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THE BREEDING SITES AND SEASONAL OCCURRENCE OF *CULICOIDES FURENS* IN GRAND CAYMAN WITH NOTES ON THE BREEDING SITES OF *CULICOIDES INSIGNIS* (DIPTERA: CERATOPOGONIDAE)

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ABSTRACT. Of the seven species of *Culicoides* found in Grand Cayman, *C. furens* (Poey) was by far the dominant species. Only *C. furens* and *C. insignis* Lutz were taken in emergence traps. The density of emergence of the former was greatest in mangrove swamp and the latter in fresh water reed swamp. Within the mangrove, emergence of *C. furens* was not evenly distributed but favored bare mud over mud with pneumatophores and non-tidal rather than tidal areas. Most non-tidal bare mud occurred around mangrove pools in the lower, wetter parts of the swamp.

C. furens adults were present all year but with major peaks of abundance in late spring and early winter. Peaks were variable from year to year and variably demonstrated by different collecting methods. Light and emergence trap catches showed a very close relationship with swamp water levels and a lesser relationship with temperature.

INTRODUCTION

A 5-year program in Grand Cayman, using light, bait, suction and emergence trapping methods, showed the presence of 7 species of *Culicoides*: *C. furens* (Poey), *C. insignis* Lutz, *C. barbosai* Wirth and Blanton, *C. hoffmani* Fox, *C. pusillus* Lutz, *C. jamaicensis* Edwards and *C. panamensis* Barbosa. Of these, *C. furens* was by far the dominant species, constituting over 95% of the total catch (of over 400,000 biting sand midges or flies). *C. insignis* was widespread but its numbers were low while *C. barbosai* sometimes occurred in large

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numbers but was very localized. The remaining 4 species were rare.

Only *C. furens* and *C. insignis* were recorded from emergence traps. Much is already known of the breeding sites of the former, a very common Neotropical nuisance species (Painter 1927, Myers 1932 and 1935, Carpenter 1951, Woke 1954, Bidlingmayer 1957, Breeland 1960, Wall and Doane 1960, Williams 1962 and 1964, Davies 1964, 1967 and 1973, Hair et al. 1966), but the Cayman data give further details of its distribution in the small island environment. Much less is known about *C. insignis,* and further data are required to explain the great variation in breeding sites reported in the literature (Forattini et al. 1957 and 1958, Wirth and Blanton 1959, Williams 1964, Davies 1964, 1967 and 1973).

C. furens was present in large enough numbers in all 5 years of the Cayman study to give a good idea of seasonal distribution, and the factors which affect this, for comparison with other areas (Shields and Hull 1943, Beck 1958, Jamnback 1965, Linley et al. 1970 and Kline and Axtell 1976 in the United States and Carpenter 1951, Fox and Capriles 1953, Fox and Garcia-Moll 1961 and Tikasingh 1972 in the Caribbean).

THE STUDY AREA

Grand Cayman is a small island lying between Cuba and Jamaica about 180 mi. away from both. It is 22 mi. long and up to 9 mi. wide but irregular in shape. The total area is about 76 square mi. and elevation is nowhere over 60 ft. above sea level.

An account of the main vegetation types is given by Swabey and Lewis (1946). There are 2 main natural zones, mangrove swamp and dry forest, which together cover most of the island. Two lesser zones are beach ridge and *Typha* (reed) swamp. The former is an elevated strip about 100 yards wide surrounding much of the island and the latter occurs mostly in small scattered patches where fresh water lenses are close to the ground surface.

Two other zones have been formed by the activities of man. Much of the dry forest has been cleared and kept open by grazing animals, and this rough pasture is now more extensive than the original forest, though there are many transition zones. Between 1969 and 1973 about 200 acres of mangrove were filled by material dredged from the sea bed. Dead mangrove trees were removed leaving barren open stretches of calcareous mud which plant communities colonized very slowly.

The mangrove swamp requires further description, being the most important zone from the point of view of biting midge breeding. A variety of habitats occurred within it. Three species of mangrove tree were present: red (*Rhizophora mangle L.*), black (*Avicennia germinans* (L.) and white mangrove (*Languncularia racemosa* Gaertn.). Buttonwood also occurred (*Conocarpus erectus* L.). Trees were mostly of good size with the general canopy at 25 to 30 ft., but there was little zonation of species as occurs in estuarine swamps of continental areas and larger islands (e.g. Davies 1967). Apart from a thin strip of pure red mangrove on the seaward fringe, most of the swamp consisted of mixed mangrove species.

The ground surface was mostly well shaded by dense canopy and subject to regular flooding. Daily tidal inundation did not, however, occur except at times on the seaward fringe. Many areas of swamp were in fact completely cut off from the sea. The general pattern was for the swamp to be mostly dry during the dry season, except when general sea level was above average, and flooded during the wet season by rain. However, drying out could occur between rain storms in the wet season.

Much of the swamp substrate consisted of mud studded with the breathing roots (pneumatophores) of black mangrove trees. These could be over 2 ft. long and so dense that the mud surface could not be seen, or widely spaced and only an inch or so long depending on the depth of flooding commonly experienced. Little ground vegetation occurred. The herb *Batis maritima* L. grew between pneumatophores in some areas and the long rambling branches of the bush *Dalbergia brownei* (Jaqu.) festooned some of the trees and pneumatophores. Some areas of completely bare mud occurred on the seaward fringe between the stilt roots of red mangrove and more rarely in mixed mangrove areas. The most extensive bare mud areas, however, occurred in the beds of many pools scattered throughout the swamp. These varied from a few square yards to several acres in extent with a few lakes of over 30 acres. They were mostly very shallow, flooding over onto the main mangrove mud level when only about a foot deep. They were the last areas to dry out in the height of the dry season.

METHODS

Two types of emergence trap were used: Cones of tar paper covering 2.8 ft^2 similar to those used by Davies (1966), and square wooden boxes covering 4 ft^2 Both collected into 3x1 inch glass tubes which were lightly greased inside with vehicle lubricating grease. Tubes were changed daily or weekly and the catches removed by filling the tubes with kerosene and detaching the flies from the sides with the flushing action of a pipette. Traps were placed in damp areas in all the main types of vegetation and were moved whenever the tube was changed to prevent the unnatural build up of larvae which can occur under stationary traps (Davies 1966).

At one emergence trapping site (station A) the muddy edge of a canal through mangrove in South Sound, one trap was sampled every day from April 1969 to November 1972, being kept just above the water line.

A long term assessment of the flying population was made at the same time using a battery operated miniature C.D.C. light trap (Sudia and Chamberlain 1962) which was modified to collect onto a 3.5 inch diameter disc of mosquito screening lightly greased with motor vehicle lubricating grease. Catches were removed from the discs by immersing in kerosene. The trap was operated about 80% of all nights from April 1969 to the end of 1973, in the Red Bay area (station 23).

Further information on seasonal activity was given by a goat-baited trap and a suction trap, but collections were not made so regularly. The former was operated an average of 9 nights a month in 1970 and the latter 7 nights a month in 1971 starting in February. The goat-baited trap, located at Thompson's Farm (station 11), was a small hut with a sticky disc, as described for the light trap, attached to the window. The suction trap was a Johnson/Taylor model (Johnson 1950) with a 12-in. fan run from the mains supply. It was located at Prospect Point (station 44). The catch was sorted dry in petri dishes.

Daily meteorological records were kept plus lagoonal tide levels, swamp water levels and sea and swamp salinities.

RESULTS AND DISCUSSION

MAIN BREEDING SITES. Fig. 1 shows the density of emergence of *C. furens* and *C. insignis* in the main vegetation zones, *C. furens* was found breeding in most types of habitat, but mangrove swamp was by far the most productive (see the following section). Next in importance was filled mangrove. No breeding occurred on deep (3 to 7 ft.) fill with a rough dry surface but the fine grained "run-off" which covered large areas of mangrove around filled areas produced large numbers of sand flies and it appeared that the fill was merely raising the normal mangrove breeding site a few inches to a few feet.

Typha swamps produced surprisingly few *C. furens* although seemingly suitable areas of damp mud often occurred in and around them. Other low salinity areas such as the edges of cow wells and damp depressions in fields and thick forest gave mostly negative results as well. Positive results in rough pasture were obtained only at the height of the wet season around extensive areas of temporary flooding. At such times the lower lying saline mangrove swamps were completely flooded and unavailable for breeding, as were *Typha* swamps.

The beach ridge was mostly too dry for sand fly breeding. Damp areas on the seaward side were mostly subjected to wave action but some breeding was found in sand less than 1 in. thick around pools cut off from all but the highest tides. On the landward side, breeding was found at the transition zone with mangrove when water levels in the latter were high.

Fig. 1 shows that *C. insignis* had a very different pattern of breeding site distribution, favoring the fresh water *Typha* swamps. A few, however, were recovered from mangrove swamps, even the wetter more saline seaward edge. Within the *Typha*, breeding was found in damp unflooded areas in the reed zone itself and the surrounding zones of marsh grass. Both heavily vegetated and bare mud areas were utilized.

In Trinidad, *C. insignis* has been recorded from both very saline and very fresh habitats (Williams 1964) and in Brazil the species is recorded as tolerating a wide range of conditions (Forattini et al. 1958). In Jamaica there was a surprizing division in breeding sites with more emergence from the seaward fringe of red mangrove and the inland, non-saline cane fields than from the mangrove zones between these two (Davies 1967). This division may point to the existence of two races, one favoring the wetter saline environment and the other fresh water habitats. Differences in biting behavior could thus be accounted for: in Jamaica *C. insignis* is said to bite man "occasionally in close proximity to the swamps," but extensive breeding was shown away from the swamps. In Grand Cayman man-biting was unknown and fresh water habitats the biggest producers, while in Brazil bad biting of humans has been experienced and saline swamp shown to be a major breeding site.

BREEDING OF *C. furens* WITHIN THE MANGROVE. Although mangrove swamp was found to be the main breeding site of *C. furens*, much emergence trapping in this zone gave negative results even when biting showed the species to be abundant. It was clear that breeding was by no means evenly distributed.

Fig. 2 shows the density of emergence in the main mangrove subzones. A large proportion of the negative results were obtained in the pneumatophore zones and there seemed to be a decrease in breeding with increase in length of the pneumatophores. Since this is an indication of the amount of flooding, this could mean a preference by *C. furens* for the drier parts of the swamp; this agrees with results from other areas (Woke 1954, Breeland 1960 and Davies 1967). Also in agreement is the low rate of emergence from bare mud under red mangrove, this being mainly in the wetter, more frequently inundated areas.

However, bare mud areas in black and mixed mangrove showed the highest production and such areas were mainly in and around mangrove pools which were not the driest part of the swamp, being at a lower level than the pneumatophore zone and only exposed at the lowest water levels. However, exposure was often for several weeks at a time. There is agreement here with Painter (1927) in Honduras, who found most breeding around pools in sandy areas and mud flats rather than in the mangrove itself. Also, in the U.S. Virgin Islands, probably a small island environment similar to Cayman, Williams (1962) found highest breeding levels on the edges of non-tidal mangrove pools. Later work in Trinidad (Davies 1973) showed more emergence from bare mud than from mud with reeds and grass in tidal areas, and this also fits in with the well documented preference for the muddy edges of drainage ditches (Bidlingmayer 1957, Wall and Doane 1960 and Hair et al. 1966).

The indications are, therefore, that *C. furens* shows a preference for bare mud over mud with pneumatophores and vegetation as a breeding site, even if the bare mud occurs in the wetter parts of the mangrove. The mud must, however, be exposed for periods of several weeks at a time at certain seasons, with no regular daily inundation. Such sites in Grand Cayman are a minor part of the mangrove swamp, the pneumatophore zones covering the greatest area. Within the

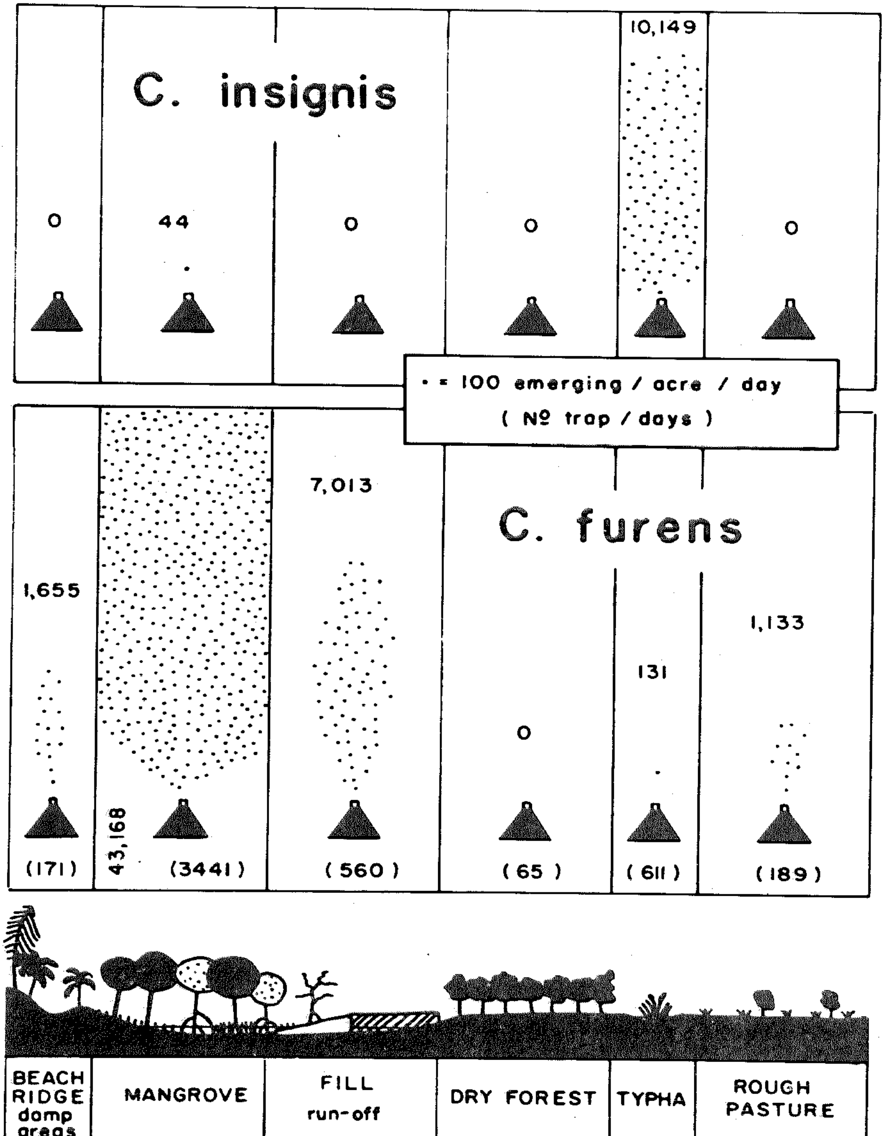

Fig. 1 Density of emergence of *C. furens* and *C. insignis* in the main vegetation zones.

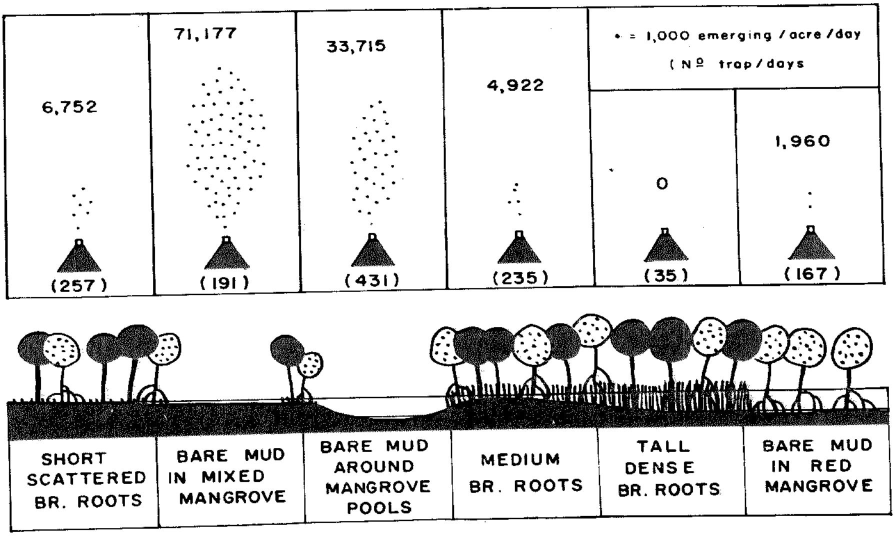

Fig. 2 Density of emergence of *C. furens* in mangrove subzones.

pneumatophores the higher levels of breeding among the shorter pneumatophores may be due to their being more scattered so that more bare mud is available between them.

SEASONAL OCCURRENCE OF *C. furens*. Fig. 3A shows the seasonal occurrence of *C. furens* in emergence and light traps. The species was present the whole year round but very distinct periods of abundance occurred. The peaks usually started in late spring and lasted into summer, a similar pattern to that found in Puerto Rico (Fox and Capriles 1953, Fox and Garcia-Moll 1961) and Trinidad (Tikasingh 1972). In Florida additional peaks have been reported, mostly in the October to January period (Shields and Hull 1943, Beck 1958, Linley et al. 1970) and in Cayman the years 1972 and 1973 showed highest light trap catches in the winter common to the 2 years. However, no hint of this peak was shown by the emergence trap, which unfortunately ended recordings in December 1972.

Further results contradicting the idea of a single annual peak in late spring came from the analysis of sand fly biting complaints, also shown in fig. 3A. The local population often reported bad biting when trap catches were low, and those reports investigated always showed *C. furens* present in large numbers inside houses. Such complaints commonly occurred in winter months. Also, results from the goat-baited trap in 1970 showed that about 45% of the total annual catch of 92,197 *C. furens* occurred in the months of October and November. This coincided more closely with the incidence of biting complaints and also with results from a horse-baited trap in Panama where peak numbers occurred from September to December (Carpenter 1951).

A possible explanation is that fewer individuals in peaks occurring in the latter part of the year are autogenous than individuals in the spring/summer peaks, so the anautogenous individuals are well shown in bait traps and noticed by the human population. They are not shown in emergence traps sited in mangrove as

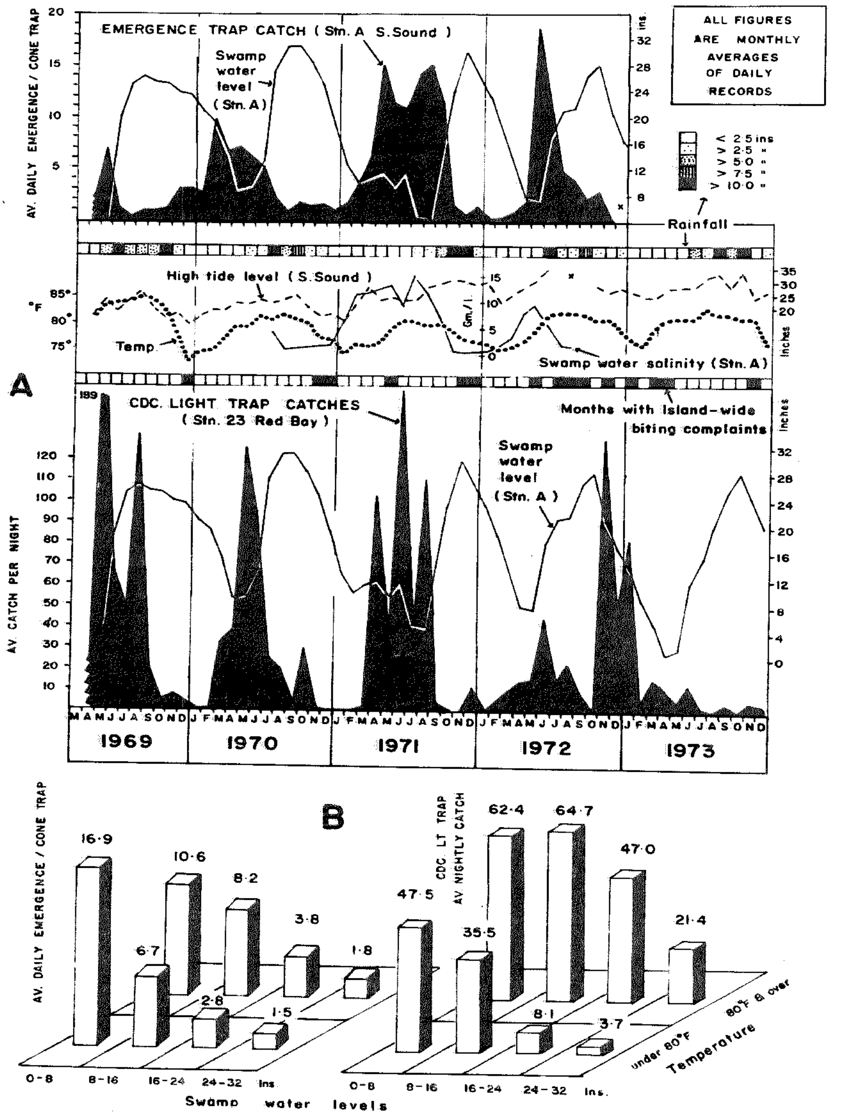

Fig. 3. A. Seasonal variations in *C. furens* numbers, biting complaints, water levels and meteorological factors.

B. Trap catches at various swamp water levels and temperatures taken from the data in A.

mangrove is largely flooded at this time of the year. Their absence from light traps is more difficult to explain, but the lower temperatures of winter may limit flight more strictly to the crepuscular periods when light traps are less efficient.

If breeding is significantly displaced from mangrove to less saline pasture and beach ridge sites during the wet season, a change in rate of autogeny could be explained by the change in larval habitat and therefore nutrition. Also these areas are in closer contact with the human population. However, as previous results have shown, wet season breeding in pasture and beach ridge was never seen to equal that in mangrove in the dry season.

That two periods of large numbers occur per year was borne out by suction trapping results during 1971. Of the 3,364 *C. furens* caught in this year, 2 well defined peaks occurred, one from April to June and the other in November.

FACTORS AFFECTING SEASONAL OCCURRENCE OF *C. furens*. Although late spring and early winter peaks seemed to be the general rule, the pattern was obviously subject to considerable variation and must be affected by those external conditions which vary a lot from year to year. Fig. 3A shows monthly rainfall and average monthly temperatures, tide levels and swamp water levels and salinity throughout the Cayman survey.

The position and extent of the rainy season varied considerably during the 5 years of the survey and all emergence trap peaks and most light trap peaks occurred during the drier months, especially just before the onset of the rainy season. Biting complaints tended to be in the drier months as well, but following the rainy season. In 1971 the rains were abnormally late and trap catches continued to be high throughout the summer for a correspondingly abnormal length of time. Thus in a sense *C. furens* numbers depend on rainfall in that it is largely a dry season biting midge, but there was no close relationship between density and the amount of rain. This result seems consistent with other parts of the Caribbean (Tikasingh 1972) though a definite relationship with rain was found in North Carolina (Kline and Axtell 1976).

Tides were found to be significant in Puerto Rico (Fox and Garcia-Moll 1961) with greater sand fly densities at low tide levels, but in Jamaica general levels did not seem important although high amplitudes inhibited emergence (Davies 1967). In Cayman no consistent relationships with tide levels or amplitudes were apparent.

Although rainfall and tides did not themselves relate well to biting midge densities, they were the main factors regulating swamp water level, and this showed a very definite inverse relationship with light and emergence trap catches. The latter was a particularly significant relationship, and this was demonstrated on the sloping edge of a canal by an emergence trap kept continuously just above the water line. Thus moisture conditions in the mud varied very little, but still there was a gradual increase in biting midge production with decrease in water level. A relationship with flooding was found in the study of Kline and Axtell (1976) and the relationship with tides in Puerto Rico, mentioned above, could be due to their effect on swamp water level.

Salinity was to a large extent inversely related to water level and therefore showed a positive relationship with biting midge abundance. It has been shown by laboratory studies (Linley 1968) that *C. furens* larvae, when well fed, thrive equally in fresh and saline environments, but perhaps under natural conditions food is more plentiful at higher salinities. A mechanism such as this may underlie the relationship with water level, however the latter was more significant than the relationship with salinity.

Linley et al. (1970) found a positive relationship between temperature and emergence, and in the Cayman study the light trap did tend to show peaks in warmer weather and evidence of inhibition when it was colder. The beginning of the spring peaks of 1970, 1971 and 1972 corresponded with temperatures rising towards their summer levels while the

November peak of 1972 coincided with abnormally high temperatures compared with the previous 3 Novembers when such peaks did not occur. However, similar high November temperatures occurred in 1973 without a peak being produced. Also, the peaks shown by the emergence trap tended to start earlier in the year when temperatures were still low, and biting complaints often occurred in cooler winter weather.

Fig. 3B shows the monthly light and emergence trap catches grouped according to swamp water level and temperature. Both above and below 80°F there was a good inverse relationship between catches and water levels, but below 80°F catches were markedly smaller, especially in the light trap. Thus temperature seemed to have some importance, but water levels gave a closer relationship to biting midge density than any other factor in the Cayman study.

If *C. furens* abundance is regulated largely by temperature and ground water levels throughout its range, it is likely that temperatures are of greater consequence towards colder latitudes while water levels became increasingly important towards the tropics where temperatures allow breeding throughout the year. Relationships with rain or tides found in some areas are probably due to direct relationships between these factors and swamp water levels. Even in a small area such as Grand Cayman it was found that these factors affected swamp water levels much more directly in some swamps than others, so it is not surprising that relationships with rain and tides have been demonstrated in some countries and not in others.

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NOTE ON CULICIDAE OF THE UPPER RICHELIEU, QUEBEC

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ABSTRACT. A bi-weekly sampling of primarily larval mosquito populations was done during the 1975 season in the Upper Richelieu region. This study revealed the presence of 23 species of Culicidae, constituting nearly 50% of species known in Quebec. Data are given on the abundance and distribution of these species.

INTRODUCTION

Studies of the importance of the spring floods on the ecology of the Richelieu River (G.R.E.R. 1974) have stimulated our interest in the local mosquito populations. Work has been done on mosquitoes throughout the province of Quebec (Twinn 1949), and, more recently on those of the southern portion of the province (Bourassa et al. 1976), but no detailed study has been carried out on the Upper Richelieu region to the southeast of Montreal (45°10′ N; 73°16′ W). A 10 mile long sector of the Richelieu Valley, from the Canadian-American border to St-Paul de l'Ile-aux-Noix, was visited regularly.

MATERIALS AND METHODS

Mosquito larvae were collected during 1975, using a 1-litre dipper. Larvae were identified at the 4th instar using the keys of Carpenter and LaCasse (1955), Rempel (1950) and Steward and McWade (1961). Although we were primarily interested in larval populations, adults were also collected, using emergence traps and