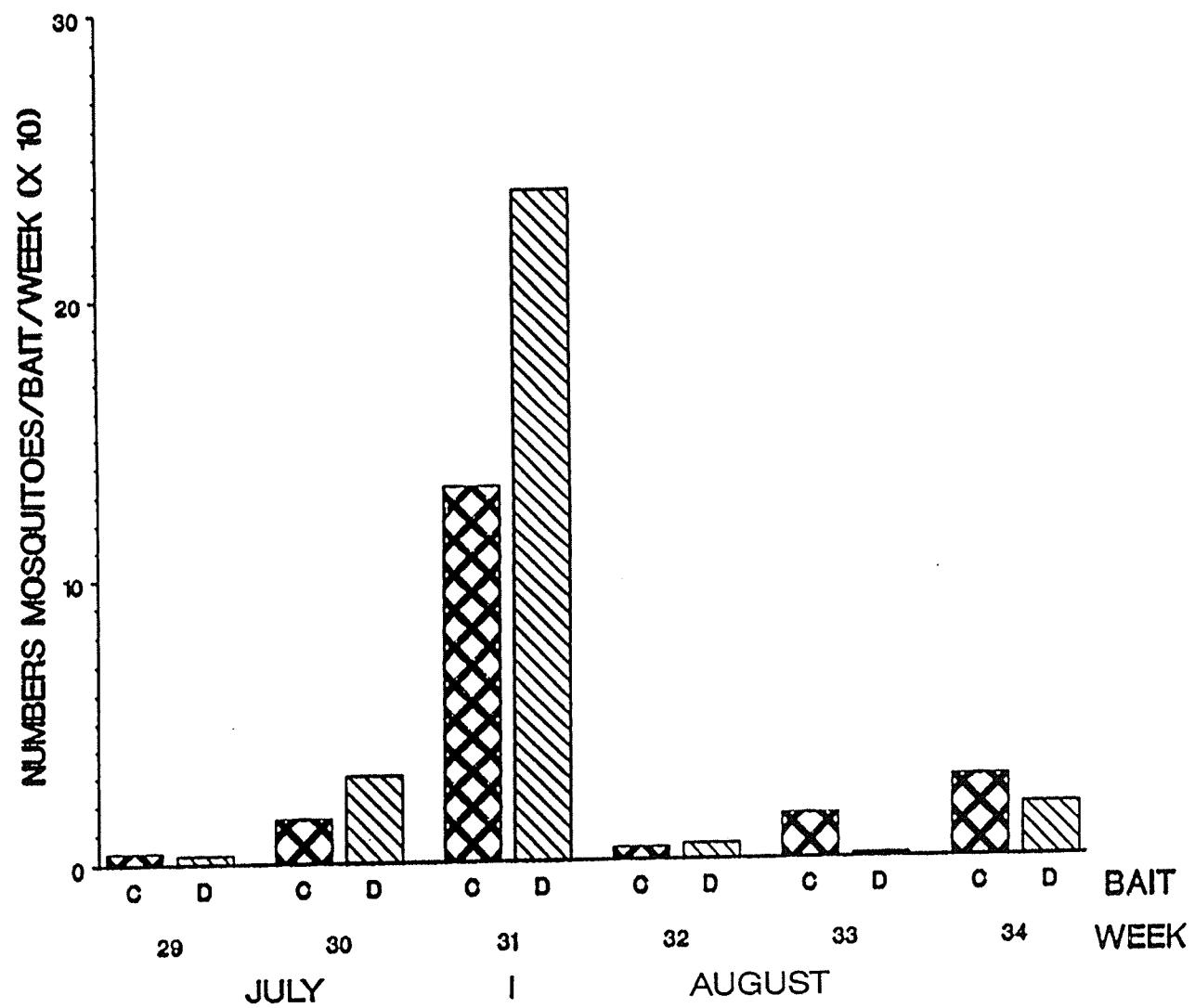


Fig. 38. Number of adult Mansonia perturbans captured per week in 1986 in traps baited with C - Domestic Chicken and D - Mallard duck.

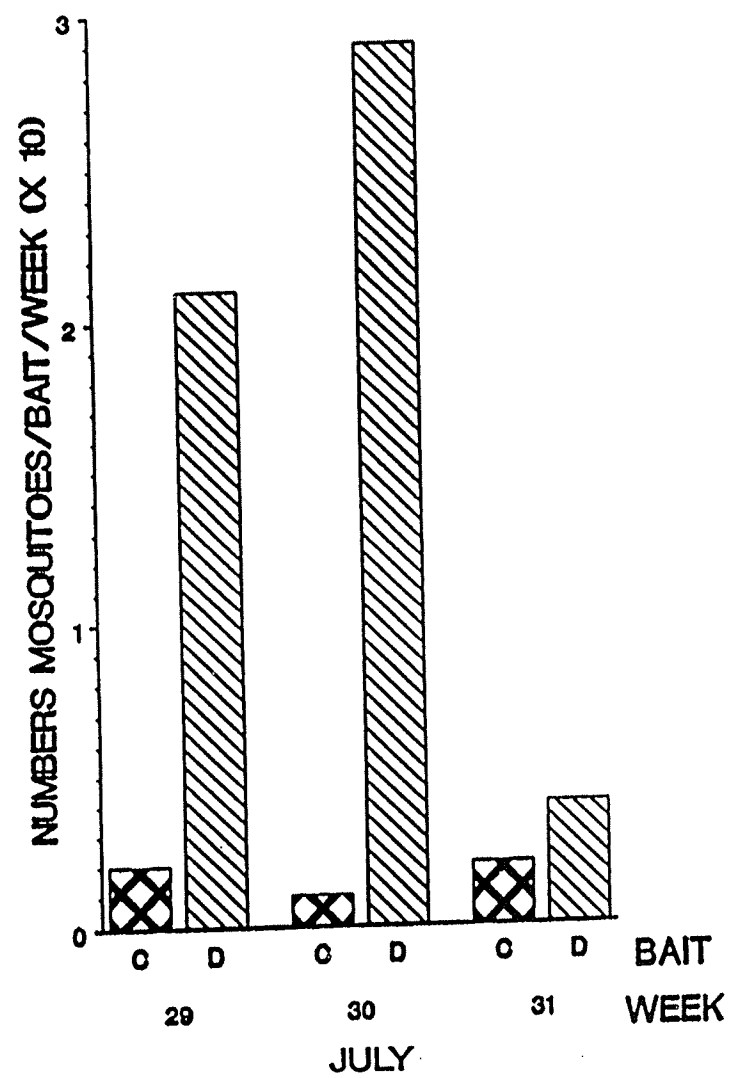


Fig. 39. Number of adult Aedes vexans captured per week in 1986 in traps C - Domestic Chicken and D - Mallard duck.

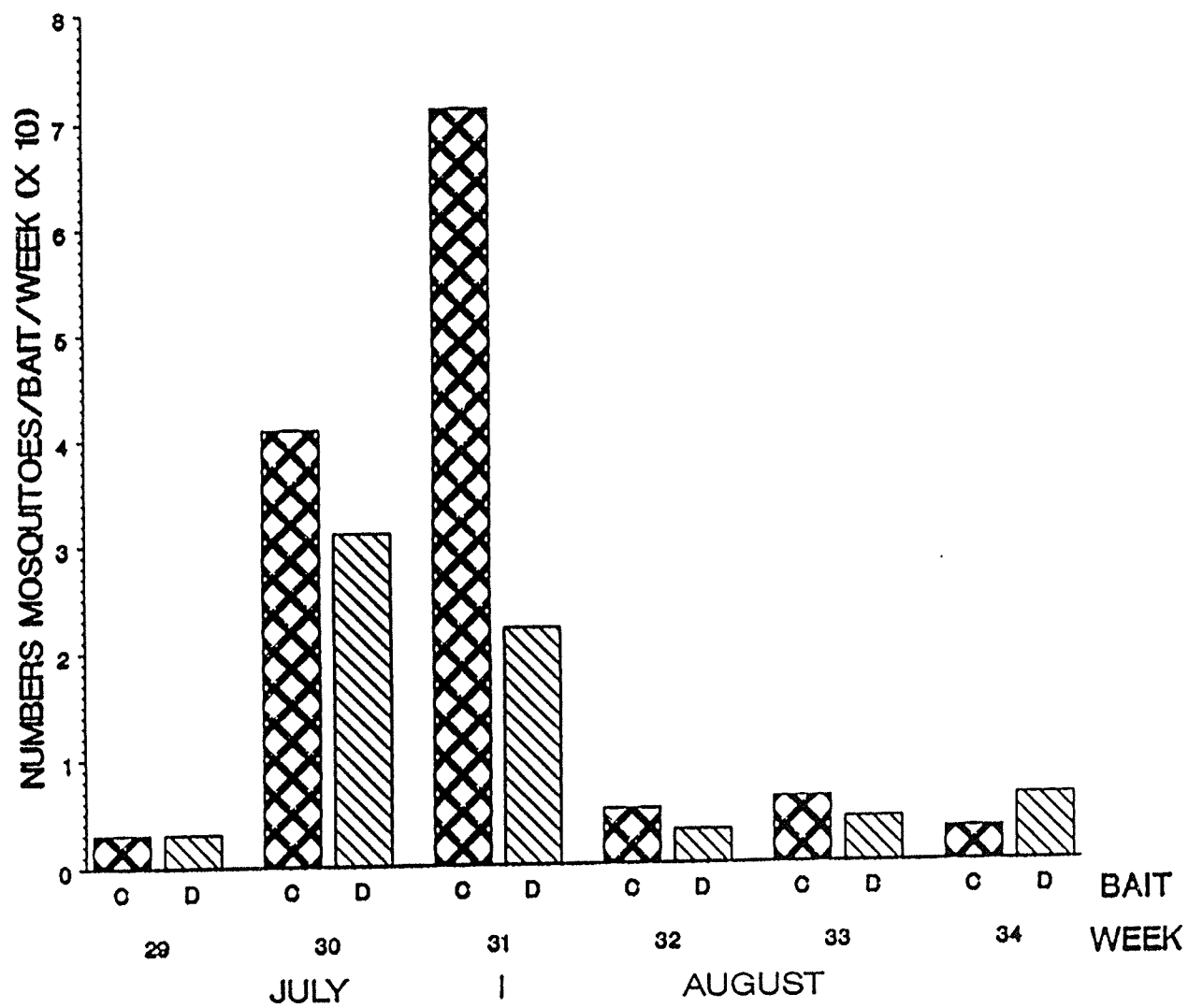


Fig. 40. Number of adult Anopheles walkeri captured per week in 1986 in traps baited with C - Domestic Chicken and D - Mallard duck.

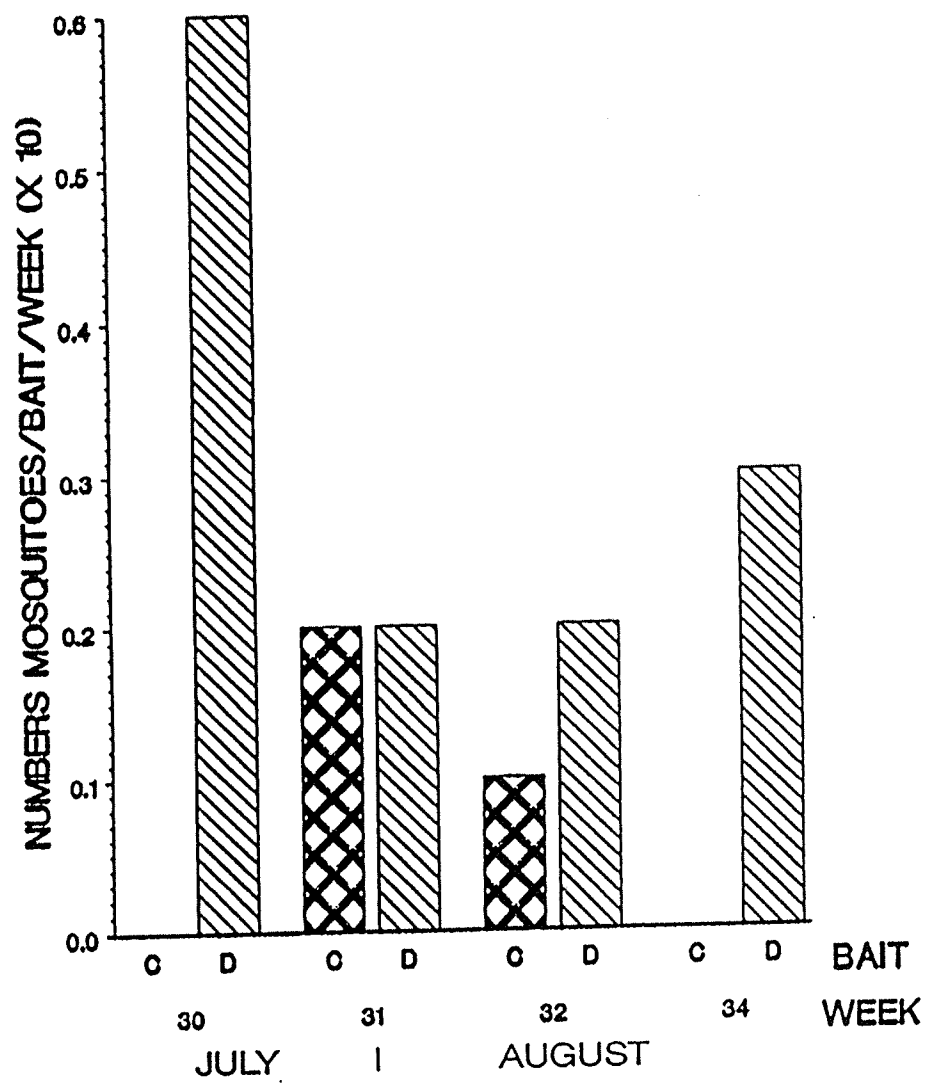


Fig. 41. Number of adult Culex tarsalis captured per week in 1987 in traps baited with B - Yellow-Headed blackbirds * C - Domestic Chicken and D - Mallard duck.

* two birds per trap

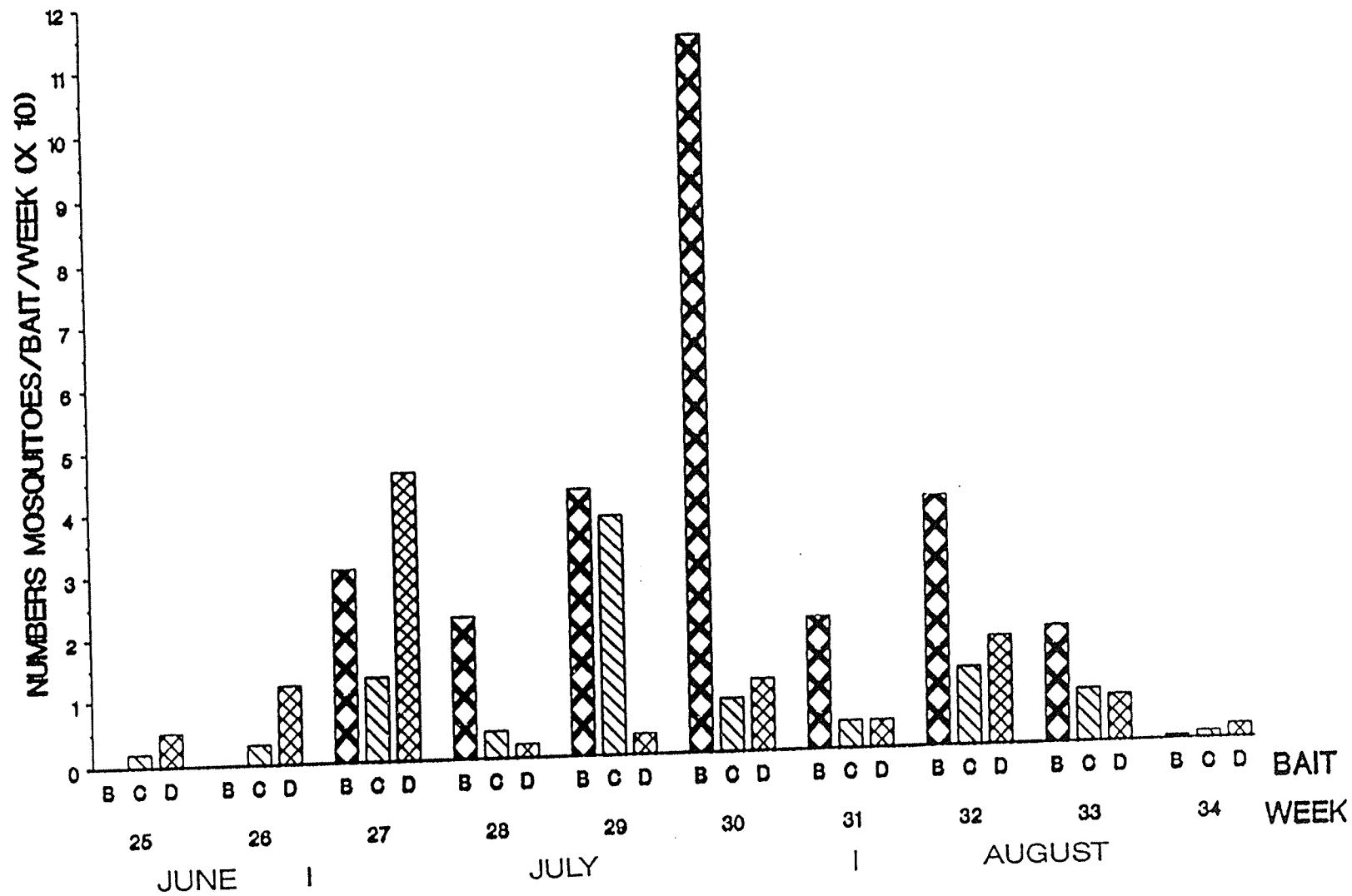


Fig. 42. Number of adult Mansonia perturbans captured per week in 1987 in traps baited with B - Yellow-Headed Blackbirds*, C - Domestic Chicken and D - Mallard duck.

* two birds per trap

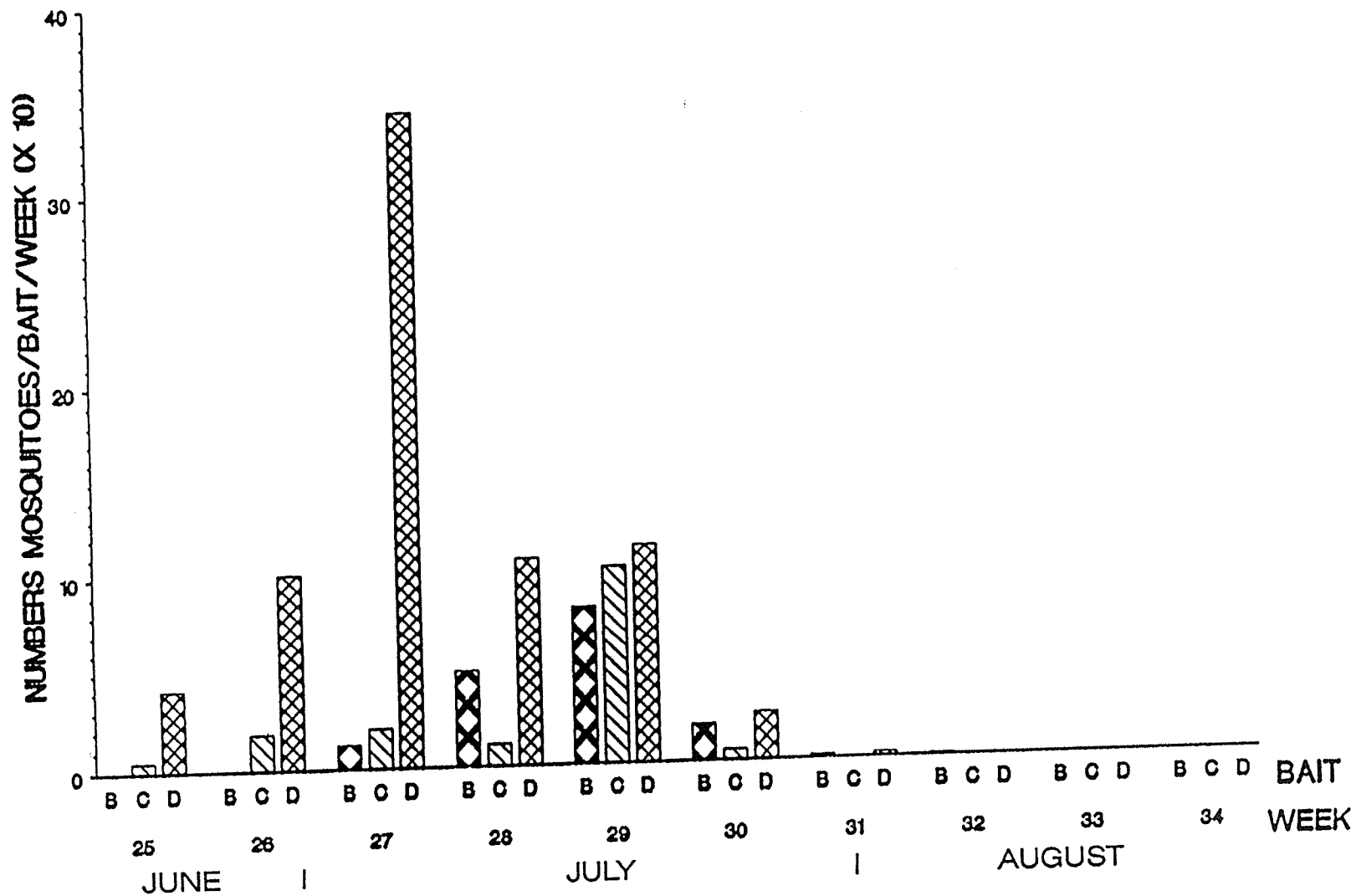


Fig. 43. Number of adult Aedes vexans captured per week in 1987 in traps baited with B -Yellow Headed-Blackbirds*, C - Domestic Chicken and D - Mallard duck.

* two birds per trap

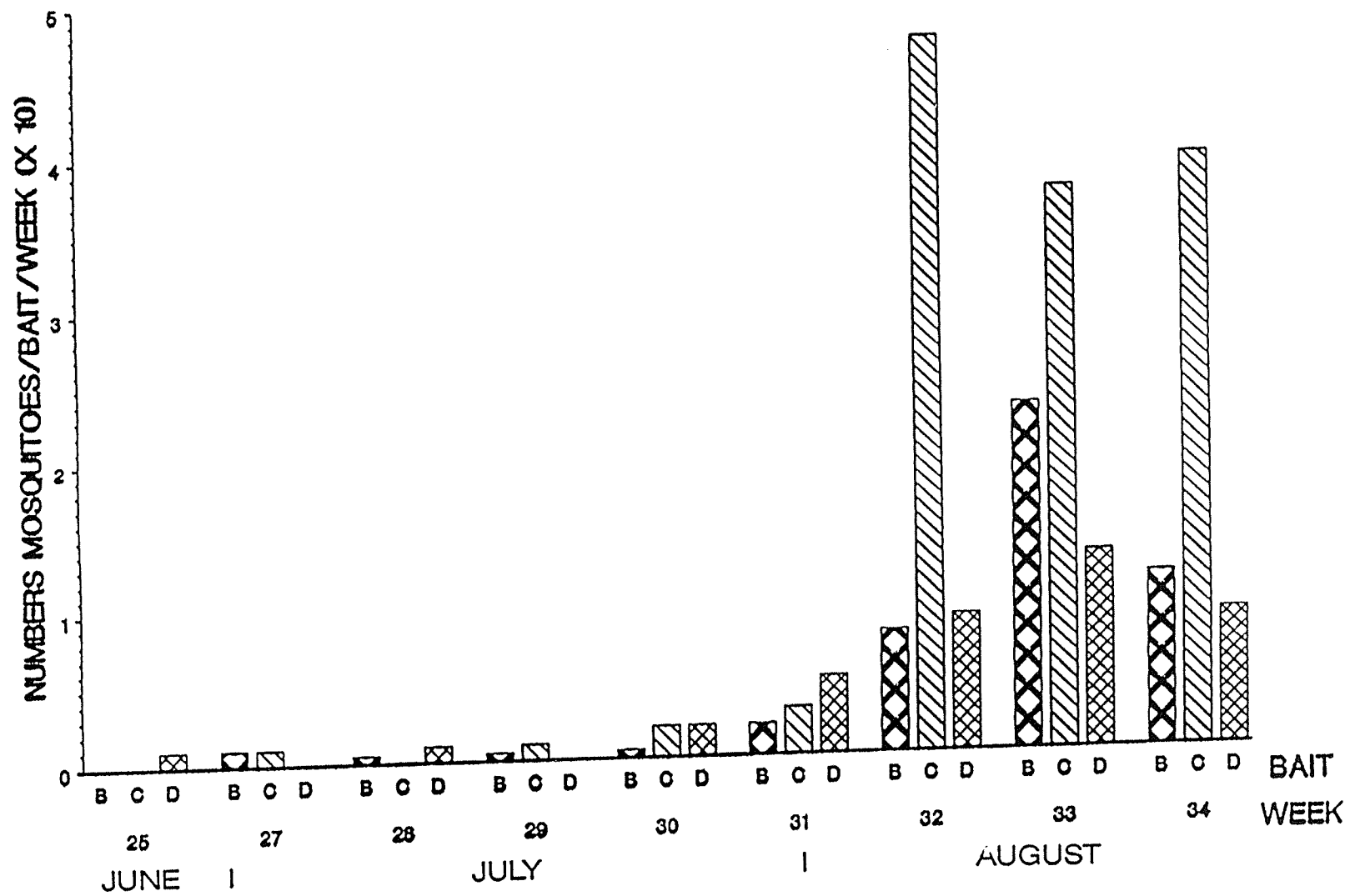


Fig. 44. Number of adult Anopheles walkeri captured per week in 1987 in traps baited with B - Yellow-Headed Blackbirds*, C - Domestic Chicken and D -Mallard duck.

* two birds per trap

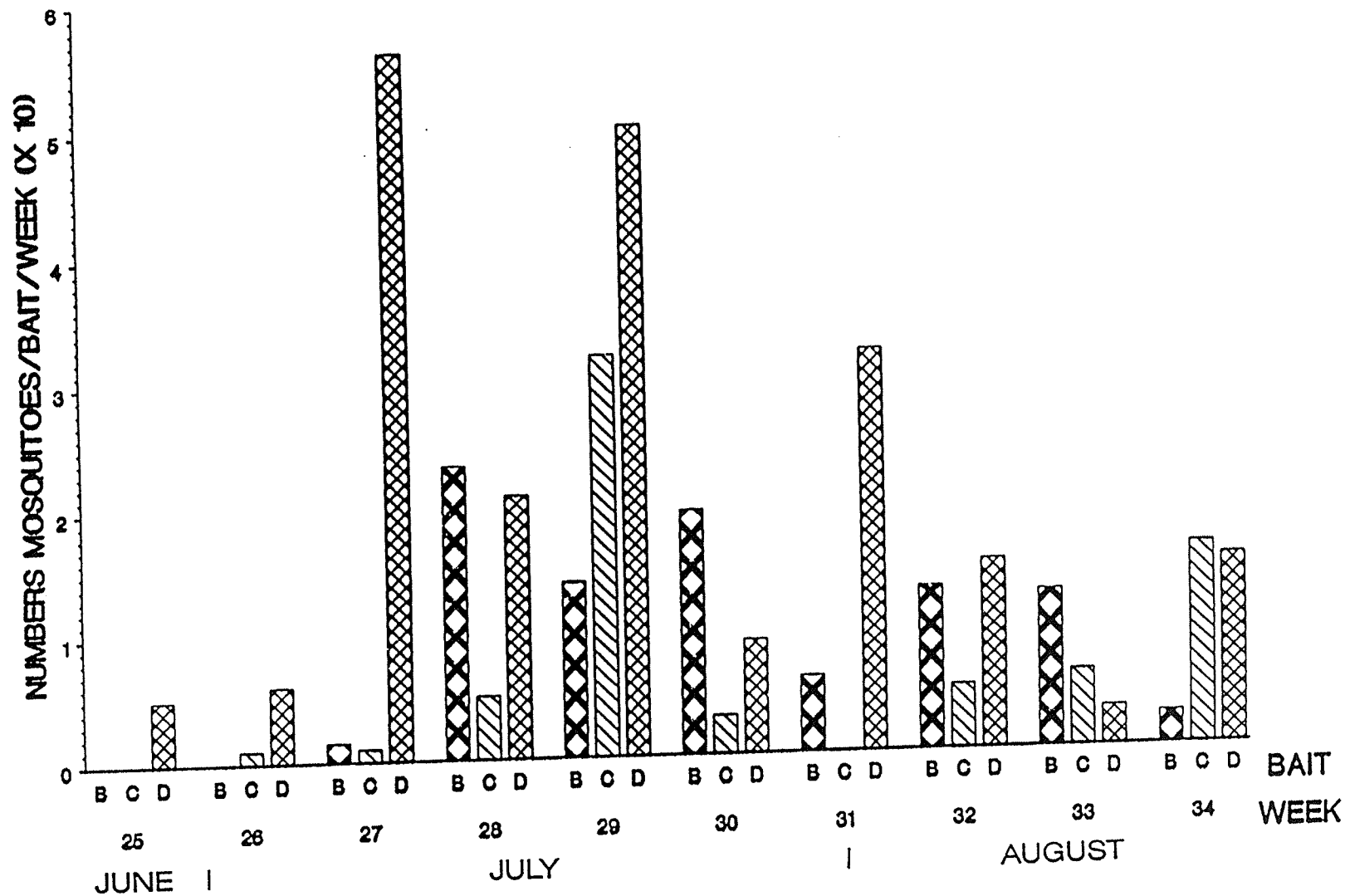


Fig. 45. Number of adult Culex tarsalis captured per week in 1986 in traps baited with flocks (7-10 birds) of C - Domestic Chicken and D - Mallard duck.

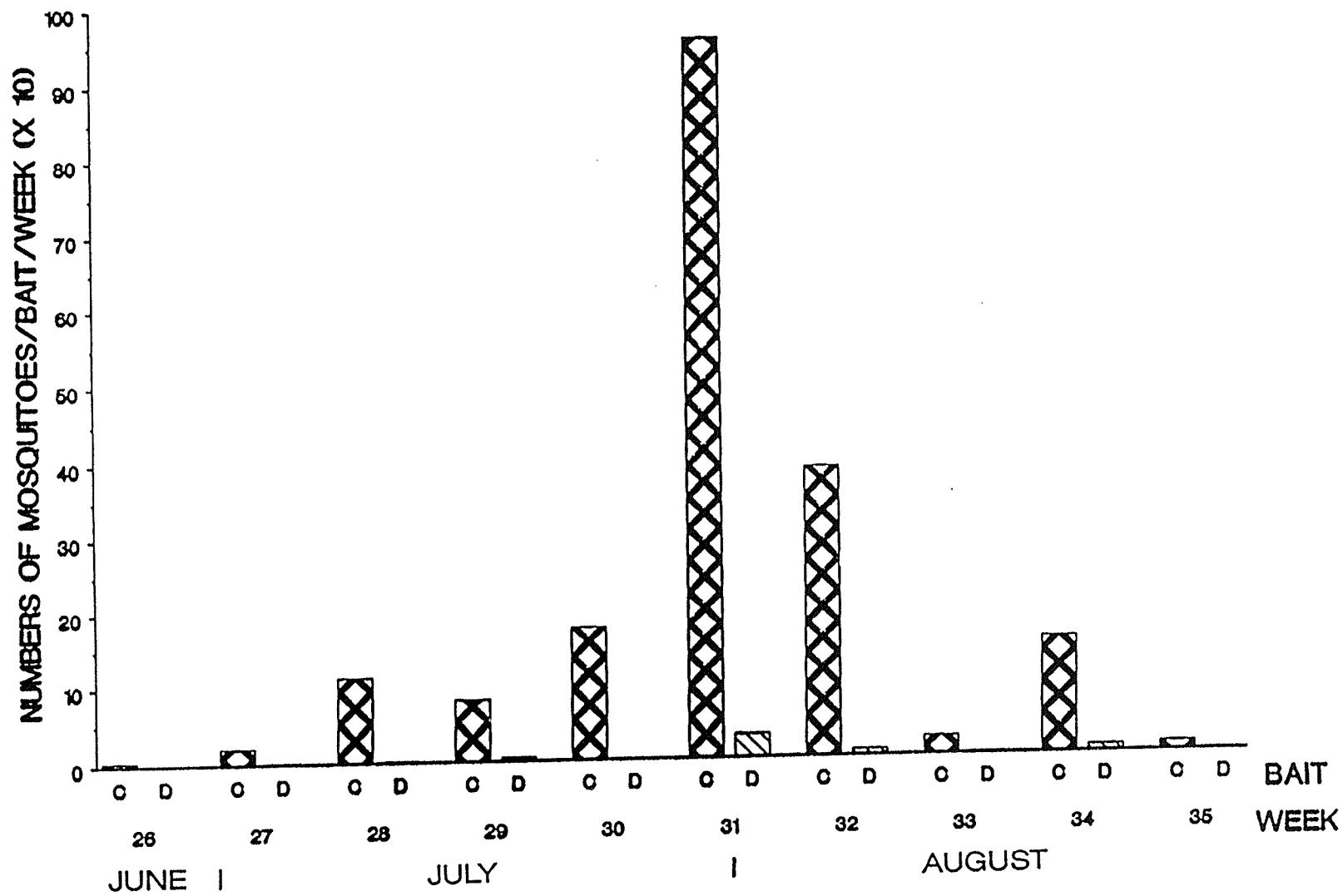


Fig. 46. Number of adult Mansonia perturbans captured per week in 1986 in traps baited with flocks (7-10 birds) of C - Domestic Chicken and D - Mallard duck.

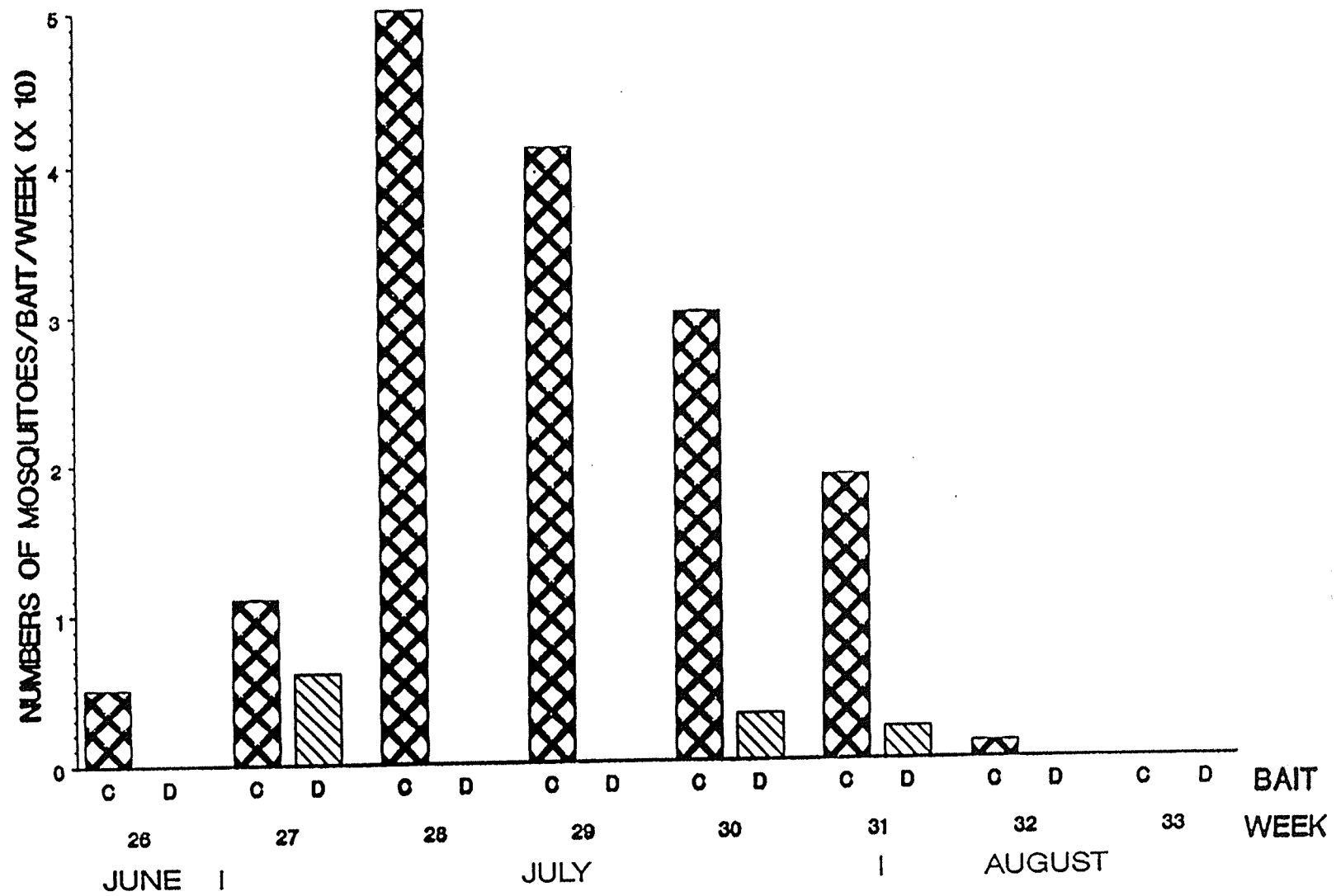


Fig. 47. Number of adult Aedes vexans captured per week in 1986 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

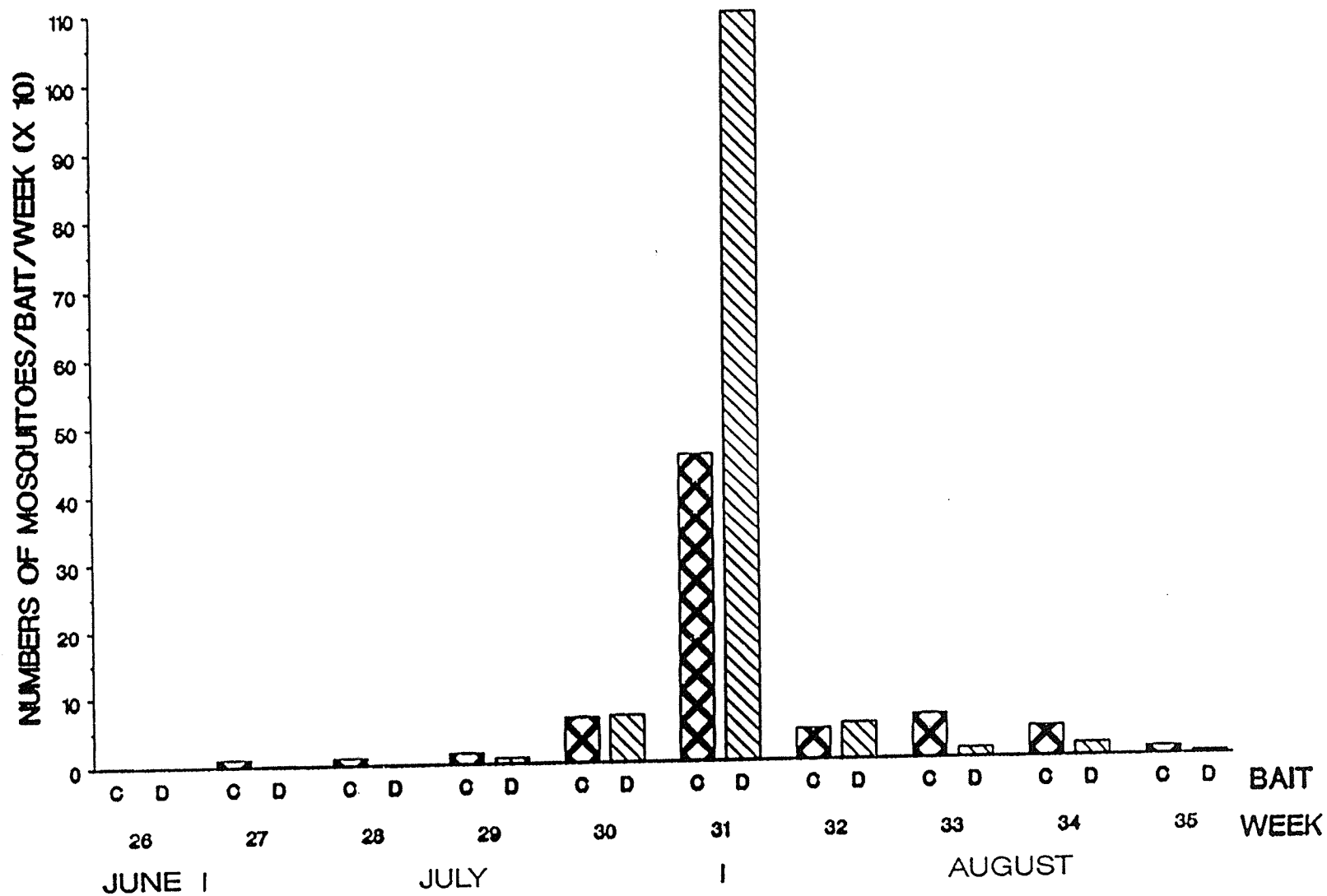


Fig. 48. Number of adult Aedes flavescens captured per week in 1986 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

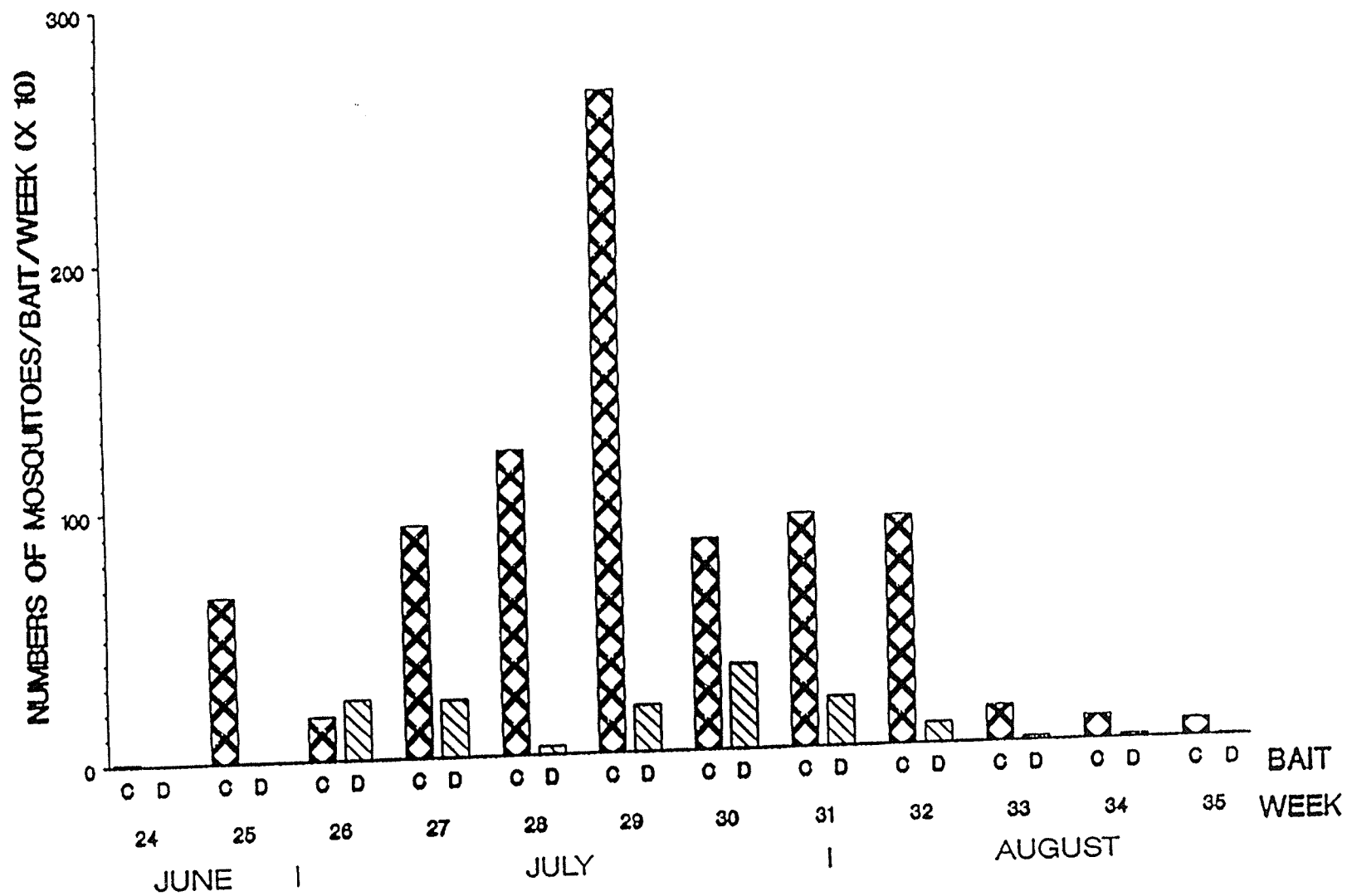


Fig. 49. Number of adult Anopheles walkeri captured per week in 1986 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

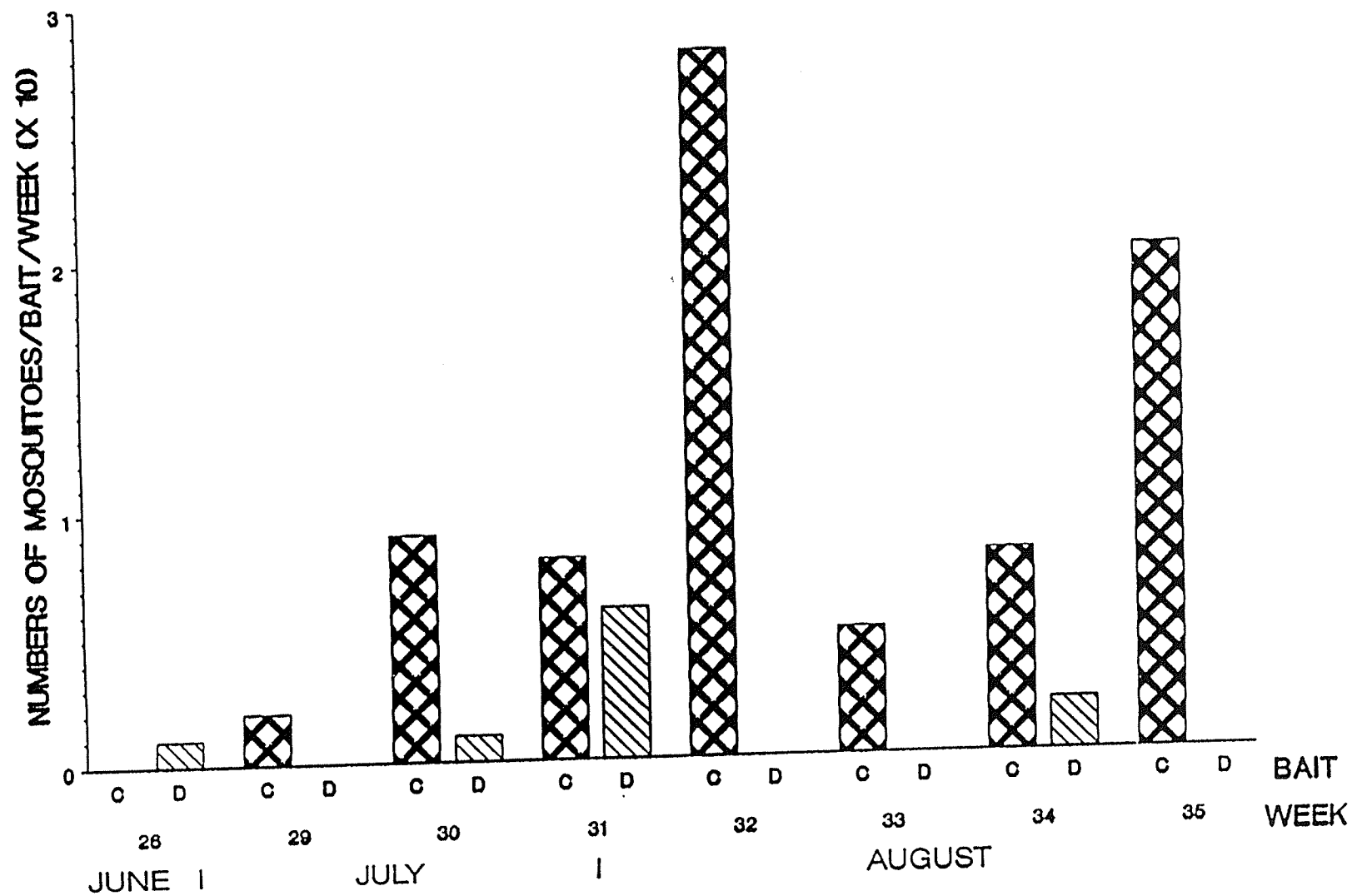


Fig. 50. Number of adult Culex tarsalis captured per week in 1987 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

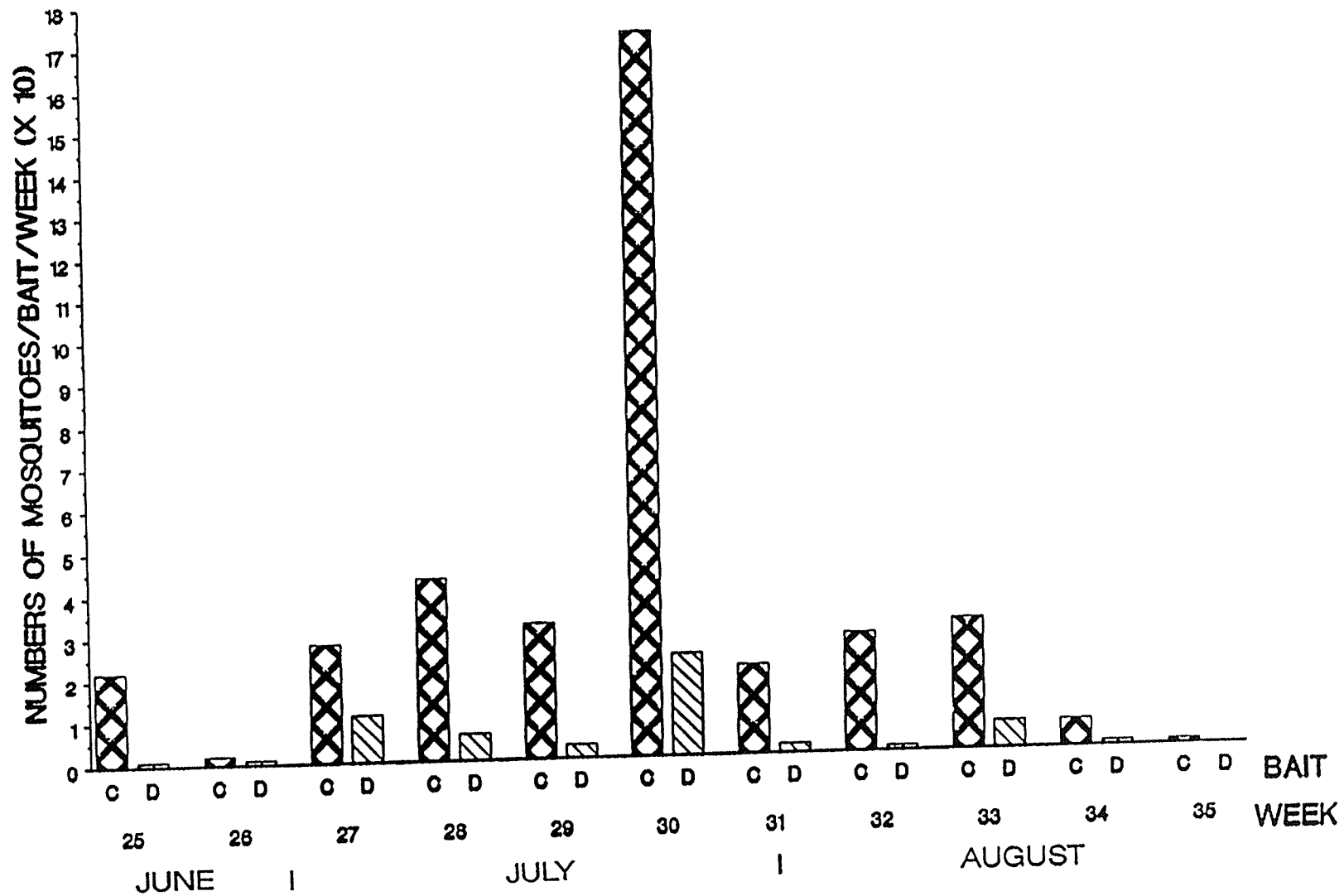


Fig. 51. Number of adult Mansonia perturbans captured per week in 1987 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

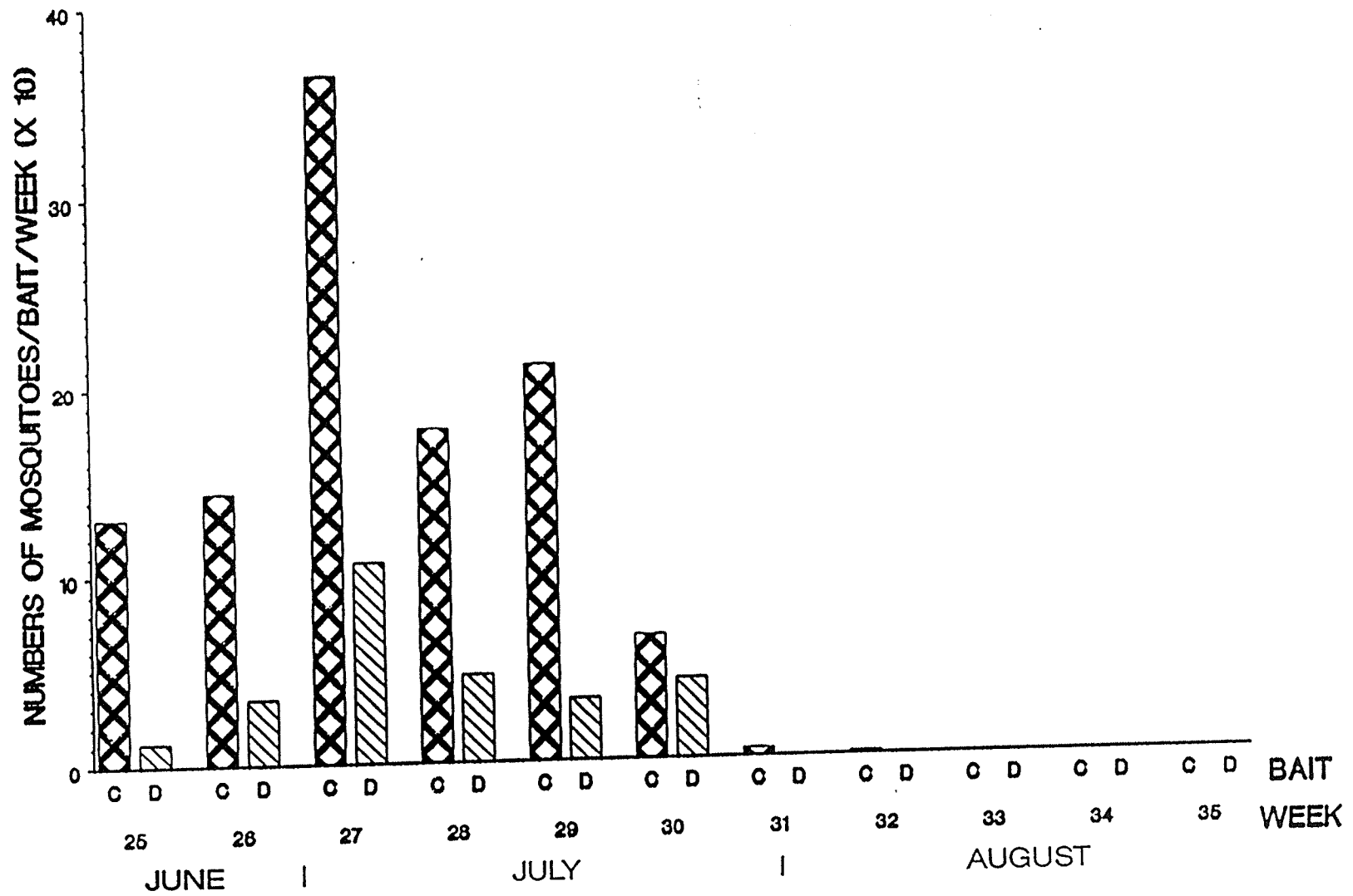


Fig. 52. Number of adult Aedes vexans captured per week in 1987 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

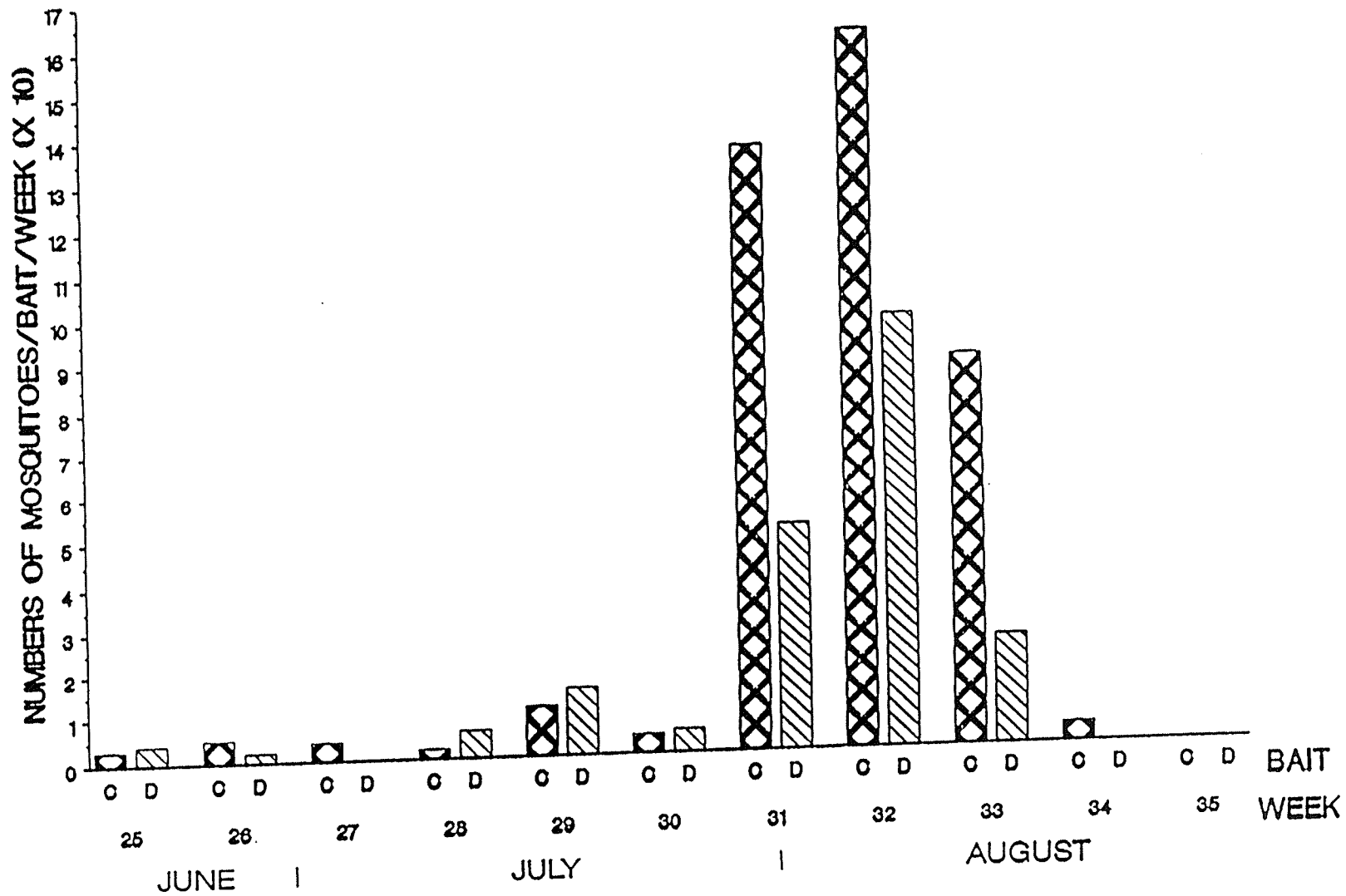


Fig. 53. Number of adult Aedes flavescens captured per week in 1987 in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.

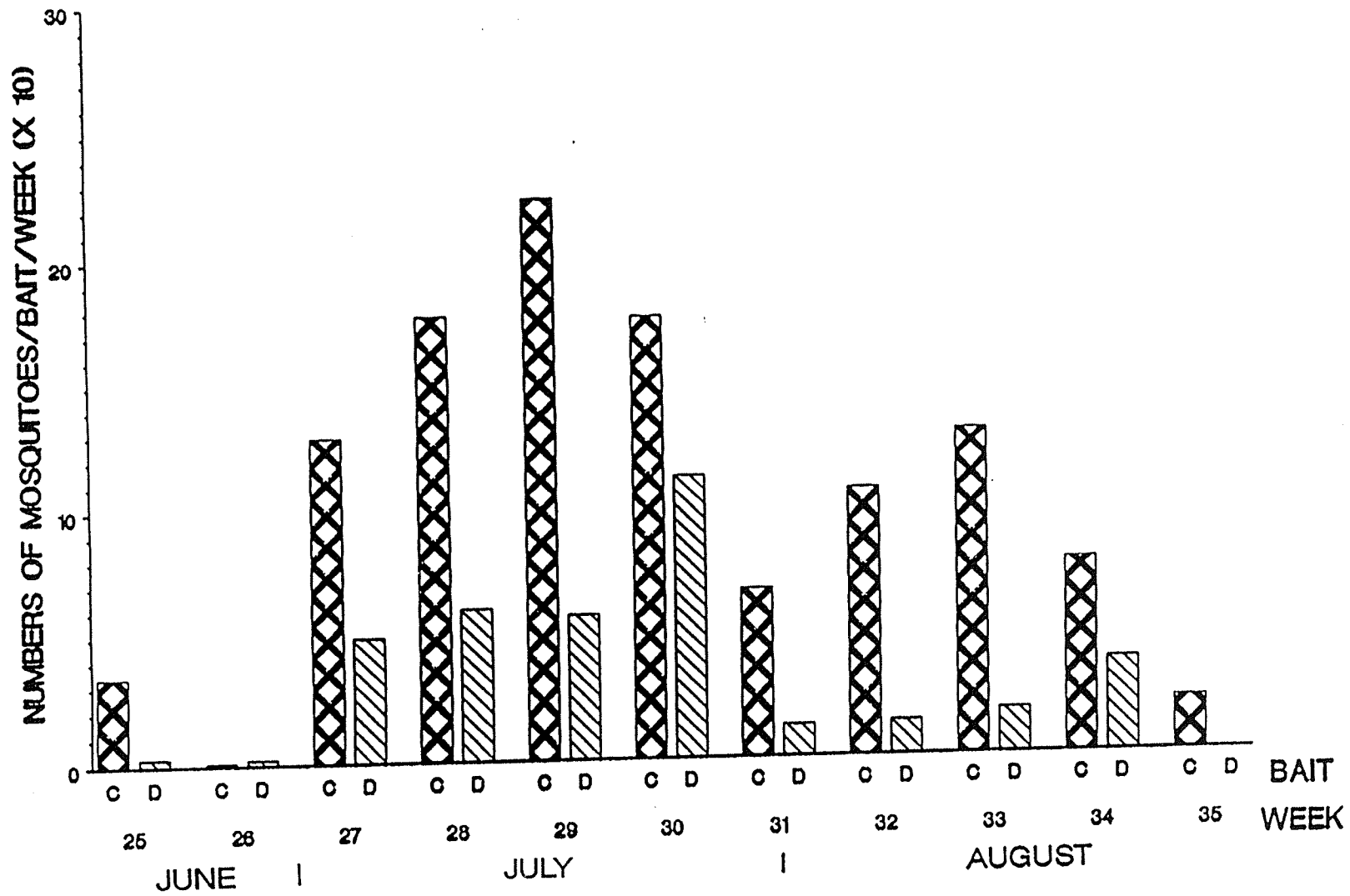
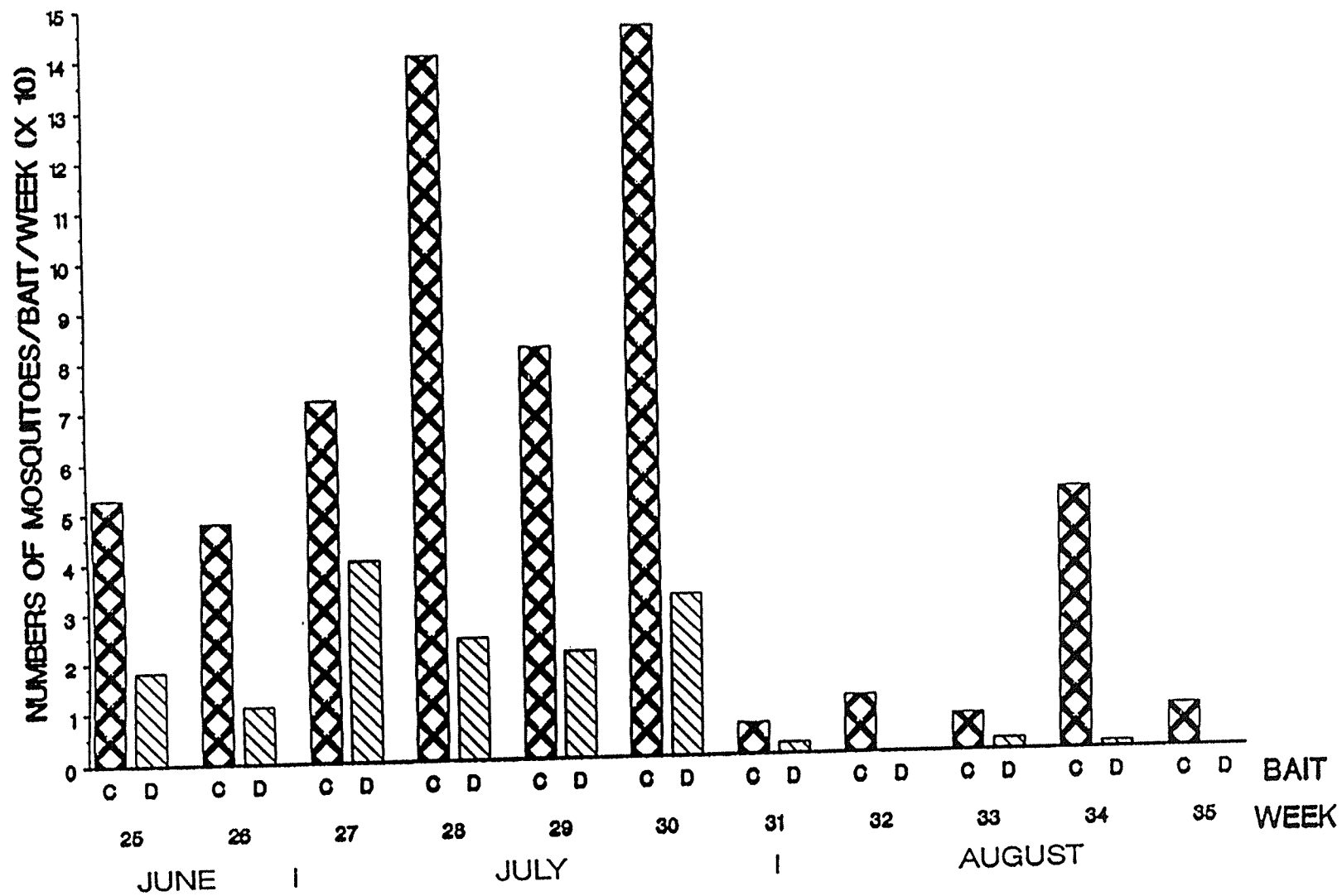


Fig. 54. Number of adult Anopheles walkeri captured per week in traps baited with flocks (7-10 birds) of: C - Domestic Chicken and D - Mallard duck.



DISCUSSION

Fortney and Ehrenberg Trap Collections

The single/paired bait traps collected 15 species of mosquitoes, but only Cx. tarsalis, Ae. vexans and Ms. perturbans were taken in significant numbers in 1986 and 1987 (Tables 9 and 10). The relative abundance of these three species varied from 1986 and 1987 but they remained in the most abundant group of species. One additional species was abundant in 1987, viz. An. walkeri (Table 10).

Culex tarsalis was the predominant species both years; this species and Ms. perturbans are primarily ornithophilic, although both species may be opportunistic, feeding on the most available or the largest available host (Tempelis et al. 1965, 1967; Downe 1962). Shemanchuk et al. (1963) and Downe (1960) suggested that Ae. vexans is usually a mammal feeder, although availability and surface areas of the potential host are determining factors in host preference. Although Oak Hammock Marsh provides habitat for a variety of small birds, mammals and herpetiles, our bait animals, the chickens and ducks, were probably the largest and most abundant host animals in the vicinity of the trap site in 1986 and 1987.

According to Nasci and Edman (1981), a mosquito species can develop an innate preference for host type due to a long association, and wild ducks and other waterfowl in the marsh may explain the trapping success using domestic chickens and mallard ducks as bait.

Culex tarsalis represented the largest proportion of the chicken-baited trap collections. It is possible that the chickens adjusted to the restrictions of the trap faster than the other bait species, representing resting or loafing birds which appear to be extremely vulnerable hosts to foraging mosquitoes. This type of behaviour could make them a more 'desirable' host animal than many of the native host species.

Several factors may determine whether an attracted mosquito obtains a bloodmeal or not: (i) the availability of the animal in the mosquito's habitat, (ii) the attraction of the host animal, (iii) the availability of a blood meal to the mosquito. The latter requires circumventing various physical barriers (Muirhead-Thompson 1982). Nelson et al. (1976) suggested that 2 factors may influence choice of host for a bloodmeal: (i) the density of the mosquitoes attacking the host, (ii) the intensity of the defensive reactions of the host. Edman et al. (1972) determined that the defensive reaction of avian hosts may vary according to host species and could affect bloodfeeding success. The Green Heron Butorides virescens, and Black Crowned Night Heron Nycticorax

nycticorax, were quite passive to attack by mosquitoes, while the White Ibis, Eudocimus albus, and Cattle Egret, Bubulcus ibis, were extremely active. The reaction of some species may be dependent on the density of the mosquitoes attacking. Host species that are usually passive during mosquito attack may become extremely active at high mosquito densities, while active host species may become even more active. Only a few more mosquitoes successfully bloodfed at densities of 200-800 mosquitoes per cage than at lower densities, when there were only 25-100 mosquitoes in the cage.

Loss of bloodfed mosquitoes in the collection may be due to feeding or trampling by the bait while the mosquitoes are in the vicinity of the host. The restraining cage was designed to prevent the bait from projecting its beak through the cage walls and eating bloodfed mosquitoes outside of the restraining cage. Once the mosquitoes had left the bait's restraining cage, the possibility of being eaten was eliminated. A screen 10 mm above the floor of the box trap prevented resting mosquitoes, that escaped the suction of the fan, from being trampled by the bait.

The probability that mosquitoes with partial blood meals will attempt to refeed may depend on the quantity of blood in the mosquito's midgut. Edman et al. (1975) determined that Cx. nigripalpus Theobald, with one half or less of a complete bloodmeal, attempted to refeed within 6 hours of the interruption. Twelve and 24 hours later fewer would attempt to

refeed. The mosquitoes with three quarters of a full bloodmeal failed to respond to a feeding opportunity and were able to develop eggs. The rate of bloodfeeding for this species, with both bait types, averaged 40%, and the presence of this species in the catch was not strictly dependent on its abundance.

Several factors may determine whether the bloodfed mosquitoes were collected in the traps where they obtained the bloodmeal. In most cases, after completion of bloodfeeding, the female mosquito seeks a resting site by dropping down from the host. The engorged mosquito flies with difficulty and may glide or walk off the host (Edman and Bidlingmayer 1969). This would be the time that the bloodfed mosquito could be drawn into the trap net by the fan. The reduced mobility experienced by mosquitoes with a bloodmeal may be overcome by defaecation of fluids within 2 hours. Forty per cent of the weight of the bloodmeal may be excreted during this period (Boorman 1960). The mosquito may then be stimulated to leave the trap by first light in the morning (Edman and Bidlingmayer 1969). This behaviour would make the mosquito susceptible to being eaten by the bait or captured by the fan, increasing the opportunity to capture the bloodfed mosquito at the trap where the bloodmeal was completed. A reduced possibility may include mosquitoes with a partial bloodmeal which may actively continue host searching in order to complete the bloodmeal (Mitchell and Millian 1981). In traps designed to prevent captured

mosquitoes from bloodfeeding on the bait, 1.5% of Cx. tarsalis trapped were observed to have visible blood in their midguts.

FLOCK TRAP COLLECTIONS

During 1986 and 1987, the chicken flock trap collected the most mosquitoes. The multiple host (7-10 birds) traps collected the same species, but in different proportions as the single/paired host traps. The seasonality profiles for the flocks were similar to the single/paired host traps (Figs. 45 to 54). Many of the species that preferred the single duck-baited traps changed their preference to the chicken baits, when both bait species were each presented as a flock. The same group of species that dominated the single/paired trap catch also dominated the flock trap catch with one exception; Aedes flavescens, a species attracted in low numbers to the single/paired bait traps, was the most abundant species attracted to flocks in 1986, and the third most abundant species attracted to flocks in 1987 (Tables 15 and 16). Hearle (1929) suggested that Ae. flavescens preferred large animals, and was a persistent pest of livestock. Downe (1960) suggested that Aedes species may not always prefer mammal species but may be attracted according to the availability or size of the host. This may account for the reversal in preference when the single-baited traps (Figures 37,38,39,40,41, and 44) and the flock-baited traps (Figures 45,46,47,49,50,51, and 54) are

compared. The chicken flock may represent a significantly larger surface area compared to the duck flock. Edman and Webber (1975) suggested that the odour plume emanating from a crowded group of individuals is not spatially equivalent to multiple smaller plumes the same individuals would produce if they were scattered over a larger area. I propose that the larger odour plume produced by the crowded group may be perceived as one originating from a much larger animal by the host seeking mosquitoes. The appearance of proportionately larger numbers of a mosquito species, normally attracted to large mammals, could be the result of responding to a large odour plume.

The feather characteristics and defensive behaviour of mallard ducks and chickens are considered components of host availability, and could determine bloodfeeding success for mosquitoes (Edman and Webber 1975). The mallard ducks were observed to interact more with each other than the chickens during the study period. The chickens were quite passive with little interaction. The type of behaviour observed with the ducks was occasional chasing or tugging on the tail feathers, and could be interpreted as establishing and/or maintaining a pecking order. This behaviour may succeed in attracting the host seeking mosquito, but may reduce bloodfeeding success for some species. Culiseta inornata, Cx. restuans and Cs. minnesotae obtained bloodmeals from single ducks, but did not bloodfeed on the birds held in a flock (Tables 9,10 and 15).

Mansonia perturbans and An. walkeri fed more readily on ducks in the flock than on single ducks or chickens, or the chicken flock (Tables 10 and 16).

Permanent water bodies provide breeding habitat for both Ms. perturbans and An. walkeri (Wood et al. 1979). If dispersal from their breeding habitats does not remove them from the immediate vicinity of the marsh, they would remain in close proximity to the avian species that inhabit the marsh. I have observed many species of waterfowl, including mallard ducks, to frequent the permanent or semipermanent ponds at Oak Hammock for breeding. I have also observed foraging and loafing behaviour. This behaviour may place Ms. perturbans and An. walkeri in close proximity to wild ducks in their natural habitat, resulting in ducks becoming the preferred host (Nasci and Edman 1981).

FACTORS AFFECTING THE MOSQUITO COLLECTION

Factors other than bait may play an important role in determining host attractiveness and mosquito capture success. Environmental conditions, trap types and site location were examined to determine their effect on species and numbers of mosquitoes collected.

(i) Effect of Trap Type

In this experiment it was determined that the Ehrenberg was a more effective trap than the Fortney Fan trap (Table 14). The fan trap was a 45 cm cube-shaped trap, with square

corners. A disadvantage of this trap is that the design could limit its effectiveness by permitting mosquitoes to occupy secluded spaces and avoid the suction of the fan. The large screened doors would permit bloodfed and unfed mosquitoes to fly out of the trap without passing in front of the fan intake. Mosquitoes in the vicinity of the host would also be prone to being eaten by the host. An advantage of this design is that bloodfeeding by mosquitoes is enhanced, and a value describing bloodfeeding rates can be established. This trap could be modified to increase fan suction and to prevent mosquitoes from leaving the trap.

The Ehrenberg design has been used with limited success for many years (Bellamy and Reeves 1952, Ehrenberg 1966). Attracted mosquitoes are prevented from reaching the host. This mechanism eliminates mosquito losses through trampling or host feeding. The funnel design of the trap net reduces loss from mosquitoes leaving the trap. Bellamy and Reeves (1952) suggested there may be a 5% loss of trapped mosquitoes overnight, which is minimal compared with other mosquito traps. On the other hand Copps (1984) found that in Ontario, when baited with pigeon or quail, the Ehrenberg collected very few mosquitoes of any species.

Trap colour is important in attracting mosquitoes to an object. Bidlingmayer and Hem (1979) showed that increasing the trap visibility may increase or decrease catching

effectiveness. In their experiments, plywood traps painted flat black were more attractive than transparent traps.

In my research, I have concluded that the Ehrenberg design was more practical and effective than the fan trap, when used with smaller bait species such as the yellow-headed blackbird. The Fortney Fan, with some modifications to reduce loss, may be superior for larger avian species and possibly small mammal species.

EFFECT OF SITE

The specific location of the traps at Oak Hammock Marsh may have affected the number and species attracted. When the traps were situated at the northern trio of sites the mosquito catch was substantially higher than at the southern or central trap sites (Table 13). Two of the northern sites were situated on an exposed edge of the willow stand (Fig. 32) and may have been more conspicuous at sunset, when mosquitoes begin host-seeking.

The trap sites located in the central area were located in tall grass and partially hidden from view at ground level. The lower catch rate at these sites is in agreement with the results of Bidlingmayer (1971) who reported that mosquitoes avoided traps bounded by shrubs on all sides.

The southern group of trap sites included open sites as well as sheltered sites, and provided the second largest collections. Site number 3 had a western exposure and was more

visible at dusk. Site numbers one and two were located on the east side of the willows, and in the shade of the vegetation during the dusk period. Bidlingmayer and Hem (1979) suggested that woodland mosquito species are attracted to conspicuous objects, whereas field species may practise avoidance.

ENVIRONMENTAL FACTORS

Environmental factors such as wind and temperature may play important roles affecting trap collection results. In my research, larger numbers of mosquitoes were collected at wind speeds 0 to 5 kmph than at wind speeds >5 kmph. Culex tarsalis was able to fly any direction at wind speeds less than 4.8 kmph. but was forced to fly downwind at wind speeds greater than 5.4 kmph (Brockway 1962). The host-seeking female orients upwind of the bait at low windspeed and would be expected to be collected in larger numbers at low windspeed. Bidlingmayer et al. (1985) found no evidence of downwind flight at any wind velocity. However, they did find a 75% reduction in numbers captured at wind speeds between 0.9 kmph. and 1.8 kmph. In my study, the numbers collected at high windspeeds (>10kph) were greater than at medium windspeeds (5-10) kmph. Snow (1976) suggested that mosquitoes collected at higher windspeeds may have been active during lulls in the wind or may be flying very close to the ground. The tall grass at my study site at Oak Hammock Marsh was a mean height of one meter. The base of the traps was at this height, and may have

been near the upper limit of access to trap entrances for mosquito species flying close to the ground.

Clark et al. (1976) noted that humidity and temperature were the two most important influences on the physiological rhythm that governs the daily activity patterns of insects. In their study, the highest daily maximum temperature (114°F) occurred immediately before the largest collection of Cx. tarsalis. The flock traps in my study were operated over a larger temperature range (7°C to 23°C) than the single/paired traps from 12°C to 21°C. Very few individuals were caught at temperatures below 11°C. The largest collections of Cx. tarsalis occurred at temperatures ranging from 14°C to 21°C, which is considerably lower than in Clark et al.'s (1976) study. The reasons for this are unknown.

GENERAL DISCUSSION

Oak Hammock Marsh provides a habitat for several mosquito species, as well as potential host species, that may play important roles in the dissemination of the Western Equine Encephalitis (WEE) virus among human and animal populations.

Cx. tarsalis is believed to be an opportunist in host selection. Tempelis et al. (1965) concluded that host preference was related to relative host abundance on the basis of blood meal identification in Cx. tarsalis.

The host selected after the winter hibernation period may depend on which host is abundant or available when Cx. tarsalis begins to search for a blood meal. If the host species present is infected with WEE, the mosquito population may become infected. Any of the potential host species could be involved in introducing the WEE virus to the mosquito population, especially those host species that experience large periodic population fluctuations. Large flocks of several blackbird species e.g. the red-winged; Agelaius phoeniceus, yellow-headed, and the Brown-headed cowbird Molothrus ater, have been observed at Oak Hammock Marsh during July and August. In the evening these flocks roost in large numbers in willows on the marsh and may provide blood-meals to infected mosquitoes. The potential host species could be a small mammal that experiences a population explosion or a migrating bird species that

periodically frequents the area in large flocks. Migrating waterfowl in the spring may re-introduce the WEE virus to the local mosquito population. Reeves et al. (1958) have demonstrated that WEE virus may persist in avian hosts as long as 10 months.

Host seeking adults may bloodfeed 3 or more times during a season. Females of Cx. tarsalis were attracted to and were able to obtain a blood meal from three avian bait species. Waterfowl may be a source of the virus and Cx. tarsalis is known to be infected with WEE in the Oak Hammock area (Sekla et al. 1980).

Several mosquito species periodically occur in very large numbers in Oak Hammock, and their roles as possible secondary vectors of WEE should be examined. Aedes vexans populations can increase to extremely large numbers in a relatively short period of time if there is sufficient rainfall. It has been reported that eggs of Ae. vexans may last up to 5 years (Gjullin et al. 1950). The large numbers of Ae. vexans in 1987 probably resulted from inundation of areas where eggs from several years had accumulated and escaped previous inundation. Aedes vexans is known to harbour WEE virus (McLintock et al. 1970) and infected females have been taken from Oak Hammock (Sekla et al. 1980). The role that this species may play in the maintenance of the WEE virus is unknown and should be explored.

Several mosquito species were collected in large numbers over the two years of study, and may play a role in the maintenance of the WEE virus in the fauna of the marsh. Aedes flavescens and Anopheles walkeri were abundant over the two years of study, and were able to bloodfeed on birds. The parity study indicates that most An. walkeri females bloodfed only once in 1987. Hence, there is probably little opportunity for this species to play a major role in either the maintenance or the transmission of WEE.

McLintock et al. (1958) collected Ae. flavescens infected with WEE virus in 1964 in Saskatchewan. Due to the large numbers collected during this study, a parity study on this species, as a means of determining its role as a vector of WEE virus would be helpful.

In Manitoba, Sekla et al. (1980) obtained the first known isolation of WEE virus from Ms. perturbans in 1977. Mansonia perturbans numbers increased significantly in 1987, but considering nearly all of the host seeking adults were nulliparous and uniparous, it is unlikely that many females took more than one blood meal. It would therefore play a minor role in the dissemination of WEE virus.

Oak Hammock covers a very large area and provides suitable habitat for all life stages of floodwater or permanent water mosquitoes. All the components necessary for the maintenance of a cycle involving WEE virus, suitable vertebrate hosts,

and a population of mosquitoes capable of vectoring this pathogen, coexist at the marsh.

Additional knowledge obtained from research concerning host preferences and blood feeding behaviours when other avian or mammalian species, native to the marsh, are presented as bait animals, would certainly compliment the results discussed in this research and perhaps would aid in understanding the overwintering mechanism utilized by the WEE virus in Manitoba.

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