EMERGENCE PHENOLOGIES AND PATTERNS OF AQUATIC INSECTS INHABITING A PRAIRIE POND

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ABSTRACT

Emergence traps were used to investigate aquatic insect emergence patterns and densities in a prairie pond in Saskatchewan. Hill's numbers, percent dissimilarity and Morisita's Index were used to measure the diversity of each insect order and changes that occurred between 1987 and 1988. Emergence between submerged vegetation habitats and emergent vegetation habitats were compared.

One hundred and fifteen species belonging to six orders were identified; three Ephemeroptera, 16 Odonata, one Neuroptera, 17 Trichoptera, eight Hymenoptera, and 70 Diptera. One new species was identified. Another was a new record for the genus in Canada. Twelve species are new records for Saskatchewan.

The emergence patterns of the abundant species ranged from unimodal for the Odonata, including *Lestes congener*, to multimodal for many of the chironomids; eg. *Corynoneura* cf *scutellata*. Some species, including *Psectrocladius simulans*, had long emergence periods of over three months while others, such as *Cladopelma viridulus*, had short emergence periods of two weeks.

Diversity and abundance of the insect community declined between 1987 and 1988. These decreases were

attributed to the pond changing from a permanent, nonaestival pond in 1986, to a permanent, aestival pond in 1987, and to a temporary pond in 1988. These changes in physical conditions of the pond reduced the numbers of adults collected for most species in 1988 because the immatures did not survive the aestival conditions. Diversity and abundance were reduced further in 1988 because the pond dried up in mid July, restricting the species collected to those emerging in spring and early summer.

Significant differences in the number of adults collected from the submerged vegetation and emergent vegetation were recorded for some species including Callibaetis pallidus, Aeshna interrupta, and Mesosmittia acutistylus?. These were due to differences in microhabitats of immature stages, eclosion requirements and water depth at the trap stations.

The insect communities of 1986 and 1987, particularly Chaoborus americanus, Callibaetis pallidus, and the Zygoptera species, were used to predict the physical conditions of the pond a year prior to the study. Knowledge of life histories and habitat requirements of the species were used to predict the insect community in 1989 based on the conditions of the pond in 1988.

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1. INTRODUCTION

1.1 Overview and Objectives

Aquatic insects inhabit all ponds and wetlands. They are important components of these habitats (Murkin and Wrubleski 1990) and contribute to the diets of many species of economically and aesthetically important birds (Driver et al. 1974; Sugden 1973). These insects are also useful in assessing the impact of agricultural and industrial chemical contamination on pond habitats (Sheheen et al. 1987). In a strictly entomological sense their diversity, ecology and life histories make them interesting subjects for study.

Few aquatic entomologists have done research on pond inhabiting insects in Saskatchewan. Therefore, basic descriptive research is needed to compile species lists and to investigate the life histories and ecologies of these insects. Such research would provide the basis for future experimental research on the insect community inhabiting ponds and pond habitats in general. Such studies would also provide useful information to water fowl managers and impact assessment researchers. Without basic descriptive research the efforts of experimental researchers are likely to fail or at least be less efficiently done.

Because so little information is available on pond insect species in Saskatchewan a classical, descriptive, study was undertaken to provide basic information that is lacking. The ideal research project would involve collecting and studying the aquatic insects from many ponds in different regions of the province over several years. However, under today's time and funding constraints this type of research is usually not possible. Therefore the present study focused on the aquatic insects emerging from a single Saskatchewan pond over a three-year period.

Studying adult emergence is the most efficient method to collect data on species composition and life histories (Davies 1984). Intensively studying a single pond provides information on the temporal changes that can occur in the pond and in its fauna.

The specific research objectives were to:

A. Determine the insect species inhabiting a Saskatchewan pond and the diversity of the insect community in the pond.

B. Determine natural year-to-year changes in species composition, numbers, and diversity of adults emerging.

C. Determine temporal and spatial emergence patterns of the more abundant species collected.

1.2 Background Information

1.2.1 Importance of Pond Habitats

The prairie pothole region covers an area of 770,000 km^2 in central North America (Sheehan et al. 1987). In this region are millions of small depressions that hold water for varying lengths of time and are called ponds, sloughs or pothole lakes. In some parts of the region ponds occur in densities of 31 to 50/km^2 and cover 8 to 12% of the land area (Driver 1977; Millar 1969). These ponds are an important physical part of the prairie-parkland biome.

Ponds provide habitats for many plants and animals in the agricultural region of the prairie provinces. Sheehan et al. (1987), using various sources, listed 44 species of plants associated with ponds in the region. These plants contribute to a large average net primary productivity of 2000 g/m^2/yr for swamps and marshes (Whittaker 1975).

More than twenty species of ducks and other waterfowl feed or nest in or near prairie ponds (Bellrose 1976). An estimated 16 million ducks and coots, or 38% of the total North American population, use the Canadian prairies and parklands as nesting grounds (Sheehan et al. 1987). Economically important fur-bearing animals such as muskrats and fox live in or forage for food in and around ponds (Murkin and Batt 1987). Many passerine birds nest in pond margins where they feed on the insects emerging from the pond (Busby and Sealy 1979).

Ponds are also important to agriculture. Naturally occurring ponds are used to supply water for livestock. Dense stands of grasses and sedges in dry pond basins are baled for winter livestock fodder. There is also evidence suggesting ponds are important in recharging ground water supplies and reducing flood damage (Zittlau 1979; Sheehan et al. 1987).

Ponds, and other wetlands, also have important aesthetic values. The animals and flowers found in ponds and pond margins provide a source of enjoyment for naturalists and artists. However, these aesthetic values are difficult to assess and are often not considered important by researchers (Leitch and Ekstrom 1989).

Ponds are often considered as waste-land that could be turned into economically profitable urban subdivisions or agricultural land. Although they are still numerous, compared to many other natural habitats in North America, the practise of draining ponds and wetlands for agricultural purposes has greatly reduced the numbers of these habitats in central North America (Reffalt 1985). Of an estimated 29.8 million ha of wetlands in the prairie states of the U.S. only about 33% remain (Sheehan et al. 1987). In Canada, up to 61% of the ponds and wetlands in some parts of the Alberta parkland region have been destroyed (Sheehan et al. 1987).

The extensive use of chemicals, such as pesticides and synthetic fertilizers, in North American agriculture is another threat to ponds and pond inhabitants. For example, in 1983, insecticides were applied to between 510,000 and 1,800,000 hectares of crop land in the three prairie provinces (Sheehan et al. 1987). Herbicides were sprayed on an estimated 20,549,000 hectares in the prairies in 1981 (Sheehan et al. 1987). The ponds in, or near, sprayed crop land can be contaminated by chemicals through spray drift, or via run off (Sheehan et al. 1987). Results show that contamination from some agricultural chemicals can cause large reductions in the biomass of larval chironomids (Morrill and Neal 1990) and other invertebrates (Sheehan et al. 1987). However, the effects of these chemicals on pond invertebrates, macrophytes and waterfowl cannot be fully evaluated due to the lack of baseline information on pond ecosystems and pond insects (Morrill and Neal 1990; Sheehan et al. 1987).

1.2.2 Importance of Pond Insects

Aquatic insects form an important basic link in the food chain of all types of aquatic habitats including ponds (Lamberti and Moore 1974; Merritt et al. 1984;

Murkin and Batt 1987). Various insect species are found at all trophic levels, from primary consumers through to top predators (Cummins and Merritt 1984). Shredding insects such as larval tipulids, caddisflies and chironomids feed on the abundant plant litter found in ponds (Cummins and Merritt 1984; Wiggins et al. 1980). This feeding process reduces the size of the litter particles and increases the area of the particles available for further microbial decomposition. These smaller particles are also food for deposit- and filter-feeding insects and macroinvertebrates (Lamberti and Moore 1984; Oliver 1971; Wallace and Merritt 1980).

Insects, such as Chironomus larvae, release nutrients from the benthos into the water through bioturbation. These released nutrients are available to primary producers (Gallep 1979; Merritt et al. 1984; Wallace and Merritt 1980; Zimmerman and Wissing 1980).

Pond insects are also very important in the diet of many duck species, especially egg-laying hens, and ducklings (Driver et al. 1974; Krupa 1979; Sheehan et al. 1987; Sugden 1973). The diet of egg-laying hens consists of 70% animal matter such as larval and adult Diptera, Coleoptera and Trichoptera (Krupa 1974; Sheehan et al. 1987; Swanson et al. 1985). Up to 72% of the diet of mallard ducklings is insects, mainly chironomids (Perrett 1962). Since ducks feed on whatever prey is available

(Sheehan et al. 1987), the abundance and availability of certain insects can influence the use of a particular habitat by ducks. Sjoberg and Danell (1982) found peak dabbling duck feeding times in Swedish wetlands corresponded to times of peak chironomid emergence.

Some pond insects are "biting flies" and may transmit diseases to man and livestock (Murkin and Wrubleski 1990). Included in this group are species of the families Culicidae, Ceratopogonidae, and Tabanidae. Each year tens of thousands of dollars are spent on spraying programs in and around urban areas of the prairies in an attempt to reduce mosquito populations. Of particular importance is the control of *Culex tarsalis*, which transmits western equine encephalitis (Galloway 1990).

Aquatic insects from all habitats, including ponds, are widely used to investigate the toxicity of contaminants, their bioaccumulation, bioavailability and sublethal affects in aquatic habitats (Clements et al. 1988; Hare et al. 1991; Walton 1989; Wiederholm 1984; Warwick 1991; Warwick and Tisdale 1988). In ponds, insects are being used to assess the impact of agricultural chemicals on ponds and pond inhabitants (Morrill and Neal 1990; Sheehan et al. 1987). However, researchers cannot assess these impacts completely, particularly the sublethal effects, because detailed species information is lacking (Murkin and Wrubleski 1990; Sheehan et al. 1987).

1.2.3 Pond Types and Pond Insects

Several physical and chemical processes, including basin size and shape, physiography, soil chemistry and local hydrological features influence the flora and fauna of wetlands (Zoltai 1987). These abiotic features and their influence on plant growth produce distinct communities that can be classified.

Zoltai and Pollett (1983) developed a three-level classification system for wetlands based on physiography, hydrology and flora. At the broadest level five classes of wetlands are distinguished; bogs, fens, marshes, swamps and shallow open waters (Zoltai and Pollett 1983). The prairie and parkland ponds are included in the marshes and shallow open water classes.

Many criteria have been used by researchers to develop a detailed classification of ponds. Driver (1977) classified ponds into three categories based on stability. Permanent ponds contain water consecutively for 25 years or more. Semipermanent ponds hold water for two or more years consecutively and temporary ponds hold water for less than one year.

The permanent and semipermanent ponds can be further subdivided based on overwintering conditions. The term aestival ponds refers to water bodies that freeze completely in the winter (Welch 1952). For the remainder to this discussion the term nonaestival will be used to refer to ponds that do not freeze completely during the winter. Temporary ponds can also be subdivided into two types based on when water is present. Wiggins et al. (1980) referred to vernal, temporary ponds as ponds that are present for a short time in spring. In contrast, autumnal temporary ponds fill in the spring and dry up during the summer, and then refill again in the fall.

Millar (1973) and Stewart and Kantrud (1971) developed detailed classification schemes for ponds based on vegetation, water chemistry, basin size and the amount of human disturbance. These classifications provide a method for resource managers, particularly those interested in waterfowl, to evaluate the various pond habitats in more detail.

The biotic features of a pond are a reflection of the length of time water is present in the pond basin. This criterion separates the ponds of the Canadian prairies and parklands into two types, temporary and permanent. Vernal temporary ponds are the most common pond habitats in the prairies and parklands. The most important feature of these ponds is the short time water is present in the basin (Driver 1977; Wiggins et al. 1980). In deeper basins permanent ponds can be found.

Depending on climatic conditions and water depth at freeze up these ponds may be aestival or nonaestival.

The number of ponds varies yearly due to changes in rates of precipitation and evaporation (Hartland-Rowe 1972). During periods of drought a permanent pond may become temporary until enough water accumulates in the basin to offset water lost through seepage, evaporation and transpiration. Conversely, increased precipitation levels can change temporary ponds to permanent ponds.

To inhabit temporary ponds successfully, insects must adapt to fluctuations in water depth, temperature and chemistry (Driver and Peden 1977), and to the absence of water for part of the year (Hartland-Rowe 1972; Wiggins et al. 1980). To insects and other organisms that have desiccation resistant life stages temporary ponds will be permanent habitats (McLachlan and Yonow 1989). However, for aquatic insects without desiccation-resistant life stages temporary ponds are available for only a short period. These insects must have short life cycles enabling them to leave the pond before it dries (Wiggins et al. 1980).

Most temporary pond insects also inhabit permanent aquatic habitats; although they usually do not occur in abundance (Wiggins et al. 1980). This is due to a number of advantages to living in temporary ponds (Wiggins et al. 1980). The dry period of the temporary pond basin exposes dead vegetation to aerial decomposition. This improves the food quality of the detritus (Barlocher et al. 1978). When the basin floods, detritus from the aquatic and terrestrial vegetation is available to detritivorous aquatic insects and other macroinvertebrates (Wiggins et al. 1980).

Predator pressure is also reduced. Fish cannot survive in temporary ponds and many carnivorous insects have not evolved desiccation-resistant stages (Wiggins et al. 1980). To exploit temporary ponds, most large predatory insects must immigrate to the pond in the spring. This delays their arrival and enables many of the detritivores to complete their life cycles before the predatory insects arrive. When the predatory insects do arrive there are large numbers of prey species available, which reduces food competition for the predatory insects as well (Wiggins et al. 1980).

Most temporary ponds are shallower than permanent water bodies and the seasonal water temperature closely follow the air temperature. Therefore the spring water temperatures increase more rapidly in temporary ponds than larger water bodies (Wiggins et al. 1980). The higher temperatures coupled with abundant food supply, increases development rates of larval insects (Sweeney 1984).

During the ice-free season, permanent ponds usually have smaller fluctuations in water depth, temperature and chemistry than temporary ponds (Driver and Peden 1977). This stability enables species that do not have desiccation-resistant life stages to complete their life cycles. The stability of the pond also enables a more diverse and complex aquatic flora to grow (Driver 1977; Millar 1973). This flora in turn increases the available microhabitats and supports a higher diversity of aquatic insects (Krecker 1939; Rosine 1955; Wrubleski and Rosenberg 1990).

Insects inhabiting both aestival and nonaestival ponds must adapt to large fluctuations in water chemistry during fall and winter when ice formation excludes or "salts out" ions (Daborn and Clifford 1974). This causes most ion concentrations to double or triple in the remaining water (Daborn and Clifford 1974). Anoxic conditions may occur during the winter months in the water and sediment under the ice (Danks 1971 p. 600; Nagell 1980). In aestival ponds, insects must also survive being embedded in ice (Daborn 1974; Sawchyn 1971). They accomplish this by seeking out less exposed microhabitats in the substrate and by producing cryoprotectant molecules, such as glycerol, in their bodies (Lee and Denlinger 1991).

In summary, the ponds of the prairies and parklands can be classified into temporary, permanent nonaestival and permanent aestival ponds based on the length of time water is present in the basin during the year and the overwintering condition. Insects inhabiting these ponds must adapt to many environmental constraints, including fluctuations in water depth, temperature and water chemistry, to complete their life cycles. Insects that live in these ponds can exploit the high levels of primary production, reduced competition and reduced predation that exists.

1.2.4 Previous Research on Pond Insects

Much of the previous research on pond insects has focused on their importance as duck food (Driver et al. 1974; Sugden 1973; Sheehan et al. 1987). More recently, insects have been included in impact assessments of agricultural chemicals (Morrill and Neal 1990; Sheehan et al. 1987). Both areas of study have concentrated on the insects in relation to waterfowl production. As a result much of the research has been conducted at a supraspecific taxonomic level. This type of study provides little or no information on the ecology and life histories of individual insect species and is therefore of very limited use to aquatic entomologists.

General taxonomic treatments such as Merritt and Cummins (1984); Wiggins (1977); Edmunds et al. (1976); Walker (1953; 1958); Walker and Corbet (1975) and Brooks and Kelton (1967) provide valuable taxonomic information on pond insects. These treatments, however, usually do not include species-level biological information.

Some studies have focused on the biology of pond insects, either using a general habitat approach or by studying a particular species or species group.

Gibbs (1979) followed the seasonal movements of Callibaetis sp. larvae in a Quebec pond. The larvae avoided the ice by moving from shallow areas of the pond to central, deeper regions in the fall (Gibbs 1979).

Corkum (1984) followed the movement of selected invertebrates, including the mayfly Caenis simulans (= C. youngi) in an Alberta marsh. Most were night active. The mature larvae moved toward the shore in May, before emerging. In mid to late summer small larvae were found moving back to the centre of the marsh (Corkum 1984).

Sawchyn (1971) found photoperiod and temperature were used by various species of damselflies to time diapause so they could survive the winter months and synchronize emergence.

Stewart (1973) sampled larval and adult Culicidae in a pond near Saskatoon, Saskatchewan. He collected 21 species belonging to five genera. He found two population peaks, the first resulted from the development of overwintering eggs of Aedes and a second, later one, from the overwintering females of Culiseta, Culex, Anopheles, and Mansonia.

Chironomids have been studied by several researchers. Rasmussen (1984, 1985) studied competition and life histories of two chironomid species in a small Alberta pond. He found that interspecies competition was low because Glyptotendipes paripes is a filter feeder while Chironomus riparius is a deposit feeder. However, the larval growth rates of both species were reduced by intraspecfic competition at high densities.

Driver (1977) studied chironomid emergence in 16 ponds near Saskatoon, Saskatchewan to determine if faunal differences could be related to pond stability. He found species diversity tended to increase from temporary ponds to permanent ponds.

Danks (1971a) studied the life history and biology of Einfeldia synchrona in a small eutrophic pond near Ottawa. He found that this species was univoltine and constructed winter cocoons to survive the winter.

In two other studies Danks (1971b; 1971c) he examined the winter habitat and biology of arctic chironomids. He found that the winter condition of a pond is influenced by topography, snowfall and temperature. Many chironomidae inhabiting north temperate and arctic ponds form closed cocoons to survive the winter.

Wrubleski (1984) and Wrubleski and Rosenberg (1990) investigated the emergence phenologies and patterns of 84 species of chironomids over a two year period from a marsh in Manitoba. Large differences in the number of adults emerging between the two years and between habitats were reported.

Other researchers have studied the entire insect fauna of a pond(s). Judd (1949; 1953; 1964) used emergence traps to survey the insect fauna and determine emergence periods and peaks for over 100 species in ponds and marshes in Ontario. Wiggins et al. (1980) divided the invertebrate fauna of temporary ponds into four groups based on survival methods used during the dry phase of the basin and recruitment time. Group 1 includes organisms such as the crustaceans and annelids that can only disperse passively. No insects occur in this group. Group 2 organisms must have water present to oviposit. The larvae aestivate in the dry basin until water returns to the basin. This group includes representatives of <u>Siphlonurus</u>, several Coleoptera species and many species of Chironomidae. Group 3 species have drought tolerant eggs and can oviposit independently of water. Species in this group include odonates such as <u>Lestes</u>, and dipterans including

Culicidae and some semiaquatic Chironomidae. Group 4 includes species that cannot survive in the dry basin and must emigrate to permanent aquatic habitats before the pond dries up. These organisms must recolonize the temporary ponds the each spring. Many species of Hemiptera and Dytiscidae (Coleoptera) belong to this group.

In a study of an Alberta pond, Daborn (1971; 1974) found that aestival conditions caused changes in species composition of the invertebrate fauna, including insects. In particular, he found a shift from Coenagrionidae species to *Lestes* species.

Dineen (1953) found decreases in most insect species and a change in the predator-prey relationships due to winter fish kill in a Minnesota pond where all the water froze. Following aestival conditions, the odonate community was greatly reduced and the caddisflies, chironomids and mayflies all decreased in numbers. He attributed these results to winter kill and a change in top predators from fish to leeches.

Kenk (1949) found differences in the macroinvertebrate fauna, including insects, of two temporary and two permanent ponds near Ann Arbor, Michigan. Species of Coenagrionidae, *Callibaetis* sp, and *Chaoborus americanus* were absent from the fauna of temporary ponds but were present in permanent ponds.

However, representatives of the genus *Lestes* were present in both pond types.

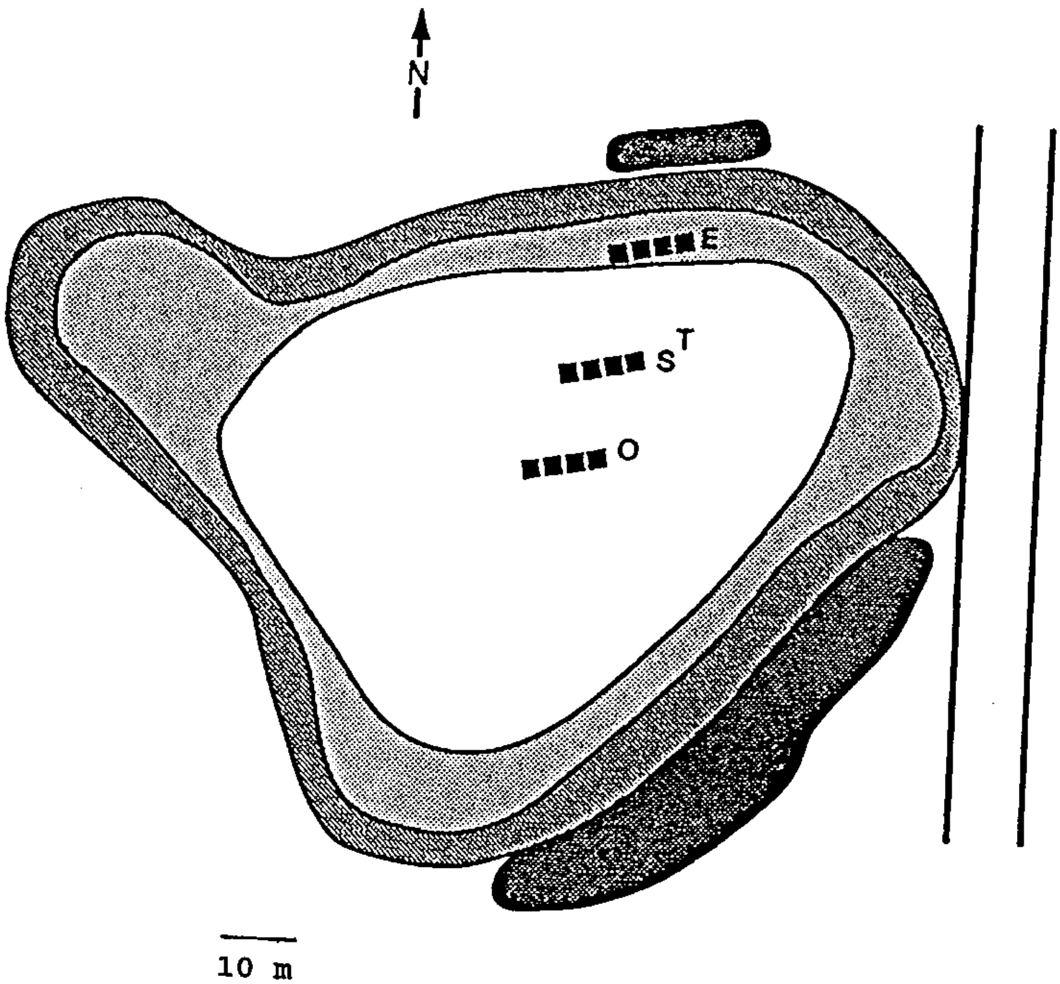
These studies, and others, illustrate that the pond insect community can be very diverse. The studies also show that the insect fauna depends on pond stability and on overwintering conditions. Some species inhabit all pond types while others are restricted to permanent habitats. These studies provide some information on pond insects but more is needed to gain a better understanding of how natural environmental changes can influence pond insect communities and pond habitats.

2. MATERIALS AND METHODS

2.1 Study Site

The study site, Pond LC, is located 9 km. east of Saskatoon, Saskatchewan (106° 30′ W long.; 52° 15′ N lat.) (Figure 1). It would be described as a semipermanent pond in the classification scheme of Driver (1977), or as an isolated 0.4 ha, relatively natural, shallow, open water wetland, in Millar's (1976) classification system. Ponds with similar features are common in this area of the prairies and parkland of Saskatchewan.

Pond LC was ringed by a three to fifteen meter band of emergent vegetation dominated by *Typha*, *Scirpus*, and *Carex*. Submerged vegetation included *Ceratophyllum*, *Myriophyllum*, *Utricularia*, *Drepanocladius* and the algae *Chara* and *Cladophora*. In 1988, a bloom of *Cladophora* covered the pond. Around the emergent vegetation band was a ring of willow (*Salix* sp.). Aspen bluffs (*Populus tremuloides*) and a strip of native grasses, ten to twenty meters wide, separated the pond basin from cultivated cropland to the North and South. To the East a gravel road bordered the pond. To the West was 500 meters of native grassland. A small temporary pond was present 20 meters to the southwest. A 2 hectare permanent pond was located 350 meters to the West.



Emergent Vegetation

Submerged Vegetation

<u>Salix</u> sp

<u>Populus</u> <u>tremuloides</u>

Figure 1: Map of Pond LC showing positions of emergence traps (O, S, E), thermograph (T) and vegetation zones.

Pond LC was outside the mosquito control area of the city of Saskatoon so it was free from mosquito larvicide chemicals. No chemicals were known to have been directly applied to the water surface.

Pond LC had a diverse noninsect fauna. During the ice-free season many species of waterfowl, shorebirds and passerines were observed foraging at the pond. Horned grebes (Podiceps auritus) and american coots (Fulica americana) nested on the pond in 1986 and 1987. Muskrats (Ondatra zibethicus) were also present in these two years. Tiger salamander larvae (Ambystoma tigrinum) were common in the pond in 1987, and garter snakes (Thamnophis sirtalis) were often seen foraging in the water. In 1987, freshwater sponge (Spongilla lacustris) was found in the pond. The largest aquatic predators in the pond, other than salamander larvae, were insects, including, Aeshna interrupta Walker, Anax junius Drury, Libellula quadrimaculata Linnaeus and Dytiscus spp. No fish were observed in the pond during the study.

2.2 Data Collection

2.2.1 Insect Samples

Insect emergence was studied using emergence traps placed in the pond during the ice-free seasons of 1986, 1987 and 1988. Chestwaders were used to access the traps. Disturbance of the substrate around the emergence traps was reduced as much as possible by following the same route on each visit.

Emergence traps are the most practical method of sampling insect populations in submerged vegetation (Davies 1984). Other samplers such as Ekmann dredges, and Gerking samplers often are inappropriate because the submerged macrophytes interfere with the operation of these samplers (Davies 1984) or they under represent the insect populations living on the submerged vegetation. Emergence trap samples are also easier to sort than substrate samples because there is no sediment or debris so more samples can be collected, sorted and identified.

Sampling adults has several advantages over sampling immature stages. First, many aquatic insects can be identified to species only as adults. Second, adult emergence is the final product of life history events (Davies 1984) and, except for species that oviposit under the water, specimens captured have completed their life cycles in the pond. And third, the timing of the emergence provides valuable insights into the life history of the insects (Davies 1984).

Disadvantages of using emergence traps include missing those species that emerge from shore and the possible avoidance or attraction of the traps to some insects. The traps can also be used as a substrate to emerge on by insects that crawl out of the water before emerging. The submerged portions of the traps may also be colonized by some insects (Wrubleski 1984).

In 1986 five, 0.5 m^2, emergence traps designed after Boyle (1979) were placed randomly in the pond. Emergence traps were sampled at approximately weekly intervals from May 1 to October 29. However, a large percentage of the insects remained in the trap body rather than moving into the trapping head, so use of this trap design was discontinued.

In 1987 and 1988, twelve 0.5 m^2 floating emergence traps designed after Wrubleski and Rosenberg's (1984) modified "week" design of Lesage and Harrison (1979) were used. The traps were placed at three stations along a randomly chosen transect running from the centre to the existing shore of the pond to provide representative collections from the different habitats of the pond (Corbet 1964) (Figure 1). These stations corresponded to the open water, submerged vegetation and emergent vegetation zones observed in 1986. However, in 1987 open water was only present for a brief time before submerged vegetation covered the pond.

At each station four traps were positioned 0.5 meters apart in a line parallel to the shore. The traps were secured by stakes driven through PVC pipe into the substrate. This kept the traps in place but allowed them to move vertically with water-level fluctuations.

Around and under the traps at the O and S stations, mixed beds of *Chara*, *Ceratophyllum*, *Myriophyllum*, *Utricularia* and *Drepanocladius* developed over the season. As the summer progressed *Cladophora* became more common. Station E was in the emergent vegetation zone. *Typha* and *Carex* spp were present around and in the traps. *Drepanocladius* and decaying *Salix* branches were common under the E traps.

In 1987 and 1988 insects were collected from the traps between 8:00 and 10:00 am local time, at alternating three- and four-day intervals during the ice free season or until no water was beneath them. An exception was made from September 14 to October 12, 1987 when samples were collected every seven days. In 1987, emergence trap collections were made from May 4 to October 12, and in 1988 from April 25 to July 11, the last sampling date when water was present under the deepest traps. In 1987 the shore traps, station E, were dry after August 24. In 1988, the last collection date for the E traps was June 6 and for the S station June 27.

Dip net samples were taken during the study to collect immature stages for taxonomic rearing. In February 1987, dip net samples were taken under the ice to collect overwintering immatures.

Insects were preserved in 70% alcohol, sorted under a dissecting microscope and identified to the lowest taxonomic level possible. Representative specimens were sent to specialists for verification. Verifications were made by D.M. Lehmkuhl and E.R. Whiting (Ephemeroptera); R. Hutchinson (Odonata and Neuroptera); F. Schmid (Trichoptera); A. Borkent (Chaoboridae:Diptera); J.A. Downes (Ceratopogonidae:Diptera); D.R. Oliver and M.E. Dillon (Chironomidae:Diptera) and J.R. Barron, G.A.P. Gibson, J. Huber, L. Masner and J. Read (Hymenoptera). Representative specimens will be sent to the Biological Research Centre. Remaining specimens will be housed at the University of Saskatchewan, Biology Department and in the authors's personal collection.

All female Chironomidae, specimens of the chironomid tribe Tanytarsini, and the Hymenoptera were not included in the study other than in the species list due to difficulties in identifying and sorting specimens. Although species of the orders Collembola, Hemiptera and Coleoptera were present in the pond, they were not collected in the emergence traps and therefore are not included in the study.

2.2.2 Physical and Chemical Data

In April 1986, the pond was divided into 10 X 10 m grid squares. Water depth was measured at each grid corner and used to make monthly estimates of the pond area. Subsequently, water depth was measured each time the pond was visited. On the first of every month the water depth at each of the traps was measured.

In 1987 and 1988, water temperature was measured 10 cm above the substrate using a continuously recording thermograph. The thermograph was operated from April 13 to October 26 in 1987; and from April 11 to July 25 in 1988. By July 10, 1988 the probe was out of the water but under a mat of algae. The average weekly temperature was calculated from 12 measurements per day taken at two hour intervals and then averaged for each day..

The pond was visited in February of 1987 and 1988 to determine water, ice and snow depth.

A 1.5 litre water sample was taken at weekly intervals during the ice-free season of 1987 and 1988, except for the following dates in 1987; April 15 to May 6 and July 1, 1987. The sample was collected between 7:30 and 9:00 am local time, at a depth of 35 cm or just above the substrate when the water level dropped below 40 cm. The water sample was analyzed for pH, carbon dioxide, total hardness, total acidity, total alkalinity, and dissolved oxygen using a Hach water analysis kit. The concentration of dissolved solids was analyzed using a conductivity meter.

2.3 Analysis of Insect Data

Insect collections from all three years were used to compile a species list for the pond. The four-day emergence trap samples collected in 1987 and 1988 were used to document emergence periods for all species collected. The three-day samples were not used in the study. The mean daily emergence density, mean number of adults emerging/m^2/day, for each station was calculated for the abundant species of each order.

Species diversity for each order was determined for 1987 and 1988 using Hill's numbers (N_0, N_1, N_2) (Hill 1973; Ludwig and Reynolds 1988). These measures of diversity were chosen because the results are in units of species and are biologically more easily interpreted than other indices such as Shannon's or Simpson's index (Peet 1974; Hill 1973; Ludwig and Reynolds 1988). Hill's numbers refer to the "effective number of species present" in the community (Hill 1973; Ludwig and Reynolds 1988). Each species is weighted by its abundance (Hill 1973; Ludwig and Reynolds 1988). Hill's first number, N_0, is the number of species in the community or species richness. Hill's second number, N_1, measures the number of "abundant species" in the community (Ludwig and Reynolds 1988). It is sensitive to changes in abundance of rare species (Peet 1974) and therefore is influenced more by species richness than N_2 (DeJong 1975). Hill's third number, N_2, is the number of "very abundant species" (Hill 1973; Ludwig and Reynolds 1988). N_2 is more sensitive to changes in the common species (Ludwig and Reynolds 1988)

Hill's N_1 is related to Shannon's Index, H':

$$N_1 = e^{H'}$$

Shannon's index measures the uncertainty in predicting the species of an individual chosen randomly from a collection of species and individuals (Ludwig and Reynolds 1988).

$$H' = \sum_{i=1}^{s} [n_i/n \ln(n_i/n)]$$

Where:
s = total number of species in the sample
n = number of individuals in the sample
n_i = number of individuals belonging to species i

Hill's third number, N_2, is the reciprocal of Simpson's diversity index λ (Hill 1973; Ludwig and Reynolds 1988).

$$N_2 = \frac{1}{\lambda}$$

Simpson's diversity index measures the probability that two individuals taken randomly from the same population will belong to the same species (Ludwig and Reynolds 1988).

$$\lambda = \sum_{i=1}^{s} \frac{n_i(n_i-1)}{n(n-1)}$$

Where:
s = total number of species in the sample
n_i = number of individuals belonging to species i
n = number of individuals in the sample

The evenness of the community for each year was calculated using Hill's modified ratio (HMR). This measure was chosen because it is relatively stable and is not affected by changes in species richness (Ludwig and Reynolds 1988). It is the ratio of very abundant species (N_2) to abundant species (N_1) in the population (Hill 1973; Ludwig and Reynolds 1988).

$$HMR = \frac{N_2 - 1}{N_1 - 1}$$

HMR tends toward 0 as evenness decreases and is 1 if each species has the same number of individuals (Alatalo 1981).

Between-year comparisons of each Order were made using one index of dissimilarity, percent dissimilarity (PD) (Gauch 1982) and one of similarity, Morisita's index (M_i) (Brower and Zar 1988). Percent dissimilarity was chosen because it linearly weights species abundances and although it emphasizes dominant species, minor species also contribute to the result (Gauch 1982). PD is also only slightly influenced by unequal sample sizes (Kohn and Riggs 1982). Values for PD range from 0 when the communities are similar to about 1 when they have no species in common.

$$PD = \Sigma \frac{|p_i - q_i|}{2}$$

Where:
p_i = proportion of species i in community A
q_i = proportion of species i in community B

Morisita's index of similarity (M_i) is based on Simpson's index of dominance which is the inverse of Simpson's diversity index (Brower and Zar 1988). Morisita's index was chosen because it is independent of sample size (Wolda 1981). It measures the probability that 2 randomly selected individuals, one from each community, will be the same species compared with the chance of taking 2 individuals of the same species from one of the communities. Values of M_i range from 0, if the two communities have no species in common, to 1 if the species composition is identical.

$$M_I = \frac{2 \Sigma x_i y_i}{(\lambda 1 + \lambda 2) n1n2}$$

Where:
$\lambda 1$ = Simpson's dominance index for community 1
$\lambda 2$ = Simpson's dominance index for community 2
n1 = total number of individuals in community 1
n2 = total number of individuals in community 2
x_i = number of species in community 1
y_i = number of species in community 2

Calculations for species diversity, evenness and community similarity done using a BASIC program described in Brower and Zar (1988).

Friedman's two way analysis of variance by ranks was used to compare the number of adults collected at each station of the very abundant species of each order (N_2). This nonparametric test was used because it does not require the data assumptions that parametric tests do: samples drawn from a normally distributed population, mean and variance independent and additive variance (Elliott 1971; Siegel and Castellean 1988; Sokal and Rolf 1981). If the Friedman test was significant ($P = \leq 0.05$) the data were further tested to determine which stations were significantly different using a procedure described in Siegel and Castellean (1988). For this procedure average ranks for each pair of stations were inserted into the following calculation to obtain a "critical value":

$$\bar{R}_1 - \bar{R}_2 \geq Z_{x/k(k-1)} \frac{k(k+1)}{6N}$$

Where:
R_1 and R_2 = Average ranks of two stations
$Z_{x/k(k-1)}$ = Abscissa value from the unit normal distribution above which lies x/x(k-1) per cent of the distribution
k = Number of conditions
N = Number of matched observations

If the difference in the average ranks of the two stations was larger than the critical value the two stations were significantly different from each other.

The Friedman tests were performed using the program "Friedman Two Way AOV" in the statistical package Statistix[R].

3. PHYSICAL AND CHEMICAL RESULTS AND DISCUSSION

3.1 Results

3.1.1 Water Depth and Pond Area

For all three years water depth was greatest in the spring and declined through the remainder of the year. However, in 1986 periods of precipitation increased water depth in May, July and September (Figure 2). The greatest water depth in 1986 was 104 cm on May 27. By October 28, 1986 the water depth was 67.5 cm. Water depth declined throughout 1987 from a high of 106.5 cm in mid April to 15.5 cm by late October. In 1988 after an early spring increase from 40 cm to 62.5 cm by April 18 water depth declined until July 14, when surface water was no longer present.

Water depth trends at each trap station followed the same patterns as maximum water depth (Figure 3). In 1987, the E station was dry by August 24. In 1988, the E station was dry by May 30, station S by June 27 and station O by July 11.

The declining water depth also decreased the area of Pond LC (Table 1). On May 1 1987, the pond covered an area of 5300 m^2. By October 1 the area was reduced to 1200 m^2. In 1988 the largest area the pond covered was 3950 m^2 on May 1. On July 1 the area of the pond had declined to 700 m^2. No surface water was present by mid July.

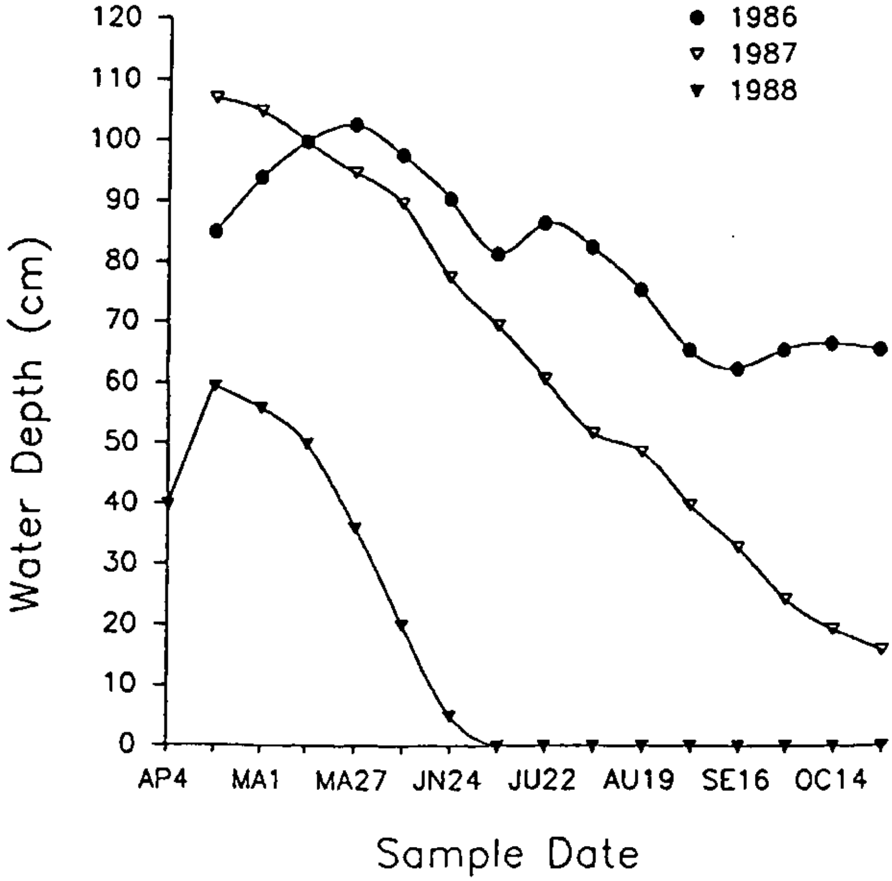


Figure 2: Maximum water depth (cm) in Pond LC during 1986, 1987, 1988 sampling seasons.

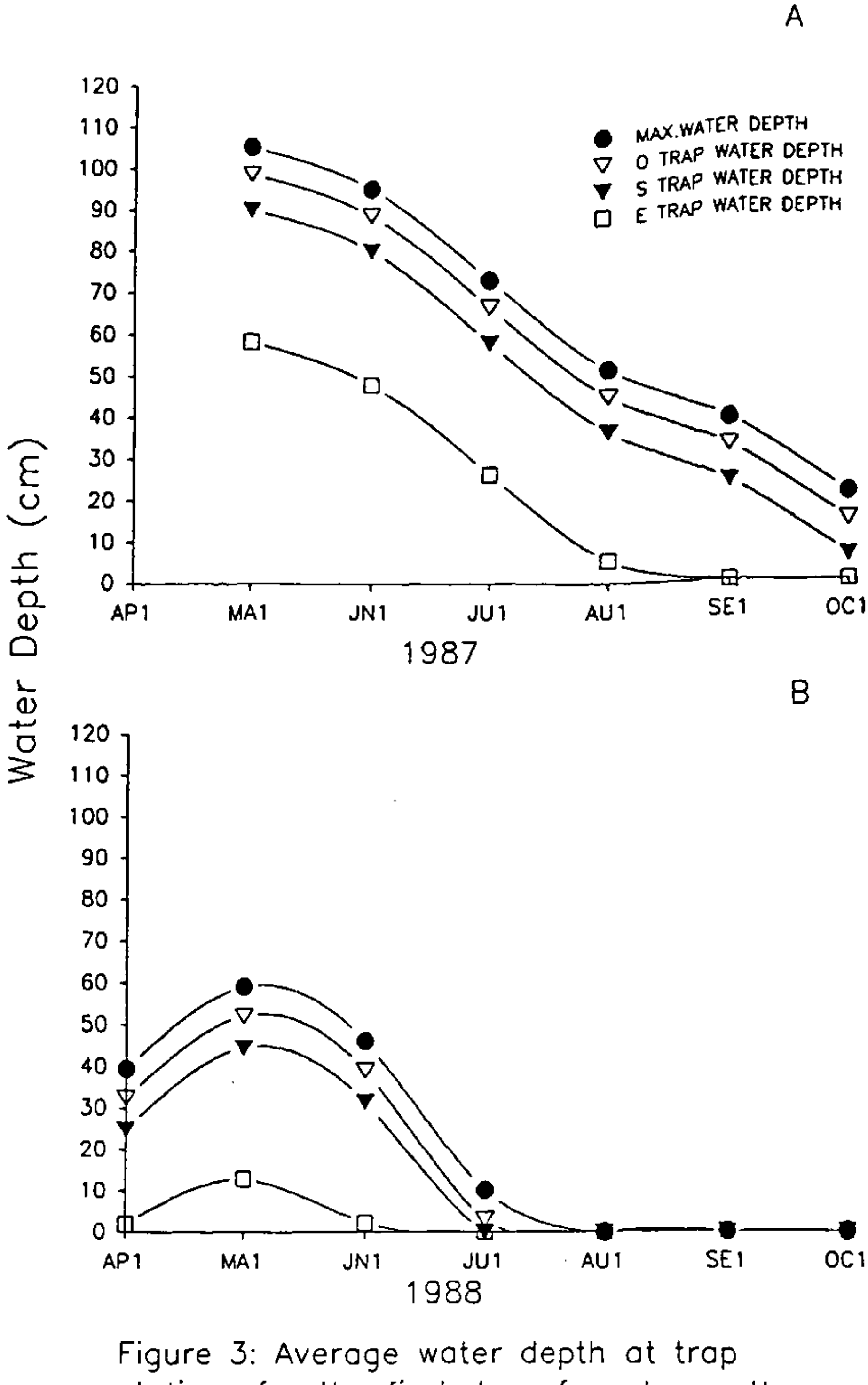


Figure 3: Average water depth at trap stations for the first day of each month during the 1987 (A) and 1988 (B) sampling seasons.

Table 1: Estimated surface water area (m^2) of Pond LC for the first day of each month during the 1987 and 1988 sampling seasons.

	1987	1988
April 1	ice	2100
May 1	5300	3500
June 1	4500	2500
July 1	3800	700
August 1	2400	0
September 1	2100	0
October 1	1200	0

3.1.2 Water Temperature

Average weekly water temperatures followed expected seasonal trends (Figure 4). Temperatures tended to rise during the spring and early summer, remained high during the summer months and then declined until freeze up. The two warmest periods of 1987 were in mid June and late July and early August when average weekly temperatures were above 22°C. The water warmed up more rapidly in 1988 than in 1987. The average weekly temperatures from late May through June 1988 were 20°C or higher, this was four to six degrees higher than most of this time period in 1987.

3.1.3 Winter Conditions

The Saskatchewan Research weather station, located 9 km West of Pond LC, reported the winter months of 1986 and 1987 tended to be warm and dry. In January 1987, the mean temperature was almost ten degrees above normal while precipitation was only half of normal. Similar mild, dry conditions occurred during the winter of 1987/88. Average temperatures were above normal from November 1987 through to April 1988. Precipitation was below normal for all these months except March 1988, which had 15.7 mm more precipitation than normal. This higher than normal precipitation was countered by April, which had only 16 per cent of normal levels.

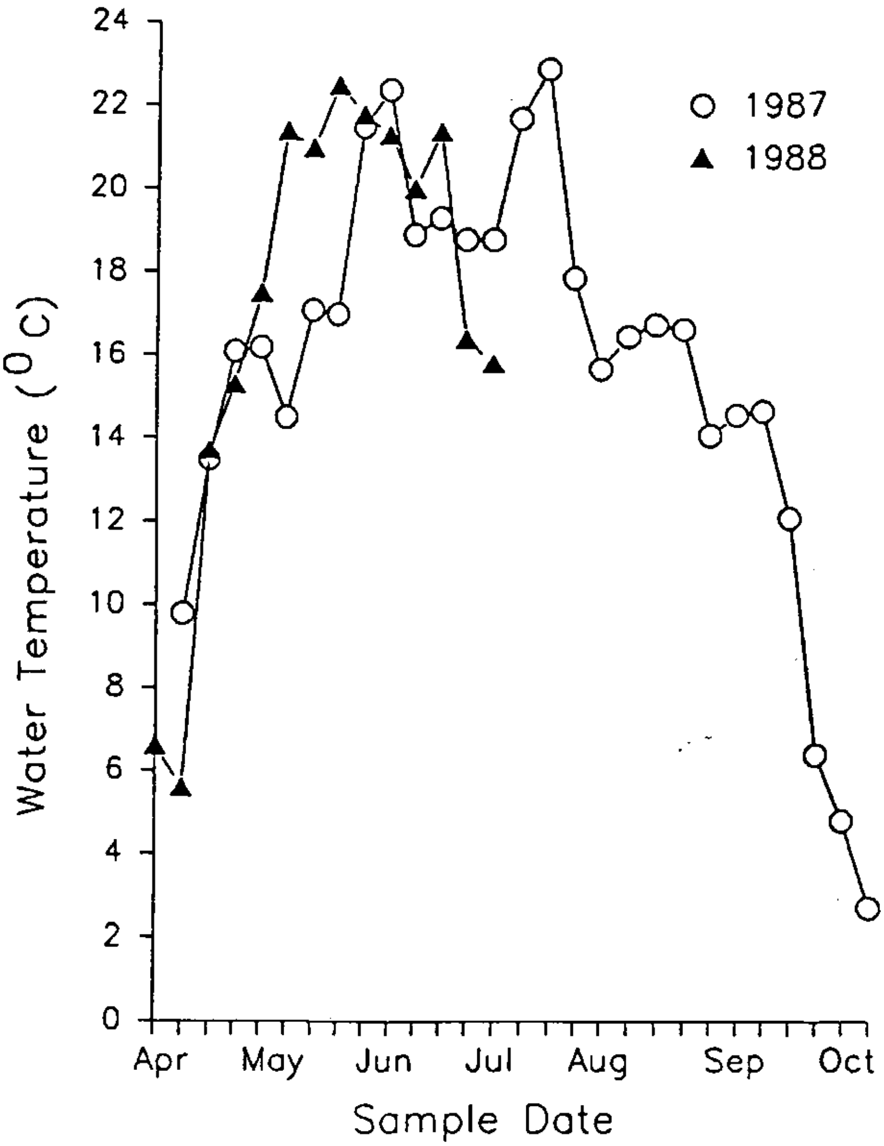


Figure 4: Average weekly water temperature (°C) in Pond LC during the 1987 and 1988 sampling seasons.

On February 3, 1987 the pond was covered by 22 cm of snow, over 33.5 cm of ice and 64 cm. of water. On February 21, 1988 the pond was covered by 25 cm of snow. All the water and substrate, to a depth of 40 cm., were frozen. By February 28, most of the snow had melted and turned to slush that covered the centre of the pond.

3.1.4 Water Chemistry

Weekly water samples were tested for seven chemical parameters to provide a general chemical profile of Pond LC (Figure 5, 6 and 7; Table 2). Total alkalinity in 1987 fluctuated between 230 and 280 ppm until the last sampling date when it increased to a high of 354 ppm. In 1988, total alkalinity increased steadily until early June and then decreased to 240 ppm by early July. It then increased to a high of 244 ppm two weeks before the pond drying up. On July 6, the last sampling date, alkalinity declined to 198 ppm. The average alkalinity in 1987 was 263.6 ppm (234-354), 19.5 ppm higher than the 1988 average of 244.1 ppm (135-334). In 1988 alkalinity fluctuated more than in 1987.

In 1987 total acidity fluctuated between 28 ppm and 195 ppm. Values increased during May and then decreased in the first three weeks of June. This was followed by an increase in late June. Acidity decreased through July

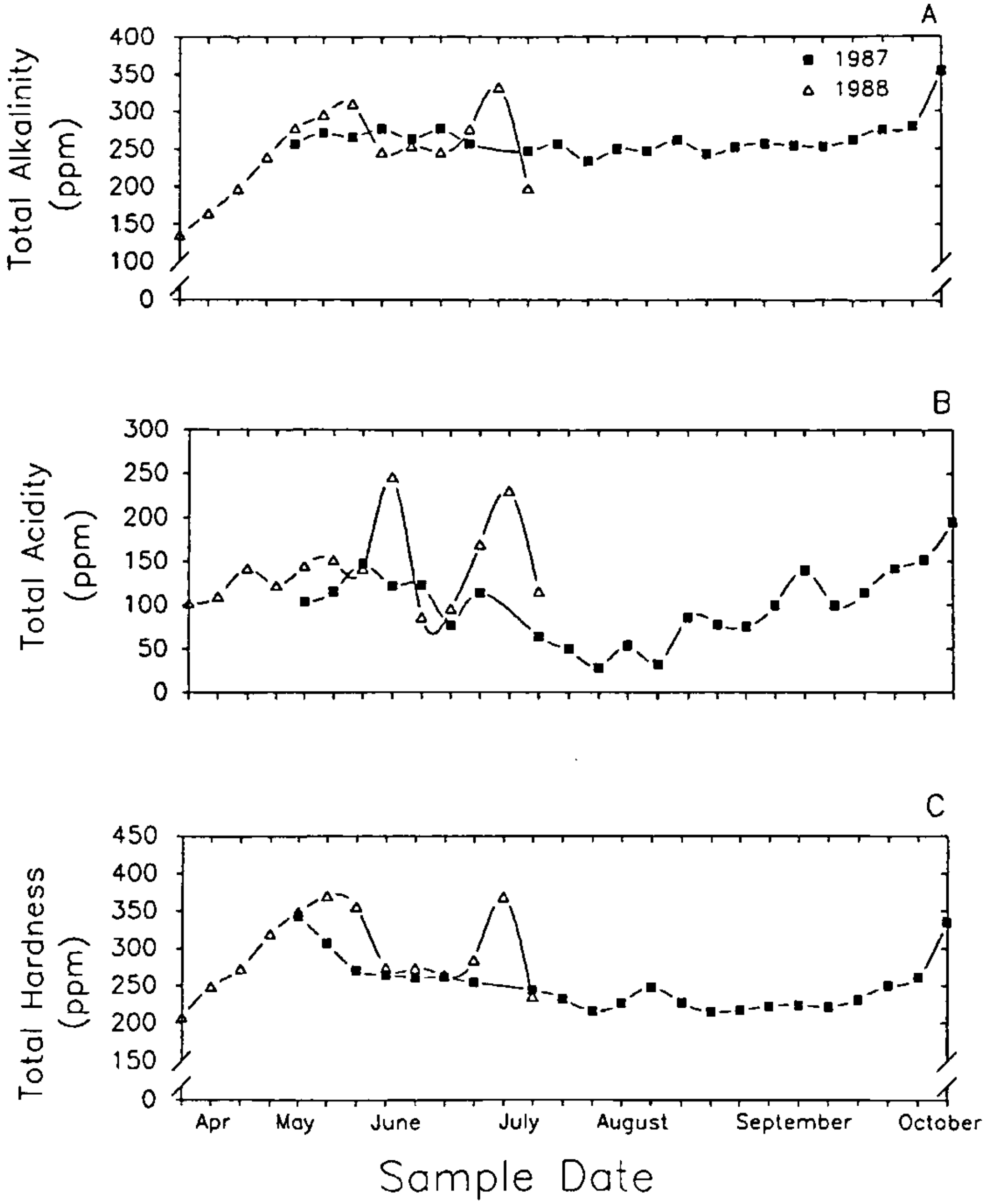


Figure 5: Changes in total alkalinity (A), total acidity (B) and total hardness (C) in Pond LC during the 1987 and 1988 sampling seasons.

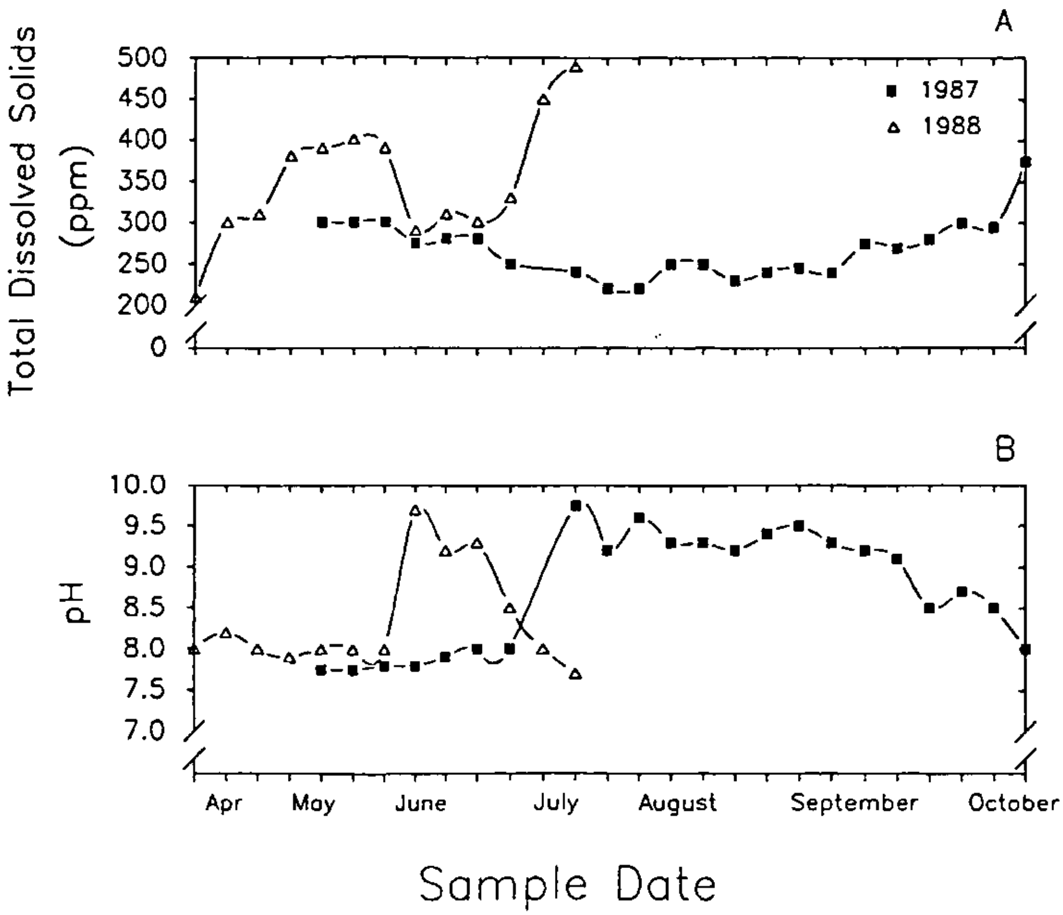


Figure 6: Changes in total dissolved solids (A) and pH (B) in Pond LC during the 1987 and 1988 sampling seasons.

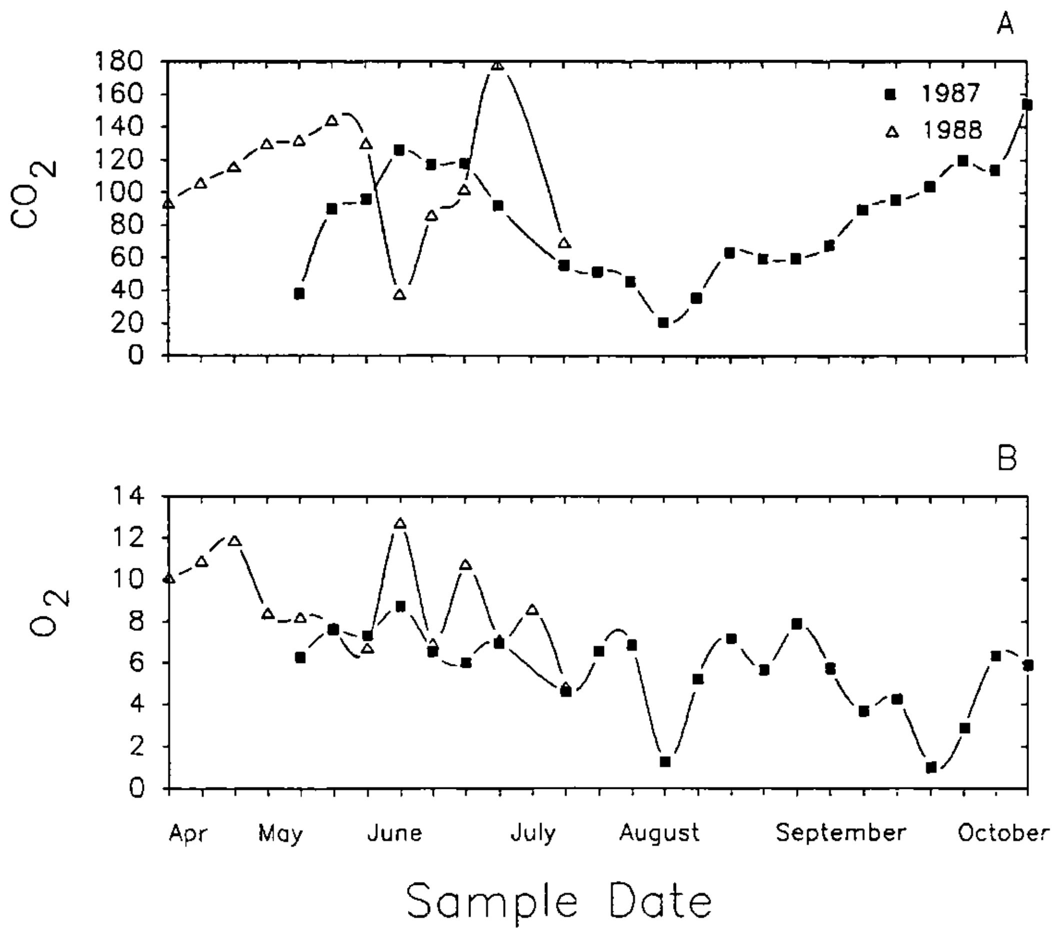


Figure 7: Changes in CO_2 (A) and O_2 (B) in Pond LC in 1987 and 1988.

Table 2: Average values (range) for water chemistry parameters in Pond LC during the 1987 and 1988 sampling seasons.

	1987	1988
Alkalinity	263.6 ppm (234-354)	244.1 ppm (135-334)
Acidity	100.7 ppm (28-195)	143.0 ppm (86-246)
Hardness	251.5 ppm (215-343)	294.2 ppm (207-355)
Dissolved Solids	268.9 ppm (230-375)	350.0 ppm (210-490)
pH	8.70 (7.7-9.3)	8.34 (7.7-9.7)
CO2	82.0 ppm (21-154)	110.5 ppm (38-178)
O2	5.66 ppm (1.3-8.8)	8.86 ppm (4.9-12.7)

to its lowest level of the year (28 ppm, July 22). In August it fluctuated at low levels before it began to increase in late August through to mid September, then decreased in late September. In October, total acidity increased until a high of 195 ppm was reached on October 14.

In 1988, total acidity tended to increase in April and May, reaching its highest level on June 1 (246 ppm). It then decreased to its lowest level the following week, 86 ppm. Over the next three weeks it increased to 231 ppm before declining to 116 ppm on the last sampling date, July 6. The average total acidity for 1988 was 143 ppm, 30 % higher than in 1987 (100.7 ppm).

Total hardness showed an almost continuous decrease in 1987 from the highest recorded value of 355 ppm on May 13 to August 19 when the lowest level was recorded 215 ppm. After a small increase and decrease in late August values increased through to October 4. The average was 251.1 ppm.

In 1988 total hardness increased from a low of 207 ppm on April 13 to 310 ppm by May 25. Hardness decreased to about 250 ppm over the next three weeks before increasing to 369 ppm on June 29. By the last sampling date, July 6, total hardness decreased to 198 ppm. The average hardness was 294.2 ppm in 1988.

Total dissolved solids ranged between 300 ppm and 220 ppm in 1987 until October 14, when it reached a high of 375 ppm. During the year dissolved solids tended to decrease from May to late July and then increase with some small decreases to the last sampling date. Average total dissolved solids was 268.9 ppm.

In 1988, total dissolved solids began at its lowest level of 210 ppm on April 13. It then increased to 400 ppm by May 18. This was followed by a decrease to 246 ppm by June 1 and then an increase to a high on July 6 of 490 ppm. The average was 350 ppm.

In 1987 pH ranged between 7.7 and 8.0 until June 24 then it increased to a high of 9.7 on July 8. Following this it fluctuated between 9.5 and 9.0 until the end of September, then decreased to 8.0 on October 14. The average pH for 1987 was 8.7.

In 1988, pH ranged between 8.2 and 7.9 until June 1 when it increased to 9.7. It then tended to decline, decreasing to 7.7 by July 6. The average pH for 1988 was 8.3, 5% lower than in 1988.

Water samples were analyzed for oxygen and carbon dioxide. Carbon dioxide levels in 1987 ranged from 21 ppm (July 29) to 154 ppm (October 14). Dissolved oxygen levels ranged from 1.3 ppm (July 29) to 8.8 ppm (June 3). In 1988 carbon dioxide levels ranged from 38 ppm (June 1) to 178 ppm (July 22). Oxygen levels ranged from 4.9 ppm (July 6) to 12.7 on June 1.

3.2 Discussion

During 1986, 1987 and 1988, above normal air temperatures and lower than normal precipitation levels were recorded for the Saskatoon area (Saskatchewan Research Council Weather Reports 1986, 1987, 1988). These warm, dry conditions were associated with a decline in water levels in Pond LC.

Shallow ponds, such as Pond LC, are considered to be in transition from permanent, aquatic habitats to terrestrial habitats (Williams 1979; Daborn 1974). The climatic conditions experienced during the study period caused Pond LC to pass through three stages of this transition. In 1986, Pond LC was a permanent, nonaestival pond. Water was present all year long and through the winter of 1986/87. The presence of a large volume of water and above normal air temperatures during the winter, plus the insulation provided by the snow resulted in water remaining under the ice throughout the winter. This was atypical: normally, very cold temperatures and low snow cover experienced during most winters in the prairies and parkland cause shallow ponds to freeze completely (Daborn and Clifford 1974). In 1987, Pond LC was a permanent aestival pond. The larger draw down, less snow and colder winter temperatures caused all the water remaining in the pond and the substrate to freeze during the winter. In 1988, Pond LC was a vernal temporary pond. All the surface water disappeared by mid July.

Unfortunately because of costs only one analysis of each chemical parameter was made for each sampling date. This limits the reliability of the results but does provide some indication of the water chemistry in the pond. Even if replicate analyses were done on a single water sample it would only provide data for one particular area of the pond and for that single time. Kollman and Wali (1976) found large changes in ionic concentrations with water depth and vegetation density. Thick stands of vegetation reduce mixing in shallow waters. This makes it difficult to obtain an accurate chemistry profile unless a large number of samples are analyzed from different regions within the pond. Daily variations in most chemical parameters also make single sample times arbitrary at best.

The values and ranges of all the chemical parameters tested were similar to those recorded from other ponds studied in the prairie pothole region and reflect seasonal and year-to-year changes in pond type (Daborn 1976; Daborn and Clifford 1974; Driver 1977; Driver and

Peden 1977; Hartland-Rowe 1966; Morrill 1985; Sawchyn 1966).

The larger variation in water chemical parameters observed in 1988 when there was less water present has been observed in other ponds. Driver and Peden (1977) found larger fluctuations in most water chemistry parameters in temporary ponds than in larger more permanent ponds. They suggested the most important process influencing water chemistry of ponds in the prairies was evaporation. The higher water temperatures and lower water levels in 1988 would have increased evaporation rates and this in turn probably produced the larger fluctuations observed in the water chemistry parameters tested. Vegetation changes may have also contributed to the fluctuations observed because as the season progressed the submerged vegetation increased and reduced mixing in the pond (Kollman and Wali 1976).

4. EMERGENCE RESULTS

4.1 Species Composition

One hundred and fifteen species of aquatic insects, belonging to six orders, were identified from emergence traps in Pond LC from 1986 to 1988 (Table 3): three Ephemeroptera, 16 Odonata, one Neuroptera, 17 Trichoptera, 70 species of Diptera, including 43 species of Chironomidae, and eight species of Hymenoptera.

In 1987, 74 species were collected: three Ephemeroptera; 14 Odonata; 1 Neuroptera; 10 Trichoptera and 46 Diptera. In 1988, the number of species collected decreased to 45; a single Ephemeroptera, 12 Odonata, four Trichoptera and 28 Diptera.

4.1.1 Ephemeroptera

The Ephemeroptera were represented in Pond LC by two Baetidae, *Callibaetis pallidus* Banks, and *Cloeon* sp., and one species of Caenidae, *Caenis youngi* Roemhild (Table 3). *C. pallidus* was collected from the pond during both 1987 and 1988, while *Cloeon* sp. and *C. youngi* were collected in low numbers in 1987 only (Figure 8). In 1987 the mayflies made up 2.3 % of the insect fauna studied. In 1988 it was reduced to only 0.02 %.

Diversity of the mayflies was low in both years. In 1987, N_1 and N_2 were 1.2 and 1.1 respectively. Evenness was also low (HMR = 0.3). In 1988, N_1 and N_2 were both 1

Table 3: List of species collected from the study pond during 1986, 1987 and 1988. $ indicate species collected in 1986; * indicate species collected in 1987; + indicate species collected in 1988.

EPHEMEROPTERA
 Baetidae
  Cloeon sp$*
  Callibaetis pallidus Banks$*+
 Caenidae
  Caenis youngi Roemhild$*

ODONATA
 Aeshnidae
  Aeshna interrupta Walker$*+
  Anax junius Drury*
 Libellulidae
  Libellula quadrimaculata L.$
  Leucorrhinia borealis Hagen+
  Sympetrum internum Montgomery$*+
  Sympetrum costiferum Hagen$*
  Sympetrum danae Sulzer*+
  Sympetrum corruptum (Hagen)*
 Lestidae
  Lestes congener Hagen$*+
  Lestes disjunctus Selys$*+
  Lestes unguiculatus Hagen$*+
 Coenagrionidae
  Coenagrion angulatum Walker$*+
  Coenagrion resolutum (Hagen)$*+
  Enallagma cyathigerum (Charpentier)$*
  Enallagma ebrium (Hagen)$*+
  Enallagma boreale (Desenty) Selip$*+

NEUROPTERA
 Sisyridae
  Sisyra vicaria (Walker)*

TRICHOPTERA
 Polycentropodidae
  Polycentropus picicornis Stephens$*
 Psychomyiidae
  Psychomyia flavida Hagen$
 Phryganeidae
  Agrypnia straminea Hagen$*
  Agrypnia pagetana McLachlan$*+
 Limnephilidae
  Limnephilus hyalinus Hagen$

Table 3: Species list continued.

Limnephilus janus Ross$
Limnephilus externus Hagen$
Limnephilus labus Ross$
Anabolia bimaculata (Walker)$*+
Philarctus quaeris Milne$
Molannidae
Molanna flavicornis Banks$
Hydropsychidae
Hydropsyche alternans?*
Leptoceridae
Triaenodes nox Ross*
Triaenodes griseus Banks*+
Hydroptilidae
Agraylea multipunctata Curtis*+
Oxyethira sp*
Hydroptila sp*

HYMENOPTERA
Mymaridae
Anagrus sp$
Ichneumonidae
Aptesis sp$
Phygadeuon sp$
Figitidae
Lonchidia sp$
Xyalophora sp$
Sceliomidae
Telonomus sp$
Pteromalidae
Cyrtogaster trypherus (Walker)$
Braconidae
Species 1$

DIPTERA
Tipulidae
Tipula illustris Doane ?$
Tipula sp 1$*
Tipula sp 2*
Psychodidae
Psychoda sp*+
Dixidae
Dixella serrata (Garrett)$*
Chaoboridae
Chaoborus americanus (Johannsen)$*
Culicidae
Anopheles earlei Vargas$*
Culex territans Walker$

Table 3: Species list continued.

Ceratopogonidae
- Alluaudomyia needhami Thomsen*+
- Bezzia cockerelli Malloch*
- Bezzia annulipes/japonica gr.*+
- Bezzia bicolor Meigen*+
- Bezzia glabra Coquillet*+
- Forcipomyia monilicornis*
- Palpomyia lineata (Meigen)*+
- Dasyhelea sp*

Chironomidae

Tanypodinae
- Ablabesmyia illinoensis (Malloch)$*+
- Ablabesmyia pulchripennis (Lund.)*+
- Ablabesmyia monilis (L.)*+
- Derotanypus alaskensis (Malloch)$*
- Guttipelopia rosenbergi Bilyi$*
- Labrundinia pilosella (Loew)*
- Procladius bellus (Loew)*
- Procladius culiciformis (L.)*
- Psectrotanypus dyari (Coquillet)$

Chironominae
- Chironomus tentans (F.)$+
- Chironomus atrella (Townes)$
- Chironomus riparius Meigen$
- Chironomus decorus gr.$
- Cladopelma viridulus (L.)*+
- Einfeldia pagana Meigen*+
- Endochironomus nigricans (Johannsen)$*+
- Dicrotendipes nervosus (Staeger)*
- Glyptotendipes barbipes (Staeger)$*
- Glyptotendipes lobiferous (Say)*
- Glyptotendipes paripes (Edwards)*
- Lauterbornia sp$
- Parachironomus forceps (Townes)*+
- Parachironomus varus (Goet.)*+
- Parachironomus monochromus (Wulp)*+
- Phaenopsectra punctipes (Wied.)*
- Polypedilum n sp.*
- Pseudochironomus middlekauffi Townes*
- Cladotanytarsus cf nigrovittatus$*+
- Paratanytarsus kaszabi gr.$*+
- Paratanytarsus laccophilus (Edwards)$*+
- Paratanytarsus tenuis gr.$*+
- Tanytarsus cf. buckleyi$*+
- Tanytarsus cf. holochlorus gr.$*+

Table 3: Species list continued.

Orthocladiinae
- _Acricotopus_ _lucens_ (Zetterstedt)$*+
- _Cricotopus_ _pilitrais_ Zetterstedt$*
- _Cricotopus_ _cylindraceus_ Kieffer$*+
- _Cricotopus_ _flavocinctus_ (Kieffer)$*+
- _Corynoneura_ cf _scutellata_ Winn.$*+
- _Limnophyes_ sp$
- _Psectrocladius_ _simulans_ Johannsen*+
- _Psectrocladius_ _flavus_ (Johannsen)*
- _Mesosmittia_ _acutistylus_? Saether +
- _Orthocladius_ _smolandicus_ Brundin+

Stratiomyidae
- _Hedriodiscus_ _vertebratus_ Say$

Dolichopodidae
- _Dolichopus_ sp*

Sciomyzidae
- _Sciomyza_ sp 1$+
- _Sciomyza_ sp 2$+
- _Pherbellia_ sp*+
- _Elgiva_ sp*+
- _Hedroneura_ sp$
- _Sepedon_ sp$*

Ephydridae
- _Setacera_ sp$
- _Parydra_ sp$

Scathophagidae
- _Cordilura_ sp$

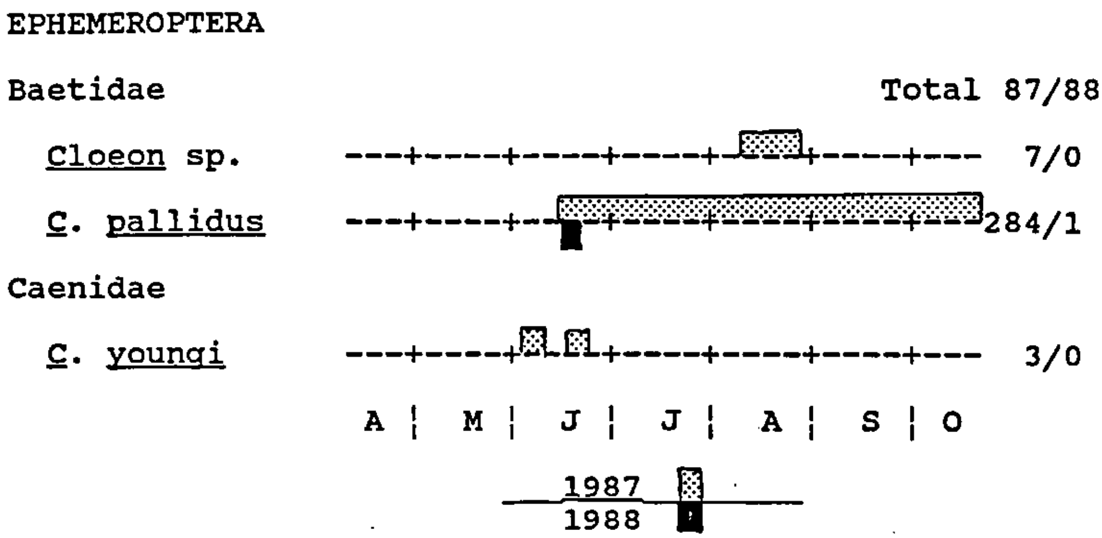


Figure 8: Emergence periods of Ephemeroptera species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

since only one mayfly, a specimen of C. pallidus, was collected. Evenness could not be calculated. Percent dissimilarity between 1987 and 1988 was only 4% because the population was dominated by C. pallidus in both years. Morisita's index could not be calculated.

4.1.2 Odonata

Sixteen species of Odonata belonging to four families were collected during the three years the pond was studied (Table 3). The females of Lestes disjunctus Selys and L. unguiculatus (Hagen) could not be reliably separated so data for these species were combined into the category Lestes disjunctus/unguiculatus for analysis.

In 1987, the Odonata made up 6.8 % of the total number of insects studied. Fourteen species were collected (Figure 9). Six belonged to the suborder Anisoptera (Aeshnidae and Libellulidae) and eight were Zygoptera (Lestidae and Coenagrionidae). Of the fourteen species collected six or seven were abundant (N_1 = 7.4, N_2 = 6.3). The odonate fauna was evenly distributed (HMR = 0.8). In 1988, the fauna was reduced to four anisopteran species and six zygopteran species making up only 5.6 % of the insects collected. Of these ten species only three or four were abundant (N_1 = 4.4; N_2 = 3.4). Evenness, however, was only slightly lower (HMR = 0.70).

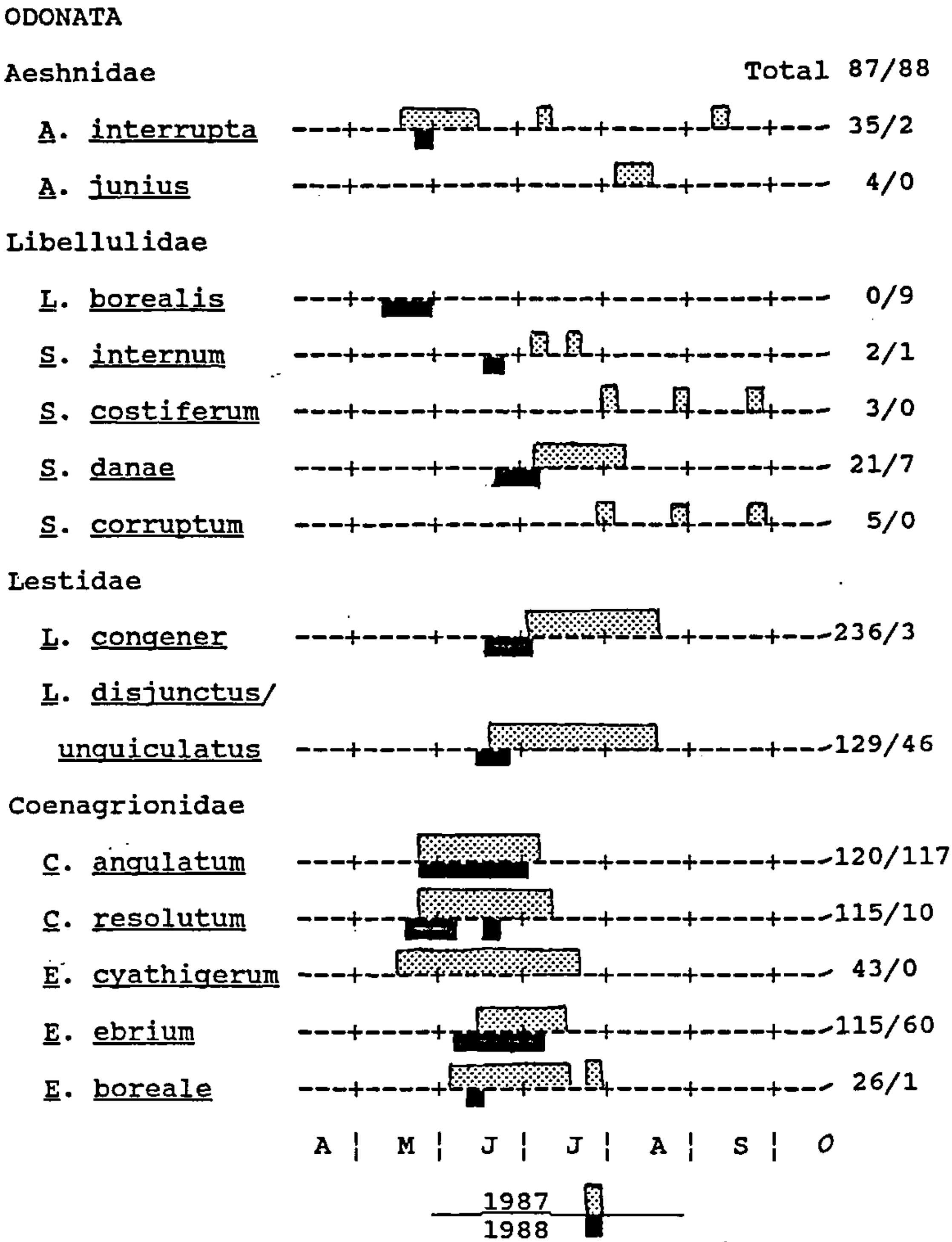


Figure 9: Emergence periods of Odonata species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

The odonate fauna differed considerably between 1987 and 1988. Percent dissimilarity for the two years was 47% while Morisita's index was 0.6. Four species collected in 1987, Anax junius Drury, Sympetrum costiferum (Hagen), S. corruptum (Hagen), and Enallagma cyathigerum (Charpentier), were absent from 1988 collections. Leucorrhinia borealis Hagen was the only additional odonate collected in 1988.

4.1.3 Neuroptera

One species of Neuroptera, Sisyra vicaria (Walker), a parasite of the freshwater sponge, Spongilla lacustris (Linnaeus), was collected from traps only in 1987 (Figure 9). Only three specimens were collected.

4.1.4 Trichoptera

The Trichoptera collected included 17 species representing eight families (Table 3). Ten species of caddisflies were collected in 1987 (Figure 10) making up a very minor part, less than 0.5 %, of the total number of insects studied. The fauna in 1987 was evenly distributed (HMR = 1.2). Of the ten species collected six or seven species (N_1 = 6.3; N_2 = 7.2) were collected in abundance compared with the other species, although none occurred in large numbers.

In 1988, only four species of Trichoptera were collected. The fauna was dominated by a single species, Agraylea multipunctata Curtis. The Trichoptera made up 4 % of the insect fauna. In 1988 N_1 and N_2, were both close to one (N_1 = 1.2; N_2 = 1.1) and evenness was close to zero (HMR = 0.2).

The caddisfly fauna was very different between 1987 and 1988. Percent dissimilarity was 88%, and Morisita's index was low (M_i = 0.2). This was due to a 98% increase in the number of A. multipunctata collected.

4.1.5 Hymenoptera

Eight parasitic wasps were identified from Pond LC during the study (Table 3). Many specimens were collected but because of taxonomic difficulties further treatment of this order could not be carried out. However, rearing studies of Stratiomyidae, Ephydridae and Muscidae resulted in the three host parasite associations. An adult specimen of Phygadeuon emerged from a larva of Hedriodiscus vertebratus (Stratiomyidae). Pupae of Ephydridae and Muscidae were found parasitized by Cyrtogaster trypherus and a Braconidae species respectively.

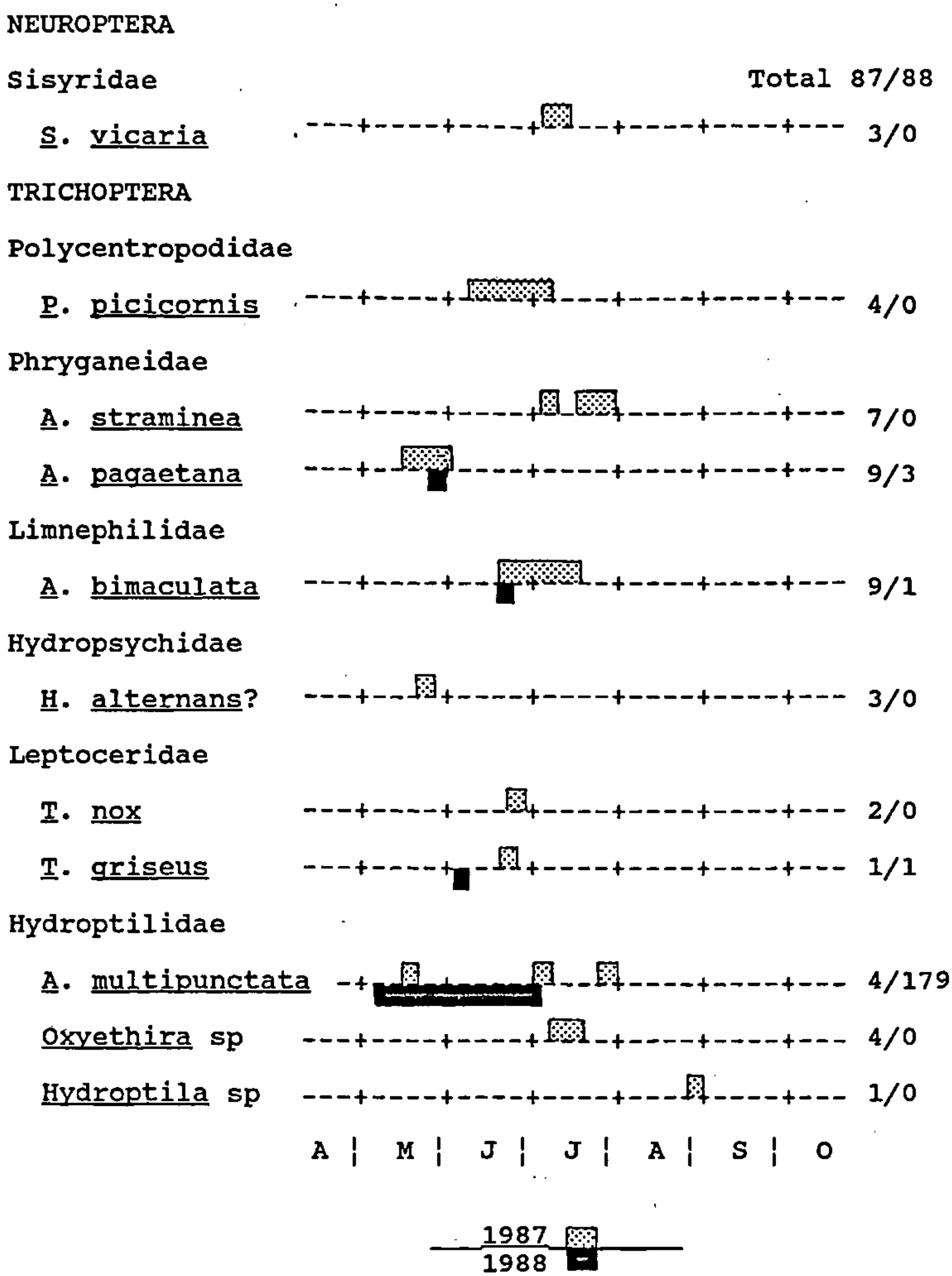


Figure 10: Emergence periods of Neuroptera and Trichoptera species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

4.1.6 Diptera

Seventy species of Diptera, belonging to twelve families, were collected from 1986 to 1988 (Table 3). In 1987, 46 species of Diptera were collected making up 91 % of the insects fauna (Figures 11 to 15). Eleven species were abundant (N_1 = 11.1), of which six were very abundant (N_2 = 5.9). Evenness of the community was low (HMR = 0.5), indicating a few numerous species and a large number of rare species.

In 1988, the number was reduced to 28 species but the Diptera still made up 90 % of the insects collected. Only five species were abundant (N_1 = 5.3) and three very abundant (N_2 = 3.1). Evenness remained the same as for 1987 (HMR = 0.5).

Both percent dissimilarity and Morisita's Index suggested the dipteran fauna of the two years were different (PD = 51%; M_i = 0.8). Twenty-six species collected in 1987 were not collected in 1988. Four additional species were collected in 1988.

4.1.7 Summary

Pond LC supported a diverse and rich insect fauna. The most abundant order in both years was the Diptera due to the large numbers of Chironomidae. This family made

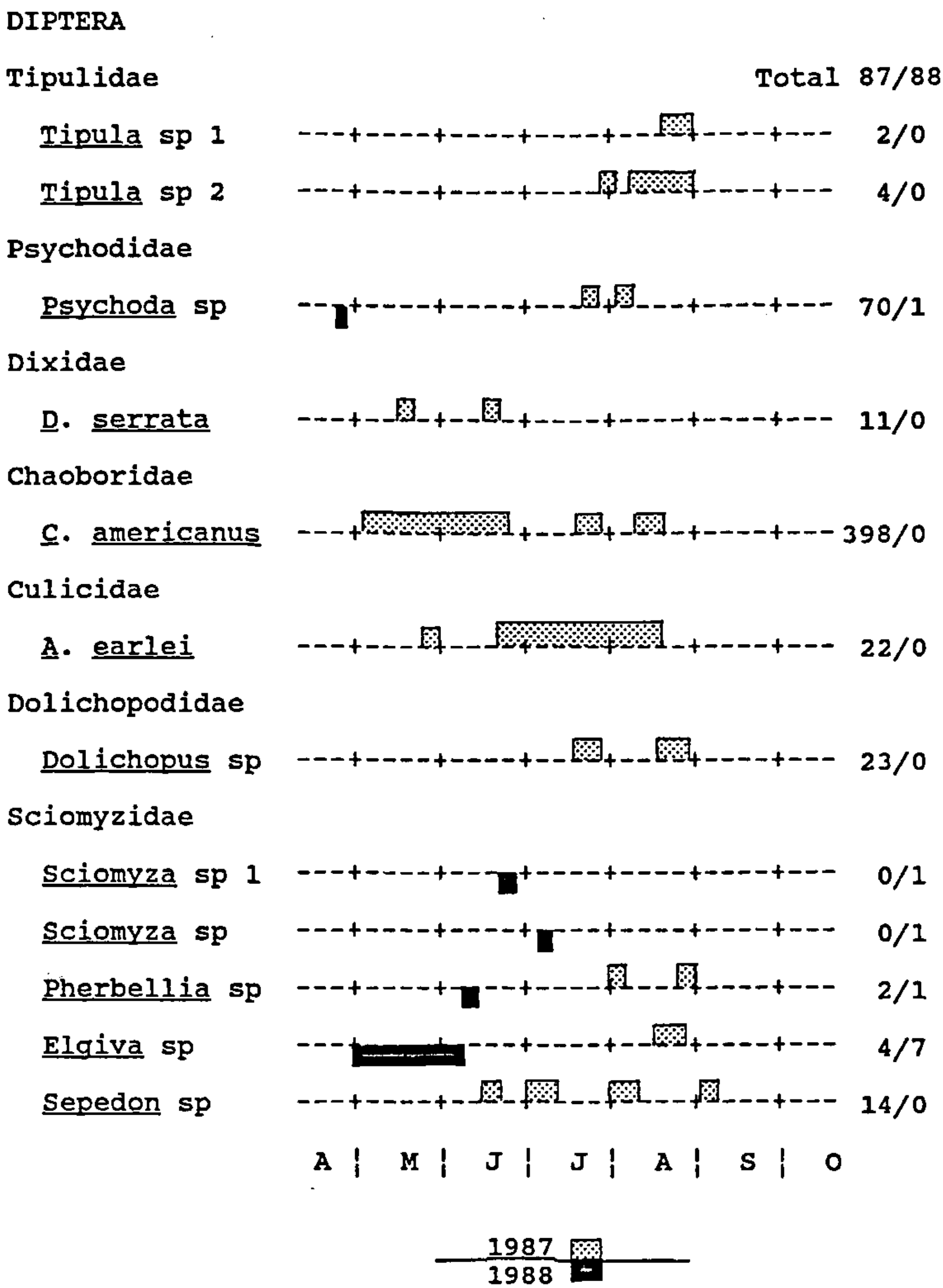


Figure 11: Emergence periods of miscellaneous Diptera species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

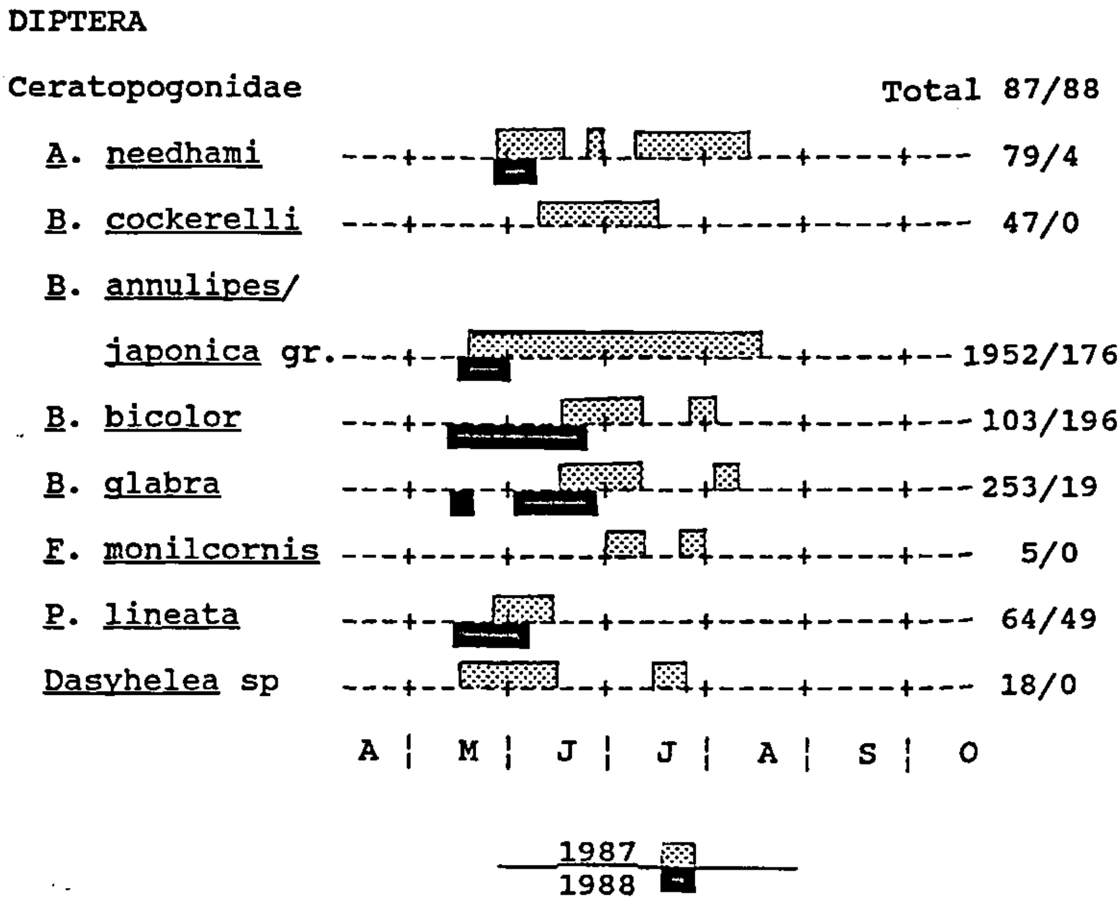


Figure 12: Emergence periods of Ceratopogonidae (Diptera) species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

DIPTERA

Chironomidae

Tanypodinae Total 87/88

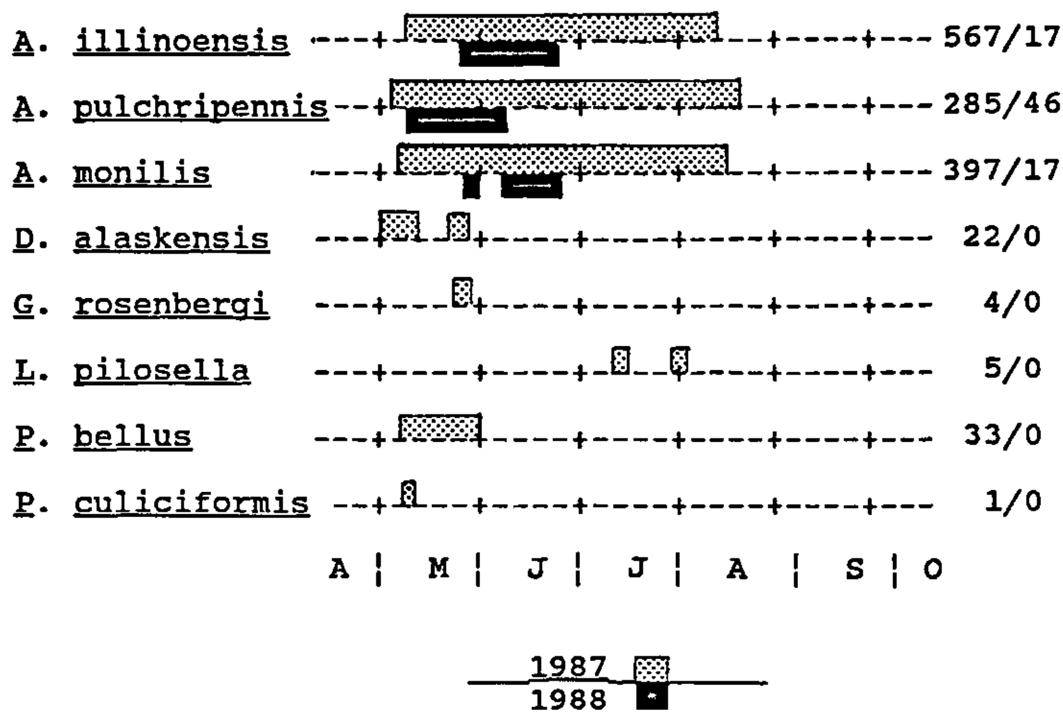


Figure 13: Emergence periods of Tanypodinae (Chironomidae: Diptera) species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

DIPTERA

Chironomidae

Chironominae

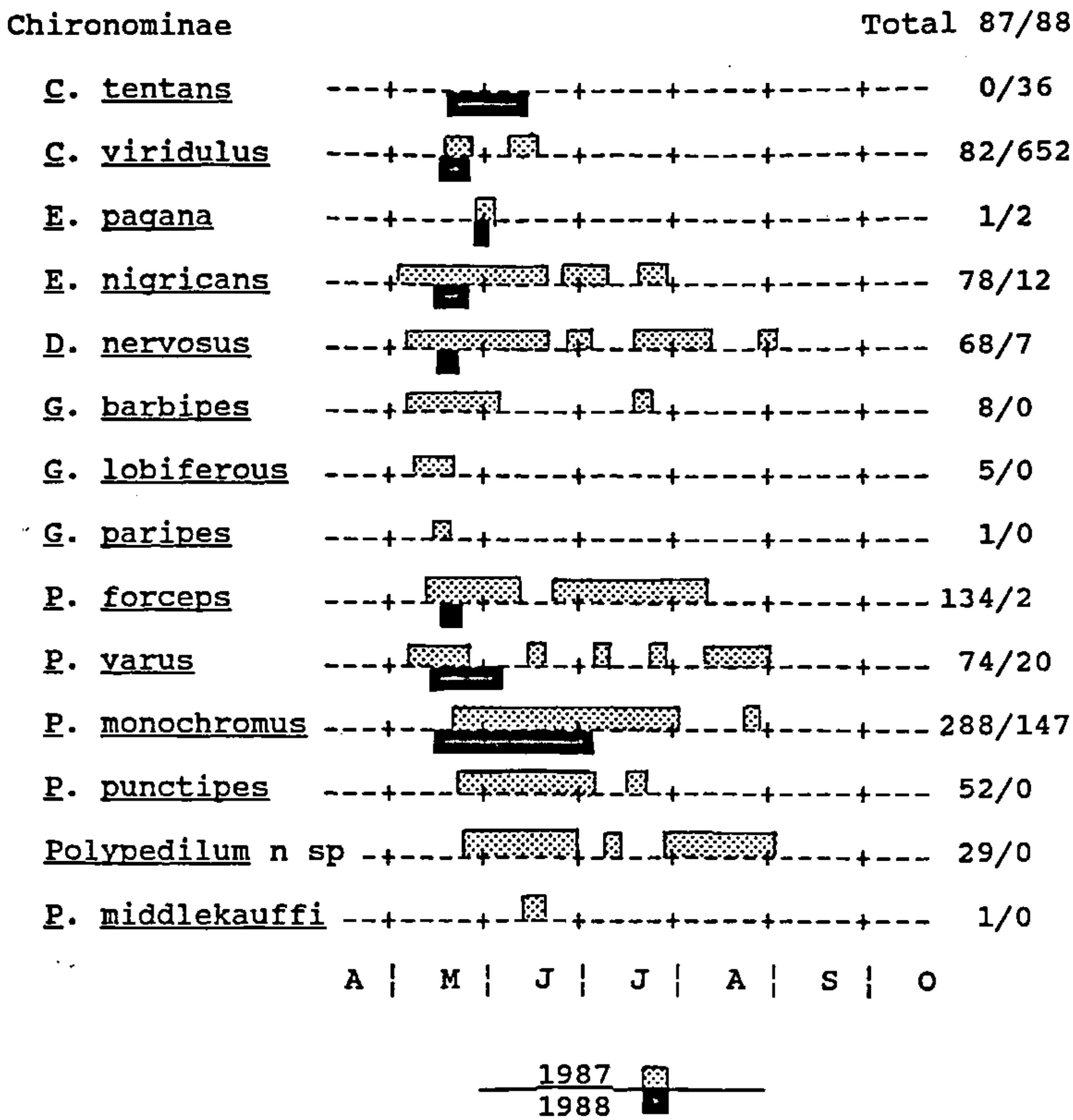


Figure 14: Emergence periods of Chironominae (Chironomidae: Diptera) species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

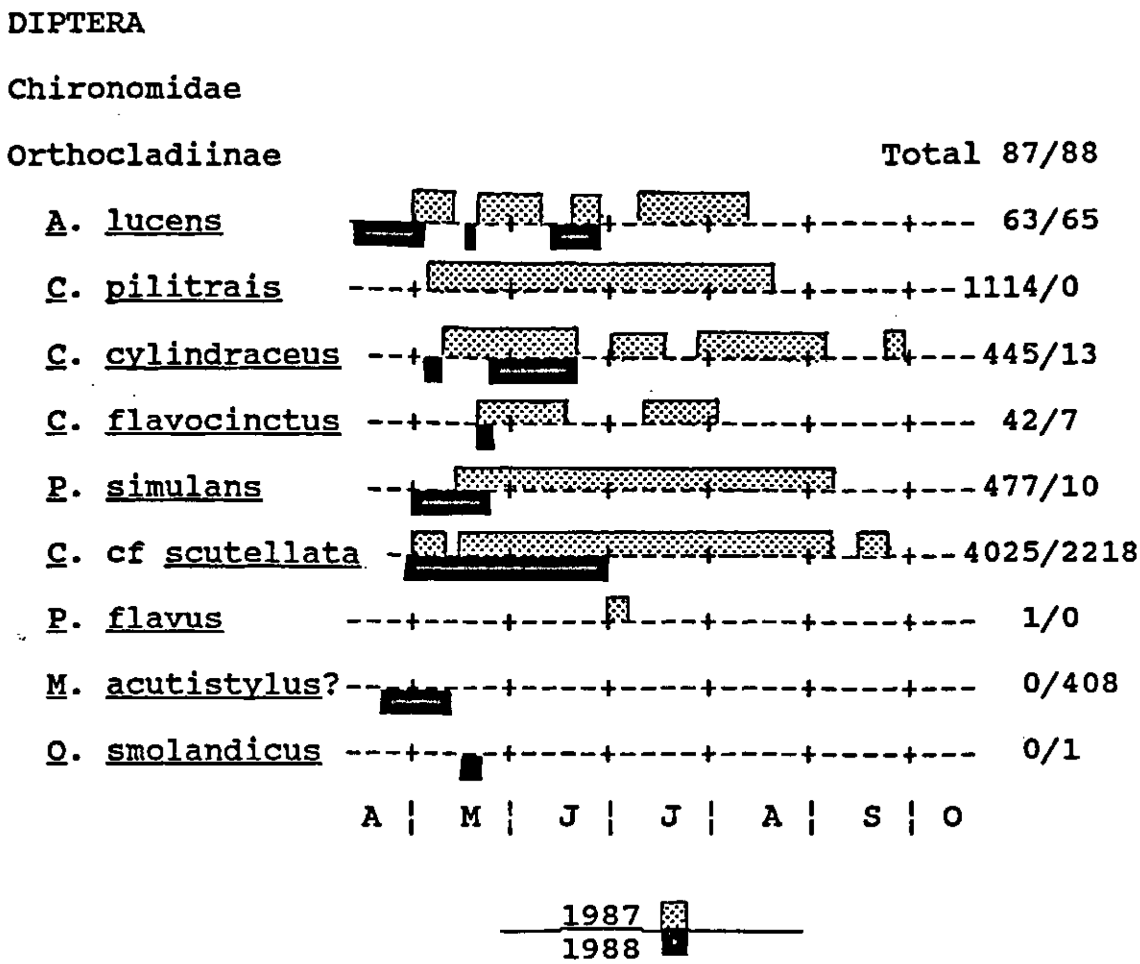


Figure 15: Emergence periods of Orthocladiinae (Chironomidae: Diptera) species and number of adults collected from emergence traps in Pond LC during 1987 and 1988.

up 66 % of the total number of insects collected in 1987 and 71 % in 1988. The numbers would have been larger if the females and the tribe Tanytarsini would have been included in the study.

Species diversity declined for all orders collected between 1987 and 1988 (Table 4). Large differences in each of the ordinal communities between 1987 and 1988 were indicated by large values for percent dissimilarity and low values for Morisita's index. The exception was the Ephemeroptera which had a low PD, due to C. pallidus dominating the mayfly community in both years even though the number collected decreased by 99% between 1987 and 1988.

4.2 Species Emergence Periods and Patterns

Emergence periods of all species, except Hymenoptera, collected in 1987 and 1988 have presented in Figures 8 to 15. The emergence results of the "very abundant species" (N_2) collected during 1987 and 1988 are presented in the following section. An exception was made for the Trichoptera in 1987 because none were collected in large enough numbers to document detailed emergence. Species examined in detail include one Ephemeroptera, seven Odonata, one Trichoptera, one Neuroptera and 14 Diptera.

Table 4: Summary of Hill's Numbers (N_0, N_1, N_2); Evenness (HMR); Percent Dissimilarity (PD); and Morisita's Index (M_i) for insect orders in 1987 and 1988.

Order	1987				1988			
	N_0	N_1	N_2	HMR	N_0	N_1	N_2	HMR
Ephemeroptera	3	1.2	1.1	0.3	1	1	1	-
Odonata	14	7.4	6.3	0.8	10	6.3	7.2	1.2
Neuroptera	1	-	-	-	0	-	-	-
Trichoptera	10	6.3	7.2	1.2	4	1.2	1.1	0.2
Diptera	46	11.1	5.9	0.5	28	5.3	3.1	0.5

	PD	M_i
Ephemeroptera	4	-
Odonata	47	0.6
Neuroptera	-	-
Trichoptera	88	0.2
Diptera	51	0.8

4.2.1 Ephemeroptera

Callibaetis pallidus was the only mayfly species collected in abundance. In 1987, 284 adults were collected between June 22 and October 12 with most of the emergence occurring in August. A peak mean emergence of 7.4 adults/m^2/day occurred during the August 17 sampling period (Figure 16). In 1987 the S traps collected significantly more adults than the E traps ($P = 0.022$). In 1988 only a single specimen of *C. pallidus* was collected.

4.2.2 Odonata

Aeshna interrupta was the largest insect collected in the emergence traps. During 1987, 35 specimens were collected from June 29 to August 10 (Figure 17). The peak emergence period occurred during the July 13 trapping period when an average of 1.2 adults/m^2/day were collected. The E traps collected significantly more adults than the other two trap stations ($P = 0.004$). In 1988 only 2 adults of *A. interrupta* were collected, both on June 27 from the O traps. Two final instar larval exuviae were also collected from the outside of the O traps on June 9, 1988.

In 1987, 236 adults of *Lestes congener* Hagen were collected. The emergence period began on July 6 and continued to August 17 (Figure 18). A peak, average

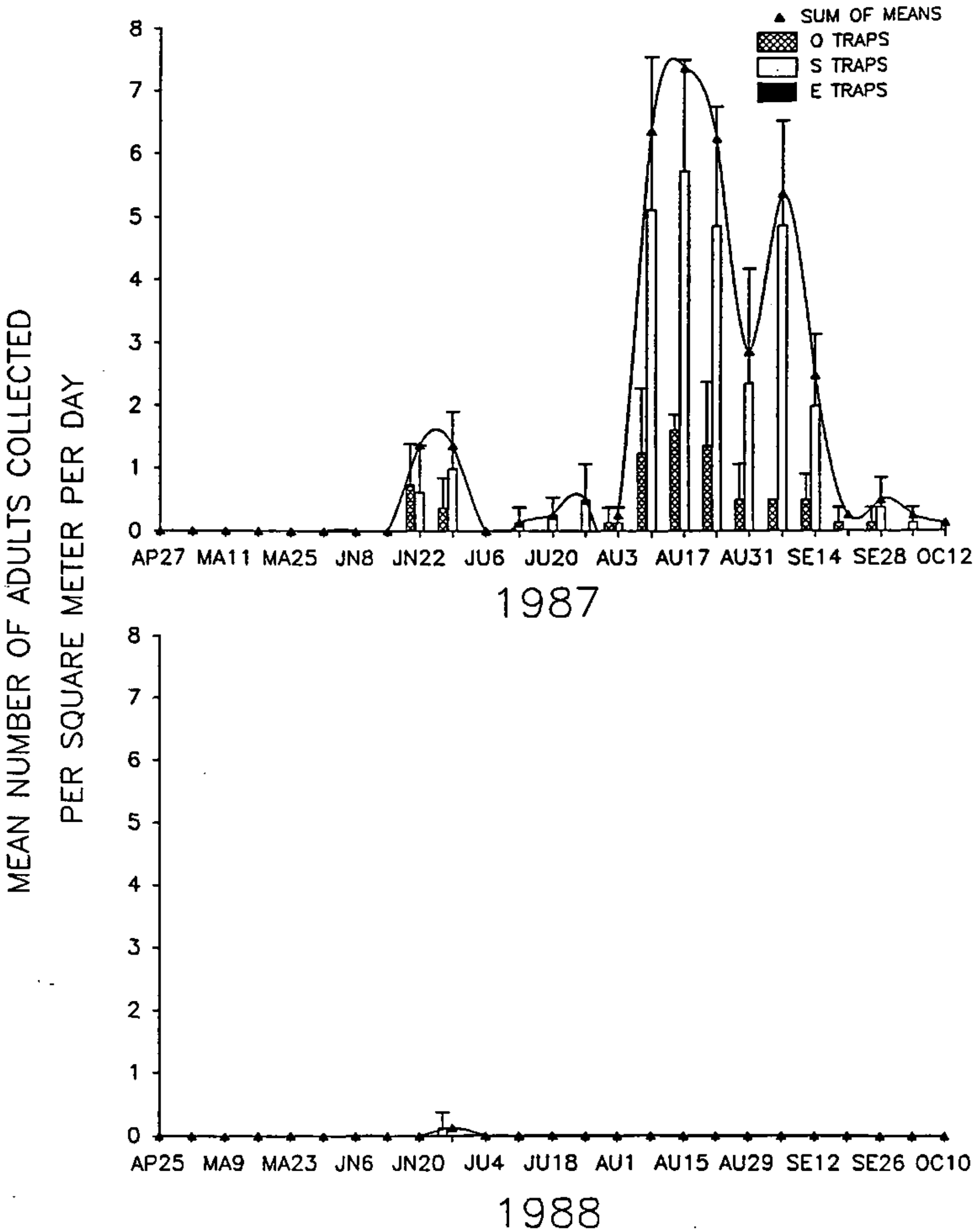


Figure 16: Mean daily adult emergence density (+1sd) of Callibaetis pallidus.

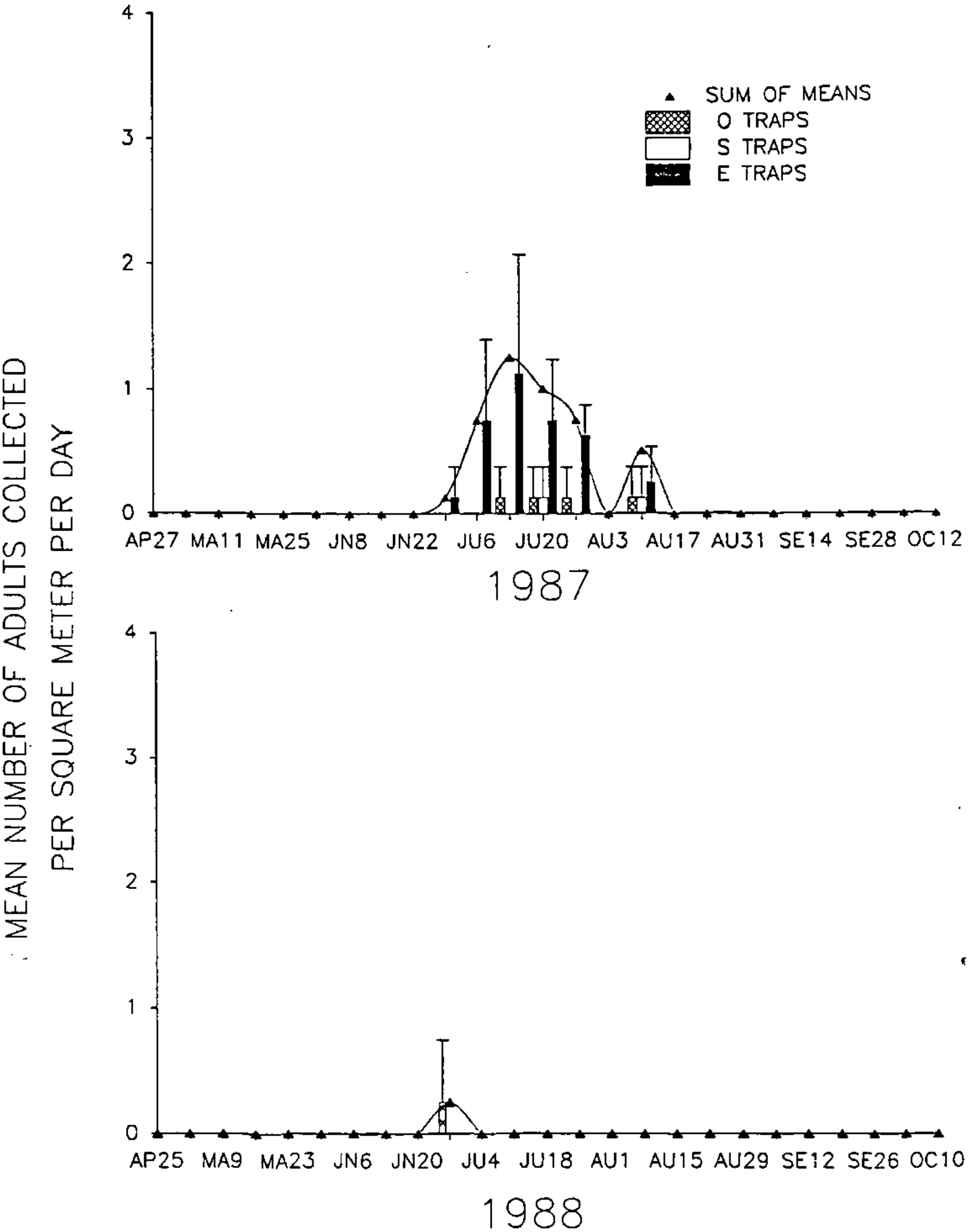


Figure 17: Mean daily adult emergence density (+1sd) of _Aeshna interrupta_.

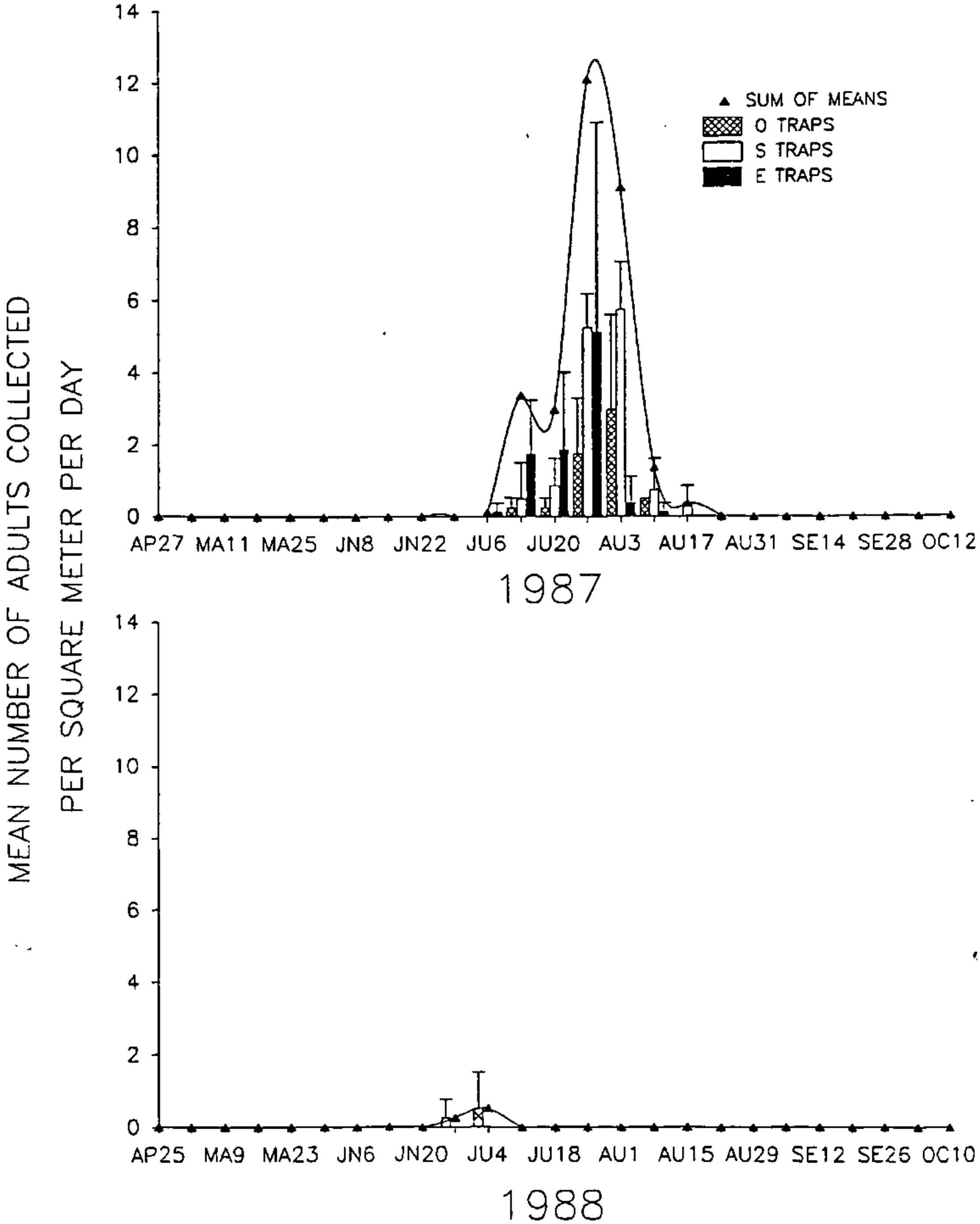


Figure 18: Mean daily adult emergence density (+1sd) of _Lestes congener_.

daily emergence of 12.2 adults/m^2 occurred during the July 27 sampling period. There was no significant difference in adult emergence between the three trap stations (P = 0.117). In 1988 only three specimens of L. congener were collected, on June 27 and on July 4.

In 1987, 129 adults of L. disjunctus/unguiculatus were collected (Figure 19). The ratio of male L. unguiculatus to L. disjunctus was 17.5:1. Emergence began on June 22 and continued to August 10 with a peak emergence during the July 6 sampling period, when an average of 6 adults/m^2/day were collected. There was no significant difference in the number of adults collected from the three trap stations (P = 0.093). In 1988 the number of adults collected was reduced to 46. The ratio of male L. unguiculatus to L. disjunctus was 1:1.3. Emergence began on June 20 and ended on June 27. Peak emergence of 4.2 adults/m^2/day occurred on June 20. There was no significant difference between the stations (P = 0.135).

In contrast to most of the other odonates, Coenagrion angulatum Walker was abundant in both years of the study. In 1987, 120 adults were collected from May 25 to July 6. A peak emergence occurred from June 8 to June 22 (Figure 20). The average number of adults collected during this period ranged from 4.2 to 4.75 adults/m^2/day. The number of adults collected in the

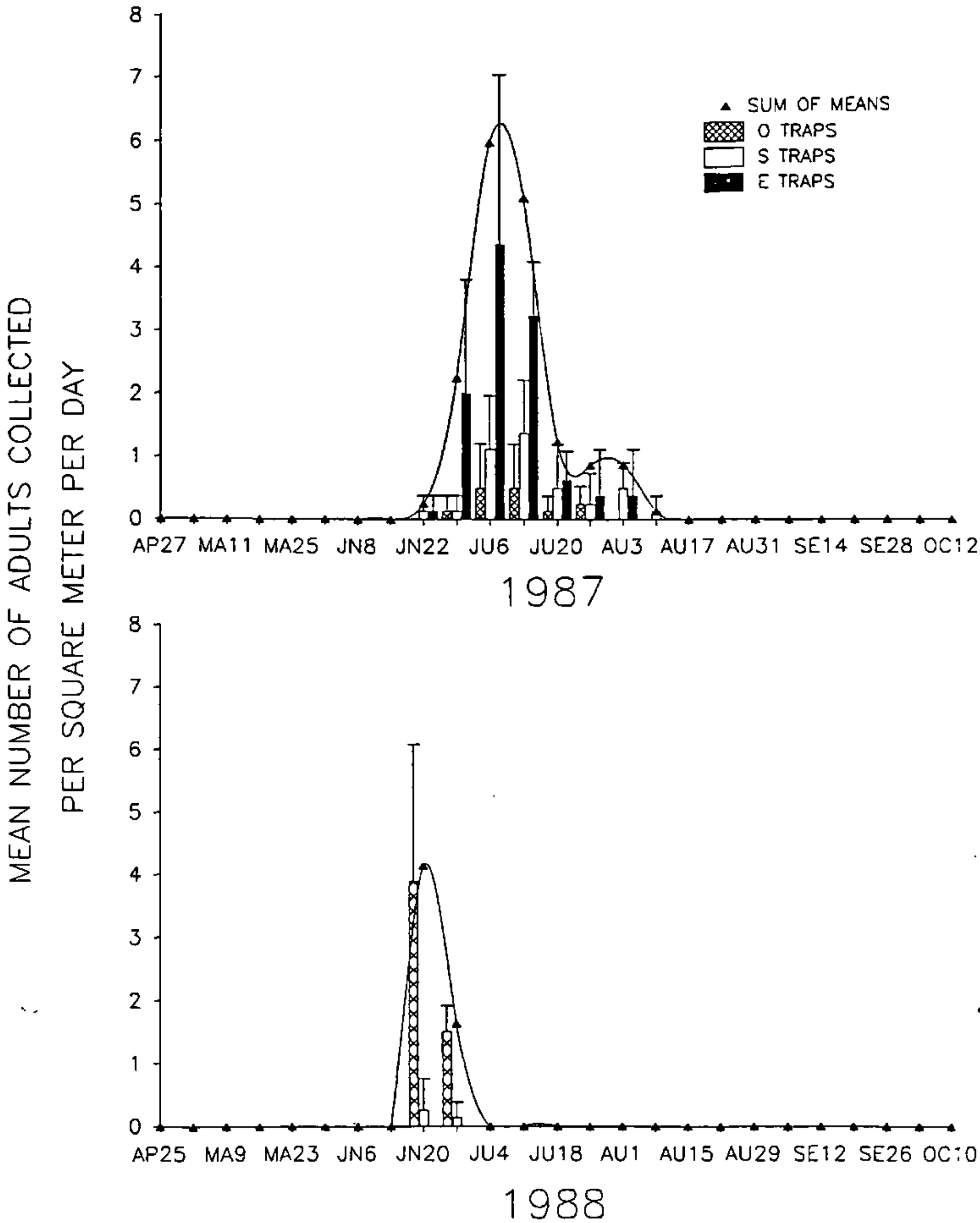


Figure 19: Mean daily adult emergence density (+1sd) of Lestes disjunctus/ unguiculatus.

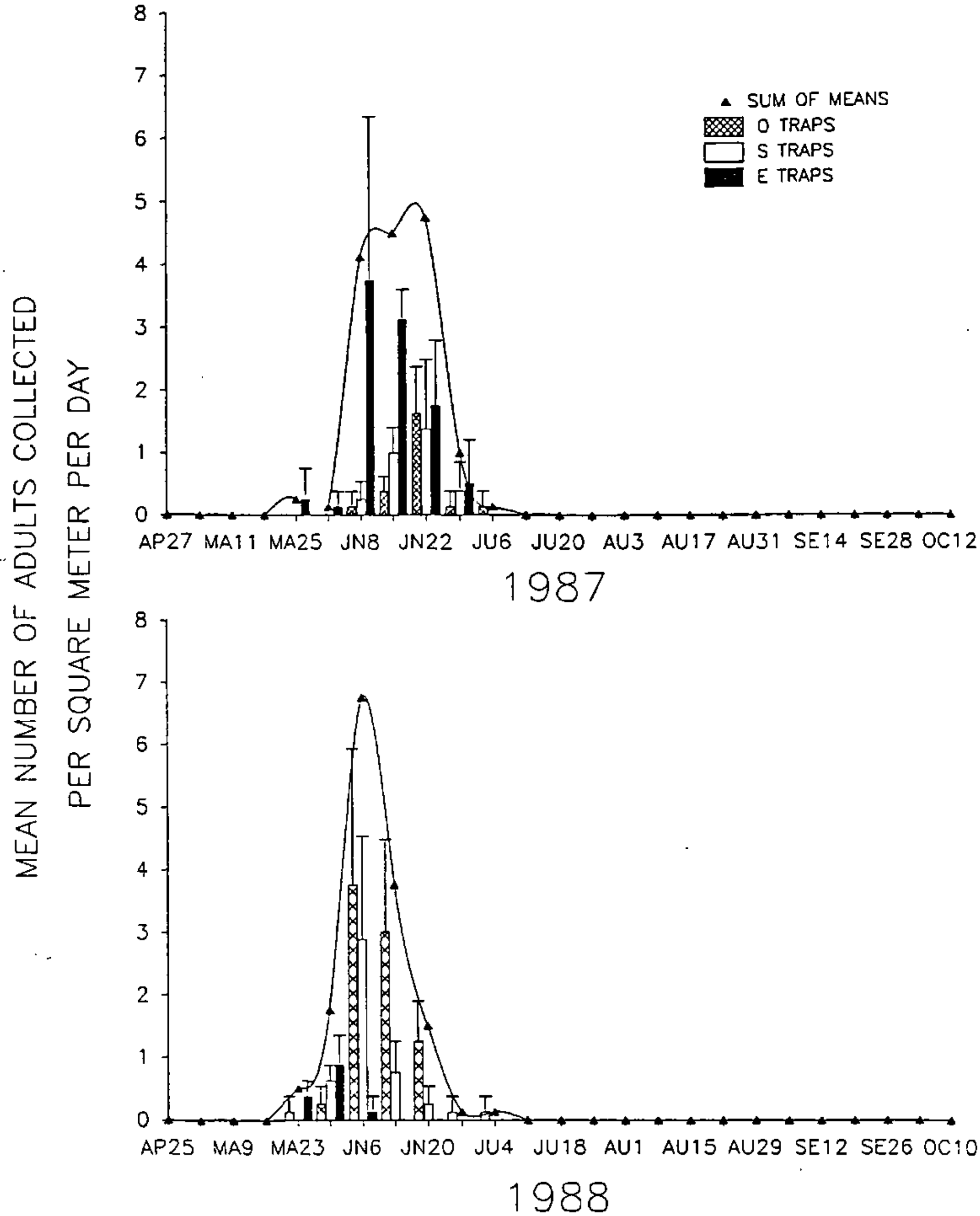


Figure 20: Mean daily adult emergence density (+1sd) of Coenagrion angulatum.

three stations were significantly different (P = 0.040), although no between station comparisons were significant.

In 1988, 117 adults of C. angulatum were collected. Emergence began on May 23 and continued until July 4 (Figure 20). The June 6 sampling period had the largest mean emergence of 6.8 adults/m^2/day. There were no significant differences in the number of adults emerging in each of the stations (P = 0.160).

In 1987, 115 adults of Coenagrion resolutum (Hagen) emerged from June 1 to July 13 (Figure 21). The highest average emergence occurred during the June 22 sampling period when 7.4 adults/m^2/day were collected. The E traps collected significantly more adults than the other two trap stations (P = 0.002). In 1988, the number of C. resolutum adults collected was reduced to ten individuals that emerged from May 23 to June 20.

Adults of Enallagma ebrium (Hagen) emerged from June 15 to July 13 in 1987 (Figure 22). A total of 115 adults were collected. Peak adult emergence occurred during the June 22 sample period when an average of 10.4 adults/m^2/day were collected. There was no significant difference in the number of adults collected among trap stations (P = 0.211).

In 1988, the emergence of E. ebrium was reduced to 60 individuals. Emergence began during the June 6 sampling period and continued to July 4 (Figure 22).

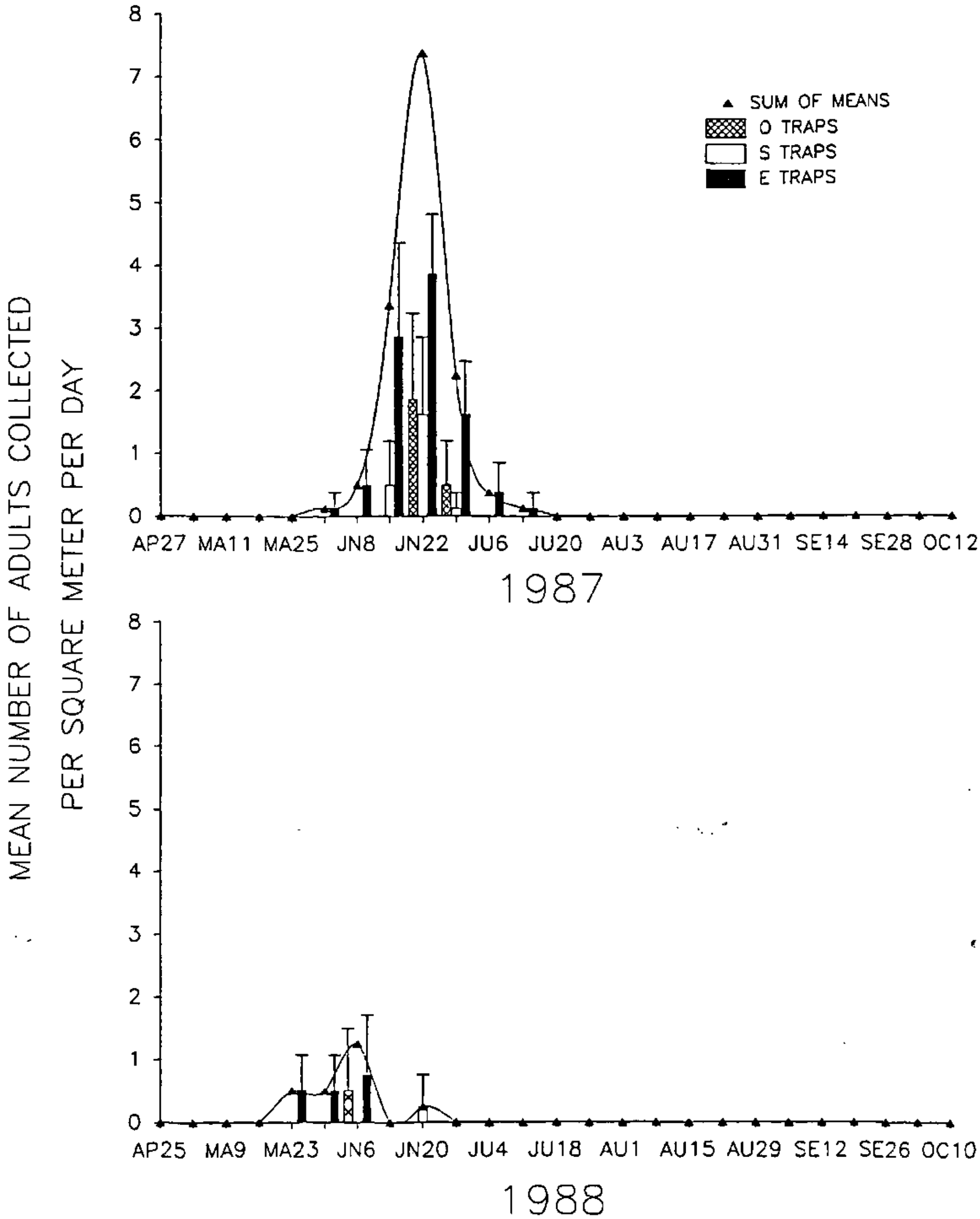


Figure 21: Mean daily adult emergence density (+1sd) of <u>Coenagrion</u> <u>resolutum</u>.

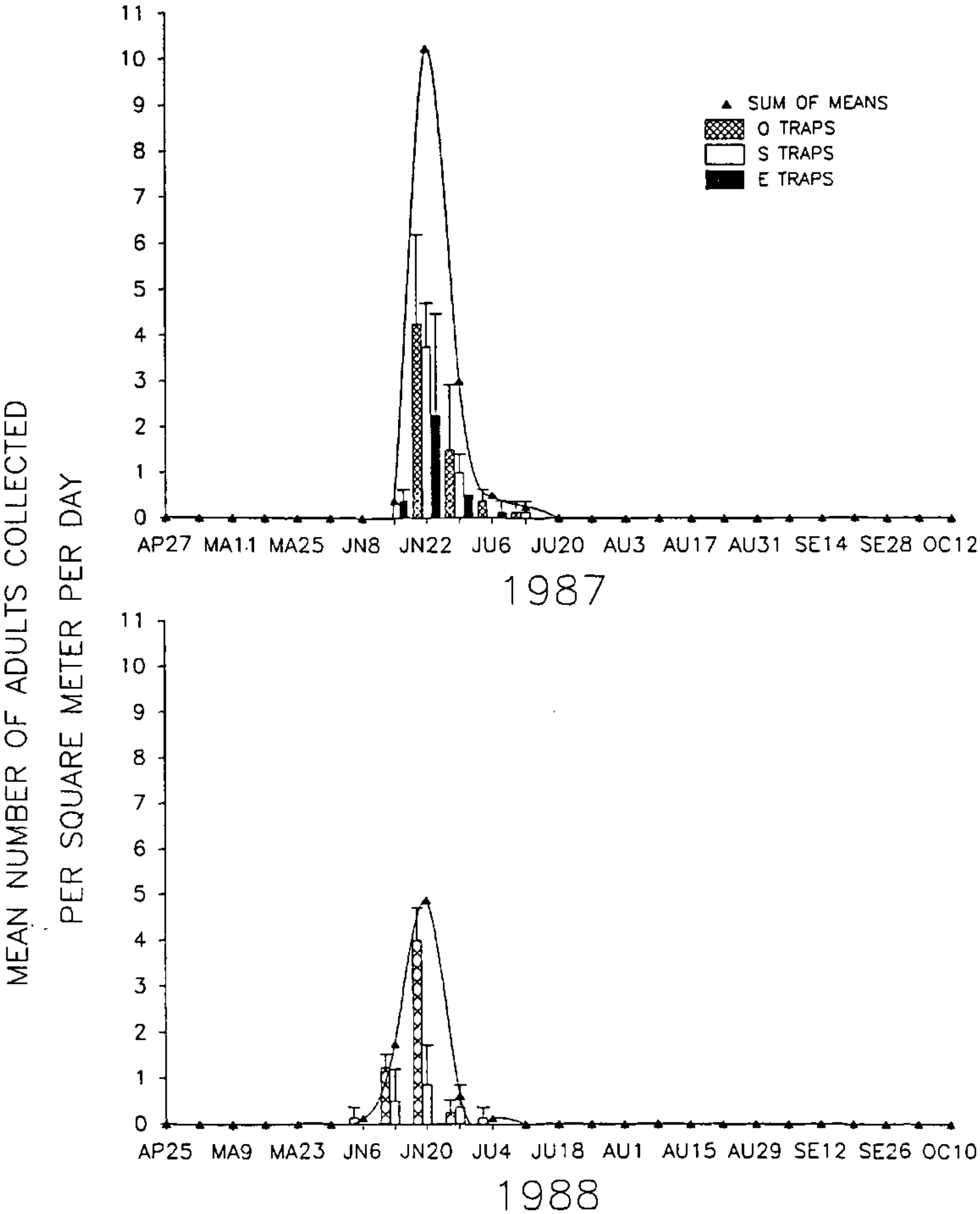


Figure 22: Mean daily adult emergence density (+1sd) of Enallagma ebrium.

Peak emergence was recorded during the June 20 sampling period when a mean of 5.0 adults/m^2/day were collected. The O traps collected significantly more adults than the E traps ($P = 0.020$), which did not collect any specimens.

Adults of Enallagma cyathigerum (Charpentier) were collected in 1987 only. Forty-three adults were collected between June 1 and July 20 (Figure 23). Peak average daily emergence of 3.2 adults/m^2/day occurred during the June 29 sampling period. There was a significant difference in the number of adults collected in the three stations ($P = 0.044$) although there was no significant difference in the station by station comparisons.

In summary, all the abundant odonates had a single emergence peak and all except Coenagrion angulatum were reduced in number between 1987 and 1988. One species, Enallagma cyathigerum was apparently eliminated from Pond LC in 1988. There were no differences of more than a week in the onset of emergence in 1988 compared to 1987 for any of the odonates examined. Aeshna interrupta and Coenagrion resolutum emerged in the E station traps significantly more than in the other trap stations in 1987. In 1988, Enallagma ebrium emerged significantly more from the O station traps than from the E station traps.

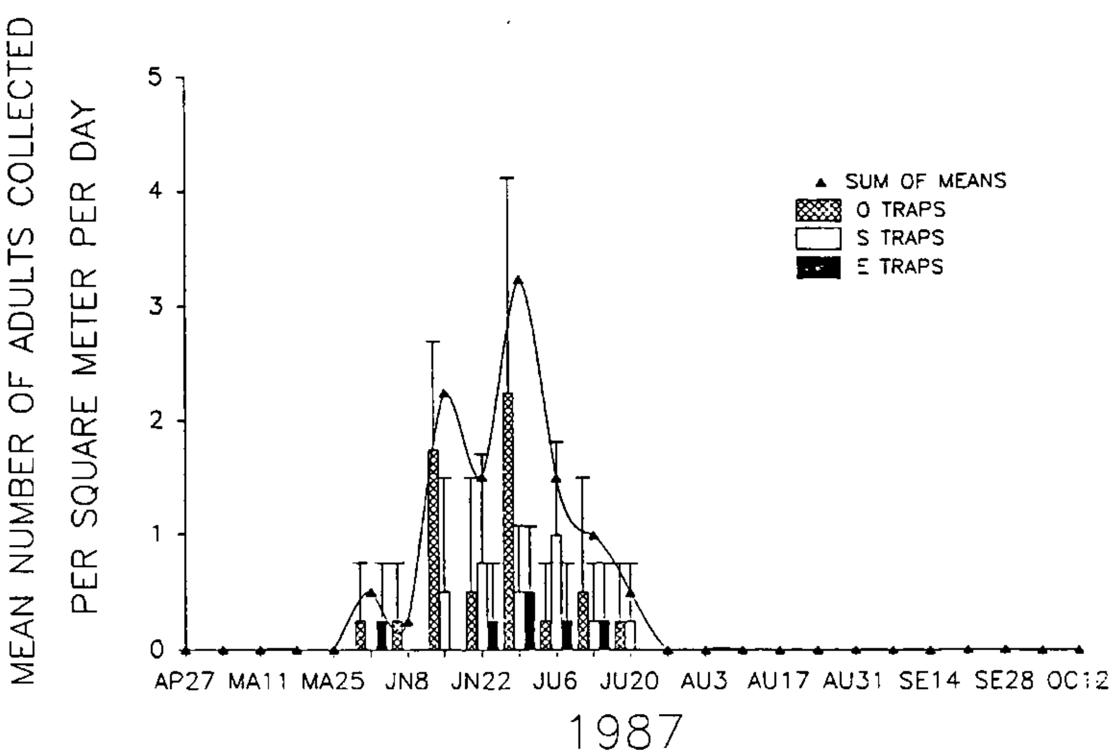


Figure 23: Mean daily adult emergence density (+1sd) of _Enallagma cyathigerum_.

4.2.3 Neuroptera

One species of Neuroptera, *Sisyra vicaria* (Walker), was collected in the pond. All three specimens were collected on June 15, 1987, two adults from station E and one from station O (Figure 10).

4.2.4 Trichoptera

The only caddisfly species collected in large numbers was the hydroptilid, *Agraylea multipunctata* Curtis in 1988. In 1987, only four adults of this species were collected between May 4 and July 13. In 1988, *A. multipunctata* was considerably more abundant with 179 adults collected. Emergence began on May 9 and continued until July 4, (Figure 24). Peak emergence occurred during the June 13 sampling period when an average of 11.9 adults/m^2/day were collected. The O traps collected significantly more adults than the E traps ($P = 0.004$) which did not collect any adults.

4.2.5 Diptera

The emergence patterns of 14 species of Diptera collected in 1987 and 1988 were examined in detail. These included one species in the family Chaoboridae, three Ceratopogonidae and ten species of Chironomidae.

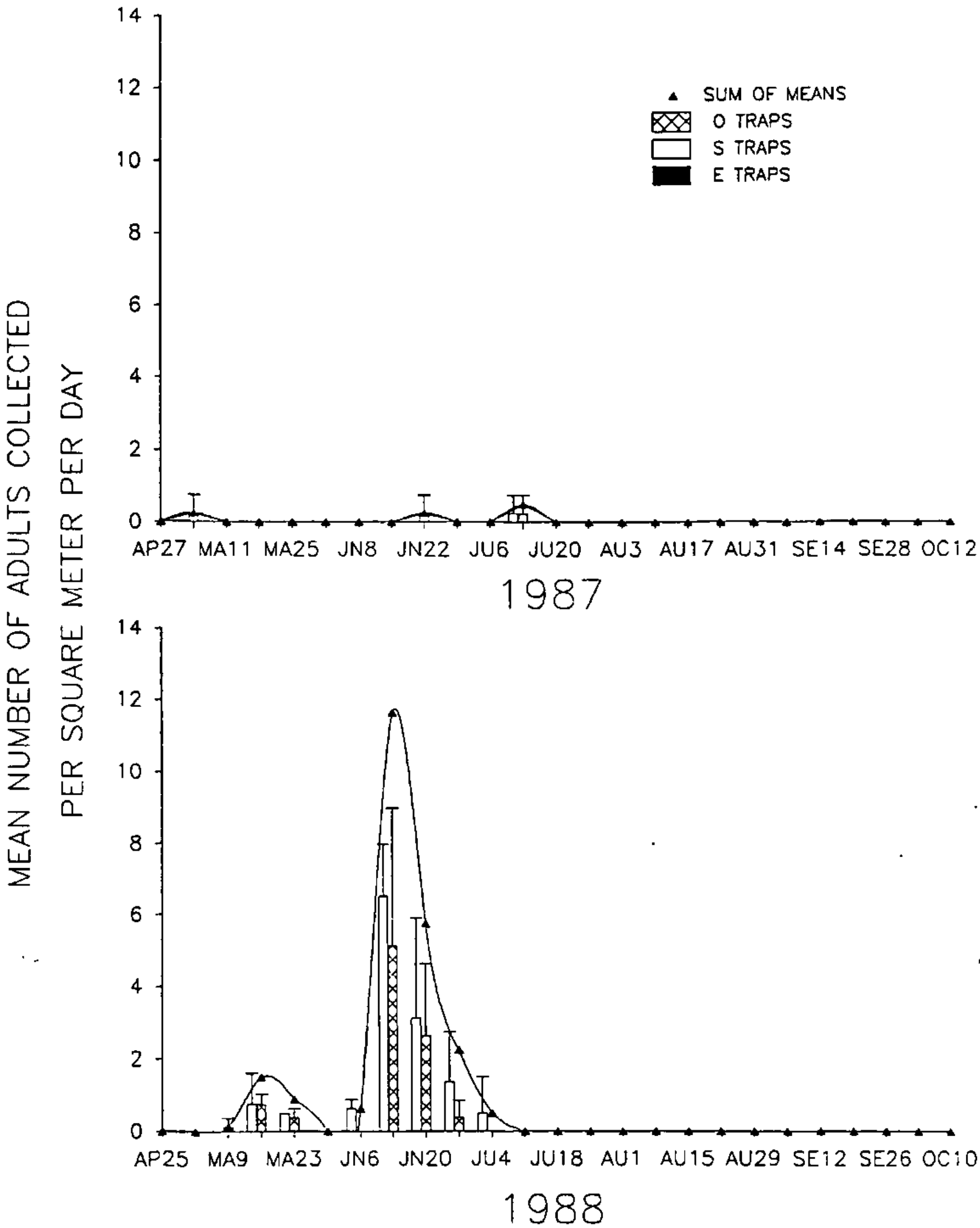


Figure 24: Mean daily adult emergence density (+1sd) of _Agraylea multipunctata_.

4.2.5.1 Chaoboridae

In 1987, 398 adults of Chaoborus americanus (Johannsen) was collected. In 1987 emergence began on May 4 and lasted until August 17 (Figure 25); however after May 11, very low numbers of adults were collected. Mean daily emergence peaked at 32 adults/m^2/day during the May 11 sampling period. There was no significant difference ($P = 0.442$) among the three stations in the number of adults collected. No adults were collected in 1988.

4.2.5.2 Ceratopogonidae

Bezzia annulipes/japonica group is defined here as B. annulipes (Meigen) and B. annulipes/japonica complex. Attempts at separating these "types" failed so they are considered together.

B. annulipes/japonica group was collected in both years (Figure 26). In 1987, emergence began on May 18 and continued until August 24. The total number of adults collected was 1952. Most of the adults emerged from May 25 to June 8. The largest mean daily emergence of 52 adults/m^2/day occurred on June 8. There was no significant difference among trap stations in the number of adults captured ($P = 0.423$). In 1988, 176 adults were collected from May 16 to June 6 (Figure 26). Peak emergence occurred during the May 23 sampling period when

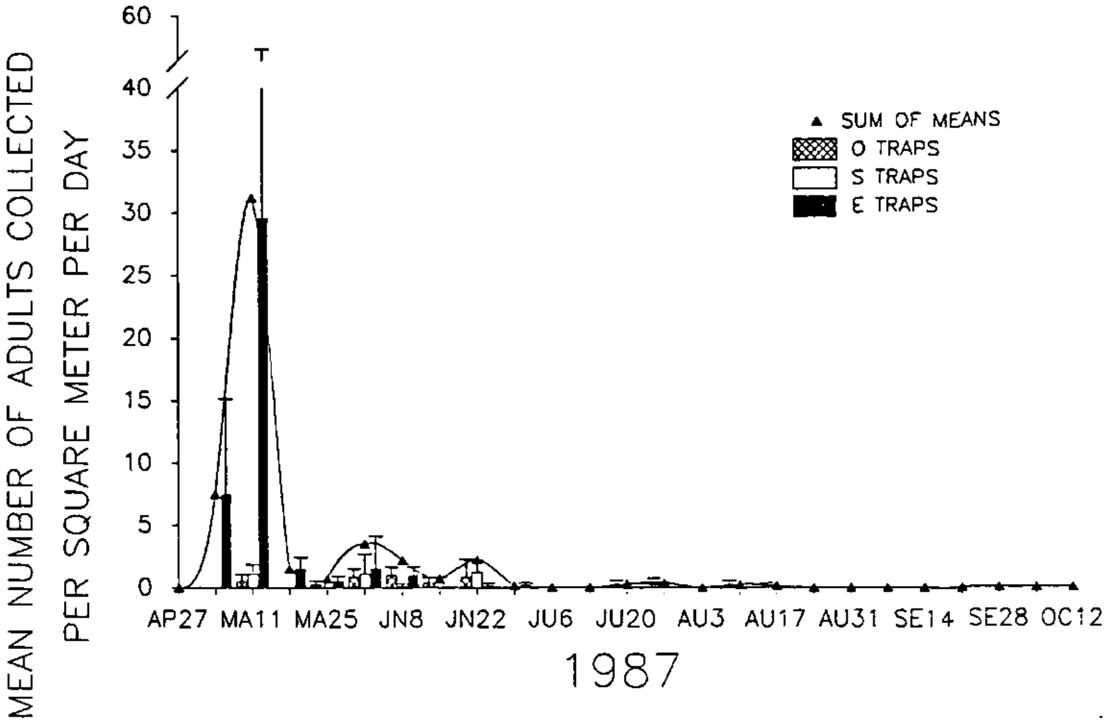


Figure 25: Mean daily adult emergence density (+1sd) of Chaoborus americanus.

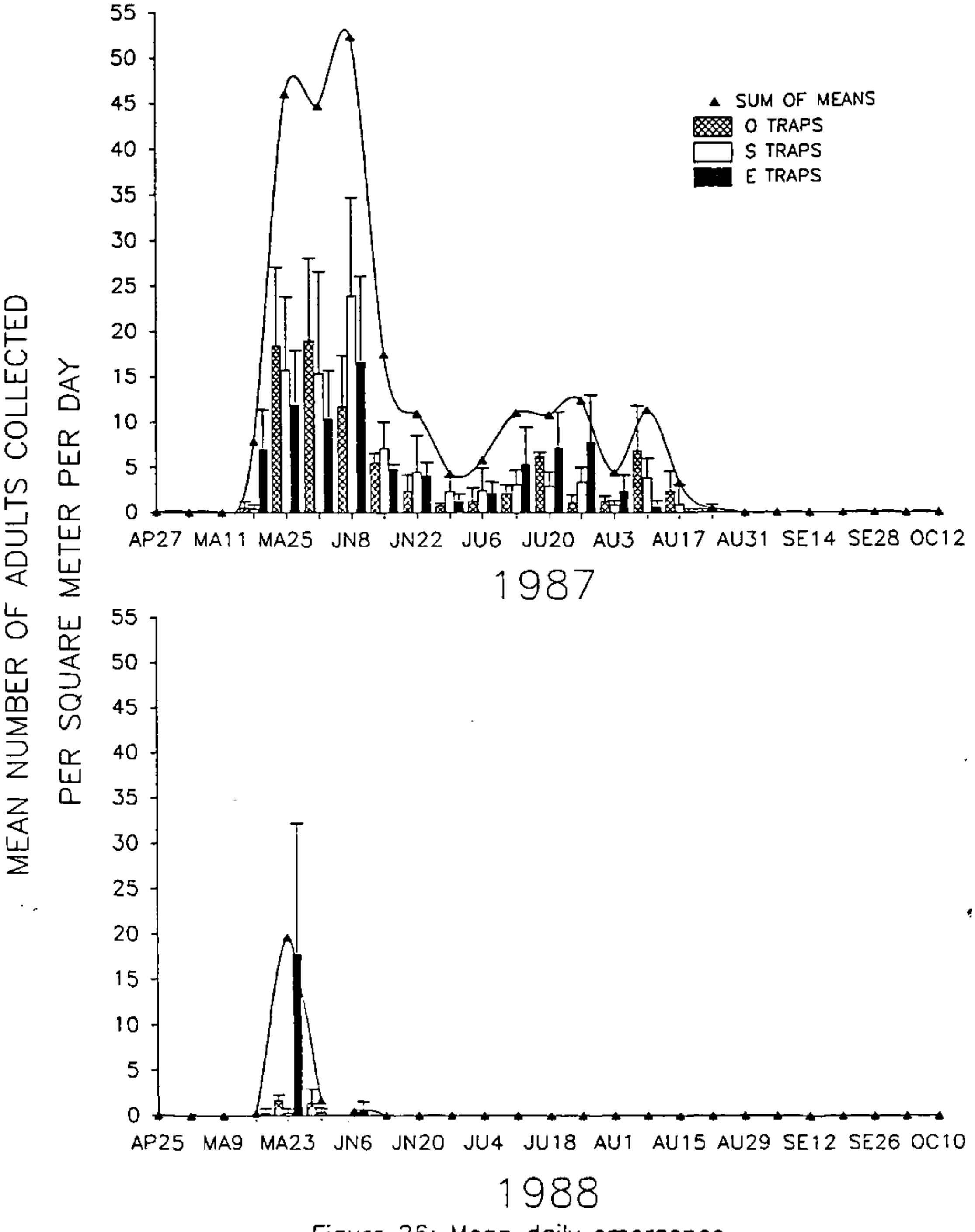


Figure 26: Mean daily emergence density (+1sd) of Bezzia annulipes/japonica group.

an average of 20 adults/m^2/day were collected. There was no significant difference among the three stations in the number of adults collected ($P = 0.323$).

_B_. _bicolor_ Meigen emerged from the pond during both years (Figure 27). In 1987, a total of 103 adults were collected from June 15 to August 3. The largest mean daily emergence of 8.2 adults/m^2/day was recorded during the June 22 sampling period. There was no significant difference in the adult numbers collected in the three trap stations ($P = 0.717$).

In 1988, 196 adults of _B_. _bicolor_ were collected. Emergence began on May 16 and continued to June 27 (Figure 27). Peak emergence of 7.7 adults/m^2/day occurred during the June 20 sampling period. There was no significant difference among the stations in numbers of adults collected ($P = 0.368$).

_B_. _glabra_ Coquillet emerged during both years as well (Figure 28). In 1987, 253 adults were collected from June 15 to August 10. The peak average daily emergence occurred on June 29 when 14.4 adults/m^2/day were collected. In 1987, the S and E traps both collected significantly more adults than the O traps ($P = 0.017$). The following year only 19 adults were collected and the emergence period was restricted to May 16 and June 6 to June 27.

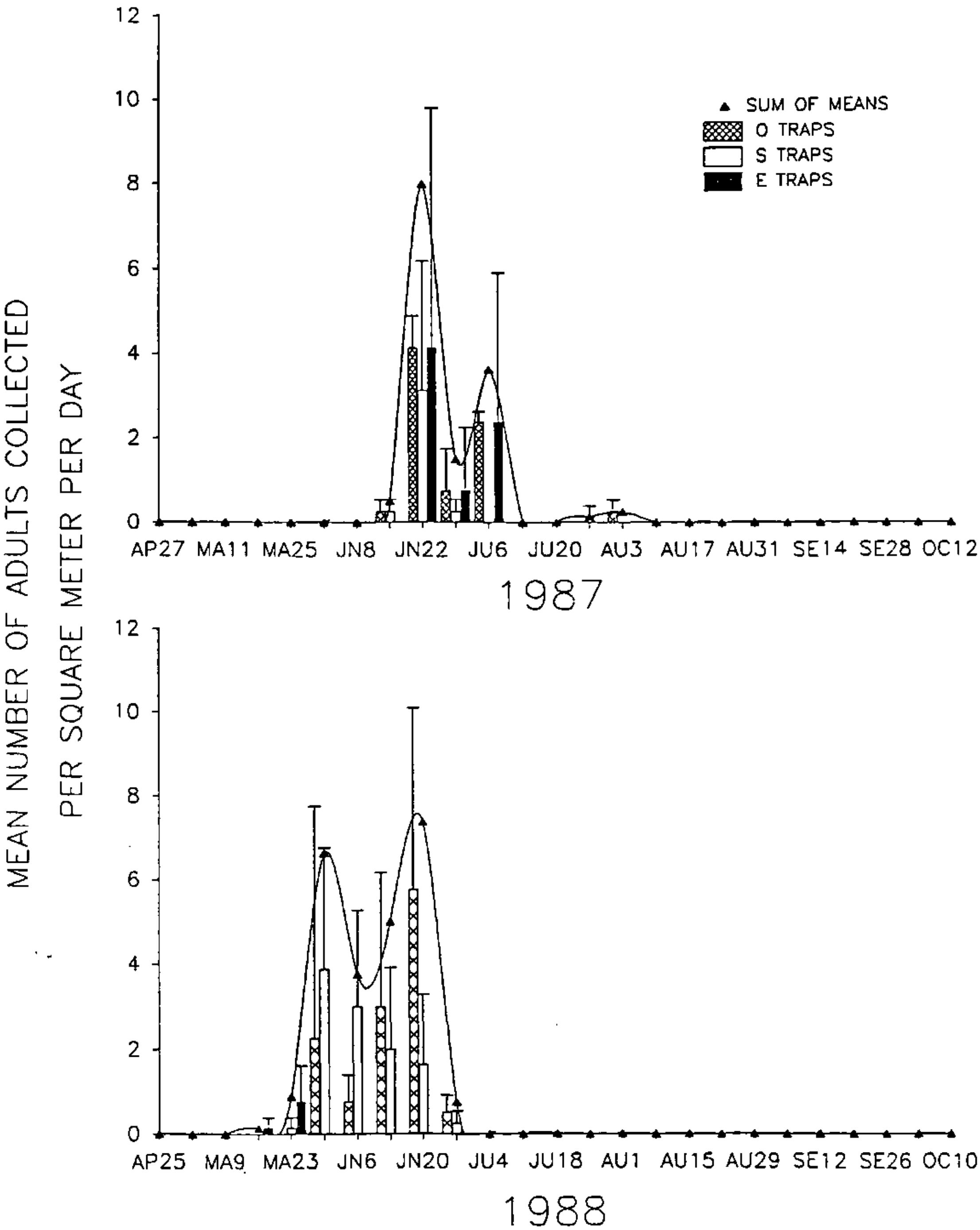


Figure 27: Mean daily adult emergence density (+1sd) of Bezzia bicolor.

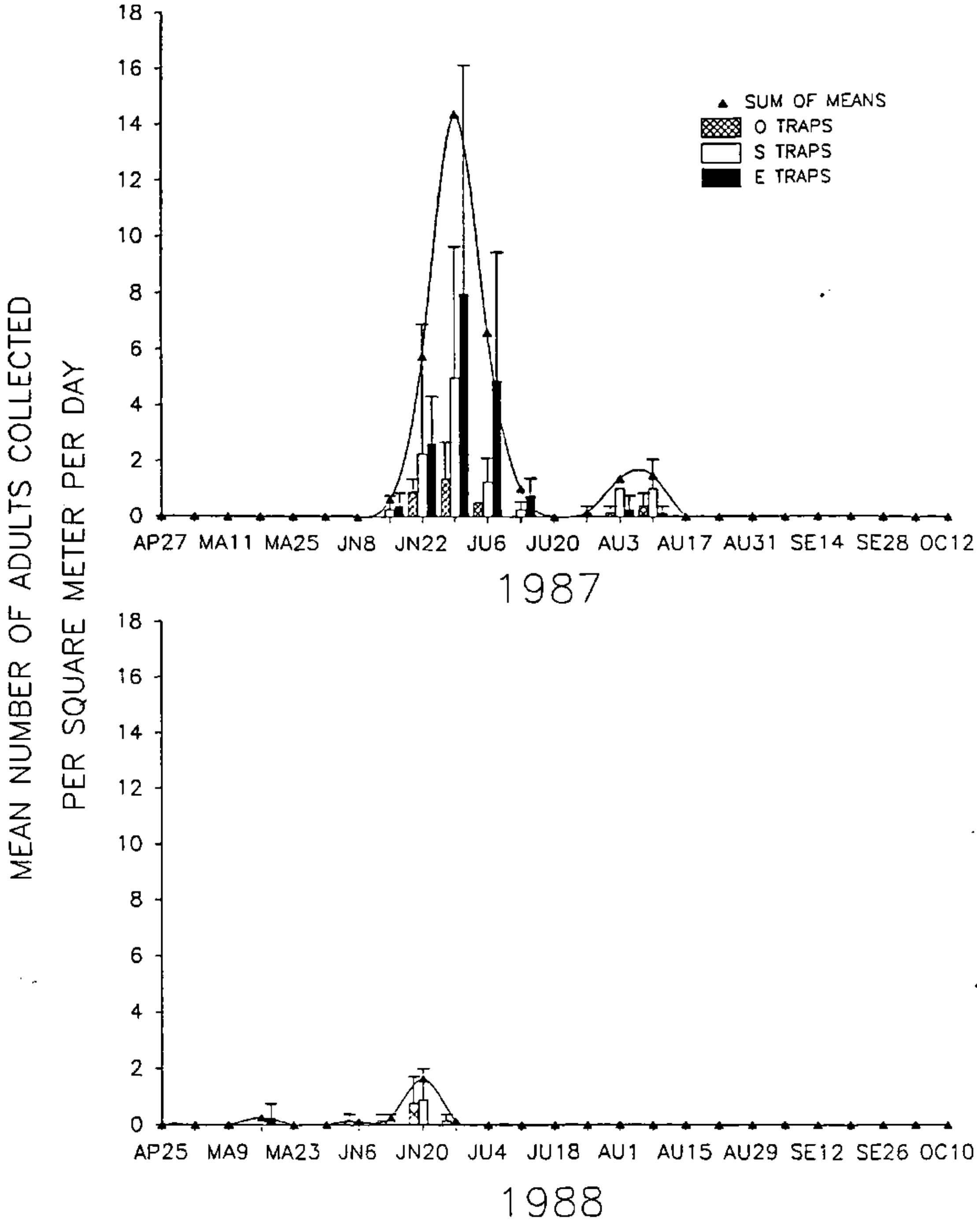


Figure 28: Mean daily emergence density (+1sd) of Bezzia glabra.

In summary, all three *Bezzia* species were collected in both years. Only *B. bicolor* increased in number between the two years. All three species had long emergence periods in 1987 lasting three to four months with multiple emergence peaks. *B. annulipes/japonica* began emerging at similar times in both years, mid May. The other two species both started emerging in 1988 one month earlier than in 1987. *B. glabra* emerged in significantly higher numbers in the S and E stations than in the O stations in 1987. The other two species showed no significant differences among stations.

4.2.5.3 Chironomidae

Ablabesmyia illinoensis (Malloch) was collected in both 1987 and 1988. In 1987, 567 adults were collected from May 11 to August 17. Two large emergence peaks were recorded, the first a mean of 17.4 adults/m^2/day during the June 8 sampling period, and the second, 14.8 adults/m^2/day, during the August 10 sampling period (Figure 29). Significantly more adults were collected in the S traps than the E traps ($P = 0.006$). In 1988, adult emergence was reduced to 17 individuals, collected from May 30 to June 20.

In 1987, the emergence period of *A. pulchripennis* (Lundbeck) began on May 11 and continued to August 24. A total of 285 adults were collected during this period.

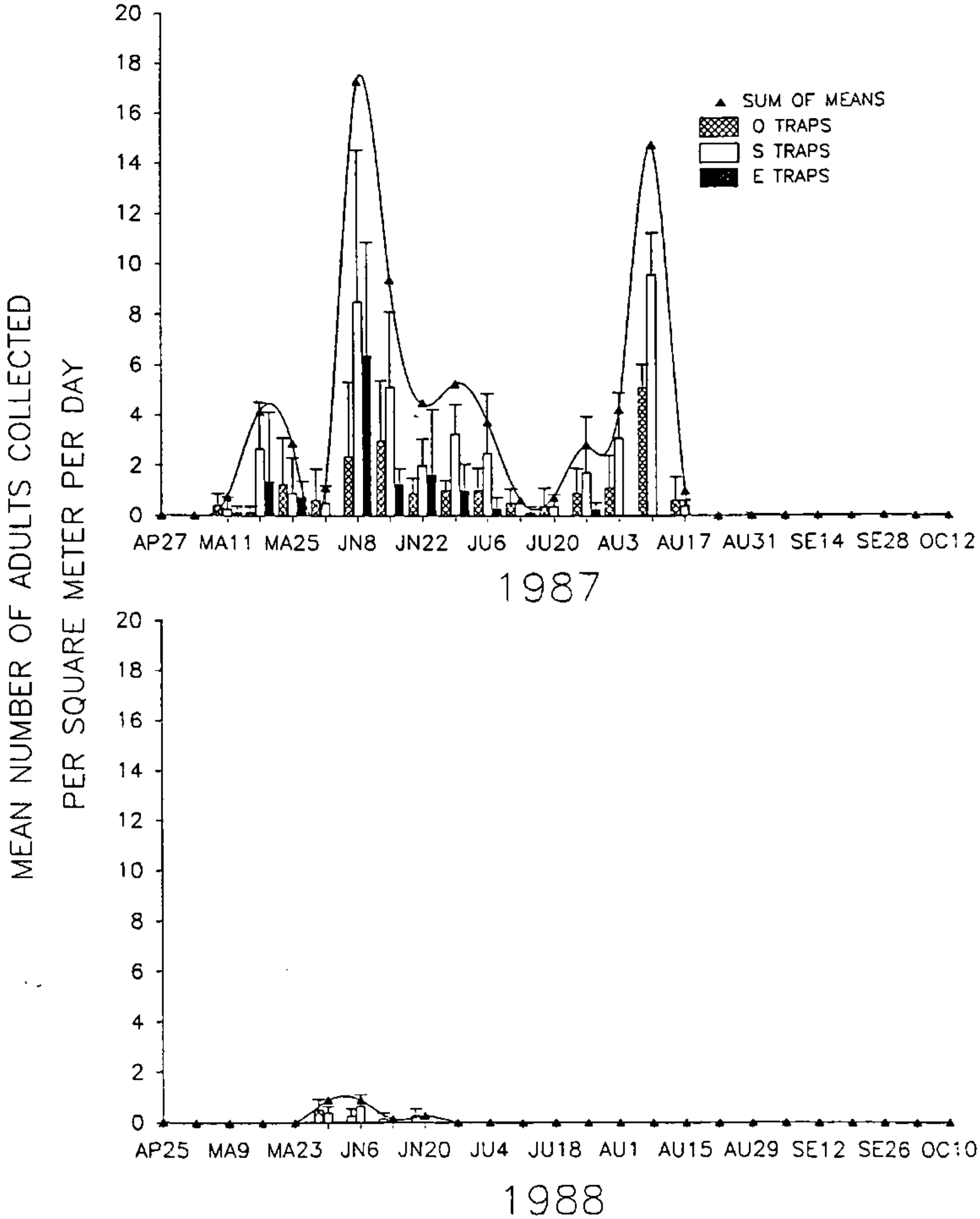


Figure 29: Mean daily adult emergence density (+1sd) of Ablabesmvia illinoensis.

There were two peak emergence periods in 1987, during the May 18 and June 15 sampling periods (Figure 30). The largest number of adults collected was during the June 15 sampling period when an average of 9.2 adults/m^2/day were collected. The S traps collected significantly more adults than the E traps (P = 0.005). In 1988, 46 adults were collected beginning on May 16 and continuing to June 6. A small peak of 2.6 adults/m^2/day was observed on May 23. There was no significant difference in the number of adults collected at the three stations (P = 0.074).

In 1987, 397 adults of A. monilis (L.) were collected from May 11 to August 24 (Figure 31). There were two emergence peaks one during the May 18 sampling period and the other during the June 15 sampling period. The June 15 peak was the largest with a mean of 13 adults/m^2/day collected. The S traps collected significantly more adults than the E traps (P = 0.000). In 1988, only 17 adults were collected. The emergence period was from May 30 to June 27.

Cladopelma viridulus (L.) was collected during both years of the study (Figure 32). In 1987, the emergence period began on May 18 and continued June 15. A total of 82 adults were collected. A peak average emergence of 7.7 adults/m^2/day was collected during the May 25 sample period. There was no significant difference in the

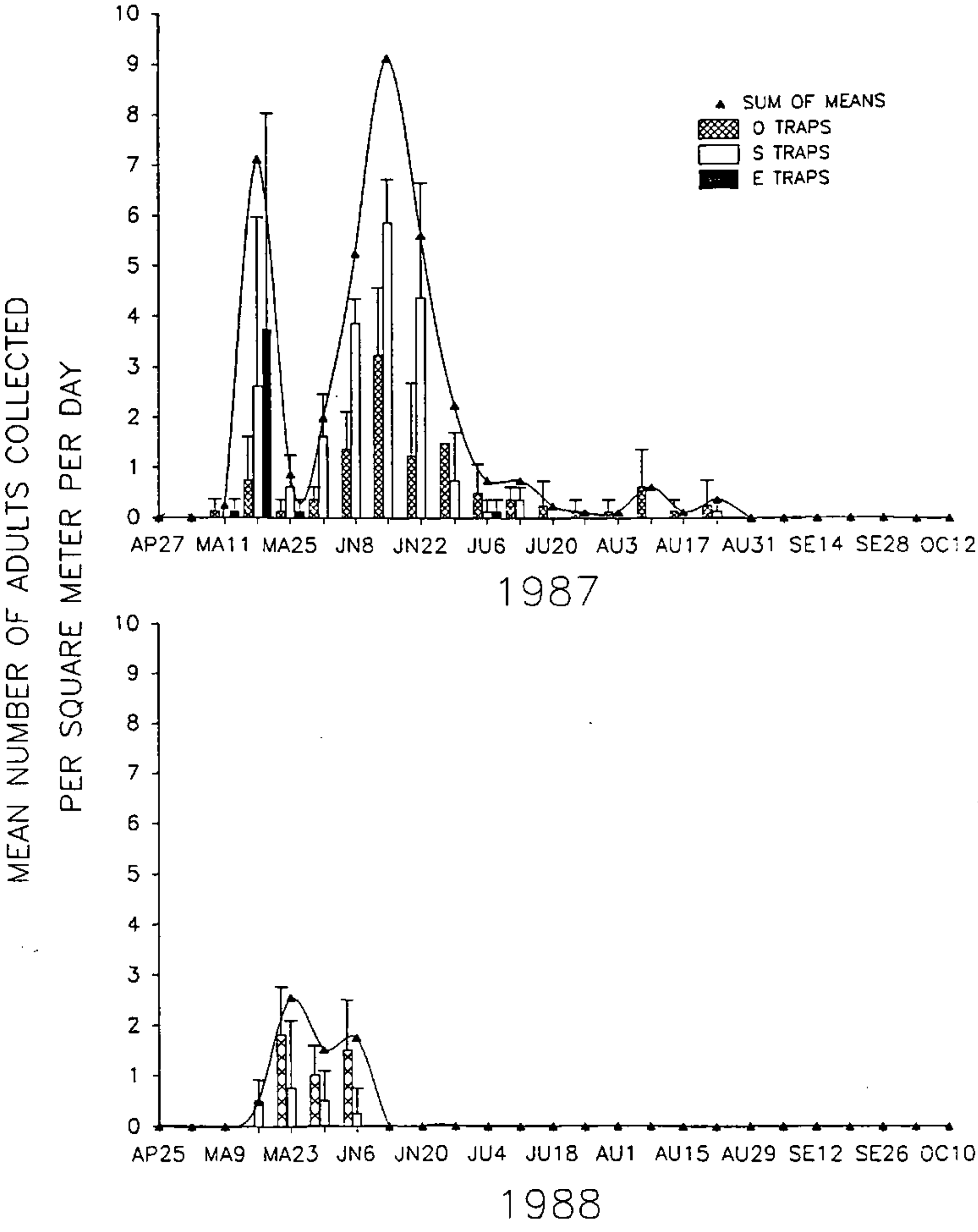


Figure 30: Mean daily adult emergence density (+1sd) of Ablobesmyia pulchripennis.

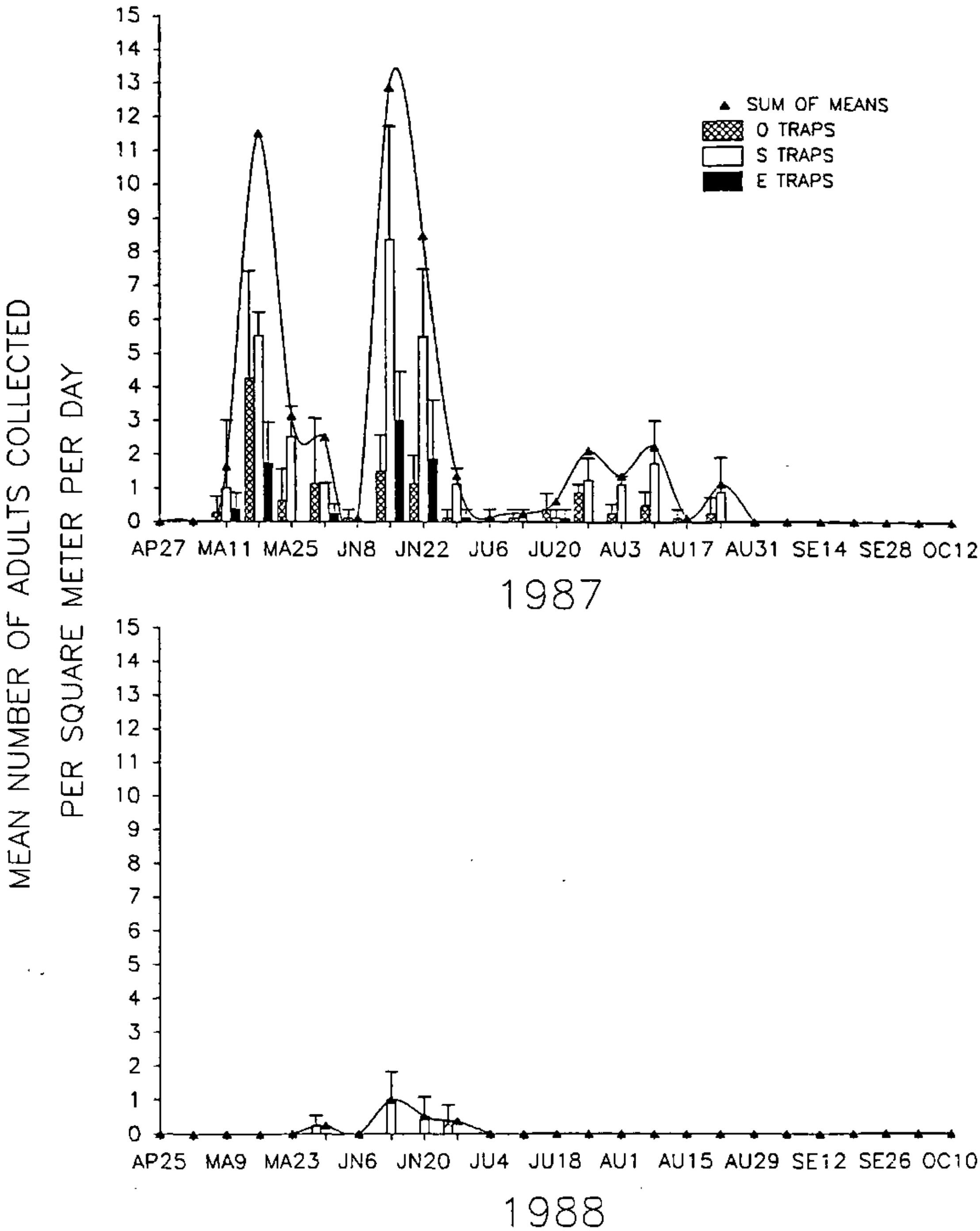


Figure 31: Mean daily adult emergence density (+1sd) of Ablabesmyia monilis.

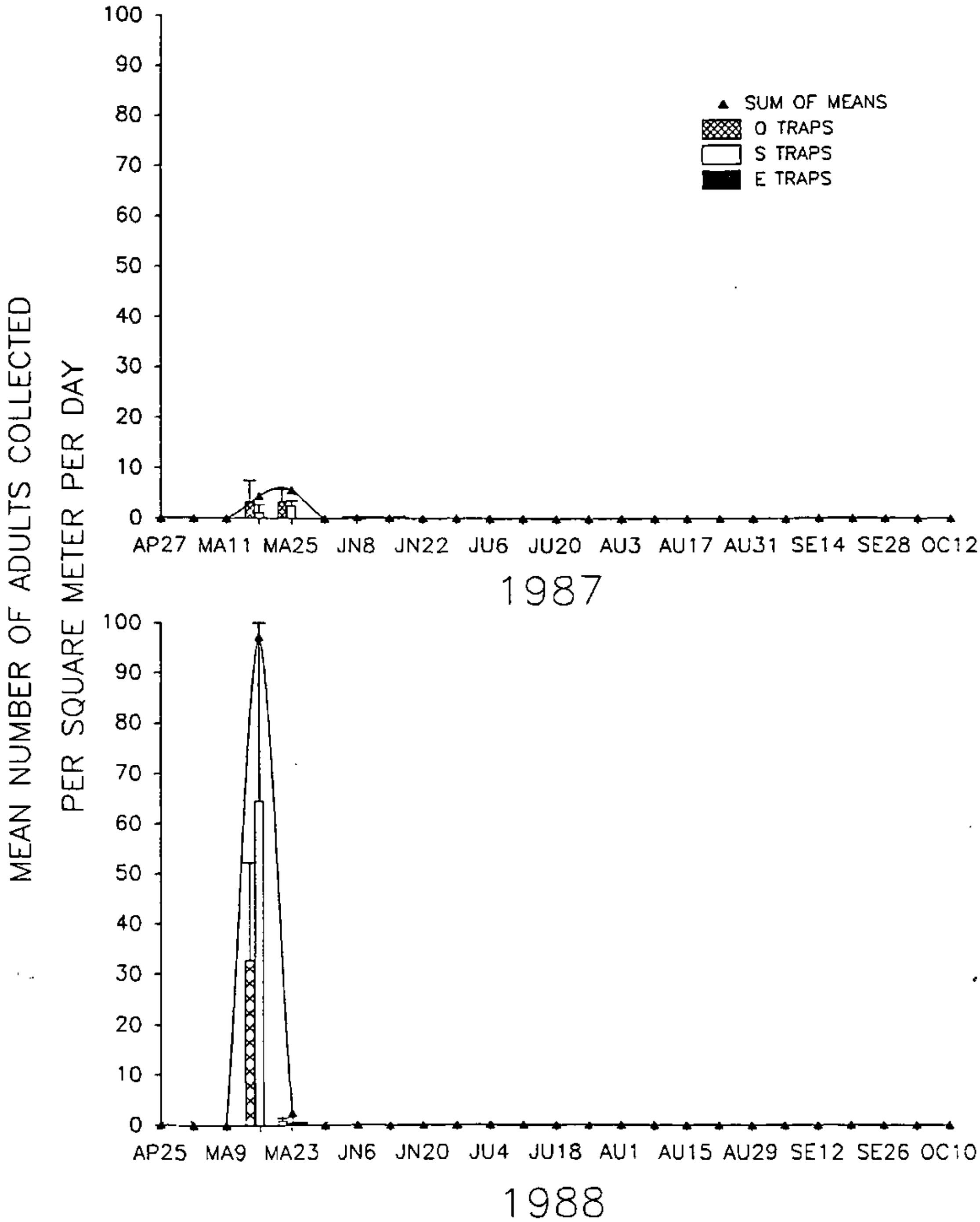


Figure 32: Mean daily adult emergence density (+1sd) of Cladopelma viridulus.

number of adults collected from each station (P = 0.257). In 1988, the emergence lasted two weeks from May 16 to May 23. A total of 652 adults were collected. The largest average daily emergence was 96 adults/m^2/day during the May 16 sampling period. There were no significant differences among the trap stations in the number of adults collected (P = 3.478).

In 1987, 288 adults of Parachironomus monochromus (Wulp) were collected from the pond. Adult emergence began May 25 and continued to August 24 (Figure 33). The largest average daily emergence of 8.2 adults/m^2/day occurred during the June 29 sampling period. The O and S trap stations collected significantly more adults than the E station (P = 0.000). In 1988, 147 adults of P. monochromus were collected. The emergence period began on May 23 and continued to June 27. The peak emergence occurred during the May 30 sampling period when an average of 8.7 adults/m^2/day was collected. The O traps collected significantly more adults than the E traps (P = 0.009).

Cricotopus pilitarsus Zetterstedt was collected in 1987 only. Emergence began on May 18 in 1987 and continued to September 7 (Figure 34). A total of 1114 adults was collected. Emergence peaks occurred during the May 25, June 15 and August 10 sampling periods. The largest average number of adults, 21 adults/m^2/day, was

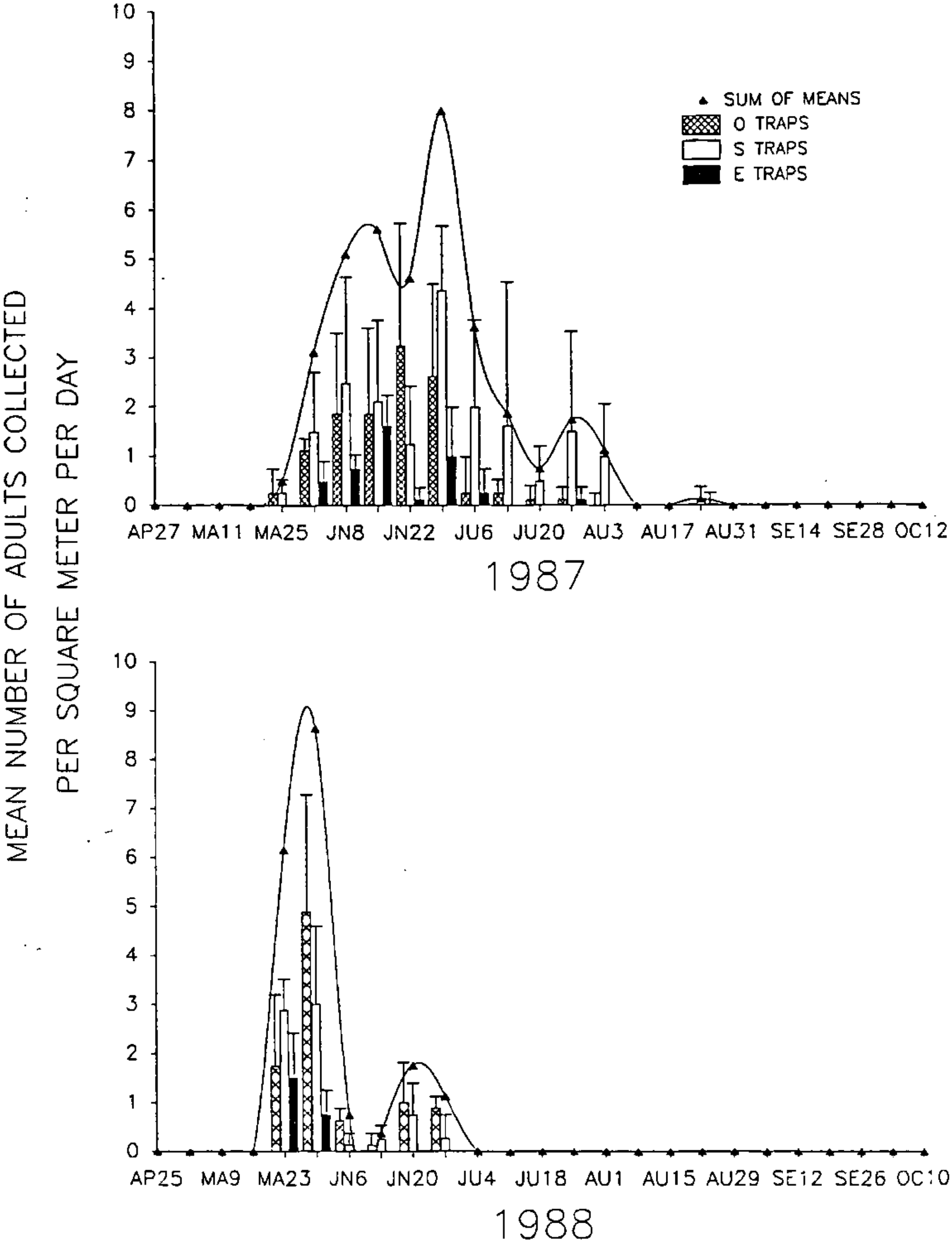


Figure 33: Mean daily adult emergence density (+1sd) of Parachironomus monochromus.

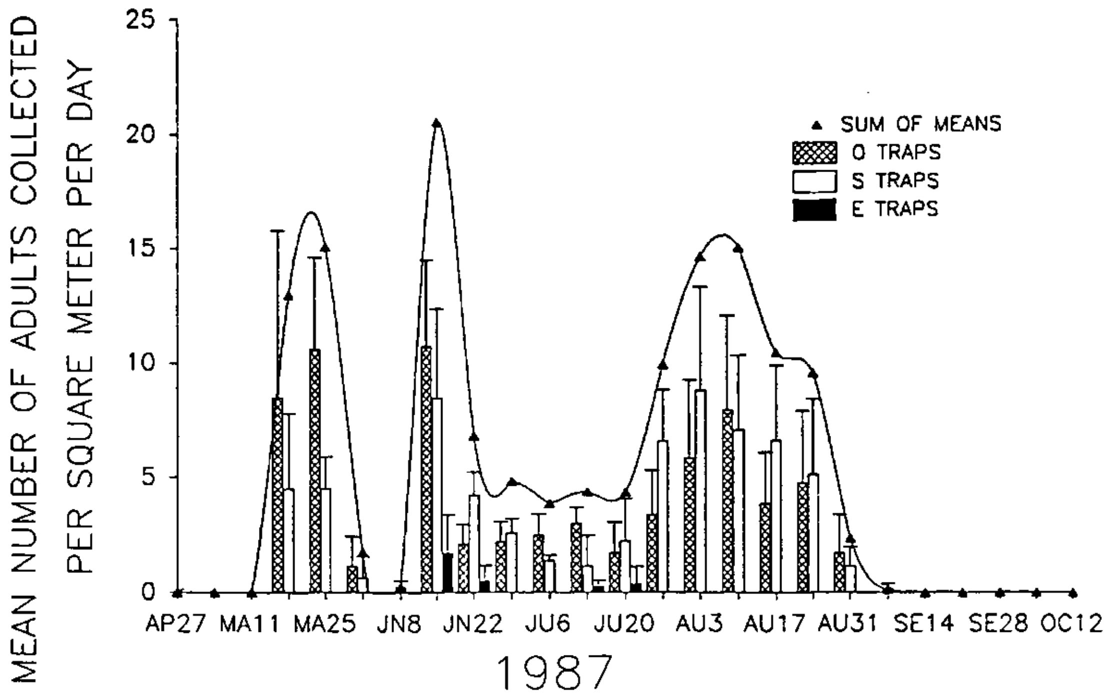


Figure 34: Mean daily adult emergence density (+1sd) of Cricotopus pilitarsus.

collected during the June 15 sampling period. The O traps and S traps collected significantly more adults than the E traps (P = 0.000).

Emergence of Cricotopus cylindraceus Kieffer, in 1987, began on May 11 and continued to September 28 (Figure 35). A total of 445 adults was collected. Peak emergence occurred during the June 15 sampling period when a mean of 31 adults/m^2/day was collected. There was no significant difference among the three stations in the number of adults collected (P = 0.106). In 1988, only 13 adults were collected from May 16 to June 20.

A total of 477 adults of Psectrocladius simulans Johannsen was collected in emergence traps in 1987 between May 11 and September 7 (Figure 36). There were two emergence peaks, one beginning during the June 15 sampling period and continuing to June 29, and another, smaller one, during the August 3 trapping period. The highest mean daily emergence occurred during the June 22 sampling period when 13.9 adults/m^2/day were collected. There was no significant difference among the stations in the number of adults collected (P = 0.138). In 1988 only ten specimens were collected from May 2 to May 23.

Corynoneura cf scutellata Winn. was collected in 1987 and 1988 (Figure 37). In 1987, 4025 adults were collected in the traps from May 4 to September 28. Three emergence peaks were recorded, one on June 15, another on

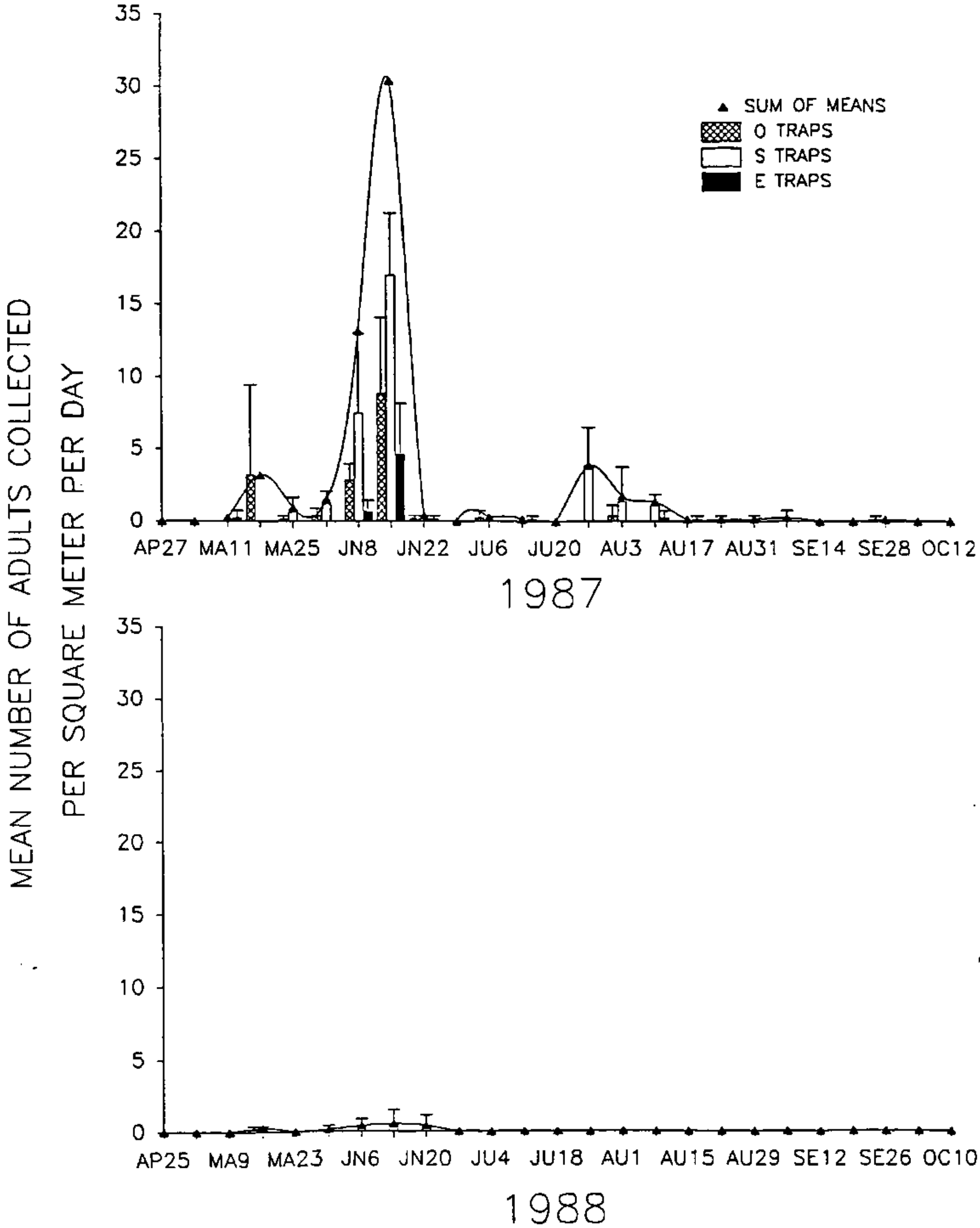


Figure 35: Mean daily adult emergence density (+1sd) of <u>Cricotopus cylindraceus</u>.

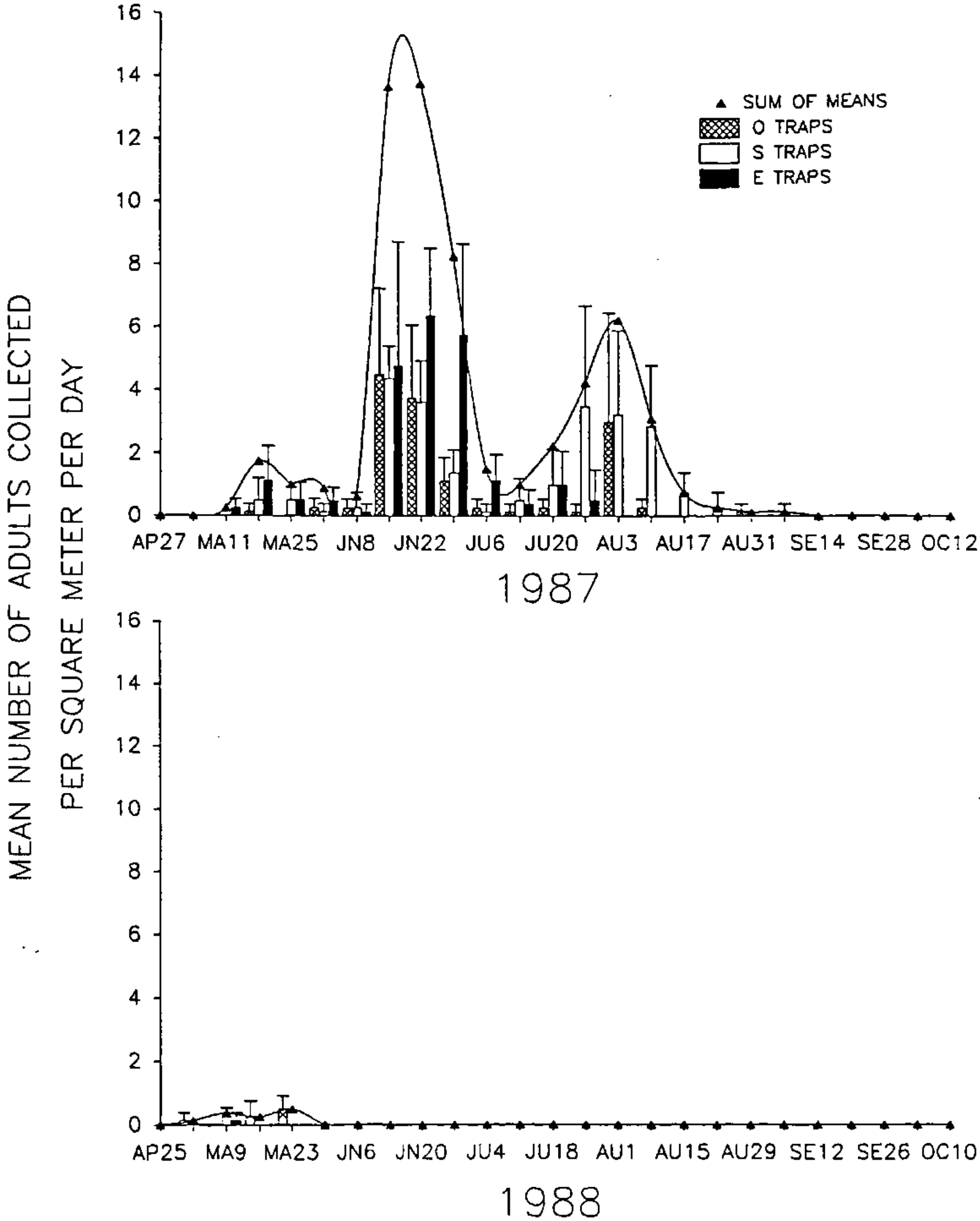


Figure 36: Mean daily adult emergence density (+1sd) of Psectrocladius simulans.

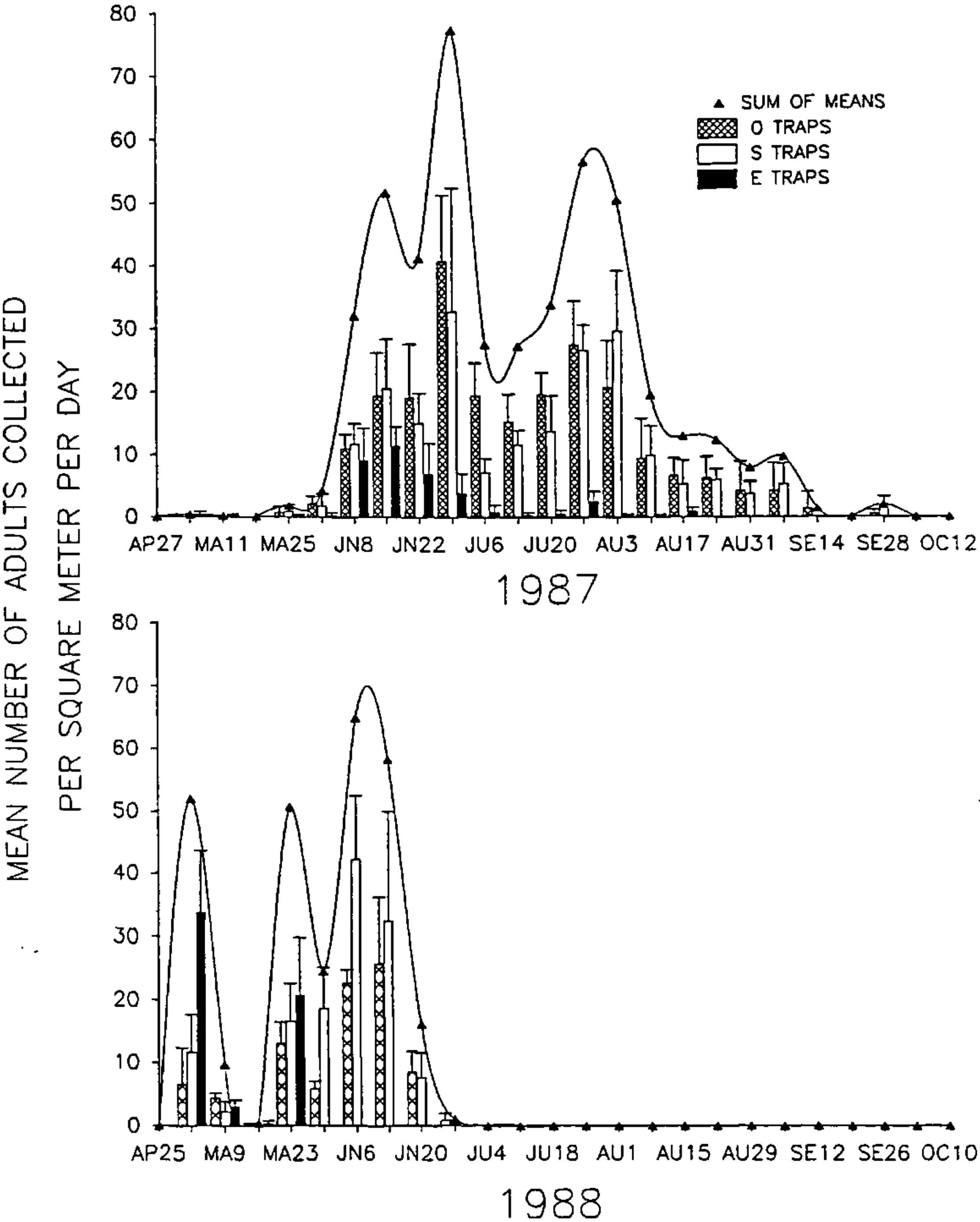


Figure 37: Mean daily adult emergence density (+1sd) of Corynoneura cf scutellata.

June 29 and a third on July 27. The largest emergence occurred during the June 29 sampling period when an average of 77 adults/m^2/day was collected. The O traps collected significantly more adults than the E traps ($P = 0.001$).

In 1988, the emergence period of C. cf scutellata was reduced to nine weeks beginning on May 2. The number of adults collected declined to 2218. There were three emergence peaks, one on May 2, the second on May 23 and another from June 6 to June 13. The largest emergence was during the June 6 sampling period when an average of 67.2 adults/m^2/day was collected. In 1988, there was no significant difference in the number of adults collected among the three stations ($P = 0.72$).

Mesosmittia acutistylus? Saether was collected in 1988 only. Emergence began on April 25 and continued to May 16 (Figure 38). A total of 408 adults was collected. The largest adult emergence occurred during the May 2 sampling period when an average of 44.5 adults/m^2/day were collected. The E traps collected 93 % of the adults which was significantly more than the other two trap stations ($P = 0.023$).

In summary, the ten abundant species of Chironomidae all declined in numbers between 1987 and 1988 except Cladopelma viridulus and Mesosmittia acutistylus?. One species, Cricotopus pilitarsus was absent from

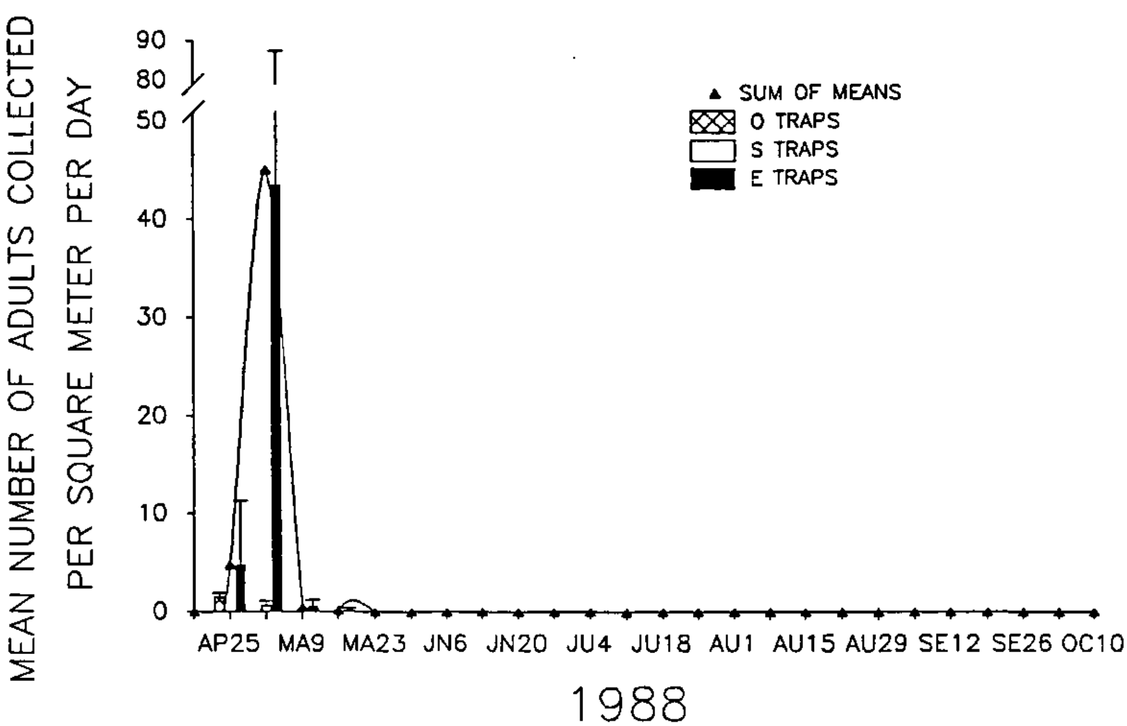


Figure 38: Mean daily adult emergence density (+1sd) of Mesosmittia acutistylus.

collections in 1988 after being abundant in 1987. In 1987 most of the species had long emergence periods of three or four months with multiple emergence peaks. In 1988 the emergence periods of these species were shorter and the peaks much smaller. Two species, *Cladopelma viridulus*, in both years, and *Mesosmittia acutistylus*? in 1988, had short, early, emergence periods lasting less than three weeks with only a single emergence peak. None of the species emerged more than 2 weeks earlier in 1988 than they did in 1987.

In 1987, all the species examined in detail except *Cladopelma viridulus*, *Cricotopus cylindraceus*, and *Psectrocladius simulans*, were collected in significantly greater numbers in the O or S traps than in the E traps. In 1988, significantly more adults of *Parachironomus monochromus* were collected in the O traps than in the E traps. For *Mesosmittia acutistylus*? significantly more adults were collected in the E traps than in either of the other trap stations in 1988.

4.3 Qualitative Sampling Results and Observations

Over five hundred successful rearings were made from immatures collected during the study. Several Coleoptera, Ceratopogonidae and Chironomidae rearings included larval, pupal and adult stages. Eight associations of parasitic Hymenoptera with host species were also made.

Larvae of Callibaetis pallidus, Aeshna interrupta, Coenagrion and Enallagma, Chaoborus americanus, and Chironomidae were collected in the late fall of 1986 and under the ice in March 1987. Early instar Lestes larvae emerged from stems of Scirpus sp. collected from the pond in March 1987 and left in water at room temperature.

In the spring of 1987 mature larvae and pupae of C. americanus and large Coenagrionidae larvae were very common in the pond. In the late fall of 1987 larvae of C. pallidus, Coenagrionidae, Aeshna, and C. americanus were numerous.

In the spring of 1988 only Coenagrionidae larvae were abundant. Mid-instar C. pallidus larvae were collected in mid June.

5. DISCUSSION

5.1 Species Composition

Over the three years Pond LC was studied 115 species were collected in the emergence traps. This represents only a portion of the insects inhabiting Pond LC. The chironomid tribe Tanytarsini and the Hymenoptera were only studied superficially due to taxonomic difficulties. The study was also restricted to male Chironomidae so any parthenogenetic species were not included. Furthermore, specimens of Coleoptera and Hemiptera were not collected in the emergence traps so species of these two orders were not included in the study although they were present in the pond. If these groups were included the species count would probably reach 150 or more.

No comparable studies of insect emergence or species lists exist for Saskatchewan ponds. The number of species collected in 1987 (74) and 1988 (45) are comparable to the numbers collected in a large, shallow marsh near London, Ontario (Judd 1949, 1953). Judd collected 41 and 68 species in 1949 and 1953 respectively from Dundas Marsh. However, Judd did not identify one third of the chironomids he collected. Although the species diversity of Dundas Marsh is similar to Pond LC, the species lists are not. Only sixteen species from the 1949, Dundas Marsh study and 14 from 1953, were also collected from Pond LC. The low number of species in common between Dundas Marsh and Pond LC is due to differences in habitat, climatic conditions and faunal distributions.

Dundas Marsh was a permanent marsh about 17 hectares in area with many streams flowing into it (Judd 1953). These streams would stabilize water levels and be a source of immigration. Pond LC was much smaller, only .4 hectares at its largest, and was isolated from all other aquatic habitats.

In the St. Lawrence Lowlands the summers are long and warm, while the winters are mild and wet (Danks 1979). Average July temperatures are between 18 and 22^0 C, while January temperatures average between 2 and -7^0 C. Precipitation averages between 800 and 1500 mm (Zoltai 1987). In the interior plains of Canada the average July temperatures are similar, but the mean January temperatures are -12 to -18^0 C and the mean precipitation is only 300 to 500 mm (Zoltai 1987). As a result the marsh studied by Judd was probably nonaestival and more stable than Pond LC.

Many of the species Judd collected including, Acerpenna pygmaea (Hagen) [= Baetis pygmaeus Hagen in Judd (1949)], Lestes rectangularis Say, and Enallagma vesperum Calvert are restricted to the eastern part of North America (McCafferty and Waltz 1990; Walker 1953). Therefore comparisons between the two studies must be further qualified by the faunal differences of the two regions.

The mayflies collected in Pond LC, Caenis youngi, Callibaetis pallidus and Cloeon sp, have all been reported from prairie pond habitats (Check 1984; Corkum 1984; Flannagan and MacDonald 1987; Provonsha 1990). Corkum (1984) collected two species of mayflies; Caenis youngi (as C. simulans) and Cloeon sp, from a nonaestival, permanent pond in central Alberta (Corkum 1984). However, Corkum apparently did not collect C. pallidus.

Wiggins et al. (1980), collected species of Siphlonurus, Leptophlebia, and Paraleptophlebia praepedita Eaton and Callibaetis ferruginous (Walsh) from nonaestival ponds and temporary ponds in Southern Ontario. Judd (1953) reported only three species of mayflies from Dundas Marsh. The lower number of species collected in Dundas Marsh and Pond LC is probably due to different sampling methods. Wiggins et al. (1980) collected immature stages some of which would probably not reach maturity in the temporary ponds. The emergence traps used in the other two studies would only collect those species that successfully completed their life cycles.

The sixteen odonate species, eight Anisoptera and eight Zygoptera, collected from Pond LC have all been recorded from ponds or marshes in Saskatchewan (Hilton 1987; Walker 1953; Walker 1958; Walker and Corbet 1975; Wiggins et al. 1980). In a permanent nonaestival pond, nine km Southwest of Pond LC, ten zygopteran species and three anisopteran species were collected (Sawchyn 1971). The lower number of Anisoptera collected by Sawchyn may be due to the emphasis of his investigation on the Zygoptera rather than real differences in the fauna of the two ponds.

Seven species were common to Sawchyn's study and this study. Enallagma ebrium was not collected from Sawchyn's pond but Lestes dryas, Coenagrion interrogatum and Enallagma clausum were collected in addition to those species found in Pond LC. The absence of E. ebrium from Sawchyn's pond may have been due to competition from other species.

L. dryas appears to prefer temporary habitats. Sawchyn collected it in low numbers from the permanent pond he was studying but found it more abundant in temporary habitats such as road side ditches (Sawchyn 1971). Cannings et al. (1980) also found L. dryas inhabiting temporary ponds in British Columbia but did not collect it from larger permanent ponds. However, Daborn (1974) recorded L. dryas along with five other damselflies, Coenagrion angulatum, C. resolutum, Enallagma boreale, L. forcipatus, and L. disjunctus, from an aestival pond in Alberta. The three Lestes species were reported only after aestival conditions and after the pond was in a transition to a temporary condition (Daborn 1974). Since Pond LC was permanent in 1986 and 1987, it may not have been a preferred habitat for L. dryas and it may have been absent, or so rare that it was not collected.

Adults of Sisyra vicaria (Neuroptera: Sisyridae) were collected from Pond LC in 1987. The larvae of this family are parasites of freshwater sponge (Clifford 1990; Pennak 1978). Freshwater sponge, Spongilla lacustris, was collected from the pond in 1986 but none was observed in 1987. The presence of S. vicaria in 1987 indicates that some sponge was present in the pond in 1987.

All but one Trichoptera species, Hydropsyche alternans?, collected from Pond LC have been previously associated with pond and marsh habitats (Flannagan and MacDonald 1987; Nimmo 1971; Nimmo 1986; Smith 1984; Wiggins 1977; Wiggins et al. 1980; Wrubleski and Ross 1989). The presence of H. alternans? was unusual. Nimmo (1987) reported that H. alternans can live in a wide range of habitats including cold or warm creeks and rivers and the wave-washed shores of large lakes. The presence of adults in the collections suggests this species was either a resident of Pond LC, or the specimens were attempting to oviposit in the pond. The latter explanation is plausible since all the specimens collected were gravid females and Hydropsychidae females are known to dive under the water to oviposit (Smith 1984).

The Diptera were the most diverse and abundant order collected. The Ceratopogonidae species, Bezzia glabra, B. bicolor, and B. cockerelli appear to be new records for Saskatchewan (Wirth 1983; Wirth et al. 1984). Of the 43 species of Chironomidae collected in Pond LC, nine are new records for the province; Guttipelopia rosenbergi, Parachironomus forceps, P. varus, Paratanytarsus laccophilus, Tanytarsus buckleyi, Acricotopus lucens, Cricotopus cylindraceus, C. flavocinctus, and Orthocladius smoclandicus (Mason et al. 1991; Oliver et al. 1990). Mesosmittia acutistylus? is a new record for the genus in Canada (Oliver et al. 1990). One species, Polypedilum n. sp., is new to science. This illustrates how little is known about pond insects, particularly the Chironomidae.

The Chironomidae was the most diverse Diptera family in Pond LC. The number of species of chironomids collected (43) is comparable to other pond studies in Saskatchewan. In a semipermanent pond 10 km south of Pond LC, 36 chironomid species were collected (Parker 1985). Only 14 species were common between the two studies suggesting there may be large differences in the composition of chironomids between ponds. This was observed by Morrill (1988) who found a total of 41 species in four semipermanent ponds. The communities of the four ponds had about 33 % of the species in common even though the greatest distance between them was less than 5 km (Morrill 1988). Driver (1977) collected 48 species in a survey of 16 ponds of differing permanence near Saskatoon, Saskatchewan. His study showed there were large differences in the chironomid communities of ponds with different stabilities.

The number of species collected from Pond LC was much lower than the 84 species reported from a marsh in Manitoba (Wrubleski and Rosenberg 1990). Only 23 species of those groups studied were common between the two habitats. This marsh was continuous with a network of marshes that kept the water level stable and was a nearby source of immigrating females.

The aquatic insect species emerging from Pond LC were predominantly species associated with vegetation. Benthic species such as the *Chironomus* species were collected in low numbers. This was probably caused by the lack of open water in Pond LC and the great abundance of submerged vegetation and algae that formed thick stands and mats throughout the pond. Thick stands of submerged vegetation are known to reduce the abundance of benthic insects. Johnson and Mulla (1983) found chironomid emergence was less over thick stands of Myriophyllum spicatum compared with nonvegetated regions, although diversity was greater in the vegetated regions. They attributed these results to an abundance of tube dwelling Chironomus and Tanytarsus larvae and substrate foraging Procladius larvae in the nonvegetated areas. These genera were greatly reduced in the vegetated regions.

Wrubleski (1989) also found differences in the chironomid communities in vegetated and unvegetated areas. He found that in exclosures, where Potomogeton pectinatus was abundant, emergence of epiphytic chironomids such as most of the Cricotopus species and Corynoneura scutellata was higher than in areas where duck feeding eliminated the pond weed. In contrast benthic chironomids such as the Chironomus species were apparently absent in the exclosures but were abundant outside the exclosures (Wrubleski 1989).

The low number of benthic chironomids in areas of dense vegetation may be caused by the shading effects of the vegetation (Johnson and Mulla 1983). The shading of the benthos by dense vegetation would reduce diatom and algal growth on the substrate which are important food for benthic chironomids (Rasmussen 1984; Wrubleski 1989). The vegetation also reduces the oxygen concentration and temperature of the benthos (Kornijow et al. 1990) which may reduce or eliminate some species.

In summary the general insect fauna of Pond LC had some similarities to the fauna of other ponds and marshes. However, differences in species between Pond LC and other ponds studied in the same region suggest there are large differences in the insect communities of different ponds. This has significance in experimental research where a number of ponds are used to examine results of an experiment on the insect community. The natural variability between ponds may obscure differences caused by the impact.

Fourteen species of Diptera collected in Pond LC are new records for the province. One is a new record for the genus in Canada and one species is new to science. Gravid females of a lotic species of Hydropsychidae were unexpectedly collected in Pond LC.

The thick vegetation in Pond LC resulted in species associated with vegetation dominating the insect community rather than benthic insects which were collected in very low numbers.

5.2 Species Emergence Periods and Patterns

Collections of emerging adults provide valuable information on emergence periods of insect life cycles. However, without detailed data on immature growth the generation period of the insect populations cannot be conclusively determined (Butler 1984). With only emergence data it is also difficult to determine if an observed emergence pattern with two peaks is the result of a truly bivoltine population or if it is two cohorts, one univoltine and the other semivoltine (Butler 1984). Extended emergence periods are also a problem to analyze since it could result from a single asynchronous population or a series of overlapping generations.

The emergence patterns in Pond LC were described by the number of obvious peaks; such as unimodal when there was a single emergence peak, rather than as univoltine, which implies the peak is the result of a single generation. Where enough life history information is available, the voltinism of the species in Pond LC is suggested.

5.2.1 Ephemeroptera

In 1987 C. pallidus appeared to have a bimodal emergence. The adults collected in the small June peak probably resulted from overwintering larvae. The larger emergence in late August and September would have been from spring oviposition by resident and immigrating females. This type of life cycle is referred to as a seasonal bivoltine winter-summer cycle (Clifford 1982). One generation overwinters in the larval stage and emerges in the spring. A second generation is completed in the summer and early fall. The females of the summer generation then oviposit to begin the winter generation.

Check (1982) reported that in temperate regions of North America C. pallidus begins emerging in March or April and emergence continues until September or October. In a Minnesota pond C. pallidus (as C. brevicostatus Daggy, Check (1982)) emerged in two peaks, one in early spring and the other in August and September (Dineen 1953). The population in Pond LC has a slightly delayed onset of spring emergence compared with Check's and Dineen's studies. This is likely due to a geographical difference in the onset of suitable temperatures for development.

5.2.2 Odonata

Aeshna interrupta had a single emergence peak in Pond LC. The emergence period observed in Pond LC corresponds to the flight period of late June through August reported for this species (Walker 1958). Most species of Aeshna, in temperate regions, overwinter as eggs during the first year (Corbet 1980) and then as larvae for the next two or three years before emergence (Norling 1971; Walker 1953).

Lestes congener, and L. disjunctus/unguiculatus had unimodal emergence patterns in Pond LC. Sawchyn (1971) reported that these species had a univoltine life cycle in a pond near Pond LC. The eggs are laid into emergent vegetation in July and August. All three species overwinter as eggs. The following spring the eggs hatch and the larvae develop to maturity and the adults emerge in June and July (Sawchyn and Gillott 1974). A similar life cycle pattern was observed by Baker and Clifford (1981) in a boreal pond for L. disjunctus.

Coenagrion angulatum and C. resolutum had unimodal emergence periods in Pond LC. Life history information from a pond near Pond LC suggests these species most likely have univoltine life cycles (Sawchyn and Gillott 1975). Similar emergence patterns and times as in Pond LC were recorded for these two species from an Alberta aestival pond (Daborn 1974). Females oviposit into submerged vegetation in late May to late July (Sawchyn and Gillott 1975). The eggs hatch shortly after oviposition and the larvae develop to the last three instars before low water temperatures in the late fall stop development for winter (Sawchyn and Gillott 1975). In early May larval development resumes until adult emergence in June (Sawchyn and Gillott 1975).

In contrast to the above population, Baker and Clifford (1981) found a population of C. resolutum in northern Alberta that was in reality two cohorts. One was univoltine, similar to the population investigated here, and the other had a two-year life cycle. Baker and Clifford (1981) attributed the two different life histories to a combination of genetic control, extended oviposition period and diet differences. There is no evidence of this occurring in the Saskatoon populations.

Enallagma ebrium had an unimodal emergence pattern in both years. Walker (1953) reported the flight period of E. ebrium was similar to the emergence periods recorded in this study. Oviposition has been reported as endophytic (Kellicott 1899, cited in Walker 1953). The general aspects of the life cycle are likely similar to other Coenagrionidae found in Pond LC.

E. cyathigerum also had an unimodal emergence pattern in Pond LC. Walker (1953) reported the flight period of this species lasted from early June to late August. The population in Pond LC emerged until early August, producing adults that would fly until the middle of August. Macan (1964) reported that some larvae of this species required three years to reach maturity in a moorland pond in Britain. Macan's pond was only a few degrees cooler than Pond LC. Food and space competition also played a role in the delay of emergence. If such processes were acting on the population in Pond LC some individuals may require more than a single year to reach maturity. The emerging population would then consist of two or possibly three cohorts as recorded for C. resolutum by Baker and Clifford (1981).

In summary, all the odonates studied in detail exhibited an unimodal emergence period. This suggests univoltine life cycles for the Lestidae and probably for the Coenagrionidae species as well. There is however evidence from the literature to suggest that some of the Coenagrionidae larvae may have taken longer than one year to complete development. Although A. interrupta had a unimodal emergence pattern in Pond LC, information from the literature suggests that it requires two or three years to complete its life cycle.

5.2.3 Neuroptera

The Sisyridae, is the only family of the order with aquatic species (Kevan 1979). Sisyra vicaria larvae are parasitic on freshwater sponges (Evans and Neunzig 1984). The larval stage develops through three instars and then the mature larva crawls out of the water and spins a pupal cocoon (Evans and Neunzig 1984). The adults collected probably resulted from larvae using the emergence traps as pupation substrates.

5.2.4 Trichoptera

Agraylea multipunctata had a single large emergence peak in 1988 suggesting an unimodal emergence. In Dundas

Marsh, southern Ontario, this species had two peak emergence periods, in the middle of May and the middle of August (Judd 1953). *A. multipunctata* may have had the potential for two emergences in Pond LC but the pond dried up in 1988 before the second emergence could occur. Females of *A. multipunctata* oviposit beneath the surface of the water (Wrubleski and Ross 1989). Therefore the number collected in the emergence traps may be a combination of emerging adults and ovipositing females swimming under the emergence traps before leaving the water.

5.2.5 Diptera

5.2.5.1 Chaoboridae

C. americanus had a single large emergence peak in early May in 1987. This species is univoltine. Eggs are laid in late spring and the larvae grow throughout the summer (Borkent 1979). The larvae overwinter as diapausing fourth instar larvae in permanent ponds and lakes (Bradshaw 1973). Pupation occurs in early spring followed by adult emergence (Borkent 1979; Fedorenko and Swift 1972). A similar pattern occurred in Pond LC. Late instar larvae were observed before freeze up in 1986. The following spring larvae and pupae were observed followed by emergence in early May 1987. Therefore the population was univoltine in Pond LC.

Although most of the population emerged by the middle of May, a small portion did not emerge until early June. This suggests a second morph in the population. Bradshaw (1973) described the existence of two larval morphs; one developing rapidly to emerge in early spring. The second develops more slowly and emerges up to 20 days later. These later emerging adults may have a better chance of survival. Bradshaw suggested that this development pattern may be an adaptation that protects the population from being wiped out by unfavourable early spring weather. Such an adaption would be very important in temperate regions such as the Canadian prairies where spring weather conditions can change rapidly. The emergence pattern of *C. americanus* in Pond LC appears to fit the pattern described by Bradshaw. Most of the population would therefore be of the early morph.

5.2.5.2 Ceratopogonidae

B. annulipes/japonica group had a long emergence period lasting 15 weeks in 1987. The emergence period was similar in length to that of *B. annulipes* in German streams (Havelka 1976). During this time it had at least a bimodal emergence pattern that suggests two generations, one emerging in May and a smaller one emerging during July. In 1988, however, there was only a single emergence peak in late May before the pond dried up. Most species of Bezzia are known to overwinter in the larval stage (Wiggins et al. 1980). The bimodal emergence pattern observed may be due to a difference in the emergence times of the species making up the group or an overwintering generation followed by a summer generation as reported for Callibaetis pallidus. Further study is needed to determine which is correct.

During both 1987 and 1988 Bezzia bicolor had an emergence period lasting about one month. In both years there were two emergence peaks. However the onset of emergence was one month earlier in 1988. This was probably caused by the earlier spring and the warmer temperatures experienced in 1988.

Bezzia glabra had a bimodal emergence pattern in 1987. Judd (1953) reported that Bezzia (=Probezzia) glabra, emerged from early June to late August with a small peak in the middle of August in southern Ontario. This emergence period was similar to that recorded in Pond LC in 1987. However the peak emergence occurred in late June and early July compared to the middle of August in Judd's study. A possible explanation is that the overwintering generation was larger in Pond LC and therefore produced a larger first emergence peak in late June compared to Judd's study.

5.2.5.3 Chironomidae

In 1987 _Ablabesmyia_ _illinoensis_ had an emergence period of 15 weeks with at least two large, distinct emergence peaks, one in the middle of June, the other in the middle of August. This species apparently had a bimodal emergence in Alabama, the first in April and the second in July (Dendy 1971). The earlier emergence times in Alabama are consistent with an earlier onset of development in the spring. Adults of _A_. _illinoensis_ were collected sporadically and in low numbers in a Manitoba marsh from the middle of May to the middle of July (Wrubleski 1984). The shorter emergence period recorded in Wrubleski's study may be due to the later emergence being missed because the species was rare.

_A_. _pulchripennis_ has been recorded from semipermanent and permanent ponds in Saskatchewan (Driver 1977; Parker 1985). In 1987, the population in Pond LC had a bimodal emergence period lasting 16 weeks. A similar emergence period for this species was reported by Wrubleski (1984), who collected _A_. _pulchripennis_ from a Manitoba marsh but the numbers were too low to determine emergence patterns.

_A_. _monilis_ had an extended trimodal emergence period in 1987 lasting 16 weeks. This suggests possibly three generations. The first from overwintering larvae, the second from spring ovipositing females and the third from later emerging females. Emergence periods of similar lengths have been reported for this species in Ontario (Judd 1964, 1953) and in Southern Indian Lake, Manitoba (Rosenberg et al. 1980). However, in Delta Marsh, Manitoba (Wrubleski 1984), the emergence period was only half as long. A. monilis had a bimodal emergence pattern in Southern Indian Lake (Rosenberg et al. 1980) that occurred about one month later than in Pond LC, which may be due to the cooler temperatures in the lake compared to Pond LC.

All three Ablabesmyia species collected in Pond LC have at least bimodal emergence patterns. Wiggins et al. (1980) suggests that species of Tanypodinae, including Ablabesmyia, are multivoltine. The larvae overwinter in permanent water and the adults emerge in early spring and a series of generations occur during the summer. This appears to agree with the emergence patterns observed in Pond LC. The first emergence peak would result from overwintering larvae while the second would be from oviposition by resident and immigrating females.

Cladopelma viridulus had an early, short, unimodal emergence period during both years. This contrasts with other studies that report prolonged emergence periods (Dendy 1971; Wrubleski 1984). The absence of any further emergence in 1987 suggests that the unimodal emergence in 1988 was not caused by the pond drying up in July.

Therefore this species was univoltine in Pond LC. C. viridulus may be a group of species or subspecies, with different distributions and different emergence times. Another possible reason for the differences in emergence periods may be that some environmental feature in Pond LC restricted the emergence to the early spring. More research is needed to investigate these differences.

Parachironomus monochromus had a long emergence of 14 weeks in 1987, beginning in late May. A similar emergence period was reported for this species from a small British pond (Learner and Potter 1974). A related species, Parachironomus potamogeti, had a comparable emergence period lasting from the middle of May to the middle of September at Delta Marsh (Wrubleski 1984). The long emergence period with three peaks suggests that P. monochromus was multivoltine or had an asynchronous emergence. The presence of two peaks in 1988 support this.

In 1987, Cricotopus pilitarsus had a 17 week emergence period beginning on May 18 with at least three emergence peaks and probably three generations. The May peak would have resulted from overwintering larvae forming a discrete emergence peak while the other two peaks would have resulted from progeny of resident and immigrant females. Different recruitment times may have caused the more extended emergence period in late July and August.

Cricotopus cylindraceus emerged sporadically throughout 1987. The population had one large emergence in the middle of June but there is evidence of smaller emergences in the middle of May and in late July. This species was rare and only emerged for a brief period in the middle of May in a pond at Delta Marsh, Manitoba (Wrubleski 1984). The short emergence time reported by Wrubleski may be due to the low numbers collected.

LeSage and Harrison (1980) studied the biology of *Cricotopus* species inhabiting a stream in Ontario. They suggested that all the species collected had five generations per year; a large spring emergence, followed by three smaller summer ones, and a variable autumn emergence. In Pond LC the emergence patterns of *C. pilitarsus*, and to a lesser extent *C. cylindraceus*, have at least three peaks rather than five. An examination of larval growth coupled with emergence data would determine the number of generations in Pond LC.

Psectrocladius simulans had a bimodal emergence in 1987 that suggests there were two generations. In the Saskatchewan River Mason (1983) reported that this species emerged in July and August. This was much shorter than the May to September emergence period observed in Pond LC.

Corynoneura cf scutellata had a long trimodal emergence period beginning in early May and continuing to early October in 1987. Three peaks, one in the middle of June, one in late June and a third, more asynchronous, one month later, was evident in the 1987 emergence period. In 1988 there was also three peaks, early May, late May and early June. In a Manitoba marsh the peak emergence was in July with a series of peaks increasing to the middle of July (Wrubleski 1984). The emergence peaks observed in Pond LC could be the result of several overlapping generations. Some species of Corynoneura are known to complete larval development in five days at 15^0 C (Mackey 1977). This would enable a large number of generations to occur in the pond. This ability to develop rapidly may have produced the early and large emergence peaks observed in 1988.

Very little is known about the species in the genus Mesosmittia. Most are considered semiaquatic or terrestrial in habit but at least one species has been collected from rivers in England (Cranston et al. 1983). The very short, unimodal emergence period suggests Mesosmittia acutistylus? was univoltine in Pond LC. The predominance of shore-collected specimens suggests that this species is probably semiaquatic.

5.2.5.4 Summary of Diptera Emergence

The emergence patterns of the Diptera species in Pond LC ranged from unimodal, for _Chaoborus americanus_, _Cladopelma viridulus_, and _Mesosmittia acutistylus_?, to multimodal for species such as _Cricotopus pilitarsus_, and _Corynoneura_ cf _scutellata_. Unfortunately there is very little information available about the life histories and emergence phenologies for most of the Ceratopogonidae and Chironomidae species that were collected in Pond LC. This makes it difficult to compare with other studies and to establish the generation time of the species in Pond LC. More research on larval growth rates would greatly improve the interpretation of the emergence data.

Slight differences between this study and others in the length of emergence period and the start of emergence appear to be related to geographic differences in the onset of suitable temperatures for immature development. One notable exception is _Cladopelma viridulus_ which appears to have a very short emergence period in Pond LC compared to other studies.

5.3 Between-Year Variation of Insect Community

Species richness and diversity of all orders decreased between 1987 and 1988 (Table 4). For the Odonata, Trichoptera and Diptera, percent dissimilarity and Morisita's index indicated that the fauna for the two years was considerably different. Even for the Ephemeroptera, where PD was low, there was a large difference in the abundance of Callibaetis pallidus.

Species level differences were also observed in the numbers of adults collected, the length of the emergence periods for 1987 and 1988, and the start of emergence (Figures 8 to 15). Most of the species examined in detail showed a reduction in the number of adults collected between 1987 and 1988. However, Coenagrion angulatum was collected in similar numbers during both years, and Agraylea multipunctata, Bezzia bicolor, Cladopelma viridulus and Mesosmittia acutistylus?, had large increases in abundance in 1988.

The emergence periods for all the species examined in detail were reduced except for Coenagrion angulatum, Enallagma ebrium, Agraylea multipunctata, Bezzia bicolor, and B. glabra. All these species emerge in spring.

Only two species, Bezzia bicolor and B. glabra, had large shifts in the onset of emergence between 1987 and 1988. Both species began emerging one month earlier in 1988 than in 1987. The other species studied in detail emerged at approximately the same time in 1988 as in 1987, or varied by only a week or two.

Natural between-year changes in pond insect communities, have been documented in several studies (Daborn 1974; Danell 1981; Dineen 1953; Driver 1977;

Learner and Potter 1974; Morrill 1988; Wiggins et al. 1980; Wrubleski and Rosenberg 1990). These changes result from environmental and biotic features working in combination to influence the insect community (Learner and Potter 1974). Many differences in the physical and chemical conditions were observed in Pond LC that possibly contributed to the yearly differences in the insect communities observed.

Hot and dry conditions existed in the area in 1987 and in 1988 (Saskatchewan Research Council Weather Station Reports 1987, 1988). This caused many of the smaller ponds near Pond LC to become temporary. This may have reduced the number of immigrating females ovipositing in Pond LC because they would have to travel farther to reach the pond. However, there was a permanent pond 200 meters West of Pond LC that was probably a source of some immigration. There is no way of thoroughly evaluating the importance of this permanent pond or the reduction of other ponds in the area because data on immigration rates are not available. All orders declined in species richness and most species had reduced abundances in 1988. Poor dispersers, such as Callibaetis pallidus, were reduced in numbers as were strong fliers like the odonates. This suggests that another factor was responsible for the declines.

The presence of water is often important for the recruitment of aquatic insects (Wiggins et al. 1980). This would not affect the community during 1987 or 1988 because Pond LC was permanent in 1986 and 1987 and oviposition would not have been restricted. However, the pond was dry by the middle of July in 1988. This would affect the recruitment of insects into the basin after this date but the results would not be observed until 1989.

Extremes in water chemistry are known to eliminate or reduce the number of macroinvertebrate species, including insects, inhabiting lakes (Hammer 1986; Hammer et al. 1990). In Pond LC the values for the chemical parameters tested (alkalinity, acidity, hardness, dissolved solids, pH, CO_2, and O_2) did not reach extreme low or high levels except on a few sampling dates. The durations of these extreme conditions and how localized they were in the pond are unknown since samples were taken weekly and from only one area of the pond. When extreme levels were reached the immatures probably moved to more hospitable microhabitats in the pond such as closer to the water surface when low oxygen levels occurred in deeper water.

Many species collected in Pond LC also inhabit bogs and fens that have a lower pH than Pond LC (Flannagan and Mcdonald 1987; Hilton 1987; Kenk 1949; Wrubleski 1987;

Zoltai 1987). Sawchyn (1971) found an abundant and diverse odonate fauna and the phantom midge, Chaoborus americanus, in a pond with similar water chemistry. Driver (1977) and Morrill (1988) found diverse chironomid communities in ponds with similar water chemistry profiles. Daborn (1974) also found a diverse insect community in an Alberta pond with a similar water chemistry profile. Evidence from the literature suggests the chemical parameters and the changes observed in Pond LC were not extreme enough to cause the large observed faunal changes.

Water temperatures were higher in the spring of 1988 than in 1987. Higher temperatures usually result in more rapid development and shorter life cycles (Sweeney 1984). The higher temperatures should produce earlier emergences similar to those reported for Pyrrhosma nymphala (Sulzer) by Macan (1964). He found that the emergence of the odonate P. nymphala could vary up to three weeks depending on when the spring water temperature rose to 12^{0}C. In Pond LC several species began emerging one or two weeks earlier in 1988 (Figures 8 to 15). Two species, Bezzia bicolor and B. glabra, began emerging one month earlier in 1988. These shifts are probably due to the increased water temperatures. However, not all species had an earlier emergence, Ablabesmyia monilis had a delayed emergence in 1988 compared to 1987. This was probably related to the reduced abundance of this species rather than an adverse effect of the higher temperatures.

In Pond LC, insects emerging (see Table 3) in 1987 included species that successfully survived nonaestival conditions of the pond during the winter of 1986/87 such as the early emerging *Callibaetis pallidus*, and *Chaoborus americanus* and *Coenagrion resolutum*. Later emergences in 1987 would result from individuals that entered the pond in the spring and completed their life cycles in the same year, such as the later-emerging *Callibaetis pallidus*, *Ablabesmyia*, *Cricotopus* and *Corynoneura* cf *scutellata* adults.

In 1988, the adults collected were from eggs and larvae that survived the aestival conditions of the winter of 1987/88. This restricted the fauna to species such as *Coenagrion angulatum* that could survive freezing. Most species, including other Coenagrionidae species, *Chaoborus americanus* and *Callibaetis pallidus*, were either reduced in number or eliminated. Larval or egg mortality caused by the overwintering conditions is the likely cause of these population reductions in Pond LC.

Other studies have reported similar reductions in the insect fauna of a habitat due to aestival conditions. In an aestival pond in Alberta three species *Coenagrion angulatum*, *C. resolutum*, and *Enallagma boreale* were collected in abundance (Daborn 1971). During a second aestival winter the abundance of all three species decreased. Daborn (1971) attributed the declines to the ice temperatures dropping below a critical level for survival of the larvae.

In Pond LC *Coenagrion angulatum* emerged in similar numbers in 1987 after nonaestival conditions and in 1988 after aestival conditions. It appears that the temperature of the ice in the winter of 1987/88 fell below the critical level that caused larval mortality for the other Coenagrionidae species but not *C. angulatum*. This is an example of congeneric species reacting differently to the same environmental change; it emphasizes the importance of species level work.

Danell (1981) found a 70% to 90% decrease in numbers of live larval Chironomidae in a shallow Swedish lake following a severe winter that caused the water and more than 20 cm of the sediments to freeze. Several groups of aquatic insects including *Chironomus*, Trichoptera and Coenagrionidae were also reduced in abundance in a Minnesota pond by aestival conditions, although this was compounded by leech predation (Dineen 1953).

The temporary condition of Pond LC in 1988 further restricted the species collected to those emerging in spring and early summer. Species such as *Aeshna interrupta*, *Lestes congener* and *Lestes disjunctus/unguiculatus* that emerge in late July or later were greatly reduced in number because the pond dried up before most of the larvae could reach maturity and the adults could emerge. Species with multiple generations such as Callibaetis pallidus, the Ablabesmyia species, Corynoneura cf scutellata and Cricotopus pilitarsus were also reduced in number because the late summer generations did not develop.

Four species, Agraylea multipunctata, Cladopelma viridulus, Mesosmittia acutistylus?, and Bezzia bicolor had large increases in abundance between 1987 and 1988. All emerged in early spring thus avoiding the dry phase of the pond. A. multipunctata can survive in frozen substrates (Paterson and Fernando 1969) although larval numbers do decline (Dineen 1953). C. viridulus has also been collected after aestival conditions (Wrubleski 1984). No information is available on the overwintering requirements for B. bicolor but it would appear that the larvae of this species can survive aestival conditions as well. The apparent tolerance to freezing, combined with a decline in predators, particularly the odonates, and the reduction of other species that compete for microhabitats and food may have been responsible for increased larval survival and subsequent increased emergence of A. multipunctata, C. viridulus and B. bicolor.

The increased emergence of _M_. _acutistylus_? may be a sampling artifact. This species probably inhabits very shallow water along the shoreline (Cranston et al. 1983). In 1987 the average water depth of the E trap station was 59 cm in early May when _M_. _acutistylus_? would have been emerging. In 1988, the water depth at the E trap station averaged only 12 cm in early May and the E trap station was much closer to the shoreline. This may have resulted in the traps being over the very shallow habitat from which adults were emerging. Another possibility is that this species was absent or rare in 1987 and was not collected.

To summarize, the main cause for the decreases in species richness and numbers of adults emerging in 1988 compared to 1987 appear to be the aestival condition of the pond which probably killed all, or most of, the overwintering larvae and eggs of species that were not adapted to survive being frozen. Adult emergence was further reduced because the surface water disappeared by the middle of July in 1988. This restricted the insect emergence to those species that could complete development and emerge before surface water disappeared from the basin. Some species that did increase in numbers probably overwintered more successfully or possibly immigrated into the pond early in 1988. Other factors such as reduced recruitment, changes in temperature, water chemistry, predator pressure or food competition may also have played a role in the emergence reductions but their possible contributions require further study.

5.4 Faunal Predictions and Indicator Species

Knowledge of the life histories and habitat requirements of the insects inhabiting Pond LC make it possible to determine the pond condition in the year previous to the study. The presence of large populations of larval and adult *Chaoborus americanus*, *Enallagma cyathigerum*, *Ablabesmyia monilis*, *Coenagrion resolutum* and *Callibaetis pallidus* in early spring 1987 indicates Pond LC was permanent the previous year (1986) and overwintered in a nonaestival condition during the winter of 1986/87 as was observed. Since these species were also present in 1986 collections (Table 3) Pond LC was probably permanent 1985 and nonaestival during the winter of 1985/86 as well.

The absence of, or very low numbers of these species but the presence of *Coenagrion angulatum*, and *Bezzia bicolor* would suggest the pond was aestival during the previous winter. This was the case for 1988. The absence of the above species coupled with the presence of a *Lestes* fauna would suggest the pond was temporary in the preceding year.

The insect fauna of Pond LC in 1989 can be predicted to some extent based on the conditions during 1988. Species such as the _Lestes_ species, and species of _Cricotopus_, _Chironomus_, and _Bezzia_ and other species of Groups 2 and 3 of Wiggins et al. (1980) that can survive in the dry basin as larvae or eggs would be present in early spring. _Callibaetis_ and _Ablabesmyia_ species and others of Group 4 of Wiggins et al. (1980) would immigrate into Pond LC in early spring 1989.

The diversity of most insect groups would decline in 1989 because many species would not survive in the dry basin. Declines in the insect community due to decreased pond stability have been reported by others. Driver found temporary ponds with wet phases of 2.5 months had only three species of chironomids while another pond that was permanent for over 6 years had 31 species of Chironomidae (Driver 1977). Daborn and Clifford (1974) also suggested that a decline of Coenagrionidae species reflected a decline in stability. Moore (1991) found that a drought eliminated three odonate species inhabiting previously permanent ponds that became temporary.

Kenk (1949) found that Coenagrionidae species, _Callibaetis_ sp., and _Chaoborus americanus_ were absent from temporary ponds, but species of _Lestes_ were present.

However, in permanent ponds all the above species were present.

Some species, Coenagrion angulatum, Lestes disjunctus/unguiculatus, Lestes congener, Corynoneura cf scutellata, Cladopelma viridulus and Parachironomus monochromus appear to be less sensitive to aestival conditions and therefore may be good candidates for use in impact studies. Their wide distribution (Driver 1977; Oliver et al. 1990; Walker 1953; Wrubleski and Rosenberg 1990) would also make it easier to compare results of impact studies from different physiographic regions.

However, life cycle timing must be considered when using any species in impact studies (Rosenberg et al. 1986). For example, Lestes species would not be appropriate for testing fall impacts because they are out of the water either as adults or eggs in emergent vegetation. The Coenagrionidae species would be better suited for fall impact studies because they will be present as larvae in the pond. Lestes species would be good candidates for spring impact studies because they would be present as larvae.

In summary, certain species were identified that may be useful in determining pond conditions in the preceding year. Knowledge of species life histories and habitat requirements can also be used to predict at least part of the insect fauna of the following spring. Such predictions may be of value in choosing ponds to be used in experimental research. In addition, certain species were identified as good candidates for environmental impact studies because they are less sensitive to natural habitat changes. The relevance of these species will also be determined by their tolerance to the particular impact being studied. To establish a good basis for an impact study, the condition of the pond the year previous to the study needs to be known to better understand the insect community of the current year. This is particularly important in studies using multiple ponds, because without knowledge of the history of the ponds it will be difficult to locate ponds that are similar for comparison.

The insect community must also be identified to species level in order to take advantage of the available life history and ecological information (Danks 1988). This will enable natural changes to be separated from experimental changes. Generic level taxonomy may lead to incorrect conclusions if there is not corresponding knowledge of what species or how many species are present in the habitat (Waterhouse and Farrel 1985).

5.5 Interstation Differences in Adult Emergence

One of the objectives of this study was to determine if there were differences in the number of adults or the species emerging from the open water, submerged vegetation and emergent vegetation zones of the pond. Unfortunately only the latter two vegetation zones existed in Pond LC during 1987 and 1988. The O and S stations were in the submerged vegetation zone while the E traps were in the emergent vegetation zone.

For all the species studied in detail, except Bezzia glabra in 1987, the number of adults collected in the O and S traps were not significantly different. This was expected since the O and S stations were similar in vegetation and depth.

In Pond LC most of the abundant species were collected from all three stations. Some species were collected in significantly higher numbers in one vegetation category than the other (Table 5). These differences can be attributed to the eclosion requirements of the insects, the vegetation type and the physical conditions at each of the stations.

Many aquatic insects, such as Callibaetis pallidus and the chironomids, emerge directly from the water surface. It is assumed for these species that the adults are emerging over the habitat of the immatures and the number of adults collected is a reflection of the density of the immatures (Davies 1984).

Table 5: Results of paired station tests for species with significant Friedman test results (ns indicates no significant difference between stations; > or < indicates first station collected significantly more, or less adults than the other station).

		Trap Station Comparisons		
	Year	O - S	O - E	S - E
C. pallidus	87	ns	ns	S > E
A. interrupta	87	ns	O < E	S < E
C. angulatum	87	ns	ns	ns
C. resolutum	87	ns	O < E	S < E
E. cyathigerum	87	ns	ns	ns
E. ebrium	88	ns	O > E	ns
A. multipunctata	88	ns	O > E	ns
B. glabra	87	O < S	O < E	ns
A. illinoensis	87	ns	ns	S > E
A. pulchripennis	87	ns	ns	S > E
A. monilis	87	ns	ns	S > E
P. monochromus	87	ns	O > E	S > E
	88	ns	O > E	ns
C. pilitarsus	87	ns	O > E	S > E
C. cf scutellata	87	ns	O > E	ns
M. acutistylus?	88	ns	O < E	S < E

In other aquatic insects the larvae migrate toward the shore before emerging. Insects like Sisyra vicaria pupate on land and emerge on shore above the water line. Therefore, these species will not usually be collected in aquatic emergence traps. In the Odonata, the mature larvae must crawl out of the water onto an aerial substrate to emerge. In these species the mature larvae migrate toward shore until they encounter a suitable substrate to emerge on (Davies 1984).

In Pond LC this migration was probably responsible for more adults of Aeshna interrupta and Coenagrion resolutum being collected in the E traps than in the O or S traps in 1987. The adults collected in the two deeper water stations probably resulted from mature larvae being intercepted by these emergence traps.

At least one species, Mesosmittia acutistylus?, was collected significantly more from the shore traps even though it emerges directly from the water surface,. The species of this genus are likely semiaquatic (Cranston et al. 1983) and the larvae are found in the shallow water along the shoreline.

Callibaetis pallidus, Cricotopus pilitarsus, Cladopelma viridulus, Parachironomus monochromus and Corynoneura cf scutellata, all emerged significantly more in the submerged vegetation zone (Table 5). Three species Callibaetis pallidus, Agraylea multipunctata and

Cladopelma viridulus were not collected from the E traps.

The submerged vegetation zone of Pond LC was dominated by Utricularia sp. and Myriophyllum sp.. Both of these macrophytes have dissected leaves and would provide more microhabitats for larval insects than morphologically simpler Typha and Carex which were the common plants of the emergent vegetation (Krecker 1939; Rosine 1955; Wrubleski 1987). More microhabitats translate into more larvae and more adults emerging from the submerged vegetation than from the emergent vegetation, as was observed.

The third factor that influenced adult emergence at the three stations was water depth. The E traps were out of the water after August 24 in 1987 and June 6 in 1988, while the O and S stations were in water throughout 1987 and were out of water by June 27 and July 14 in 1988 respectively. Species that were collected in all three trap stations after early June in 1987 such as Lestes disjunctus/unguiculatus and Enallagma ebrium would only be collected in the O and S traps in 1988 because the E station was out of the water before they emerged.

To summarize, most of the abundant species examined were collected in all three trap stations. Some species such as Callibaetis pallidus, Aeshna interrupta, Coenagrion resolutum, Cladopelma viridulus and Mesosmittia acutistylus? tended to be collected from either the O and S stations or from the E traps. These preferences resulted from a combination of differences in vegetation at the trap stations, eclosion requirements of the species and the water depth at the trap stations.

6. SUMMARY

1. Pond LC had a diverse and abundant aquatic insect fauna dominated numerically by the Chironomidae. Over the three years the pond was studied 115 species of aquatic insects belonging to five orders Ephemeroptera, Odonata, Trichoptera, Neuroptera, Hymenoptera and Diptera were collected. The Hymenoptera and the tribe Tanytarsini (Chironomidae: Diptera) were only examined superficially and the Coleoptera and Hemiptera not at all. Over 70 % of the specimens collected during the study belonged to the dipteran family Chironomidae.

2. Working at the species level provided valuable taxonomic and biogeographic information. Fourteen species, three Ceratopogonidae and 11 Chironomidae, are new records for the province. One species of Chironomidae, *Polypedilum* n. sp., is new to science and another, *Mesosmittia acutistylus*?, is a new record for the genus in Canada. Eight associations of parasitic Hymenoptera species with host aquatic species were also made.

3. This study showed that ponds can undergo large and rapid natural changes in physical conditions in response to climatic changes. Pond LC underwent two significant

physical changes due to drought during the years it was studied. In 1986 and the winter of 1986/87 it was a permanent nonaestival pond, in 1987 and the following winter it was a permanent aestival pond, and in 1988 a temporary pond.

The study confirmed results of other researchers that changes in overwintering conditions and stability influence the abundance of many species of pond insects. The number of adults collected for most species decreased between 1987 and 1988 due to such changes. In 1987, the fauna was characterized by insects such as *Chaoborus americanus* that overwinter in permanent, nonaestival habitats. In 1988, the insect community consisted of species that could overwinter in aestival conditions including; *Coenagrion angulatum*, the *Lestes* species and *Cladopelma viridulus*. The adult emergence in 1988 was further reduced because Pond LC dried up in mid July. This restricted emergence to species that emerged in spring and early summer such as *C. angulatum* and *C. viridulus*, and *Mesosmittia acutistylus*?.

4. Certain species were identified as useful indicators of pond conditions because of their habitat requirements. In particular, *Chaoborus americanus* is a good indicator of permanent nonaestival conditions in the previous year. Early spring insect communities that lack *C. americanus*

and species of Coenagrionidae would indicate an aestival condition for the previous year. These indicators provide a means of determining the history of ponds that can be used by researchers to select ponds for experimental research.

5. Species, including Coenagrion angulatum, Lestes disjunctus, Lestes congener, Corynoneura cf scutellata, Cladopelma viridulus and Parachironomus monochromus, are identified as indicator species that may be useful in contaminant assessment studies. These species were collected after aestival and nonaestival conditions and they are also widely distributed in North America. These features make them good candidates for assessment studies because they will be present in most ponds and direct comparisons can be made with other studies. However considerations must be made regarding the life history of the insects and the timing of the impacts.

6. This is the first study to determine the emergence phenologies and patterns of pond insect species in Saskatchewan. For several species this is the first time emergence information from a pond habitat is presented. This information can be used for comparisons by other entomologists studying the life histories of these species in other circumstances.

7. Differences in the numbers of adults collected from the submerged vegetation zone and the emergent vegetation zone were observed for several species confirming results from other studies. These differences were attributed to differences in larval microhabitats for species such as *Callibaetis pallidus* and *Mesosmittia acutistylus*? and to emergence requirements for species such as *Aeshna interrupta* and *Coenagrion resolutum*.

8. This study provides information on the life history and ecology of many pond insects that ultimately can be used for future ecological research on Saskatchewan ponds.

7. FUTURE RESEARCH

This study examined species diversity, emergence periods and emergence patterns of aquatic insects inhabiting a Saskatchewan pond over a three year period from 1986 to 1988. During this time Pond LC passed through nonaestival, aestival and temporary phases. The results suggest that large and rapid changes in the physical conditions of a pond can cause dramatic changes in the aquatic insect community. Longer term research (five years or more) must be done to understand more fully the effects natural physical changes have on individual species and the pond ecosystem over time. This would enable impact assessment researchers to separate faunal changes caused by natural conditions from those caused by manmade impacts.

Research is also needed into species level taxonomy, in conjunction with life history and ecology studies. Of importance is the association of immature stages with adults, particularly for the chironomids, so that samples of immatures can be identified to species and be used to determine life history patterns. In most ecological and impact studies species-level taxonomy is the norm for fish, birds and mammals, but, it is ignored or avoided for aquatic insects because it is viewed as too difficult and too time consuming.

However, research done at a supraspecific level can lead to incorrect generalizations (Waterhouse and Farrell 1988). It has also been proven that species level studies provide a more accurate basis for ecological and management decisions than does supraspecific work (Danks 1988; Lehmkuhl et al. 1984; Resh and Unzicker 1975; Rosenberg et al. 1986). Species level identifications enable between study comparisons to be made without having to make qualified generalizations because there is uncertainty about which species are being compared.

More research is needed to identify indicator species in a variety of pond types for use in assessing and identifying the impact of natural and manmade events on pond habitats. This will provide a better understanding of the pond ecosystem and the insect inhabitants, and thus be useful in protecting ponds for the future.

Research on the effects of habitat and vegetation manipulations on insect species composition and abundance would also be useful, particularly for waterfowl researchers. The development and management of waterfowl habitat is becoming increasingly important to the survival of waterfowl. If the production of prey insects could be increased with minor habitat alterations waterfowl production would also be increased.

Although any research on pond-inhabiting insects will provide new information, the most valuable research will be done at the species level. For too long pond insects; and most aquatic insects from other habitats as well; have been studied at the genus level or the family level or simply as size classes. This has resulted in the poor state of knowledge of pond insects that exists today. Insects fill all trophic levels in pond habitats from primary to top level consumers. Often insects are the top predators in ponds. Only through studies that appreciate the importance of insects in pond habitats will researchers gain an understanding of the pond habitat.

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