THE UNIVERSITY OF MANITOBA

# TAXONOMY AND ECOLOGY OF THE WATER MITES OF MARION LAKE, BRITISH COLUMBIA, WITH A DESCRIPTION OF A NEW SPECIES, *PIONOPSIS* NOV. SP. (ACARI: PIONIDAE).

by

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J.C. CONROY

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

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## ABSTRACT

Water mites in Marion Lake, British Columbia, are represented by 38 species, 24 genera and 16 families. A new species, Pionopsis nov. sp., is described. Another form was assigned to Sperchon but not identified at a specific level. Of the remaining species, Attractides glandulosus (Walter) is a first record from North America, while five others (Oxus gnaphiscoides Habeeb, Hydrochoreutes intermedius Cook, Tiphys vernalis (Habeeb), Arrenurus pseudocylindratus (Piersig) and A. solifer (Marshall) ) are first records for Canada. The seasonal changes in numbers of individuals and of species are discussed and a marked seasonal succession in mite species was observed. Thirteen species accounted for over 98% of all mites examined - with Unionicola crassipes the dominant species (64.6%). The life cycles of eleven species (U. crassipes, U. gracilipalpis, Piona carnea, P. constricta, P. debilis, P. variabilis, Forelia ovalis, Frontipoda americana, Arrenurus cascadensis, A. pseudocylindratus and A. solifer) have been worked out by me and the larval hosts of two others (Eylais extendens and Neumania semicircularis) identified. The phenomenon of interspecific associations in mites was examined and on application of the Williams and Lambert methods the species were assembled into a hierarchial system. The initial division was made on Arrenurus pseudocylindratus. Water temperature was found to influence the distribution of this species and of Piona debilis. Mites were found to show distinct

seasonal preferences and species were classified as late Spring forms (Eylais extendens, Frontipoda americana and Hydrochoreutes intermedius,) as early summer forms (Lebertia porosa, Oxus connatus, Neumania semicircularis, Piona constricta and P. debilis), as mid-summer forms (Limnesia maculata, Pionopsis nov. sp., Piona variabilis, P. conglobata, Forelia ovalis and Arrenurus pseudocylindratus), as late summer forms (Unionicola crassipes, Piona carnea, P. interrupta, Arrenurus cascadensis and Hydrodroma despiciens) and as autumnal forms (Unionicola gracilipalpis, Forelia borealis and Arrenurus solifer). Since only 62 of 739 vertebrate predator stomachs examined contained a total of 75 adult and nymphal mites present, I concluded that mites were unimportant to the diets of these predators: Salmo gairdneri Richardson, Oncorhynchus nerka (Walbaum), Taricha granulosa granulosa (Skilton) and Ambystoma gracile gracile (Baird).

# INTRODUCTION

Water mites are found in a wide variety of aquatic habitats but little is known about their ecological requirements. Only one broad ecological study (Young 1969) is available for North America. This study was primarily concerned with the ecological distribution of water mites in Colorado with special reference to the effects of altitude and to the mites' chemical requirements. Other ecological studies on water mites in North America were concerned with the host-parasite relationships between mite larvae and their hosts (Unionidae-Mitchell and Pitchford 1954; Mitchell and Wilson 1965a and Mitchell 1965b; Odonata - Mitchell 1959, 1961, 1964, 1966, 1967a and 1968; Munchberg 1935; 1937, 1951, 1952 and 1953; Chironomidae - Munchberg 1937, 1954; Crowell 1957; Modlin 1971; Trichoptera - Crowell 1967). The bulk of the information on mite ecology is in short notes in taxonomic studies and in a few distributional works.

European workers have been more active in studying the ecology of mites though the basic information is confined to a few works, for example Pieczynski (1960a, 1960b, 1964 and 1969), whose work is the only study comparable to mine.

My work was concentrated on Marion Lake primarily because no previous worker had studied the mites in one lake in detail. Pieczynski's (1960a, 1960b, 1966 and 1969) work although similar concerned mites in several lakes. An added benefit was that Marion Lake has been intensively investigated and considerable relevant supporting data were available.

The aims of the present study were multifold: to increase our knowledge of the taxonomy of water mites of western Canada with specific reference to the mite species present in Marion Lake, to determine the seasonal changes both in numbers of individuals and of species present, to examine the life cycles of the species present, to learn the extent of interspecific competition for food, living space and larval hosts, to examine the effects of predation by both vertebrates and invertebrates, and to examine the phenomenon of interspecific associations in water mites and see how they relate to the seasonal abundances of the different mite species.

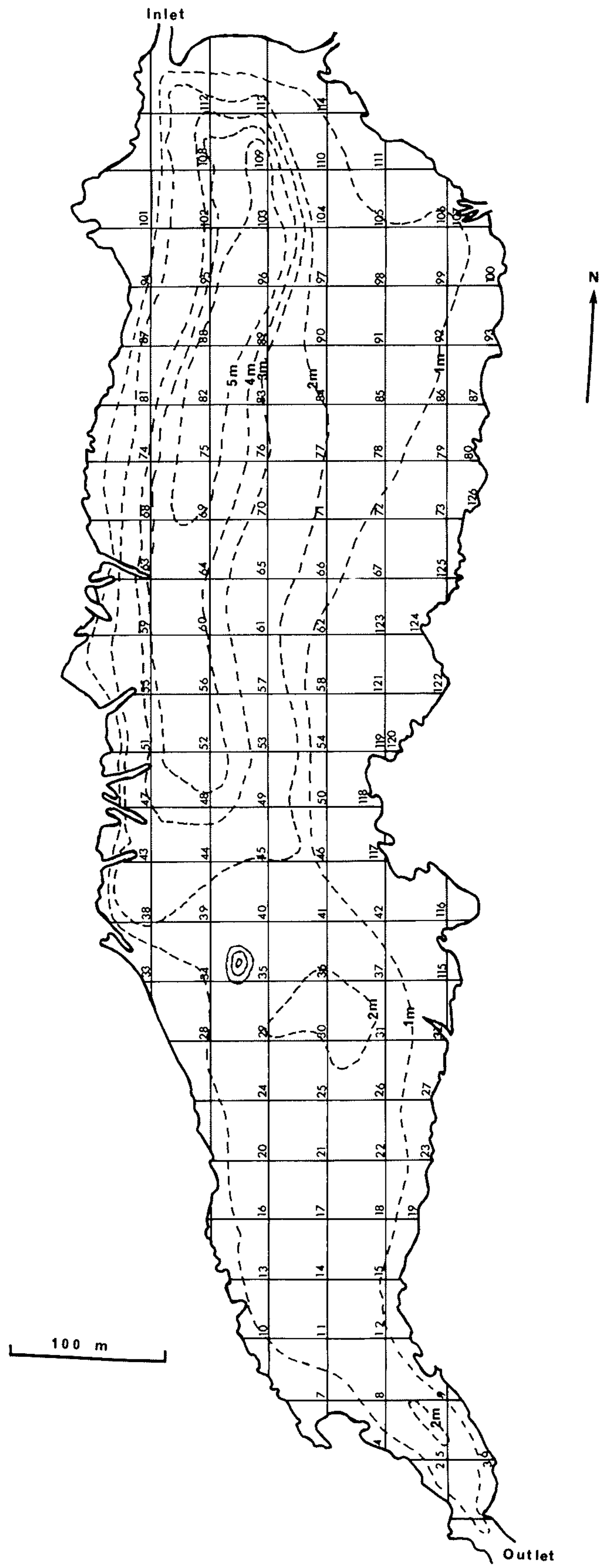
## DESCRIPTION OF MARION LAKE

Marion (or Jacob's) Lake is situated in the University of British Columbia Research forest, 50 km. E of Vancouver and 10 km NNE of Haney (49° 19' N, 122° 33'W).

The lake is in a long narrow valley, running in a north-south direction, at an altitude of 300 m above sea level, bordered on the west by a steep ridge 300 m above the lake level and on the east by the southern slopes of the coastal mountains. The lake is 800 m long and about 200 m wide. It is shallow with a maximum depth of about 7 m and a mean depth of 2.4 m. The bottom is of a soft, uniform brown ooze (gyttja), except near the inlet and outlet streams where it is of a firm gravel-sand. Several small springs open into the lake, the most important of which lies about two thirds of the way down the lake (in grid square 35, fig. 1). The north end is the deepest portion of the lake especially near the western shore. The south end is uniformly shallow with a maximum depth of just over 2 m. The lake is fed, at the north end, by a small inlet stream and is drained, at the south end, by a small outlet stream which is a tributary of the North Alouette River about 1 km below the lake.

Submerged vegetation included Potamogeton epihydrus (Raf.), Chara globularis (Thuill) and Isoetes occidentalis (Henderson). Emergent vegetation included Potamogeton natans

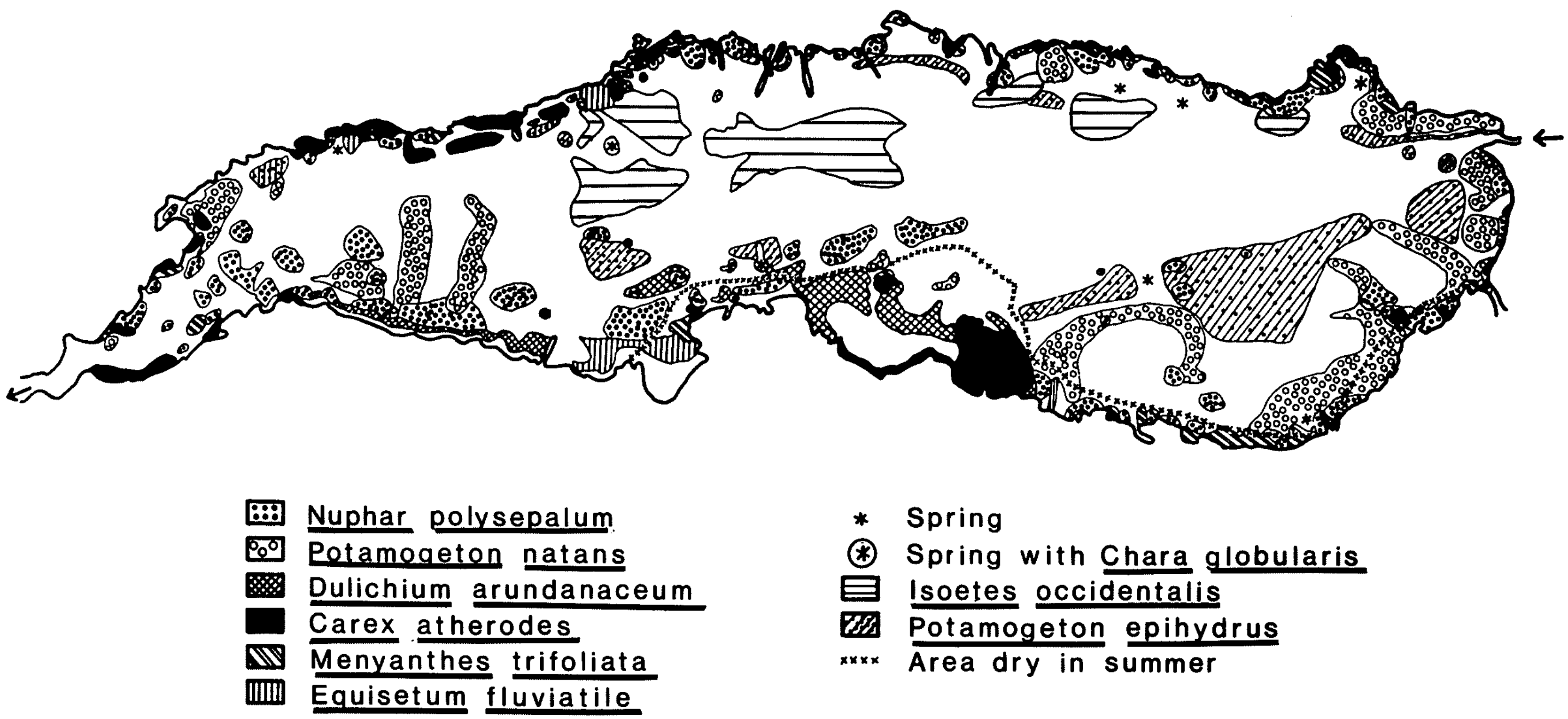
Fig. 1: Map of Marion Lake, British Columbia (The grid system was marked by means of numbered floats at the intersection of the transects).


Inlet
Outlet
N
100 m
5m
4m
3m
2m
1m

(Linne) and Equisetum fluviatile Linne which occurred together, Nuphar polysepalum (Englemann), Menyanthes trifoliata Linne and the sedges, Carex atherodes Spreng and Dulichium arundanaceum (Linne) (fig. 2).

The lake margins are poorly defined and consist of a boggy zone in which the water level varies considerably. Davies (1970) said that the lake is weakly stratified from spring through autumn and is isothermal in winter. Due to the relative mildness of the winters in some years the lake does not regularly have permanent ice cover, but in severe winters the lake is covered by ice from December to April. Rainfall greatly affects the water level of Marion Lake and a change in water level of over one meter in a day has been recorded on several occasions. This rapid rise in water level is balanced by a rapid runoff. "During heavy spates, the equivalent of the total volume of the lake may be flushed out in less than 24 hours" (Efford, pers. comm.). The lake may be regarded as being oligotrophic with a total dissolved solids content of 15 ppm (Efford 1967). The water is clear and the bottom visible at all times except the height of summer.

Fig. 2: Vegetation map of Marion Lake


Nuphar polysepalum
Potamogeton natans
Dulichium arundanaceum
Carex atherodes
Menyanthes trifoliata
Equisetum fluviatile
Spring
Spring with Chara globularis
Isoetes occidentalis
Potamogeton epihydrus
Area dry in summer

# LITERATURE REVIEW

## Taxonomy

Studies on water mites in North America were restricted mainly to the mid-western United States and few workers considered the Canadian fauna. Koenike (1895, 1912) made the first major survey of the mite fauna of Canada and described 39 species. Marshall (1921, 1924 and 1929b) described 62 more species and Conroy (1968) reported 140 species for western Canada. Further unpublished work by me will add 15 more species. The present study adds seven species to the Canadian list. Habeeb (1950, 1953a, 1953b, 1954a, 1954b, 1954c, 1955a, 1955b, 1955c, 1955d, 1955e, 1956b, 1956c, 1956d, 1957a, 1957b, 1957c, 1957d, 1957e, 1958a, 1958b, 1962, 1968a, 1968b, 1968c, 1968d, 1968e and 1969) published records of water mites principally from New Brunswick and added a further 80 species to the list.

The general keys published for North America (Wolcott 1905, 1918; Pennak 1953 and Newell 1959) are neither sufficiently detailed nor complete for advanced work on water mites. Several workers have published papers on the United States fauna including Wolcott (1894-1918), Marshall (1903-1946), Lundblad (1934), Habeeb (1950-1969), Crowell (1957-1967), Cook (1954-1970) and Mitchell (1954-1969). These papers form the bulk of the knowledge of North American water mites. Persad and Cook (1972) described water mite larvae from North America.

The excellent works on the European fauna (Viets 1928; 1936, 1955, 1956; K. Viets and K. O. Viets 1960; Motas 1928; Lundblad 1927, 1956, 1962, 1968; Soar and Williamson 1925, 1927, 1929)are indispensible basic references. This is particularly true of the two volumes by Viets (1955, 1956) who gave complete synonymies and bibliographies for all the known species of water mites. Sparing (1959) described the larvae of many European water mites and gave much information on their hosts.

## Ecology

The ecology of water mites has been largely ignored. Only the studies of Pieczynski (1960a,1960b, 1961b, 1963, 1964, 1965, 1969); Motas (1928); Viets (1930); Uchida (1932) and Schwoerbel (1959) have dealt exclusively with mite ecology. Pieczynski (1960a, 1960b) examined the formation of groupings of mites in different habitats in Lake Wilkus. He also (1961b) examined the development of the populations of several species of mites. While interested in the numbers of egg-bearing females, egg diameters and numbers of eggs laid, he failed to link up the species examined with their larvae or larval hosts. In 1963 he repeated his (1960a, b) work in Lake Mikolajskie, concentrating on the groupings of mites noted in each environment in the lake. His 1964 paper centered on the seasonal aspects of mites and some aquatic insects and he briefly investigated the phenomenon of species groupings in mites. Motas (1928) discussed the general ecology of the group as part of his introduction to the taxonomy of the mites of Southern France. Uchida (1932) was concerned with mite reactions to sunlight, with their method of copulation, with their egg-laying and with their post-embryonal development. Wesenberg-Lund (1918) dealt with the post-embryonal development and expanded his observations later (Wesenberg-Lund 1939). Lundblad (1927, 1962, 1968) dealt with the taxonomy of the Swedish mites and devoted large sections to the ecology of the group. Walter (1922) discussed the ecology of alpine mites while Viets (1936) made only passing reference to some aspects of mite life-histories.

Viets (1936), Sparing (1959) and Pennak (1953) gave the mite life cycle as follows:-

The eggs are laid in a gelatinous capsule (either in groups or singly). This gelatinous capsule is termed the schadonophan (within which the larva may be seen developing). After a variable period, the larvae hatch and actively swim about searching for their host (aquatic insect, emerging insect, clam or sponge). This search is random (Mitchell 1961) and the mite only responds to the host on contact. The parasitic phase is of variable duration after which the larva enters a quiescent phase. This may occur while still on the host or may not occur until after the larva drops off its host. The nymphochrysallis forms with the nymphophan developing within it. The nymphochrysallis may be found on plants or on the larval host. The free-living nymph hatches from the nymphochrysallis and feeds and wanders about for a time. It then becomes quiescent, attaches itself to an aquatic plant and forms the teleiochrysallis, within which the teleiophan is found. The teleiochrysallis bursts liberating the adult or prosopon.

Mitchell (1969) defined the probability of larval success at finding the host as:-

$$P_{larval\ success} = P_h \times P_r \times P_t \times P_a \times P_f \times P_d$$

where $P_h$ is the probability of a larva meeting a host;

$P_r$ is the probability of the larva recognising the host;

$P_t$ is the probability of the mite correctly transferring from the aquatic stage to the emerging insect (since mites may parasitize aerial adults of aquatic insects, they must first find the host before the host leaves the water and rest on the host - without feeding - until the host leaves the water for the final ecdysis; when this occurs the mite must respond correctly and transfer from the aquatic stage to the emerging imago):

$P_a$ is the probability of attaching itself to the host;

$P_f$ is the probability of success in feeding from the host; and

$P_d$ is the probability that when the larva drops off the host, it does so over a suitable medium.

Mitchell pointed out that $P_h$ may be considered as a measure of the effective overlap of mites and hosts in both time and space. "It cannot be measured directly but it can be estimated from the incidence of parasites" (Mitchell 1969, p. 334) - the more larvae there are on a host, the greater is the overlap. Parasite-free hosts indicate that no mites met the hosts, or, if they do, fail to recognize them as such. Mitchell (1964) noted that "even if the larvae hatch, the population can fail if the larvae fail to find hosts". The efficiency of the search activity of the mite larva is thus the key to the mite species success.

In North America, Crowell (1967) and Mitchell have concentrated on host-parasite relationships between mite larvae and insects and/or molluscs. Young (1969) was interested in the ecological distribution of mites and the physical and chemical factors influencing the distribution.

Mites were found in the stomachs of various predators by a number of authors. Stankovitch (1921) reported mites in the gut contents of the alevins of Cyprinids. Elton (1923) found hungry stickle-backs rejecting bright red mites (Eylais spp.). Scott (1927) reported that "water mites formed a considerable item in the food of the brook, rainbow and native trout". This was based on 302 stomachs with 450 mites in them. Marshall (1933a) examined this and other material obtained later by Scott. Motas(1928) told of tropical fish eating some mites and rejecting others. Marshall (1940a) found more than 200 mites in 50 turtle stomachs and one in the stomach of a Great Blue Heron (*Ardea herodias* Linn.).

Pritchard (1964) reported 'Hydracarina' from the gut contents of dragonfly nymphs (*Aeshna* spp., *Leucorrhina* spp., *Sympetrum* sp., *Libellula* sp., and *Cordulia* sp.). He summed up their role in the food of dragonflies as accidental, probably being eaten while attached to other organisms. Pritchard and Leischner (1973) found from 1.2-3.4% of the larvae of *Sialis cornuta* Ross examined had mites in their gut.

Motas (1928) and Uchida (1932) commented on the cannibalistic tendencies of some genera of water mites (notably *Eylais* spp., *Limnesia* spp., and large *Piona* spp.).

A series of papers by Williams and Lambert (1959, 1960, 1961), by Lambert and Williams (1962, 1966) and by Williams, Lambert and Lance (1966) suggested the methods used to analyse the interspecific associations formed between different water mite species.

# SAMPLING TECHNIQUES

Mites were sampled by two main methods; active and passive capture. Samples were also obtained incidentally from examination of stomach contents and from insect emergence trap catches. The sampling procedures are described under these major headings below.

## Active Methods

i - Plankton Hauls:

Mr. D. J. McQueen made a series of horizontal plankton hauls with a number 2 mesh net (mesh size 0.04 cms, 63 meshes to the inch) with a mouth diameter of 0.5 m, over a distance of 100 m along a line from float 69 to float 88 (fig. 1), at a depth of 1.5 m. On each sampling date the hauls were duplicated (one going from 69 to 88, the other from 88 to 69). The number of mites/haul was assumed to be that in a column of water of 19.635 $m^3$. This figure was converted to the number of mites/$m^3$.

ii - Pump Samples:

Mr. McQueen took the pump samples at the same time as the plankton hauls. 100 l of water were pumped through a number 25 mesh net (mesh size 0.1 mm, 254 meshes to the inch) in three minutes using a diaphragm pump. These samples were taken at four depths (surface, 1.0 m, 2.0 m, and 3.0 m) at float 88. Samples from each depth were duplicated and the numbers of mites/sample converted to the number of mites/$m^3$.

iii - Net Sweeps:

Net sweeps were made by drawing a net in a swift movement through the water over the mud-water interface and amongst the vegetation along a sweep of about 2 m in length. The net was made of number 25 mesh netting (mesh size 0.1 mm, 254 meshes to the inch) and had a mouth diameter of 40 cms. Sweeps were replicated ten times and the number of mites/haul calculated. This was assumed to be the number of mites in a column of water of 0.25 $m^3$. This number was converted to the number of mites/$m^3$. The sweep method was used in depths of 2.0 m. or under.

Passive Methods

i - Conroy Bottom Trap:

The Conroy Bottom Trap was designed for the present survey and has been described by Conroy (1973) (fig. 3). The trap covers an area of 0.1 $m^2$. In 1966-7 the trap was left on the lake bottom for periods of 3-4 days and the number of mites.$trap^{-1}$.$week^{-1}$ calculated. In 1969 the traps were changed every two days and again the numbers of mites.$trap^{-1}$.$week^{-1}$ calculated. This trap could not be used in depths less than 35 cms.

ii - Pieczynski Bottom Trap:

The Pieczynski Bottom Trap was designed by Pieczynski

Fig. 3: Conroy Bottom Trap

#1 - nylon line to float

#2 - 8 oz. jar

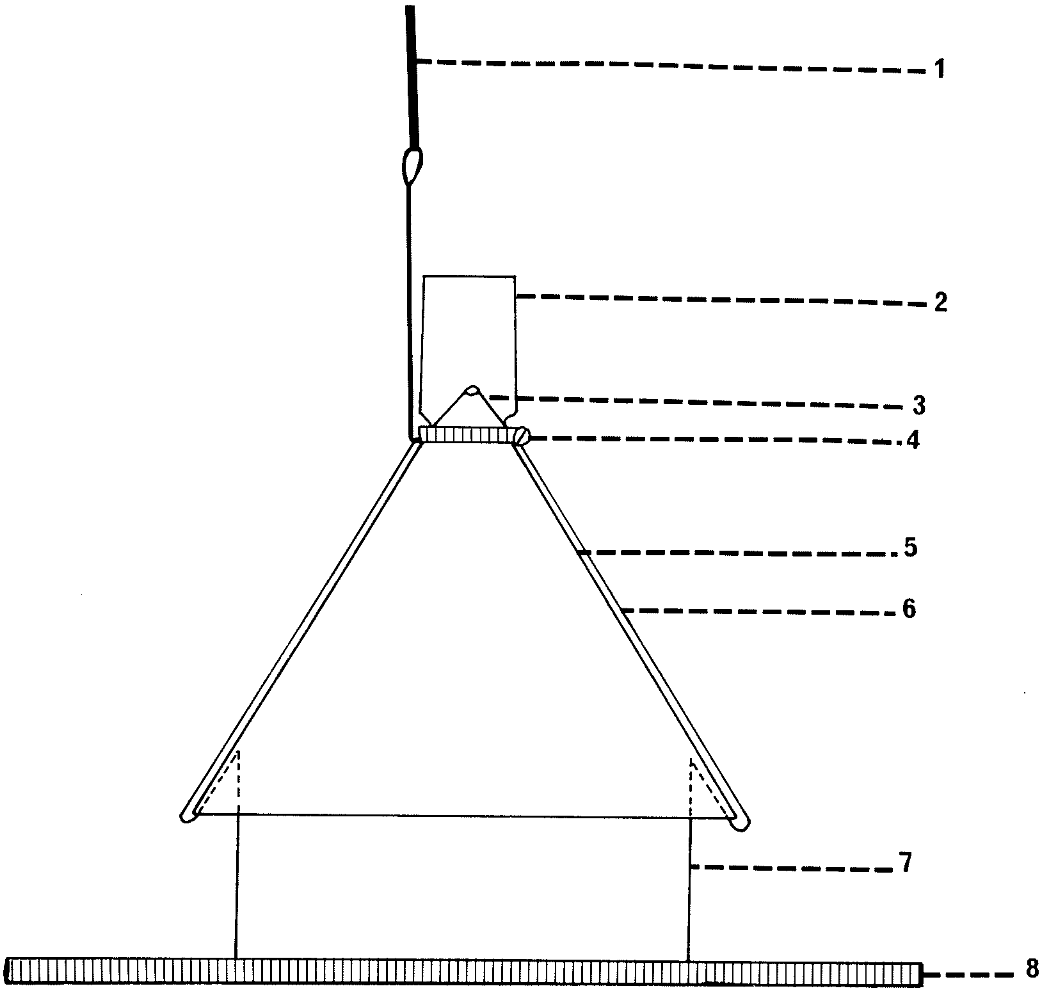
#3 - small cone

#4 - #32 clamp

#5 - large cone

#6 - supporting wire attached to clamp

#7 - supporting wire to (#8) base


1
2
3
4
5
6
7
8

(1961a, 1969). The collecting jar had a volume of one gallon and the funnels a mouth diameter of 15 cms (area 176.8 $cms^2$). Various modifications of these traps were tested including formalin traps (25 $cms^3$ of 10% formalin in the collecting jar) and traps with funnels 12.6 cms in diameter (area 0.0125 $m^2$).

iii - Hargrave Bottom Sampler:

Hargrave (1969) described a sampler with a sample area of 0.0225 $m^2$. Twenty samples were taken at monthly intervals during 1968 and 1969. The numbers of mites/sample was calculated and converted to the number of mites/$m^2$. Mr. K. Tsumura took these samples.

iv - Perspex Cylinders:

A perspex cylinder (0.63 cm thick perspex, 20 cm in diameter, and 70 cm long) was used to trap water mites when lowered rapidly into the water. The ends of the cylinder were sealed before it was lifted from the water. This was repeated five times and the number of mites/sample calculated. This was assumed to be the number of mites in a column of water of 0.022 $m^3$. This figure was converted to the number of mites/$m^3$. This method could not be used in depths greater than 75 cms.

Incidental Samples

i - Stomach Contents:

The stomach of the four vertebrates present in the lake (the rainbow trout, *Salmo gairdneri* Richardson; the kokanee salmon, *Oncorhynchus nerka* (Walbaum); the rough-skin newt, *Taricha granulosa granulosa* (Skilton); and the North-western salamander, *Ambystoma gracile gracile* (Baird) ) were examined for water mites.

ii - Insect Emergence Traps:

As part of a study on the chironomid fauna carried out by Mr. V. J. McCauley (1969, 1970, 1971, 1972) the emerging chironomids were examined for mite larvae. A transect of insect emergence traps was set up in squares 65, 66, 67, 70 and 125. A series of three emergence traps were set at each of six depths (0.5 m, 1.0m, 2.0 m, 3.0 m, 4.0 m, 4.5 m). The traps were of the design described by Hamilton (1965). They were changed every two days and the insects in them counted. All insects with mite larvae attached were separated out and identified. The mite larvae were identified by direct comparison with larvae bred by me from identified adult female mites.

# PART I: TAXONOMY

## Materials and Methods

The mites were preserved in Koenike's fluid (glycerine - 5 parts, distilled water - 3 parts, glacial acetic acid - 2 parts). This kept the mites in a pliable condition for dissecting and mounting. A fine scalpel and both coarse and fine dissecting needles were used for dissecting.

When discussing mite anatomy the terminology used follows Mitchell (1967b). The coxal plates I-IV will be referred to in the text as CP I, CP II, CP III and CP IV. Unless otherwise stated all measurements of CP III and CP IV were on the inner margins, nearest to the mid-line. All measurements were in microns ($\mu$); means are given first, followed by minima and maxima in parentheses. Drawings were made using a Leitz Laborlux with a *camera lucida* attachment.

For dissection soft-bodied mites were placed dorsal side up. A median, frontal incision cut the mites into dorsal and ventral halves. Care was taken to avoid damaging the four pairs of legs or the pedipalps. Each half was carefully cleaned of all internal organs, with especial care in removing the muscles attached both to the chitinised CP I-IV and to other parts of the body (genital plates, dorsal shield, ventralia, dorsalia, excretory plates and glandularia). In males extreme caution was used in removing the penis which may be small and is usually delicate.

The dorsal shield of hard-bodied forms was carefully prised off and then cleaned as for soft-bodied forms, with all the internal organs and muscles carefully scraped off the inner parts of the fused body-plates.

For mounting legs I-IV and the palps were removed from the ventral half of the body. The legs separated from the body between the CP and the first moveable leg segment - the trochanter. The five-jointed pedipalps were separated from the capitulum at the coxae. Some authorities (Lundblad, Halik, Soar and Williamson) favoured leaving the capitulum in place on the ventral surface of the body, while others (Mitchell, Cook, Efford and both Viets) preferred to remove it. The chelicerae were removed from their location in the capitulum. The mites and their dissected body-parts were next transferred to glycerine jelly, in which they were permanently mounted. The arrangement of the mite and its dissected body-parts in the final mount followed that recommended by Viets (1936) and by Efford (pers. comm.). Once the glycerine jelly hardened, cover-slips were added. Care was taken during this process to ensure that no air bubbles were trapped under the cover-slip. The entire mount was ringed with varnish. The ends of the slides were painted white and the pertinent information about the mite written on the white paint. Clear shellac was painted over the writing to protect it.

In the species list, the zoogeographic range and the North American distribution and bibliography of each species is given. For distribution in other areas see Viets (1956) and Crowell (1961). The species are presented in order of frequency.

The complete systematic classification of the water mites of Marion Lake will be found in Appendix A.

Marion Lake Species

Thirty-eight species representing eight super-families, sixteen families and twenty-four genera, were recorded from Marion Lake. One of these, *Pionopsis* (*Neotiphys*) nov. sp., is described. A second species was assigned to *Sperchon* but not identified at a specific level: only a single nymph was found. Nymphs of this genus are difficult to assign to a definite species as many of the adult characters are not apparent until the final moult to the adult. A third species, *Attractides glandulosus* (Walter), represents the first record for North America. Hitherto it was known only from Switzerland, Austria and Spain. Five other species (*Oxus gnaphiscoides* Habeeb, *Hydrochoreutes intermedius* Cook, *Tiphys vernalis* (Habeeb), *Arrenurus pseudocylindratus* (Piersig) and *A. solifer* (Marshall) ) are new records for Canada. *O. gnaphiscoides* was previously known from New Jersey; *H. intermedius* from Colorado and Montana, though I found it in Alberta and Saskatchewan (unpublished records); *T. vernalis* is known from Michigan and New Jersey; *A. pseudocylindratus* from Indiana, Louisiana, Michigan, New Hampshire, Tennessee, Wisconsin and Wyoming while I found it in Newfoundland (unpublished record); *A. solifer* from Michigan, New Hampshire, New York and Wisconsin with a further record by me from Saskatchewan (unpublished record).

Unionicola crassipes crassipes (Miller)

Synonyms: Viets 1956, pp 353 - 355.

Zoogeographic Range: Palearctic, Nearctic, Neotropical, Ethiopian, Oriental.

North American Distribution: Alaska, California, Colorado, Indiana, Iowa, Maine, Michigan, Montana, Nebraska, New York, Ohio, Tennessee, Washington, Wisconsin, Wyoming, Alberta, British Columbia, Manitoba, Ontario and Saskatchewan.

North American Bibliography: Wolcott, 1898, 1899; Miller 1925; Marshall 1924, 1926, 1927c, 1929a, b, 1930a, b, 1940a, 1943b; Hoff 1944; Conroy 1968; Young 1969; Conroy 1973.

Male: Length of CP III and CP IV 297 (200-473); palp length 422 (302-728).

Female: Length of CP III and CP IV 325.4 (230-620); palp length 478 (300-890); number of eggs/egg-bearing female 19.6 (1-173); egg diameter 159 (100-195).

Nymph: Length of CP III and CP IV 154.3 (82-213).

Larva: Piersig (1896-1899), Arndt and Viets (1938) and Sparing (1959) described the larva. Koenike (1909), Soar and Williamson (1927), Wesenberg-Lund (1939) and K. O. Viets (1955) reported the genus Spongilla (Porifera: Spongillidae) as the larval host. Lundblad (1927) gave S. lacustris as the host, while Arndt and Viets (1938) and Sparing (1959) list several genera and species of sponge (Spongilla, lacustris, S. fragilis Leidy, S. biseriata Weltn. (?), Ephydatia fluviatilis (L), E. mulleri (Liebk.) and Trochospongilla horrida Weltn.)

as the host of U. crassipes. Walter (1922) reported that "die Larven von U. crassipes (Mull.) auf Susswasserschwammen schmarotzen, wahrend Nymphe und Imago Freilebend sind" (op. cit., p 150). Marshall (1933b) reported U. crassipes in large numbers........in beds of fresh-water sponge". Wolcott (1899) reported both nymphs and adults in "considerable numbers" in bivalves (Pyganodan grandis footiana Lea, Anodanta fragilis Say and Sphaerium simile Say) in Lake Michigan. Viets and Plate (1954) recorded U. crassipes from Anodonta berigana Middff., A. marginata Say and Pyganodon grandis footiana. In Marion Lake the larval host is Spongilla lacustris (Linn.).

Habitats: U. crassipes is found usually in lakes, occasionally in ponds and sporadically in slow-flowing streams and rivers (Lundblad 1968, Conroy 1968 and unpublished records). Walter (1922) found it at an altitude of 974 m. Lundblad (1968) reported it at temperatures between 2.9 and 22 $^{o}$c. Viets (1924, 1936), Lundblad (1968) and I (unpublished records from West Blue Lake, Manitoba) found U. crassipes in the plankton. In Marion Lake I found U. crassipes at all depths from January to December and in the plankton from May to October. Pieczynski (1969) said U. crassipes was mainly a bottom dweller (98% of all specimens found). This contrasts with Marion Lake where 51.1% of the specimens of U. crassipes found in 1966-7 were from the plankton (U. crassipes made up 90.2% of all planktonic mites). Lundblad (1968) found the species in dredges at 36 m; Zschokke (1911) found it at 40 m deep;

Marshall (1924) reported it from a deep tow with 150 ft. line; and Walter (1922) found it at 84 m deep.

Notes: I noted a strong correlation between palp size and the length of CP III and CP IV in both sexes (Appendix G, test a-1, a-2).

If one considered only the smallest and largest palps for Marion Lake, one got:-

males : largest - n = 16, mean 543; smallest - n = 15, mean 328

females : largest - n = 16, mean 733; smallest - n = 18, mean 348.

Müller (1776) first described *U. crassipes* as *Hydrachna crassipes*. Soar (1900) reported a new subspecies (*U. crassipes minor*) in contrast to the 'normal' *U. crassipes major*. Halbert (1911) reported a third variety (*U. rivularis*) which Soar and Williamson (1927) and Viets (1956) synonymized with *U. crassipes minor*. Imamura (1953) described *U. crassipes miyazakii*, based on minor differences in the shape of the genital plate of the two males and on the featheration of the bristles of P II of all five specimens obtained (two males, three females). He also recorded *U. crassipes minor*. Two other subspecies by Lundblad (1924) and Maglio (1924) are termed 'monstrosities' by Lundblad (1962) who said (p. 124) he preferred to ignore species which are distinguished by small size and thick palps. Keiding (1948) described material from the River Susaa and compared it with *U. rivularis*, *U. crassipes crassipes* (i.e. *major*) from Tamose and with *U. crassipes minor* from Forest Stream.

Examination of the palp sizes given by all the above authors yielded: *U. crassipes* s. str. - males 720, females 880; *U.c. minor* - males - 350, females 381; *U.c. miyazakii* - males 352, females 392; *U. crassipes* s. str. (Tamose) - females 580; *U.c. minor* (Forest Stream) - females 340. For comparison purposes the Marion Lake data were: males - 422 (302-728), females 478 (300-890).

It would appear that the Marion Lake material is somewhere midway between *U. crassipes* s. str., and *U. crassipes minor*. The largest specimens from Marion Lake fit *U. crassipes* s. str., while the smallest fit *U. crassipes minor*.

No evidence of bimodality in the distribution of palp size for either males or females was found (fig. 4).

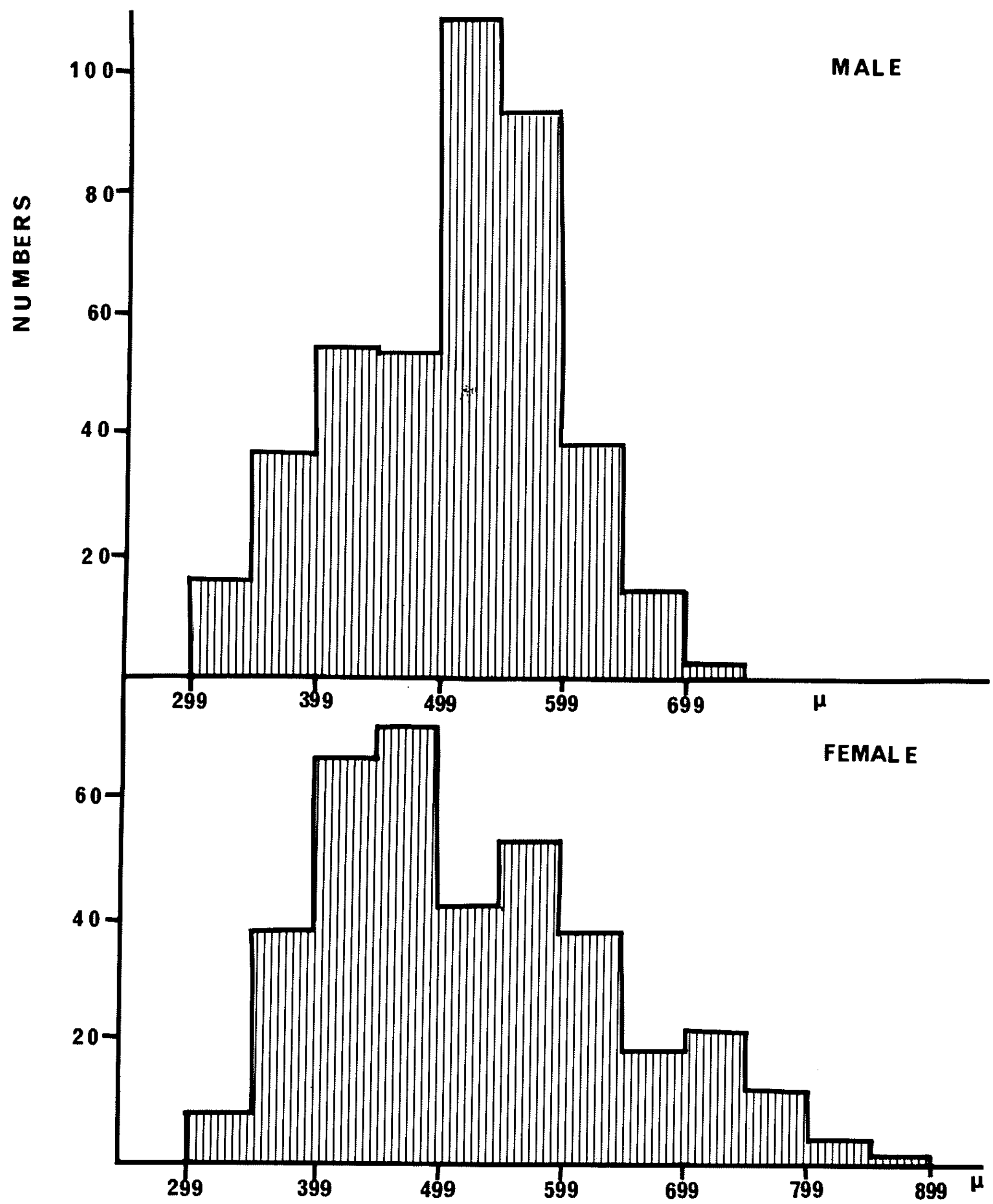
Keiding (1948) gave the following for CP III and CP IV:

| | |
|---|---|
| R. Susaa: | males - 263; females - 276. |
| Tamose ("Major") | females - 420 |
| Forest Stream ("minor") | females - 285 |
| For Marion Lake I got: | males 297.2 (200-473); |
| | females 325.4 (230-620). |

Keiding (1948) reported no even transition between the *minor* and the main species.

Comparison of the Marion Lake material with the results of other workers led me to the same conclusion as Lundblad (1962) - the subspecies *minor* is of dubious standing and should be discarded.

Fig. 4: Distribution of palpal lengths of males and females of *Unionicola crassipes crassipes*.


MALE
FEMALE
NUMBERS
100
80
60
40
20
299
399
499
599
699
799
899
μ

I found two female *U. crassipes* in the stomachs of *Taricha granulosa* (7-7-1964, 10-6-1966) and four in *Oncorhynchus nerka* (10-6-1966, 3 and 1). Marshall (1933a) reported *U. crassipes* from the stomachs of grayling.

*Piona carnea* (Koch)

Synonyms: Viets 1956, pp 434-435.

Zoogeographic Range: Palearctic, Nearctic.

North American Distribution: Alaska, Colorado, Idaho, Michigan, Montana, Wisconsin, Wyoming, British Columbia, Manitoba, Saskatchewan, and Alberta (unpublished record).

North American Bibliography: Wolcott 1902; Marshall 1924, 1937; Bergstrom 1953; Cook 1960; Conroy 1968; Young 1969; Prasad and Cook 1972; Conroy 1973.

Male: Length of CP III and CP IV 338 (260-420) with one male removed from a teleiochrysallis measuring 78; number of acetabula 11 (3-16).

Female: Length of CP III and CP IV 314 (215-430) with one female removed from a teleiochrysallis measuring 88; number of acetabula 12 (8-17); egg diameter 215 (180-270); number of eggs/egg-bearing female 4 (1-14); volume of eggs 0.004 $mm^3$. Walter (1922) found an average of 16 eggs/female with a mean diameter of 235.

Nymph: Length of CP III and CP IV 107 (63-210).

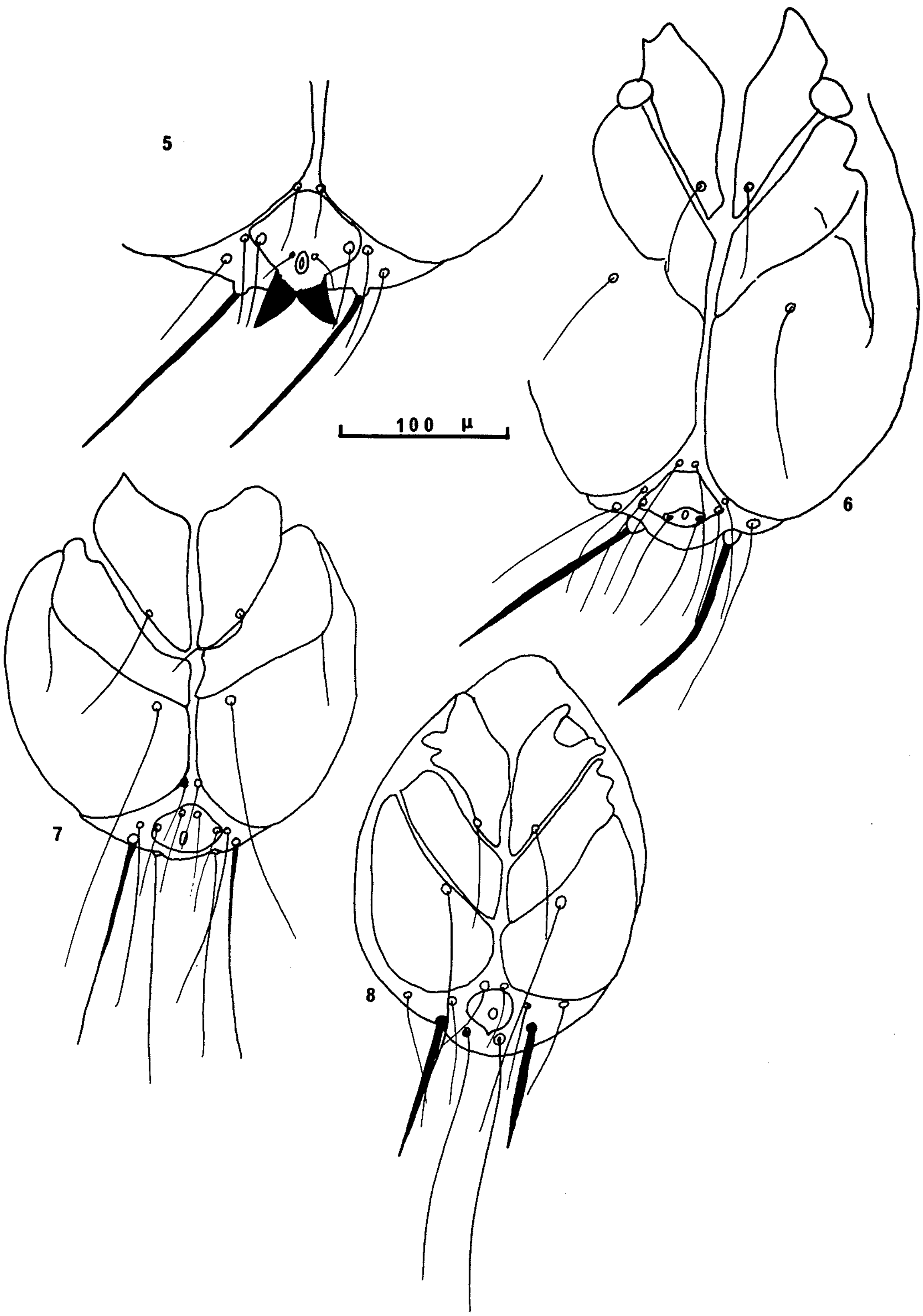
Larva: Length 428, width 272, (fig. 5).

Fig. 5: Posterior body and excretory plate region of the larva of _Piona carnea._

Fig. 6: Larva of _Piona constricta_, ventral view.

Fig. 7: Larva of _Arrenurus pseudocylindratus_, ventral view.

Fig. 8: Larva of _A. cascadensis_, ventral view.


5
6
7
8
100 μ

Larval Hosts in Marion Lake: Chironomous (Limnochironomus) modestus Say, C. remplii, Procladius denticulatus Sublette, Tanytarsus sp. B. (excavatus group), and T. verralli Edwards. Parasitized hosts were found during July and August.

Notes: In Marion Lake, one specimen occurred in a Hargrave Sample on March 19, 1969, and a second adult on December 30, 1969. A teleiochrysallis containing a female was found on Chara globularis on April 24, 1967. With these three exceptions,

P. carnea occurred in the lake from May 22 to October 15 only.

Piersig (1896-1899), Thor (1925), Lundblad (1927), Imamura (1954) and Sparing (1959) described the larva. Lundblad (op. cit., fig. 230), Thor (Op. cit., figs. 25, 26) and Imamura (op. cit., fig. 64) gave drawings of the Larva which corresponded exactly to the specimens I reared from eggs laid by P. carnea females. Sparing (op. cit., fig. 87) illustrated the larva of P. nodata which corresponded in every way to the figures of Lundblad (1927), Thor (1925), Imamura (1954) and Prasad and Cook (1972) for the larva of P. carnea. Sparing's figure for the larva of P. carnea (fig. 89) agrees with Viet's (1936, fig. 387) for P. nodata. Sparing's description for P. carnea fits her diagram for P. nodata (fig. 87) but not the drawing she labelled P. carnea (fig. 89). It seems that the numbers of her figures have been mixed up. In describing P. carnea's larva, Lundblad

(1927, p. 390)said "die eine charakteristiche Exkretionsplatte hat". This shows up clearly in his figure, in that of Thor, of Imamura, of Prasad and Cook and in Sparing's figure for P. nodata. It was also distinct in the Marion Lake larvae of P. carnea. Sparing (1959, p 81) gives the larval measurements as 440 long by 270 wide.

Habitats: Lundblad(1968) regarded P. carnea as a pond form, more rarely a lake form and occasionally in quiet stretches of rivers. The ponds or lakes were oligotrophic though he found the species many times in dystrophic and in mesohumic conditions. In such waters he found the greatest number of individuals. He recorded the species at 14 m deep and at temperatures between 6.2-25 C. Most of his records were for shallow water (less than 2 m) and at temperatures between 11.5-19 C. He (Lundblad 1968) found the species at altitudes of up to 950 m but he added that it was basically a lowlands and coniferous forest type. Walter (1922) found P. carnea in the Alps at 2006 m altitude. He regarded it as eurythermal. Cook (1960) stated that P. carnea is "known from a wide variety of standing-water habitats". Conroy (1968 and unpublished data) reported the species from lakes, ditches and slow-flowing rivers at altitudes up to 1500 m.

P. constricta (Wolcott)

Synonyms: Viets 1956, p. 442

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Michigan, Minnesota, Montana, Nebraska, Wisconsin, Alberta, British Columbia, Manitoba, Ontario, Saskatchewan.

North American Bibliography: Wolcott 1902; Marshall 1929b, 1930a, 1937, Cribbins 1959; Cook 1960; Conroy 1968; Young 1969; Prasad and Cook 1972; Conroy 1973.

Male: Length of CP III and CP IV 251 (180-363); number of acetabula 11 (6-18).

Female: Length of CP III and CP IV 206 (110-323); number of acetabula 10 (7-16); number of eggs/egg-bearing female 8 (1-26); egg diameter 168.5 (148-240); mean egg volume 0.002 $mm^3$.

Nymph: Length of CP III and CP IV 82.3 (50-125); number of acetabula 3, arranged on a triangular plate, one acetabulum at the apex, two at the base.

Larva: Length 312; width 230; division between CP II and CP III distinct but incomplete; Ep 4 inserted 26 μ posterior to this division; excretory plate triangular, with the apex cut off; Exp 2 in the basal angles; Exp 1 and the excretory pore on a slight prominence on the mid-posterior edge of the plate; Ex 1 on the anterior border of the excretory plate; Ex 4 on a raised prominence on the posterior edge of the body (fig. 6).

Larval Hosts in Marion Lake: *Chironomus modestus*, *Tanytarsus* sp. B (*excavatus* group), *T. lestagei* aggregate sens. Lindeman, *Procladius denticulatus* and *Protanypus* sp. A nymph of *P. constricta* occurred on *Ablabesmyia monilis* on July 13, 1969. Parasitized hosts occurred from June to

August.

Notes: P. constricta occurred in Marion Lake at all depths from March to early December. Prasad and Cook (1972) pointed out that the nodata-complex of which constricta is a member is the most difficult species-group to separate in the genus Piona. They obtained two distinct larval types from females that fitted very closely the description of the type specimen. The Marion Lake larvae differed from those described by Prasad and Cook yet the females from which they were bred were identical to specimens of P. constricta loaned by Dr. Cook for comparison purposes. It would appear that Prasad and Cook's supposition that there is pronounced intra-specific variation in P. constricta is correct.

Habitats: Cook (1960), Conroy (1968) and Young (1969) reported this species as being most abundant in semidrainage conditions and temporary pools. I (unpublished records) also found it in rivers, streams and lakes.

Arrenurus pseudocylindratus (Piersig)

Synonyms: Viets 1956, p 595

Zoogeographic Range: Nearctic.

North American Distribution: Indiana, Louisiana, Michigan, New Hampshire, Tennessee, Wisconsin, Wyoming and Newfoundland (Conroy, unpublished data), British Columbia.

North American Bibliography: Marshall 1903, 1908, 1910, 1914, 1927c, 1930a, 1940a, 1940b; Hoff 1944; Cook 1954; Conroy 1973.

Male: Width of genital field 396 (320-510); body width 634 (560-750); width of dorsal plate 458 (372-540).

Female: Width of genital field 599 (497-745); body width 923 (710-1068); width of dorsal shield 668 (512-780); number of eggs/egg-bearing female 13 (1-33); egg diameter 158.2 (105-188); egg volume 0.002 $mm^3$.

Nymph: Width of genital plates 241 (190-280); length of CP III and CP IV 88.3 (62-115).

Larva: Length of body 218; width 197; globular reddish-coloured larvae; excretory plate triangular-ovoid shape with the apex anteriorly; excretory pore in the posterior one third of the plate; Ep 4 84 μ long, reaching past the posterior rim of the body, inserted 7 μ from the anterior edge of CP III; pseudocapitulum well-developed; Ex 3 and Ex 4 both about 75 μ long (fig. 7).

Larval Hosts in Marion Lake: Enallagma boreale (Selys); Procladius denticulatus; P. bellus; and Ablabesmyia monilis. Parasitized hosts emerged in June and July. (E. boreale nymph and adults both months; chironomids only in July).

Habitats: Marshall (1903, 1908, 1910, 1914, 1927c, 1929a, 1940a, b), Hoff (1944) and Cook (1954) reported this species from all types of standing water except bogs.

Notes: A. pseudocylindratus occurred in Marion Lake at all depths from May to December. I found it eight times in the stomachs of Oncorhynchus nerka - three times in February 1964 and five times in June 1966.

Unionicola gracilipalpis gracilipalpis

Synonyms: Viets 1956, p. 356.

Zoogeographic Range: Palearctic, Nearctic

North American Distribution: British Columbia, Manitoba, Michigan.

North American Bibliography: Conroy 1969; Prasad and Cook 1972; Conroy 1973.

Male: Length of CP III and CP IV 29 7 (199-350) with a single individual measuring 590; distance between right and left CP IV 40 (10-68); length of palps 980 (890-1050).

Female: Length of CP III and CP IV 339 (240-410); distance between right and left CP IV 54 (1-100); length of palps 1200 (1000-1300); number of eggs-egg-bearing female 60 (1-135) ; egg diameter 145 (115-160).

Nymph: Length of CP III and CP IV 147 (80-200); distance between right and left CP IV 52 (3-105).

Larva: The larva was not identified with certainty. However, specimens of Spongilla lacustris brought into the laboratory on July 6th,1969 contained in their tissues a few eggs, many larvae and many nymphochrysallids of Unionicola spp. These sponges were isolated from each other in separate vials. On July 31, I observed nymphs and adults of Unionicola spp. swimming around in the vials; most of the adults were U. crassipes with a few U. gracilipalpis of both sexes. The nymphs were of both species in about equal numbers. As far as I could determine there was only one morphological type present in the sponge tissues. This larva was identical in all respects to the descriptions and figures of the larva of *U. crassipes*. This suggests to me that *U. gracilipalpis* needed the sponge to complete its life cycle. Prasad and Cook (1972) described the larva of *U. gracilipalpis* but made no comparisons between this species and *U. crassipes*.

Notes: *U. gracilipalpis* occurred at all depths in Marion Lake from early May to Mid-November. Motas (1928) gave the egg diameter as 140 $\mu$. Viets (1956) said *U. gracilipalpis* had a wide distribution in Europe. Lundblad (1968) classified it as predominantly a lake-form (any of oligotrophic, eutrophic or dystrophic) with a few records from streams and rivers and added that it was a shore-dwelling form with no positive records of the species deeper than 2 m. Cronholm (1946) recorded it from 0-1.5 m. Lundblad (1968, p 187) noted "*U. gracilipalpis* ist fast ebenso wenig wahlerisch wie die vorige Art (*U. crassipes*) und als verhaltnismassig eurytop zu bezeichnen". Conroy (1968) reported the species from Betula Lake, Manitoba, in association with both *U. crassipes* and *U. aculeata* Koenike.

*Arrenurus cascadensis* Lavers

Synonyms: Viets 1956, p 554

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Washington, British Columbia, Manitoba, Saskatchewan.

North American Bibliography: Lavers 1945; Bergstrom 1953; Conroy 1968; Young 1969; Conroy 1973.

Male: Width of genital plates 582.5 (510-668); body width 726.6 (610-811); width of dorsal shield 456.4 410-558).

Female: Width of genital plates 729.5 (598-825); body width 984 (805-1108); width of dorsal shield 643 (458-720); number of eggs/egg-bearing female 12.3 (1-38); egg diameter 142.2 '80-160); mean egg volume 0.001 $mm^3$.

Nymph: Width of genital plates 337 (175-380); length of CP III and CP IV 90 (72-123).

Larva: Length 197; width 163; globular bluish-grey larva; Ex 4 very long (144 μ); Ex stout; excretory plate rounded anteriorly, coming to a point posteriorly; excretory pore in posterior third of plate; pseudocapitulum broad and robust; Ep 4 elongate, lying slightly posterior to the anterior edge of CP III (fig. 8).

Larval Hosts in Marion Lake: *Aeshna interrupta* Walker, *Enallagma boreale* and *Zoniagrion* sp.

Notes: *A. cascadensis* occurred at all depths in Marion Lake from late April to late October. One male was found in the stomach of *Taricha granulosa* (August 8, 1963), another in *Oncorhynchus nerka* (February 19, 1964) and a third in *Ambystoma gracile* (October 21, 1964). Lavers (1945) found this species in lakes and ponds at altitudes up to 1700 m and from a river on Vancouver Island. Bergstrom (1953) recorded it at 2850 m altitude in a lake. Conroy (1968) (and unpublished data) reported it from lakes and rivers while Young (1969) recorded it in montane and semi-montane drainage lakes.

Piona debilis (Wolcott)

Synonyms: Viets 1956, p 443.

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Massachusetts, Michigan, Minnesota, Montana, North Carolina, Pennsylvania, Washington, Wisconsin, British Columbia.

North American Bibliography: Wolcott 1902; Marshall 1930a, 1937; Cribbins 1959; Cook 1960; Conroy 1968; Young 1969; Prasad and Cook 1972; Conroy 1973.

Male: Length of CP III and CP IV 226 (120-310); number of acetabula 18 (10-25).

Female: Length of CP III and CP IV 198 (135-290); number of acetabula 17 (10-24); number of eggs/egg-bearing female 10.7 (1-46); egg diameter 155 (127-260); egg volume 0.002 $mm^3$.

Nymph: Length of CP III and CP IV 84 (57-155); number of acetabula 2.

Larva: Length 252; width 216; division between CP II and CP III incomplete but distinct; Ep 4 very close to this division (within 5 μ); Ep 4 distinctly feathered; excretory plate 19 μ deep and 39 μ wide; Exp 1, Exp 2 and excretory pore in a line along the posterior margin of the plate (fig. 9.).

Larval Hosts in Marion Lake: Procladius denticulatus. Parasitized hosts emerged from mid-July to late August.

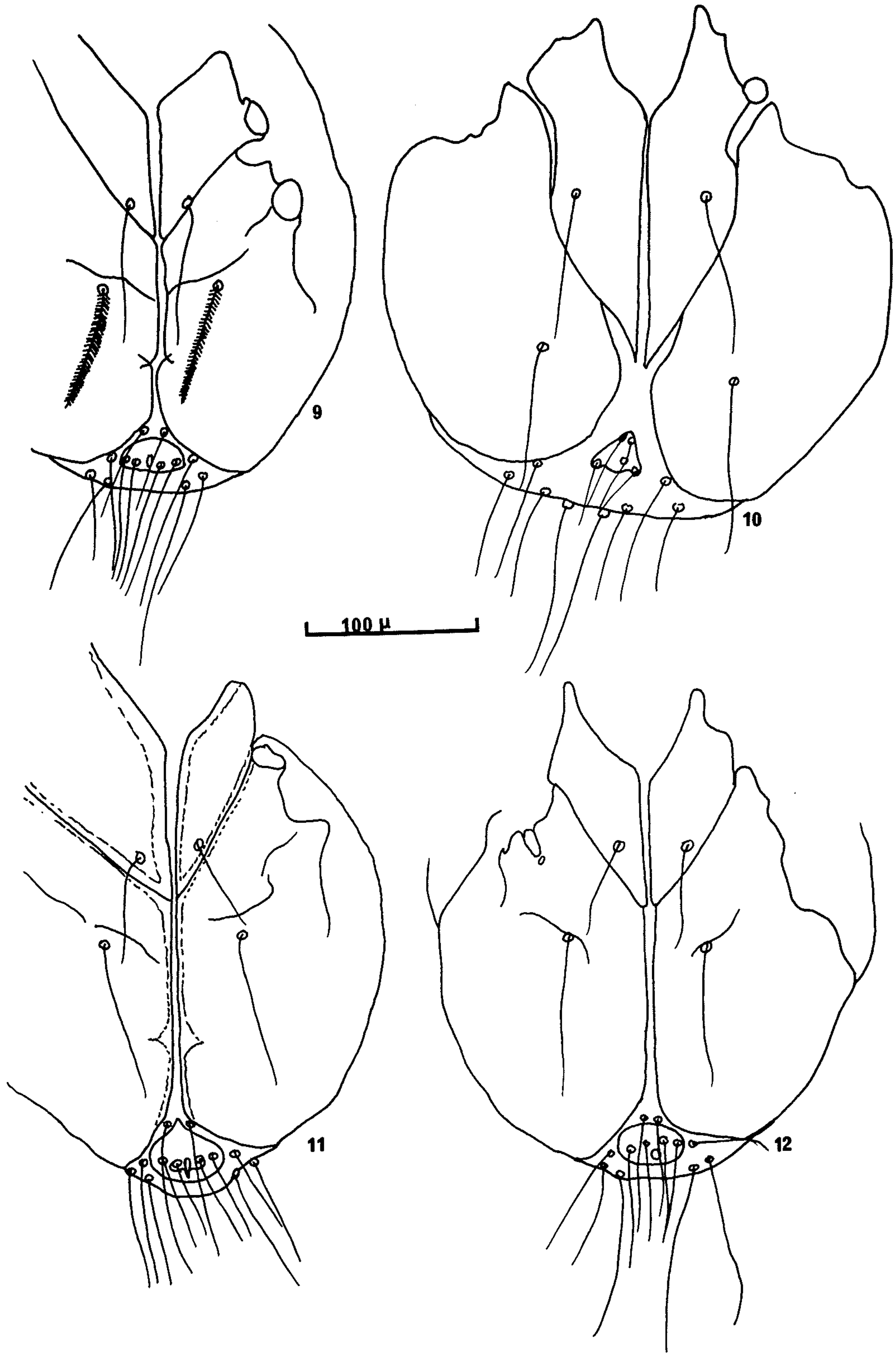
Notes: P. debilis occurred at all depths in Marion Lake from late May to mid-September. Wolcott (1902) reported P. debilis from lakes, while Marshall (1937) and Cook (1960) reported it from lakes and permanent ponds.

Fig. 9: Larva of *Piona debilis*, ventral view.

Fig. 10: Larva of *Frontipoda americana*, ventral view.

Fig. 11: Larva of *Piona variabilis*, ventral view.

Fig. 12: Larva of *Forelia ovalis*, ventral view.


9
10
100 µ
11
12

Frontipoda americana Marshall

Synonyms: Viets 1956, p 231.

Zoogeographic Range: Nearctic.

North American Distribution: California, Colorado, Indiana, Iowa, Louisiana, Michigan, Minnesota, Maine, New Jersey, New York, Tennessee, Wisconsin, Alberta and New Brunswick.

North American Bibliography: Marshall 1914, 1922a, 1926, 1929a, 1930a, 1932, 1940a, 1943b; Hoff 1944; Habeeb 1955c; Conroy 1968; Young 1969.

Male: Distance between the posterior margin of the capitular bay and the most anterior margin of the genital bay 46 (20-60); distance between coxal plates posterior to the genital bay (at the anus) 8 (2-12).

Female: Distance from the posterior margin of the capitular bay to the anterior margin of the genital bay 32 (25-45); distance between the coxal plates at the anus 8 (5-10); number of eggs/egg-bearing female 4 (1-9); egg diameter 163 (120-188).

Nymph: Distance between the posterior margin of the capitular bay and the anterior margin of the genital bay 16 (2-28); distance between the posterior projections of CP IV 135 (23-200).

Larva: Length 300; width 312; blue-green colour; CP I extends three-quarters down the ventral surface; posterior projection of this plate close to excretory bay; CP II and CP III fused with little or no indication of the point of junction between them; excretory plate more or less triangular with the base angles rounded; excretory opening in the centre of the plate; Exp 2 in the basal angles, Exp 1 in the apex of the plate; Exp 1, Exp 2, Ex 1, Ex 2, and Ex 3 weakly developed in this species; Ex 4 elongate (fig. 10).

Larval Hosts in Marion Lake: *Ablabesmyia monilis* and *Tanytarsus* sp. B (*excavatus* group).

Notes: *F. americana* occurred at all depths in Marion Lake in low numbers from mid-April to late October. Four adults were found in the stomachs of *Oncorhynchus nerka* (February 19,1964; June 10 and June 16, 1966) and of *Ambystoma gracile* (June 16, 1966). Marshall (1922a) found this species in lakes at depths of 5 m. Hoff (1944) reported it from beds of 'coontails'.

*Piona variabilis* (Koch)

Synonyms: Viets 1956, p 460-462.

Zöogeographic Range: Palearctic, Nearctic

North American Distribution: Colorado, Michigan, Montana, Alberta, Saskatchewan and British Columbia (Conroy, unpublished data).

North American Bibliography: Cook 1960; Conroy 1968; Young 1969.

Male: Length of CP III and CP IV 198 (145-218); number of acetabula 11 (7-18).

Female: Length of CP III and CP IV 210 (160-275); number of acetabula 13 (9-21); number of eggs/egg-bearing female 43 (1-64); egg diameter 160.5 (150-210); egg volume 0.002 $mm^3$.

Nymph: Length of CP III and CP IV 159 (135-190); number of acetabula 2.

Larva: Described by Sparing (1959); Marion Lake material - length 300; width 203; division between CP II and CP III incomplete; Ex 4 10 μ from this division; excretory plate 26 μ long by 40 μ wide (fig. 11).

Larval Hosts in Marion Lake: *Ablabesmyia monilis*, *Tanytarsus* sp. B (excavatus group) and *T. verralli*. Parasitized hosts emerged in mid-June and in mid to late August.

Notes: *P. variabilis* occurred at all depths in Marion Lake from late May to late September. 93% of the specimens occurred in 1969. Cook (1960) found *P. variabilis* in lakes; Conroy (1968) found it in a lake and in two sloughs; and Young (1969) stated that "it occurs in semi-drainage conditions with much greater frequency and abundance". Lundblad (1968) found it at depths up to 10 m in lakes, bogponds, calcareous ponds, rivers, streams and brackish water at temperatures from 9-25 C.

*Forelia ovalis* Marshall

Synonyms: Viets 1956, p 467.

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Illinois, Michigan, New Jersey, North Carolina, Wisconsin, Wyoming, Tennessee, Ontario.

North American Bibliography: Marshall 1929b, 1930a, 1935; Hoff 1944; Bergstrom 1953; Habeeb 1954b; Cook 1955; Habeeb 1956a; Young 1969; Prasad and Cook 1972.

Male: Length of CP III and CP IV 202 (147-225); number of acetabula 36 (28-46); P-I 32, P-II 101, P-III 56, P-IV 100, P-V 45.

Female: Length of CP III and CP IV 126 (65-210); number of acetabula 40 (31-57); number of eggs/egg-bearing female 9 (1-20); egg diameter 164.5 (144-190); egg volume 0.002 $mm^3$; dorsal plates 81 long (72-89), 28 wide (26-32).

Nymph: Length of CP III and CP IV 23 (18-35); number of acetabula 2.

Larva: Length 283; width 233; division between CP II and CP III incomplete; Ep 4 lying on this division; excretory plate oval, measuring 24 long by 36 wide; excretory opening near posterior border of plate; Exp 1 and Exp 2 in a line near the anterior edge of the excretory plate; Ex 1 close to posterior edge of CP III; Ex 2 forms a line with Exp 1 and Exp 2; Ex 3 and Ex 4 on the posterior body margin (fig. 12).

Larval Hosts in Marion Lake: Chironomids.

Notes: *F. ovalis* occurred at all depths in Marion Lake from late May to late September. One female was found in the stomach of Oncorhynchus nerka (16 June 1966). When I compared specimens of F. ovalis from Marion Lake with the figures in Marshall (1929b), Habeeb (1954b and 1956a) and in Cook (1955) and with specimens loaned to me by Dr. Cook, I observed the following:

Male: Ventral view (fig. 13a), end segments of IV-Leg and palps are identical with those illustrated for F. ovalis (Cook op. cit., figs. 33, 43, 39) and quite different from those shown for F. liliacea americana (op. cit., figs. 12-13). The measurements for the male palp from Marion Lake are well within the range given by Cook (1955, p 300) for F. ovalis - P-I 28-35, P-II 92-112, P-III 43-52, P-IV 84-107, P-V 37-50, yet are at the same time outside the values for F. liliacea (P-I 23-28, P-II 80-89, P-III 39-49, P-IV 76-85, P-V 36-40). The big difference is that the dorsal plates illustrated by Cook (1955, fig. 15) for F. liliacea americana are the same size and shape as those noted in the Marion Lake specimens (fig. 13b) which are in turn quite different from those shown by Cook (figs. 35, 40, 44 and 45) for F. ovalis.

Female: The Marion Lake material (figs. 14a, b) is identical with the figures in Cook (1955, figs. 34, 36 and 41) for F. ovalis (i.e. dorsal plates, ventral view and segments of I-Leg). The dorsal plates fit into the range in size as given by Cook (1955, p 300) for F. ovalis - 57 - 118 long by 26 - 33 wide. Cook (1955, p 304) gave the dorsal plate

Fig. 13: *Forelia ovalis*, male

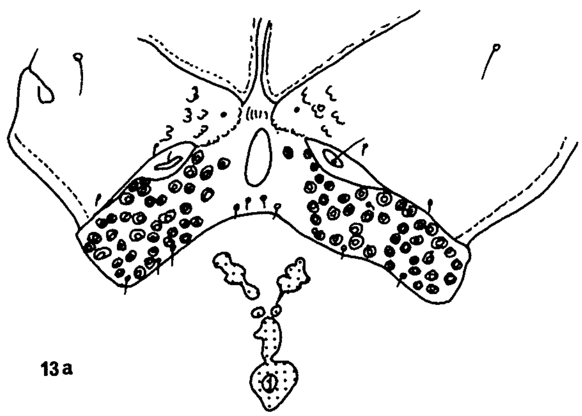
(a) genital region

(b) dorsal plates

Fig. 14: *F. ovalis*, female

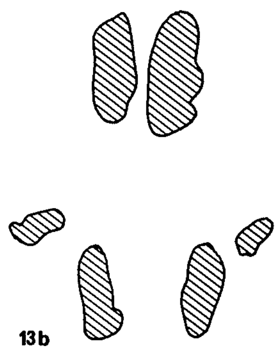
(a) genital region

(b) dorsal plates

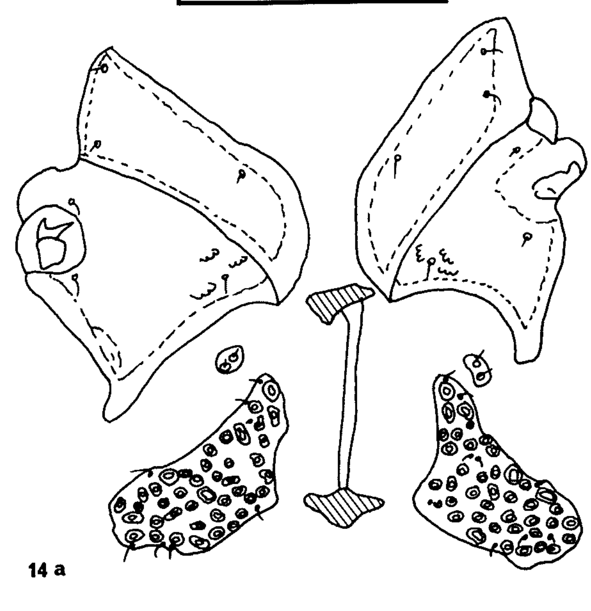


13a

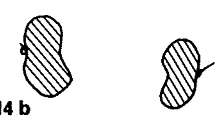
250 μ



13b



14a



14b

measurements of F. liliacea americana as 47-64 long by 18-28 wide.

Genital acetabula: In considering the number of genital acetabula, the Marion Lake material is closer to the range for F. ovalis than to that for F. liliacea americana (Cook 1955, p 300, 302, 304). For males, Cook gave the ranges as 26-38 for F. ovalis and 22-31 for F. liliacea americana. For females Cook gave the ranges as 22-38 for F. ovalis and 32-43 for F. liliacea americana.

General comments: Habeeb (1954b, 1956a) gave drawings and descriptions for F. ovalis which agree with the Marion Lake material and Cook (1955, p 300) stated that "in certain of the Barton Pond individuals, some suggestion of three pairs of plates............may be seen." It is therefore possible in the future, individuals from other populations may be found which have three pairs of smaller plates, rather than one large plate. "Even in such a case, the structure of the acetabular plates will serve to separate the species from all others". After comparing the Marion Lake specimens with specimens of both F. ovalis and F. liliacea americana, loaned by Dr. Cook, I concluded that the Marion Lake species was F. ovalis.

Habitats: Cook (1955) recorded F. ovalis from lakes and permanent ponds to depths of 5 m. Marshall(1929b) recorded the species from a lake at a depth of 6 m and Bergstrom (1953) found the species at 3,000 m altitude. Young (1969) using Pennak's topology (1958) found F. ovalis on plains in both alkaline and non-alkaline waters and in montane drainage and in semi-drainage conditions. Habeeb (1954b) found F. ovalis in a pond.

## Pionopsis nov. sp.

Type Locality: Marion Lake, British Columbia

Specimens Studied: 25 males, 99 females, 88 nymphs and 61 larvae.

Type Specimens:

Holotype: Male, mount number 69-10-09 (to be deposited with the Entomology Research Unit, Canadian Department of Agriculture, Ottawa). Specimen found on July 15, 1969 at 1.5 m deep and 13 C.

Allotype: Female, mount number 54-04 (to be deposited with the Entomology Research Unit, Canadian Department of Agriculture, Ottawa). Specimen found on July 15, 1967, at 5.0 m deep and 11 C.

Paratypes: in collection of the author; one male, one female sent to Dr. D. R. Cook, Wayne State University.

Diagnosis:

The new species can be separated from P. lutescens (Hermann) on the basis of size (it is considerably smaller). The male differs in the size and shape of the palps, in the shape of CP IV, in the arrangement of the genital acetabula (fig. 15), in the setation on IV-Leg-4 and IV-Leg-5 (Pionopsis nov. sp. has a large hook-like seta

Fig. 15: *Pionopsis* nov. sp., male

(a) right palp

(b) ventral view

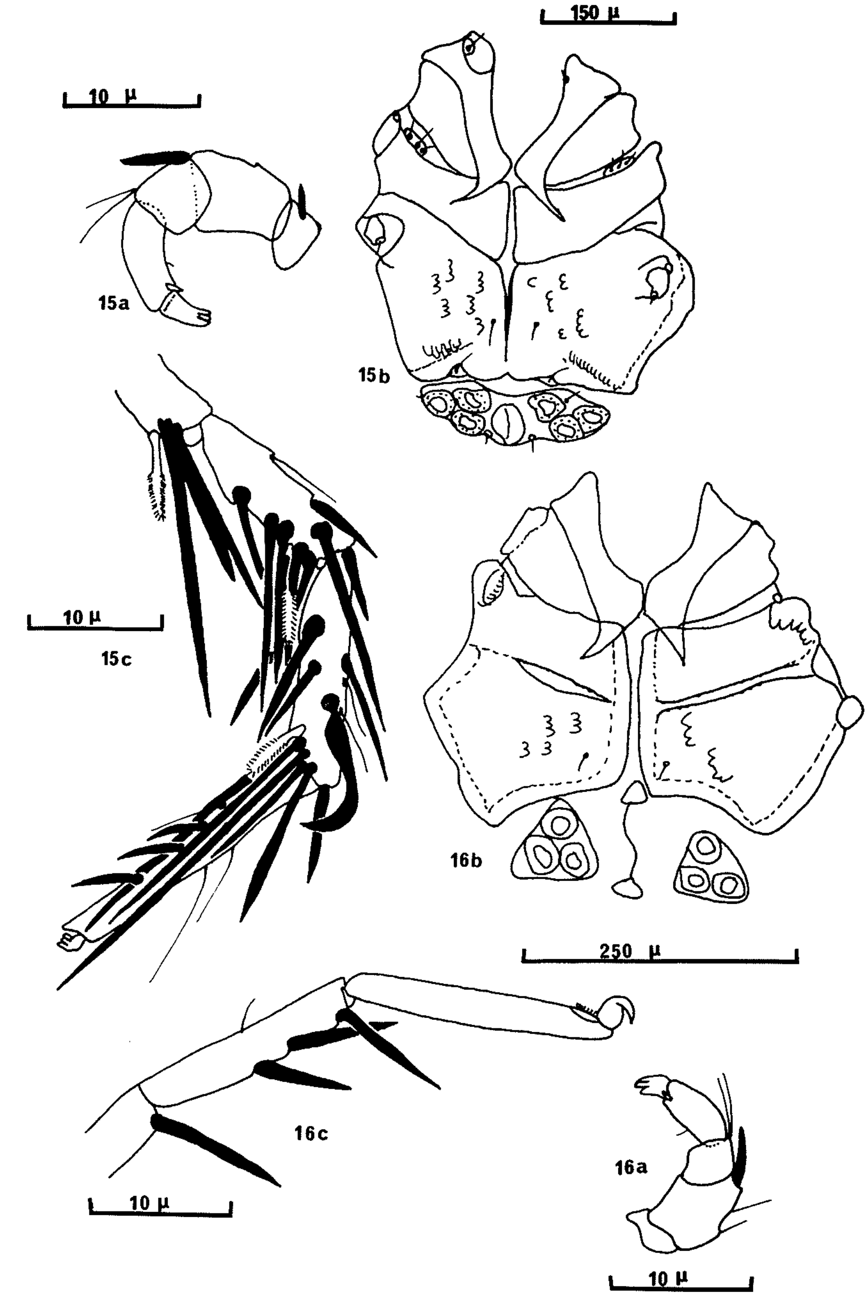
(c) IV-leg terminal segments

Fig. 16: *Pionopsis* nov. sp., female

(a) palp

(b) ventral view

(c) I-leg terminal segments



150 µ
10 µ
15a
15b
10 µ
15c
16b
250 µ
16c
16a
10 µ
10 µ

which is absent in P. lutescens), in the size of III-Leg-5 and III-Leg-6, and in the shape of the genital opening. The females differ in the shape of CP IV, in the arrangement of the genital acetabula, in the size and shape of the palp, and in the size of I-Leg-5 and I-Leg-6 (figs. 16, 18). Pionopsis nov. sp. can be separated from P. pionidellus (Habeeb) by the following:- (1) the posterior margins of CP IV in P. pionidellus are markedly concave while in Pionopsis nov. sp. they are almost straight; (2) IV-Leg-4 and IV-Leg-5 of P. pionidellus males lack the short, plumose blade-like setae noted in Pionopsis nov. sp.; (3) the four long hair-like setae on the flexor surface of IV-Leg-5 of the male Pionopsis nov. sp. are subequal to IV-Leg-6 while in P. pionidellus males, these setae are only half the length of IV-Leg-6.

Zoogeographic Range: Nearctic

Male: Length between the anterior margin of CP I and posterior margin of CP IV - (a) 194-243 (b) 302-332; body oval; integument thin; CP IV approximately as long as wide; two pairs of setae midway along the posterior border of CP IV; posterior border of CP IV straight or very slightly concave; genital bay very slight; partial fusion of CP IV posteriorly; three pairs of genital acetabula present, arranged in a triangle; no secondary schlerotization noted in the region of the acetabular plates (fig. 15b); genital opening round; length of CP III and

CP IV 170 (112-200); length of III-Leg-5 121-138; length of III-Leg-6 165 (153-178); a few swimming hairs noted on III-Leg-5; IV-Leg-4 short, not flattened with one short plumose, blade-like seta and three long, needle-like setae at or near the distal end; IV-leg-5 with one short, plumose, blade-like seta at the distal extensor surface, four long, hair-like setae originate near the plumose seta and run parallel to, and are the same length as, IV-leg-6 (fig. 15c); palp short with P-II twice as long as P-III (fig. 15a).

Female: Palp same as for male (fig. 16a); length between anterior margin of CP I and posterior margin of CP IV (a) 170-227 (b) 291-397; length of CP III and CP IV 131.7 (76-178); body rounded-oval; integument thin; genital acetabula arranged in the form of a triangle with one above, two below (fig. 16b); posterior corners of CP IV weakly angled; posterior borders of CP IV concave; length of I-leg-5 138 (113-162); length of I-Leg-6 146 (113-178) (fig. 16c); number of eggs/egg-bearing female 4 (1-9); egg diameter 128 (115-143); egg volume 0.001 $mm^3$.

Larva: (fig. 17); length 341; width 300; division between CP II and CP III interrupted (i.e. not continuous); Ep 4 inserted 20 μ posterior to this division; Ep 4 90 μ long; excretory plate triangular with basal angles rounded and containing Exp 2; excretory pore in posterior part of excretory plate; Exp 1 lateral about half way down the plate; Ex 4 100 μ long; Ex 2, Ex 3 and Ex 4 inserted posterolaterally to the excretory plate in a close triangular grouping.

Fig. 17: *Pionopsis* nov. sp., larva, ventral view.

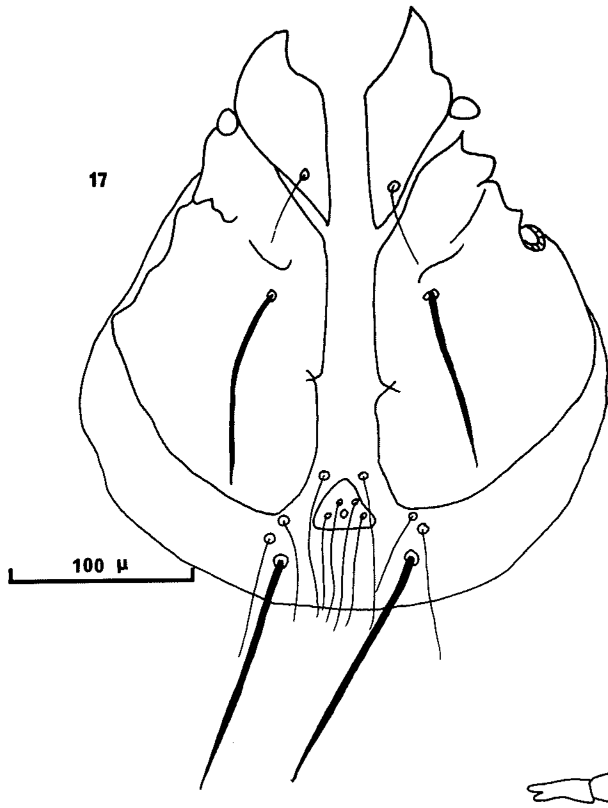
Fig. 18: *P. lutescens* female

(a) ventral view

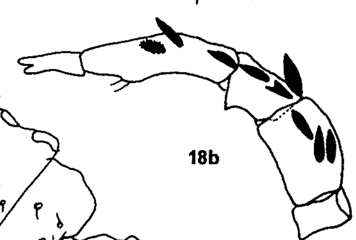
(b) palp

(c) I-leg, terminal segments

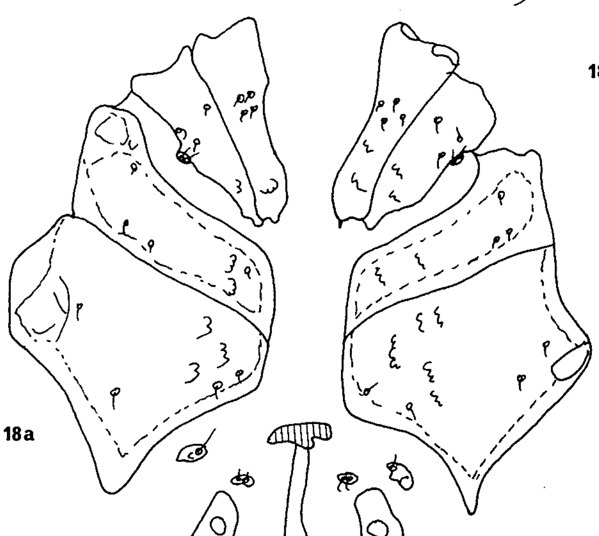
17




18c



18b



250 μ

18a

Larval Host in Marion Lake: *Psectrocladius* sp. A.

Parasitized hosts emerged from May to mid-June. In mid-August one *Ablabesmyia monilis* had a *Pionopsis* sp. larva attached.

Notes: *Pionopsis* nov. sp. at all depths in Marion Lake from April to November. One female was found in the stomach of *Oncorhynchus nerka* (16-Vi-1966).

*Forelia borealis* (Habeeb)

Synonyms: Viets 1956, p 468

Zoogeographic Range: Nearctic

North American Distribution: Michigan, New Jersey, North Carolina, Ontario, New Brunswick and Alberta (Conroy, unpublished data).

North American Bibliography: Habeeb 1954a, b; Cook 1955; Habeeb 1957c.

Male: Length of CP III and CP IV 49 (25-85); number of acetabula 9 (7-11).

Female: Length of CP III and CP IV 143 (105-167); number of acetabula 10 (6-13); number of eggs/egg-bearing female 9 (1-17); egg diameter 171.2 (152-203); egg volume 0.002 $mm^3$.

Nymph: Length of CP III and CP IV 62 (47-78).

Notes: *F. borealis* occurred at all depths in Marion Lake from April to November. A female was found in the stomach of *Salmo gairdneri* in July 1967.

Arrenurus solifer (Marshall)

Synonym: Viets 1956, p 598.

Zoogeographic Range: Nearctic

North American Distribution: Michigan, New Hampshire, New York, Wisconsin, and Saskatchewan (Conroy, unpublished data).

North American Bibliography: Marshall 1908, 1910, 1940b; Cook 1954.

Male: Body width 721 (650-760); width of dorsal shield 511 (477-538); width of genital plates 429.4 (390-503).

Female: Body width 1032.1 (890-1188); width of dorsal shield 738.3 (655-868); width of genital plates 658 (580-845); number of eggs/egg-bearing female 8 (1-20); egg diameter 184.5 (162-203); egg volume 0.002 $mm^3$.

Nymph: Length of CP III and CP IV 91.1 (72-108); width of genital plates 233 (193-278).

Larva: (fig. 19); length 300; width 343; globular reddish larva; excretory plate round with centrally placed excretory pore; Exp 1 anterior and lateral to excretory pore; Exp 2 near posterior border of plate; Ex 3 120 μ long; Ex 4 84 μ long; skin with wavy lines; pseudocapitulum well-developed.

Larval Hosts in Marion Lake: Aeshna interrupta, Zoniagrion sp.

Notes: A. solifer occurred in low numbers at all depths in Marion Lake from late April to October. Of the 122 specimens obtained, 118 occurred in 1966-7. In June 1966

Fig. 19: *Arrenurus solifer* larva ventral view.

Fig. 20: *Neumania semicircularis* larva ventral view.

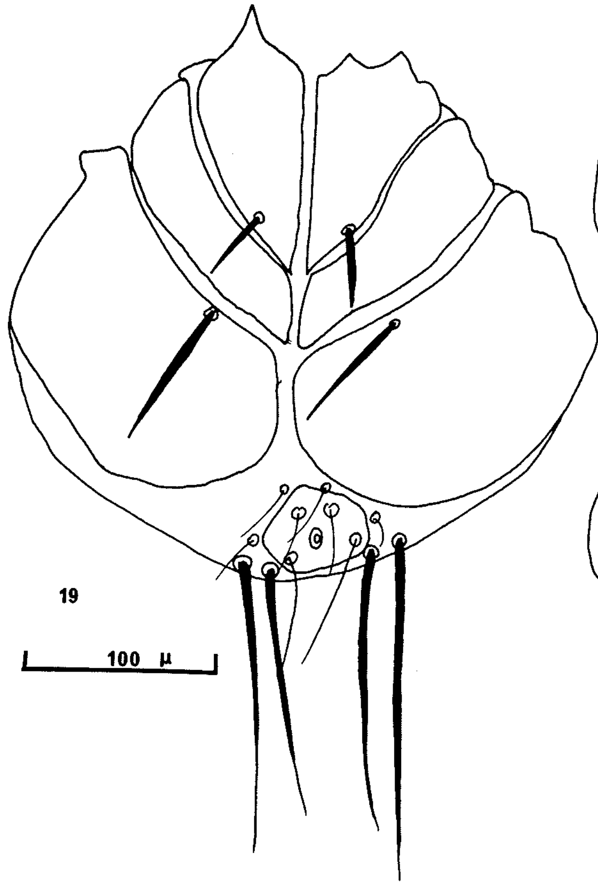
Fig. 21: *Limnesia maculata* male

(a) Unusual genital plates - mount 62-10

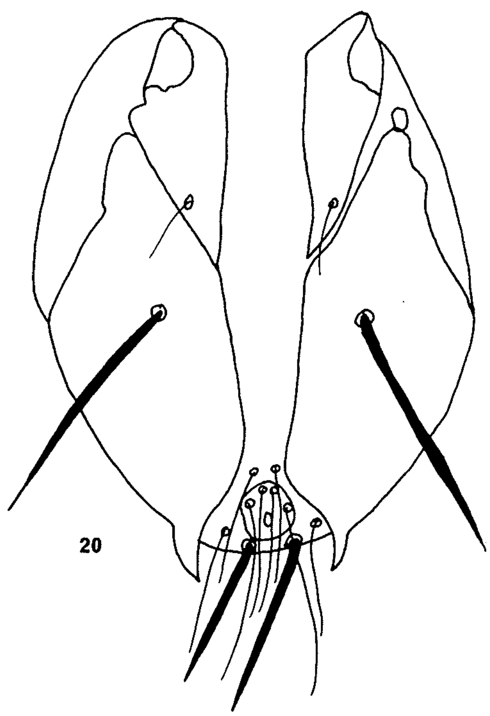
(b) Normal genital plates

(c) Palp of mount 62-10

(d) Palp of normal male.




19



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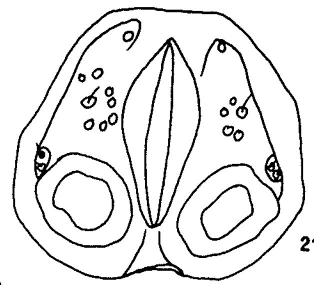
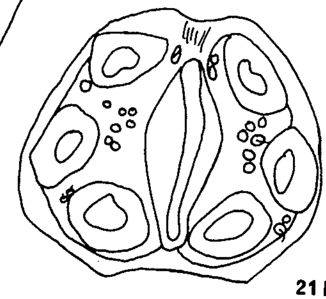
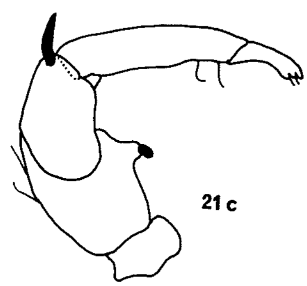


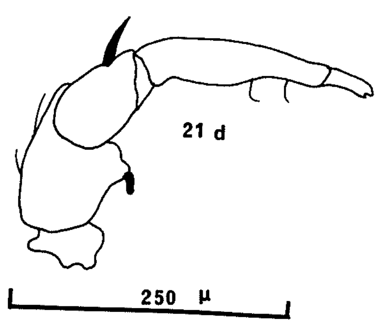
21a



21 b



21 c




21 d

I found one male and one female in the stomachs of two *Oncorhynchus nerka* and two females in the stomachs of two *Taricha granulosa*. Cook (1954) reported *A. solifer* from a weedy, peat-bottomed lake. I found a male in the Kingsmere River, Prince Albert National Park (unpublished data). This was a slow-flowing river with much emergent and submerged vegetation (*Potamogeton* spp., *Equisetum* spp. and *Myriophyllum* spp.) and a sandy bottom. The collection was made where the river enters Waskesiu Lake. Most individuals of this species from Marion Lake were taken near the mouth of the inlet stream (fig. 1, 2).

*Piona interrupta* Marshall

Synonym: Viets 1956, p 446

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Michigan, Montana, New York, Wisconsin, Alberta, British Columbia, Manitoba, Ontario, and Newfoundland (Conroy, unpublished data).

North American Bibliography: Marshall 1929b, 1930b, 1937; Bergstrom 1953; Cook 1960; Conroy 1968; Prasad and Cook 1972; Conroy 1973.

Male: Length of CP III and CP IV 290 (265-330).

Female: Length of CP III and CP IV 307 (260-338); number of eggs/egg-bearing female 58 (32-99); egg diameter 214.2 (197-250); egg volume 0.004 $mm^3$.

Nymph: Length of CP III and CP IV 114 (80-145); number of acetabula 2.

Notes: *P. interrupta* occurred at all depths in Marion Lake from late April to late September. Two females occurred in late April; three females and nine nymphs in June; one male, seven nymphs in July; four males, five females and fourteen nymphs in August, two males, two females and three nymphs in September. Marshall (1929b, 1930b and 1937) reported the species from lakes and ponds to depths of 12 m. Cook (1960) reported it from lakes and permanent ponds and Conroy (1968) found *P. interrupta* in a ditch and in a slow-flowing creek.

*Neumania semicircularis* Marshall

Synonyms: Viets 1956, p 380

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Illinois, Iowa, Michigan, Montana, Pennsylvania, Wisconsin, British Columbia, Ontario, Saskatchewan.

North American Bibliography: Marshall 1922b, 1926, 1929b, 1930a, b, 1933b, 1940a; Cribbins 1959; Conroy 1968; Young 1969.

Male: Length of CP III and CP IV 300 (280-320); distance between right and left CP IV 28 (20-35).

Female: Length of CP III and CP IV 325 (290-360); number of eggs/egg-bearing female 2 (1-4); egg diameter 190; egg volume 0.003 $mm^3$.

Nymph: Length of CP III and CP IV 138 (110-165); number of acetabula 2.

Larva: (fig. 20); length 300; width 223; division between CP II and CP IV visible on lateral edge; posterior border of CP III produced into a spine projecting past the posterior body edge; Ep 4 100 μ long, Exp 1 inserted near the anterior rim of the round excretory plate; Exp 2 inserted laterally midway down the plate; Ex 1 well developed and inserted near the posteromedian angle of CP III; Ex 4 on the posterior body edge, very strong and 150 μ long.

Larval Hosts in Marion Lake: *Tanytarsus* sp. B (*excavatus* group), *Ablabesmyia monilis*, *Procladius denticulatus* and *Psectrocladius* sp. Parasitized hosts emerged from mid-July to late August.

Notes: *N. semicircularis* occurred in the middle or south end of Marion Lake at depths from 0.5-4.5 m. I found one adult on June 5, 1966. The other 11 adults occurred between July 15 and October 7; 22 nymphs occurred in June, 14 nymphs in July and one nymph in August. Conroy (1968) reported *N. semi-circularis* from a creek. Marshall (1933b) found the species at depths of 10 m and (1929b) at 23 m in Lake Simcoe, Ontario. Young (1969) reported that "*Neumania semicircularis*...............(is) limited to non-alkaline waters".

## *Hydrozetes lacustris* (Michael)

North American Distribution: *H. lacustris* is widely distributed in both Europe and North America (Newell 1945).

Zoogeographic Range: Palearctic Nearctic

Notes: Eight females occurred in June; nine in July; seven in August; and one in September. They occurred at all depths in Marion Lake from 0.5-5.0 m. Two females occurred in the stomach contents of Salmo gairdneri on February 18 and 19, 1964 and nine in Oncorhynchus nerka (eight in three stomachs on February 18 and one on February 19, 1964).

Limnesia maculata maculata (Muller)

Synonyms: Viets 1956, pp 277-279.

Zoogeographic Range: Palearctic, Nearctic, Ethiopian.

North American Distribution: Alaska, Iowa, Michigan, Montana, New York, Tennessee, Wisconsin, British Columbia, Alberta, Manitoba, Ontario and Saskatchewan.

North American Bibliography: Wolcott 1903; Marshall 1924, 1926, 1927c, 1929b, 1930a, 1932, 1943b; Hoff 1944; Conroy 1968.

Male: Length of CP III and CP IV 70-100; distance between right and left CP III 85-450.

Female: Length of CP III and CP IV 90-140. No egg-bearing females found.

Nymph: Length of CP III and CP IV 45-60.

Notes: One male and two female. L. maculata maculata occurred in Marion Lake samples in May; one male one female and five nymphs in June; one male and five nymphs in July; one male, four females and a nymph in August; two males three females in September; and a male in October. I found a male in the stomach of Oncorhynchus nerka (10-vi-1966) and a female in the stomach of Salmo gairdneri (16-vi-1966). The species occurred only in water deeper than 1.0 m.

The number of acetabula was reduced in one male (mount 62-10) from three/genital plate to one/plate (fig. 21a, b). Only the most posterior of the three acetabula was present. Size and shape of the genital plates was typical for the species. They measured 267 long and 251 wide. For comparison purposes a drawing of a normal genital plate and a normal palp is included (fig. 21c, d).

Marshall (1929b) reported L. maculata at depths to 7 m and Lundblad (1968) found it to 11 m deep at temperatures from 6.5-27 C. Soar and Williamson (1927) and Sparing (1959) described the larva and indicated it was found on chironomids. Chironomids emerging from Marion Lake were examined for Limnesia larvae but none were found.

## Hydrochoreutes intermedius Cook

Synonyms: Cook 1970.

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Montana, Alberta, Saskatchewan (Canadian records, unpublished data by Conroy).

North American Bibliography: Cook 1956; Young 1969; Cook 1970.

Male: Length of CP III and CP IV 120-250.

Female: Length of CP III and CP IV 158-213; distance between right and left CP III 28-170; number of eggs/egg-bearing female 21; egg diameter 150; egg volume 0.001 $mm^3$.

Nymph: Length of CP III and CP IV 85-115; number of acetabula 2; distance between right and left CP IV 25-105.

Notes: Six male and six female. H. intermedius occurred in Marion Lake in June; one male one female and four nymphs in July; one nymph in August; one female in September and one female in October. I found the species at all depths to a maximum of 4.5 m. All records for June were from the south end of the lake, and, with one exception, all other records were from the north end of Marion Lake. The exception was a female found at 1.5 m on the 11-viii-1966 in square #22 (fig.1). Cook (1956) reported H. intermedius from lakes and the mouths of sluggish streams. Young (1969) reported it from lakes and said that it "possibly.........(is) limited to nonalkaline waters". I found a female in an unnamed slow-flowing creek in Prince Albert National Park and a nymph in Maskinonge Lake, Waterton National Park (both records August 1967). Comparisons made between the Marion Lake material and specimens loaned by Dr. Cook confirmed my material as H. intermedius.

Hydrodroma despiciens despiciens (Muller)

Synonyms: Viets 1956, pp 148-150

Zoogeographic Range: Palearctic, Nearctic, Neotropical, Ethiopian, Oriental, Australia.

North American Distribution: Colorado, Indiana, Iowa, Michigan, North Carolina, Ohio, Wisconsin, Wyoming, British Columbia, Manitoba, Ontario, Saskatchewan. Crowell (1961) reported it as being found in "about half the states in the Union".

North American Bibliography: Marshall 1926, 1927a, b, c, 1929b, 1930a, 1931, 1933a, 1940a; Hoff 1944; Marshall 1946; Crowell 1957, 1960; Conroy 1968; Young 1969; Prasad and Cook 1972.

Male: Length of CP III and CP IV 63-100; distance between right and left CP III 50-403.

Female: Length of CP III and CP IV 100-105; distance between right and left CP III 98-130; number of eggs/egg-bearing female 6; egg diameter 138.

Nymph: Length of CP III and CP IV 40-43; distance between right and left CP III 95-190.

Notes: One adult *H. despiciens* occurred in Marion Lake in May, an adult and a nymph in June, two adults and a nymph in July, eleven adults in August and an adult in a teleiochrysallis in December. All records were from water less than 3.5 m deep. I found two adults in the stomach of *Oncorhynchus nerka* on 10-vii-1966. Crowell (1957, 1960) reported *H. despiciens* from standing water with much vegetation. Walter (1922) gave the egg diameter as 160 and added that there were numerous eggs/female. This contrasted with the 6/female from

Marion Lake.

*Piona conglobata conglobata* (Koch)

Synonyms: Viets 1956, pp 440-441

Zoogeographic Range: Palearctic, Nearctic

North American Distribution: Colorado, Minnesota, Michigan, Montana, Pennsylvania, Wyoming, Alberta, British Columbia, Manitoba, Saskatchewan.

North American Bibliography: Marshall 1930a, 1935; Bergstrom 1953; Cribbins 1959; Cook 1960; Conroy 1968; Young 1969; Prasad and Cook 1972.

Female: Length of CP III and CP IV 170 (160-178); number of eggs/egg-bearing female 6.7 (6-8); egg diameter 177.3 (168-213); egg volume 0.002 $mm^3$; number of acetabula 12 (11-13).

Notes: Four female *P. conglobata* occurred in Marion Lake in June; six females, one nymph in July; three females, two nymphs in August. I found them at depths ranging from 0.5-4.5 m. Cook (1960) reported *P. conglobata* from lakes and permanent ponds. Bergstrom (1953) recorded *P. conglobata* from a lake at 2000 m altitude. Conroy (1968) reported *P. conglobata* from lakes, sloughs, slow-flowing creeks, and a ditch. Young (1969) recorded the mite from ponds in non-alkaline plains, from areas of montane drainage and montane semi-drainage. He stated that this species with *P. carnea* "are common in habitats with sparse vegetation". Lundblad (1968) recorded *P. conglobata* from lakes, pools, calcareous ponds, bog lakes, brackish water and from streams. He found it at depths of 3 m at temperatures ranging between 14 and 32 C. Walter (1922) found the mean number of eggs/female was 20-30 with a mean diameter of 190. Viets (1936) gave the egg diameter as 165. Sparing (1959), Munchberg (1935) and Prasad and Cook (1972) described the larva which Sparing said parasitized chironomids. No chironomids parasitized by P. conglobata larvae emerged from Marion Lake.

Eylais extendens extendens (Muller)

Synonyms: Viets 1956, pp 49-51 and pp 62-65

Zoogeographic Range: Palaearctic, Nearctic

North American Distribution: Colorado, Michigan, New Mexico, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Alberta, Manitoba, Northwest Territories, Ontario and Saskatchewan.

North American Bibliography: Koenike 1895, 1912, Banks 1919, Marshall 1927c, 1930a, 1931, Hoff 1944, Marshall 1946, Bergstrom 1953, Crowell 1957, Cribbins 1959, Crowell 1960, Conroy 1968, Young 1969 and Lanciani 1970.

Larval Hosts in Marion Lake: Lethocerus americanus (Leidy) and the four species of Gerris (notabilis, remiges, buenoi and incurvatus).

Notes: Eight adult E. extendens occurred in Marion Lake in June and seven in July. I observed this large red mite on many occasions swimming in shallow (less than 0.5 m) parts of the lake. The species was not found in water deeper than 1.5 m. These observations suggest that the animal preferred shallow water. Sparing (1959) described the larva and discussed the known hosts.

Attractides nodipalpis americanus (Marshall)

Synonyms: Viets 1956, p 336

Zoogeographic Range: Nearctic

North American Distribution: California, Colorado, New Mexico, Wyoming, Alberta (Conroy, unpublished records), British Columbia and Manitoba.

North American Bibliography: Marshall 1933a, 1943b; Bergstrom 1953; Habeeb 1959; Conroy 1968 and Young 1969.

Male: Length of CP IV100-150; distance between right and left CP IV 80-88.

Female: Length of CP IV 163-200; distance between right and left CP IV 60-150. No egg-bearing females found.

Notes: Five male and four female. A. nodipalpis americanus occurred in Marion Lake in June; one male and one female in July; and one male in August. I found another male in the stomach of Oncorhynchus nerka in July 1967. A. nodipalpis americana occurred only in the north end of the lake at depths up to 2.5 m. Motas (1928) and Young (1969) both reported A. nodipalpis as stream-dwelling.

The Marion Lake specimens may have been washed into the lake from the inlet stream.

Oxus connatus (Marshall)

Synonyms: Viets 1956, p 226

Zoogeographic Range: Nearctic

North American Distribution: Colorado, Michigan, New Jersey, Pennsylvania, Wisconsin, British Columbia and Ontario.

North American Bibliography: Marshall 1929b, 1930a, 1932, 1940a; Habeeb 1955d; Cribbins 1959; Conroy 1968; Young 1969 and Prasad and Cook 1972.

Adult: Distance from the most posterior point of the capitular bay to the most anterior point of the genital bay 390-530.

Notes: Three adult and two nymphal O. connatus occurred in Marion Lake in June; four adults in July, and three adults and a larva in August. I found the species at all depths from 0.5-2.5 m. The larval host in Marion Lake is unknown.

Hygrobates neooctoporus (Marshall)

Synonyms: Viets 1956, p 315

Zoogeographic Range: Nearctic

North American Distribution: Alaska, California, Colorado, Montana, Wisconsin, Wyoming, Alberta, British Columbia, Manitoba, New Brunswick, Ontario and Saskatchewan.

North American Bibliography: Marshall 1924, 1926, 1929b, 1933a, 1943b, Bergstrom 1953, Habeeb 1955c, Conroy 1968, Young 1969, Modlin 1970, 1971.

Male: Length of CP IV 185-240; distance between right and left CP IV 100-120.

Female: Length of CP IV 248; distance between CP IV 50-75; no egg-bearing females found.

Nymph: Length of CP IV 88-230; distance between right and left CP IV 20-140.

Notes: The species was found in Marion Lake only in 1966. All records were from the north end of the lake near the inlet stream entrance at depths of 2.0-5.0 m. I found six nymphs in July and August; three males and two females in September; and one male in October. Modlin (1970) described the larva and found that it parasitized the genus *Metriocnemus* sp. (Chironomidae) (Modlin 1971). I found no chironomids emerging from Marion Lake to be parasitized by this mite.

## *Lebertia porosa porosa* (Thor)

Synonyms: Viets 1956, pp 202-203

Zoogeographic Range: Palaearctic, Nearctic

North American Distribution: California, Colorado, Alaska, Illinois, Indiana, Iowa, Michigan, Montana, New Mexico, New York, Ohio, Wisconsin, Wyoming, Alberta, British Columbia, Manitoba, Newfoundland (Conroy, unpublished record), Northwest Territories, Ontario and Saskatchewan.

North American Bibliography: Marshall 1912; Banks 1919; Marshall 1924, 1926, 1927c, 1929a, b, 1930a, 1932, 1933a, 1943b; Bergstrom 1953; Crowell 1957, 1960; Conroy 1968; Young 1969.

Male: Distance from the most posterior part of the capitular bay to the most posterior point of CP II 450 (420-480); distance between the most posterior points of CP IV (lit. the widest point of the genital bay) 290 (260-310).

Female: Distance between the most posterior point of the capitular bay to the most posterior point of CP II 360 (300-420); distance between the most posterior points of CP IV 435 (410-460); number of eggs/egg-bearing female 31; egg diameter 198 (185-200).

Nymph: Distance between the most posterior point of the capitular bay and the most posterior point of CP II 255 (240-270); distance between the most posterior points of right and left CP IV 198 (190-210).

Notes: A female L. porosa occurred in Marion Lake in May; a male, a female and two nymphs in June; a female and a nymph in July; a nymph in August; and two males in November. The species occurred at depths up to 4.25 m. Soar and Williamson (1927) and Viets (1936) described the larva. Sparing (1959) found it parasitic on chironomids. I recovered no Lebertia larvae from chironomids emerging from Marion Lake. Walter (1922) gave the number of eggs/female as four and the egg diameter as 210. Many authors recorded L. porosa from lakes, rivers and streams at altitudes up to 3,000 m Lundblad (1968) reported it from a depth of 22 m at temperatures between 4-22 C. I found both males and females in the Exploits

River, Newfoundland (Entomology Research Unit, #68-81 and 68-200) for the Department of Fisheries, St. John's Newfoundland (unpublished record).

*Pseudohydryphantes orbicularis* (Marshall)

Synonyms: Viets 1956, p 157

Zoogeographic Range: Nearctic

North American Distribution: British Columbia

North American Bibliography: Marshall 1929b; Conroy 1968.

Male: Length of CP III and CP IV 98-110; distance between right and left CP III 105-120.

Nymph: Length of CP III and CP IV 58; distance between right and left CP III 50; number of genital acetabula 2.

Notes: One male *P. orbicularis* occurred in Marion Lake in June; three males and a nymph in July; and four males in August. With one exception (at 1.5 m on 12-vii-1967) all records for the species were at depths greater than 2.5 m.

*Protzia constans* (Marshall)

Synonyms: Newell 1959, p 1095

Zoogeographic Range: Nearctic

North American Distribution: California, Colorado, New Mexico, Utah, Wyoming, British Columbia.

North American Bibliography: Marshall 1943a; Bergstrom 1953; Habeeb 1960; Conroy 1968; Young 1969.

Adult: Length of CP III and CP IV 180; distance between right and left CP III 380.

Notes: Eight adult P. constans occurred in Marion Lake in vertebrate stomachs; one in Salmo gairdneri, and one in Oncorhynchus nerka, three in Taricha granulosa and three in Ambystoma gracile. P. constans was eaten in February, March, May, June, August and October. P. constans is a stream-dwelling mite and probably was eaten in either the inlet or outlet streams. Bergstrom (1953), Marshall (1943a) and Conroy (1968) reported P. constans from rivers and streams under stones.

## Pionacercus leuckarti (Piersig)

Synonyms: Viets 1956, pp 427-428.

Zoogeographic Range: Palaearctic, Nearctic

North American Distribution: New Brunswick, British Columbia.

North American Bibliography: Habeeb 1958b; Conroy 1968

Male: Length of CP III and CP IV 108-190.

Notes: Only the male of this species occurred in Marion Lake at depths up to 5.5 m. Lundblad (1927) and Sparing (1959) described the larva and both said it was non-parasitic. Walter (1922) found P. leuckarti in lakes at altitudes of up to 432 m while Lundblad (1968) reported the mite from lakes at depths of 36 m at altitudes of 1112 m.

Attractides glandulosus (Walter)

Synonyms: Viets 1956, p 332

Zoogeographic Range: Palaearctic, Nearctic

North American Distribution: Not previously recorded from North America. Known previously from Switzerland, Austria and Spain.

Male: Length of CP IV 125-128; distance between CP IV 55-63.

Female: Length of CP IV 100; distance between CP IV 33-35.

Notes: Two male and two females. A. glandulosus occurred in Marion Lake in June 1967 near the mouth of the inlet stream at 2.5 m. This extremely rare species is characterized by the incorporation of the large glandularia on the ventral side into the posterior margins of CP IV. The inner margins of CP IV are rounded.

Homocaligus muscorum (Habeeb)

Synonyms: Wood, 1969, p 726.

Zoogeographic Range: Nearctic

North American Distribution: Maine, New York, New Brunswick

North American Bibliography: Habeeb 1962, 1966; Wood 1969.

Notes: Two specimens of H. muscorum occurred in Marion Lake in the stomachs of Oncorhynchus nerka that were caught near the outlet stream (18-ii-1964). The mite is described as a slow crawler over sphagnum moss (Habeeb 1962, 1966, Wood 1969) and was probably eaten by accident as the fish foraged among the moss.

Teutonia lundbladi (Habeeb)

Synonyms: Viets 1956, p 160.

Zoogeographic Range: Nearctic

North American Distribution: New Brunswick, Northwest Territories (Conroy, unpublished data).

North American Bibliography: Habeeb 1955c, 1962.

Female: Length of CP III and CP IV 440-442; genital plates topped by a smaller plate; total length of genital field 165; species characterized by a small canal going from the inner margin of CP IV to the gland area.

Notes: Two female T. lundbladi occurred in Marion Lake on 18-vi-1969 and 22-vi-1969.

Lebertia martisensis (Marshall)

Synonyms: Viets 1956, p 223

Zoogeographic Range: Nearctic

North American Distribution: California, Colorado, Alberta (Conroy, unpublished record), British Columbia.

North American Bibliography: Marshall 1943b; Conroy 1968; Young 1969; Conroy 1973.

Male: Distance from the most posterior point of the capitular bay to the most posterior point of CP II 340; distance between the most posterior points of CP IV (lit. the widest point of the genital bay) 250.

Notes: A single male on 29-vii-1966 at 1.75 m, close to the mouth of the inlet stream. Because *L. martisensis* occurred in Marion Lake all previous records are for streams or rivers, it seems probable that *L. martisensis* was washed into the lake from the inlet stream.

*Oxus gnaphiscoides* (Habeeb)

Synonyms: Viets 1956, p 226

Zoogeographic Range: Nearctic

North American Distribution: New Jersey

North American Bibliography: Habeeb 1955d, 1965.

Adult: Distance between the most posterior point of the capitular bay and the most anterior point of the genital bay 400.

Notes: I found a single adult of this species in the north end of Marion Lake on 22-vi-1967 at 2.5 m.

*Pionopsis lutescens* (Hermann)

Synonyms: Viets 1956, pp 425-426.

Zoogeographic Range: Palaearctic, Nearctic

North American Distribution: Colorado, New Jersey, New York, Alberta.

North American Bibliography: Habeeb 1954c; Cook 1956; Habeeb 1961, 1962; Conroy 1968 and Young 1969.

Female: Length of CP III and CP IV 243; distance between right and left CP IV 478; length of I-leg-5 170; length of I-leg-6 186 (fig. 18a, b, c.)

Notes: A female P. lutescens occurred in Marion Lake in the insect emergence traps at 4.0 m on 15-vi-1969. Sparing (1959) described the larva and said it parasitized chironomids. No chironomids emerging from Marion Lake were parasitized by P. lutescens larvae. The specimen from Marion Lake were identical to the specimen loaned to me by Dr. Cook (which specimen Prasad and Cook (1972) later synonymized with P. paludis (Habeeb) ). The Marion Lake mite was also identical to a specimen of P. lutescens loaned to me by Dr. Halik. I therefore reject Prasad and Cook's synonymy and consider that Marion Lake form (and P. paludis) to be P. lutescens.

## Tiphys vernalis (Habeeb)

Synonyms: Viets 1956, p 424.

Zoogeographic Range: Nearctic

North American Distribution: New Jersey, Michigan

North American Bibliography: Habeeb 1954c; Cook 1956.

Female: Length of CP III and CP IV 162; distance between right and left CP IV 373; Length of I-Leg-5 97; length of I-Leg-6 122 (fig. 22).

Notes: A female T. vernalis occurred in Marion Lake on 14-vi-1969 at a depth of 1.5 m and a temperature of 21.5 C.

Mideopsis orbicularis (Muller)

Synonyms: Viets 1956, pp 519-520

Zoogeographic Range: Palearctic, Nearctic, Neotropical

North American Distribution: Yucatan, California, Colorado, Oregon, Michigan, Wisconsin, British Columbia, Manitoba and Ontario.

North American Bibliography: Koenike 1895; Marshall 1927c, 1929a, b, 1930a, 1937, 1940a, b; Habeeb 1958a; Conroy 1968; Young 1969.

Adult: Body width 910; dorsal plate width 800

Notes: One adult M. orbicularis occurred in Marion Lake on 22-v-1967 near the inlet stream mouth. Marshall (1940a) found M. orbicularis in lakes, ponds, streams, rivers and creeks. She found it at depths of 10 m while Lundblad (1968) found it at depths of 16 m and Conroy (1968) at 7 m.

Arrenurus megalurus intermedius (Marshall)

Synonyms: Viets 1956, p 592

Zoogeographic Range: Nearctic, Neotropical

North American Distribution: Illinois, Indiana, Iowa, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, Tennessee, Washington, Wisconsin, Manitoba, Haiti.

North American Bibliography: Marshall 1903; 1940b; Lavers 1945; Cook 1954; Hoff 1944; Conroy 1968; Prasad and Cook 1972.

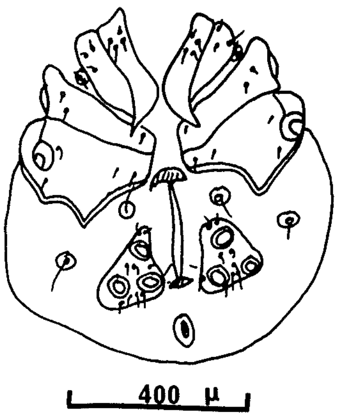
Fig. 22: *Tiphys vernalis* female, ventral view.

Fig. 23: *Sperchon* sp. nymph

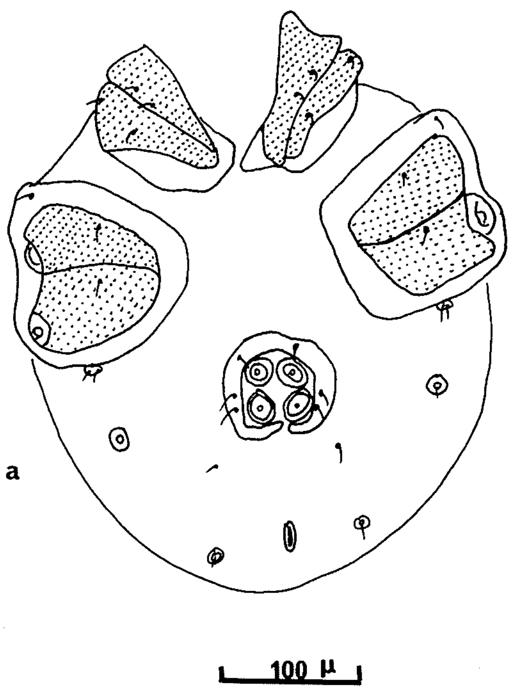
(a) Ventral view

(b) Palp

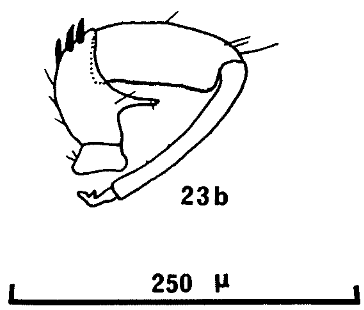
22




23 a




23b



Notes: A male *A. megalurus intermedius* occurred in Manitoba at 4.5 m deep on 20-vii-1967. The temperature was 13.5 C. Prasad and Cook (1972) described the larva.

*Sperchon* sp.

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Notes: I found one nymph of the genus *Sperchon* Kramer in Marion Lake. I have not assigned it to any species as the adult characteristics used to separate the different species are not fully developed in the nymphal form. I found the nymph on 11-v-1967 at a depth of 2.0 m near the mouth of the inlet stream. This nymph may have been washed into the lake as the genus is stream-dwelling. The length of CP III and CP IV was 110; the distance between right and left CP III was 130 (fig. 23).

# ZOOGEOGRAPHIC DISTRIBUTION

Of the 38 species found in Marion Lake, 23 are wholly Nearctic. Two (Hydrodroma despiciens and Unionicola crassipes) have a wide distribution - H. despiciens is found in all zoogeographic regions of the world and U. crassipes in all but Australia. Two species have been recorded from three zoogeographic regions - Mideopsis orbicularis (Nearctic, Palaearctic and Ethiopian) and Limnesia maculata (Nearctic, Palaearctic and Neotropical). Eleven species have been found in two zoogeographic regions - ten (Eylais extendens, Lebertia porosa, Attractides glandulosus, Unionicola gracilipalpis, Pionopsis lutescens, Pionacercus leuckarti, Piona carnea, P. conglobata, P. variabilis and Hydrozetes lacustris) from the Palaearctic and Nearctic and one (Arrenurus megalurus intermedius) from Nearctic and Neotropical. Appendix B gives the zoogeographic distribution of the water mites known from Marion Lake in detail.

# PART II: ECOLOGY

## Introduction

The only previous study on the ecology of water mites in North America was by Young (1969). He was primarily concerned with the ecological distribution of water mites in Colorado with special reference to the effects of altitude and of the chemical requirements of the mites. In Europe, Pieczynski (1960a, 1960b, 1961b, 1964 and 1969) examined the seasonal distribution of mites in Polish lakes, mobility, habitat preferences and briefly looked at interspecific associations. Other studies, notably the work of Mitchell and Imamura, Munchberg, Crowell, Modlin and Karl Viets have concentrated on host-parasite relationships in mites. No previous author attempted to link seasonal distribution and fluctuations in numbers with larval hosts.

The object of this section of my study was to describe the seasonal fluctuations of the major mite species present in Marion Lake, to examine their interspecific associations and see how they may be influenced by the seasonal preferences of mites, to work out the major mite species' life histories, to observe the habitat preferences of the mites and to examine their role in the food of the four vertebrate predators (O. nerka, S. gairdneri, T. granulosa and A. gracile) present in the lake. This study is unique in two ways - it is the first detailed study of mites in one lake and it is the first such study of mites in North America.

## Materials and Methods

Sampling methods were described earlier (pp 12-16). For an efficiency evaluation of the different sampling methods and the justification for the use of the Conroy Bottom Trap see Appendix C.

In 1966 and 1967, Dr. M. Dickman measured the water temperature at a depth of 1 m using a precision thermometer (range -8 to =32 C, calibrated in 0.1 C divisions). In 1969, Mr. V. J. McCauley and I measured the water temperature at six depths (0.5 m, 1.0 m, 2.0 m, 3.0 m, 4.0 m and 4.5 m). Both maximum and minimum thermometers and precision thermometers were used. The water temperatures for 1966-1967 and 1969 will be found in Appendix D.

Two methods were used to measure the pH in Marion Lake - Hydrion pH papers (6.0 to 8.0 and 8.0 to 9.0) and the titration method.

I used the methods of Williams and Lambert (1959, 1960) to analyse the interspecific associations in water mites.

If we let the observed number of samples in which two species, A and B, occur equal $O_{AB}$. The expected number of occurrences of both A and B in the samples is $E_{AB}$. The probability that $O_{AB}$ differs from $E_{AB}$ by chance alone can be determined by computing the Yates's correction for $X^2$. The smaller the value of $X^2$, the greater the probability that $O_{AB}$ and $E_{AB}$

differ only by chance. If the calculated value of the corrected $X^2$ is greater than 3.841, this probability is less than 5%. Here something other than random variation causes species A to occur, or not to occur, in the same sample as species B. By calculating the $X^2$ for each species pair from uncorrected values, we can determine the species showing the greatest interaction with other species. It will be the species with the largest sum of $X^2$ values. The samples were sorted on the basis of the presence or absence of that species and two new sets of tables constructed.

Using the Conroy Bottom Trap, 370 random samples were taken between June 8 and August 26, 1969. Twelve of the samples were rejected as unsuitable and the remaining 358 used in the analysis. Eight of the twelve samples rejected had the traps overturned while on the lake bottom and the remaining four samples were spilt while the collecting jars were being removed from the traps. The sampling method was as follows: the lake was marked out into 33 m square squares, each of which was assigned a number from 001-125 (fig. 1). Since squares 115 to 125 were dry for most of the summer these squares were not used in the analysis. A table of random numbers was consulted and ten numbers, from 001-114, selected at random. Bottom traps were placed in each of the ten squares selected and left in the lake for two days at the end of which the entire process was repeated.

Williams and Lambert (1959) recommended that species occurring in less than 2% or in more than 98% of the samples not be considered. In the present study this meant rejecting any species occurring in less than seven or in more than 351 samples. Twelve species were not considered because of this restriction. The twelve species were: Eylais extendens, Hydrodroma despiciens, Pseudohydrphantes orbicularis, Teutonia lundbladi, Lebertia porosa, Oxus connatus, Attractides nodipalpis americanus, Unionicola crassipes, Tiphys vernalis, Piona conglobata, Arrenurus solifer and Hydrozetes lacustris. The fifteen species considered were Frontipoda americana, Limnesia maculata, Unionicola gracilipalpis, Neumania semicircularis, Hydrochoreutes intermedius, Pionopsis nov. sp., Piona carnea, P. constricta, P. debilis, P. interrupta, P. variabilis, Forelia ovalis, F. borealis, Arrenurus cascadensis and A. pseudocylindratus.

The Williams and Lambert method was used because it is simple to apply, because it has been shown that it provides information of ecological significance, and because its statistical efficiency has been demonstrated (Williams and Lambert 1959).

For breeding and feeding studies I placed male and female mites of the same species in small vials kept at 13 C. Food, in the form of Sida crystallina (Muller), Chydorus sphaericus (Muller), Cyclops bicuspidatus thomasi Forbes, Diaptomus oregonensis Lilljeborg, Ostracoda and small Chironomidae, was added at regular intervals. The water was changed once a week and any food remains removed. Once the female laid her eggs, the male was removed and preserved in a labelled vial. When the larvae were observed moving within the egg capsules, the female was removed and preserved with the male. When longevity experiments were in progress, the females were transferred to another vial for further observation. Some of the larvae were preserved with their parents.

Parasitized insects were obtained from the Insect Emergence Trap Series. Some were preserved immediately while others were placed in vials with some water and a small piece of styrofoam to rest on in the hope the larvae would complete their development. These experiments were unsuccessful.

Pieces of the fresh-water sponge (Spongilla lacustris) were kept in small vials and were observed the development of the unionicolid mites in them. I did not see either species of Unionicola ovipositing on the sponge.

The density of the sponges varied in different parts of the lake and estimates of the population size of sponges by counting was difficult. Counts of sponges required calm, sunny days. All my observations were from the south end of the lake in squares # 26-34 and in # 36, 37, 41, 42 and 115 (fig. 1). There were two reasons for concentrating in this limited area - (a) sponges were plentiful there and (b) the lake was so shallow that they were more easily observed.

Aquaria kept in the laboratory with mites in them had food organisms added periodically. The mites' response to the introduced food was observed. The results of these experiments will be found in Appendix E.

To investigate possible lake habitat preferences (using the Sorensen Index) I divided the lake into three general habitats -

Littoral I (water less than 1.5 m deep), Littoral II (up to the limits of rooted emergent vegetation - i.e. up to 3.5 m) and Sublittoral (water deeper than 3.5m). The Sorensen's Similitude Index is a simple phytosociological index. It can be stated as: $P = \frac{2c}{a + b} \times 100\ \%$ where 'c' is the number of species common to both the compared environments, 'a' is the number of species in one environment and 'b' is the number of species in the other environment.

Four vertebrate predators live in or around Marion Lake. These are the rainbow trout (Salmo gairdneri Richardson), the kokanee salmon (Oncorhynchus nerka (Walbaum) ), the rough-skin newt (Taricha granulosa granulosa Skilton) and the Northwestern salamander (Ambystoma gracile gracile (Biard) ). These were caught using gill nets (fish) or special traps (salamanders) and their stomachs removed and their contents examined for mites.

To avoid confusion and to save space a coding of the generic names of both water mites and their larval hosts was used in all tables but not in the text. This coding will be found in Appendix F.

# Results

## Number of water mites examined

Thirteen of the species recorded (*Unionicola crassipes*, *U. gracilipalpis*, *Piona carnea*, *P. constricta*, *P. debilis*, *P. variabilis*, *Pionopsis* nov. sp., *Forelia borealis*, *F. ovalis*, *Arrenurus cascadensis*, *A. pseudocylindratus*, *A. solifer* and *Frontipoda americana*) account for 99.1% of the 85,085 mites examined during the Marion Lake survey (Table 1).

## Seasonal abundance

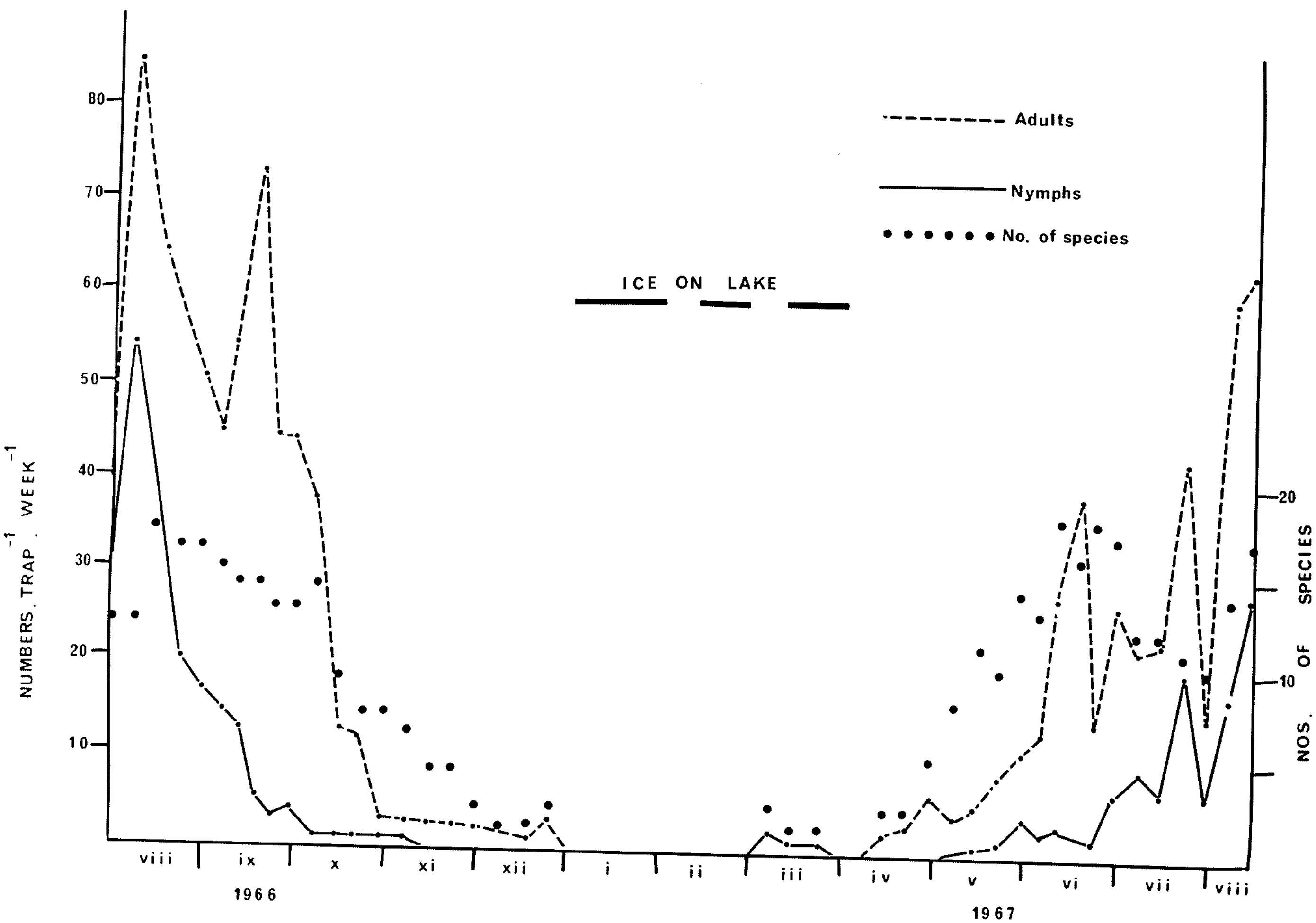
The seasonal changes in numbers of individuals and of species for 1966-7 are presented in fig. 24 and for 1969 in fig. 25. A marked peak of abundance of both adults and nymphs in early August 1966 was followed by a second peak of adults only in late September. In August 1967 a similar peak of adults and nymphs appeared (fig. 24) while in 1969 it appeared to be slightly later (fig. 25). The increase in numbers of adults in June 1967 (fig. 24) was not preceded by,nor did it coincide with, a mass emergence of nymphs. The three peaks noted during the summer of 1969 (fig. 25) were caused by increases both in numbers of nymphs and of adults.

The greatest number of species occurred from mid-May to mid-October (mean 14, range 10-18) and a decline was noted from mid-October to mid-May (mean 2, range 1-4) (fig. 24).

Table 1: Total number of water mites sampled in Marion Lake.

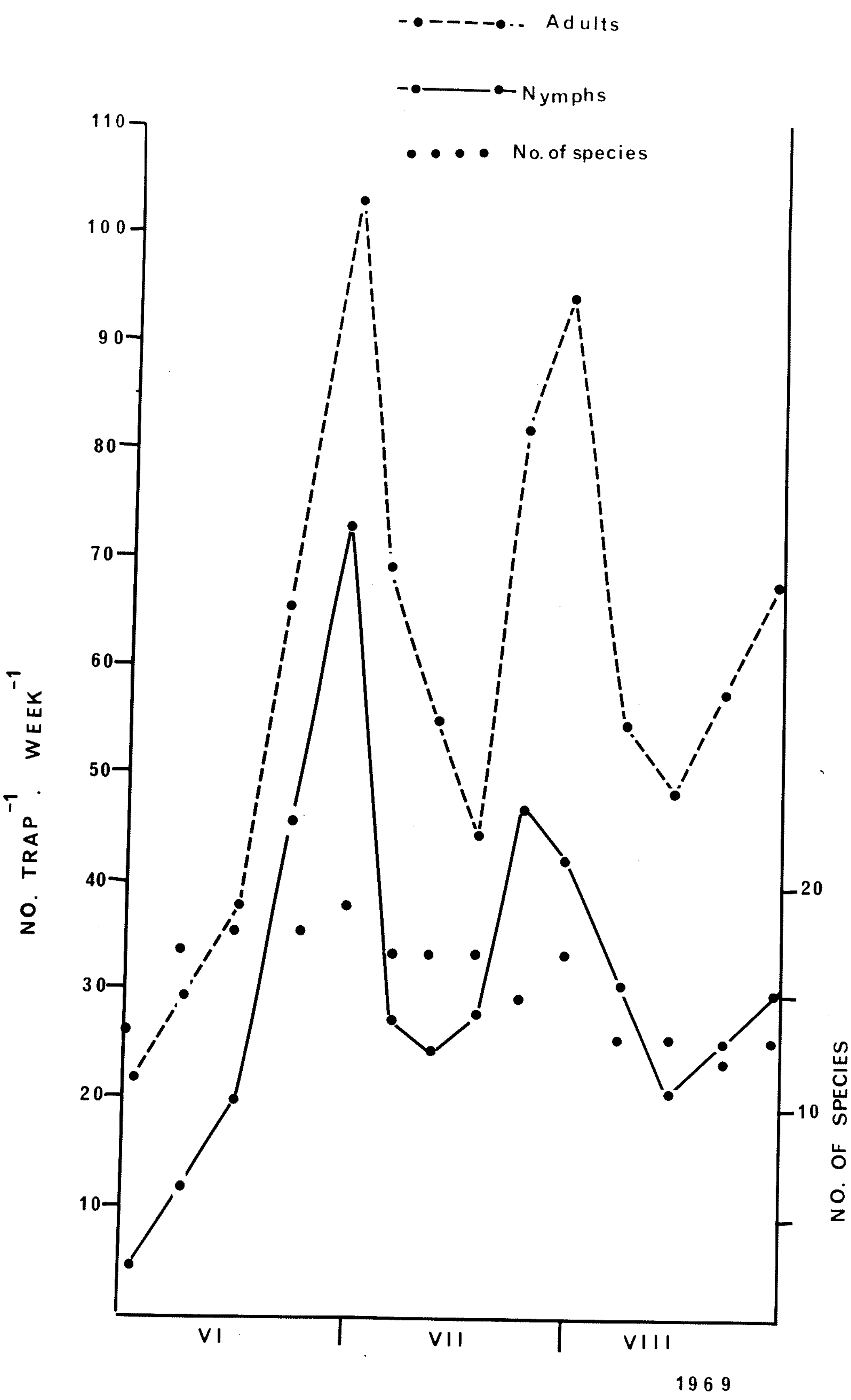
| Species | Number Sampled | Percentage Males | Percentage Females | Percentage Nymphs | Percentage Of Total |
|---|---|---|---|---|---|
| *U. crassipes* | 54981 | 27.3 | 23.0 | 49.7 | 64.6 |
| *Pi. carnea* | 15118 | 23.6 | 49.3 | 27.1 | 17.8 |
| *Pi. constricta* | 6576 | 39.6 | 23.6 | 36.8 | 7.7 |
| *Ar. pseudocylindratus* | 1688 | 22.0 | 52.3 | 25.7 | 2.0 |
| *U. gracilipalpis* | 1310 | 19.9 | 22.2 | 57.9 | 1.5 |
| *Ar. cascadensis* | 1196 | 54.2 | 19.7 | 26.1 | 1.4 |
| *Pi. debilis* | 967 | 28.3 | 55.7 | 16.0 | 1.1 |
| *Fr. americana* | 895 | adults | 94.5 | 5.5 | 1.1 |
| *Pi. variabilis* | 686 | 15.5 | 69.0 | 15.5 | 0.8 |
| *Fo. ovalis* | 385 | 43.9 | 44.9 | 11.2 | 0.2 |
| *Pionopsis* nov. sp. | 212 | 11.8 | 46.7 | 41.5 | 0.3 |
| *Fo. borealis* | 160 | 9.4 | 30.6 | 60.0 | 0.2 |
| *Ar. solifer* | 122 | 25.4 | 63.9 | 10.7 | 0.1 |
| *Pi. interrupta* | 52 | 13.4 | 23.1 | 63.5 | + |
| *N. semicircularis* | 49 | 16.2 | 8.2 | 75.5 | + |
| *Hz. lacustris* | 36 | adults | 100.0 | - | + |
| *Li. maculata* | 28 | 25.0 | 35.7 | 39.3 | + |
| *Hd. intermedius* | 22 | 31.8 | 40.9 | 27.3 | + |
| *Hy. despiciens* | 20 | adults | 90.0 | 10.0 | + |
| *Pi. conglobata* | 16 | | | | + |
| *E. extendens* | 15 | | | | + |
| *At. nodipalpis americanus* | 13 | | | | + |
| *O. connatus* | 13 | | | | + |
| *Hg. neooctoporus* | 12 | | | | + |
| *Le. porosa* | 10 | | | | + |
| *Ps. orbicularis* | 9 | | | | + |
| *Pr. constans* | 8 | | | | + |
| *Pa. leuckarti* | 6 | | | | + |
| *At. glandulosus* | 4 | | | | + |
| *Ho. muscorum* | 2 | | | | + |
| *Te. lundbladi* | 2 | | | | + |
| *Le. martisensis* | 1 | | | | + |
| *O. gnaphiscoides* | 1 | | | | + |
| *Pp. lutescens* | 1 | | | | + |
| *Ti. vernalis* | 1 | | | | + |
| *M. orbicularis* | 1 | | | | + |
| *Ar. megalurus intermedius* | 1 | | | | + |
| *Sperchon* sp. | 1 | | | | + |
| Unidentified larvae | 465 | | | | 0.6 |
| Total | 85085 | | | | |

Fig. 24: Seasonal changes in numbers of individuals and of species in Marion Lake during 1966-7.



Adults
Nymphs
No. of species
ICE ON LAKE
NUMBERS TRAP$^{-1}$ WEEK$^{-1}$
NOS. OF SPECIES
80
70
60
50
40
30
20
10
20
10
viii
ix
x
xi
xii
i
ii
iii
iv
v
vi
vii
viii
1966
1967

Fig. 25: Changes in the numbers of individuals and of species of water mites in Marion Lake during the summer, 1969.



Adults
Nymphs
No. of species
110
100
90
80
70
60
50
40
30
20
10
NO. TRAP$^{-1}$ . WEEK$^{-1}$
20
10
NO. OF SPECIES
VI
VII
VIII
1969

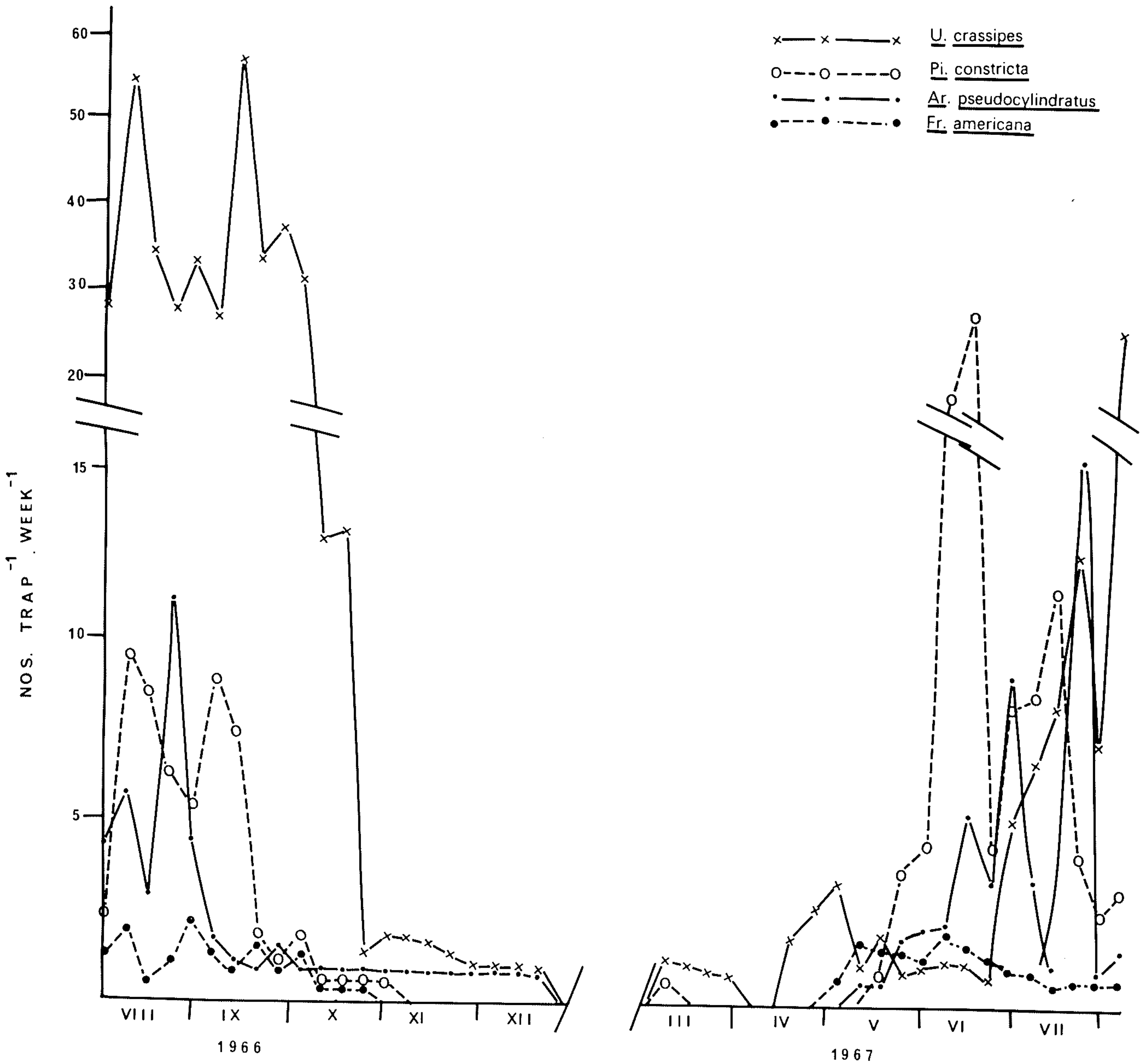
A significant correlation between water temperature and the number of mites.trap$^{-1}$ . day$^{-1}$ (Appendix G, tests b-1, b-2) occurred for the 1966-7 data but no such correlation occurred for the 1969 data. A second test to see if the sample value of 'b' came from a population with a parametric values $\beta = 0$ for the regression coefficient (Appendix G, test b-1, b-2) found a significant regression for 1966-7 and a non-significant regression for 1969 data.

Seasonal species dominance

During 1966-7 marked seasonal changes in mite species dominance occurred (fig. 26 ) . The seasonal succession of mite species in 1966-7 was Unionicola crassipes in March 1967, Frontipoda americana in early May, U. crassipes in mid-May, Piona constricta from late May to mid-June, Arrenurus pseudocylindratus in late June, P. constricta to mid-July, A. pseudocylindratus in late July and U. crassipes from early August. Seasonal succession in species dominance was not noted in 1969 (fig. 27).

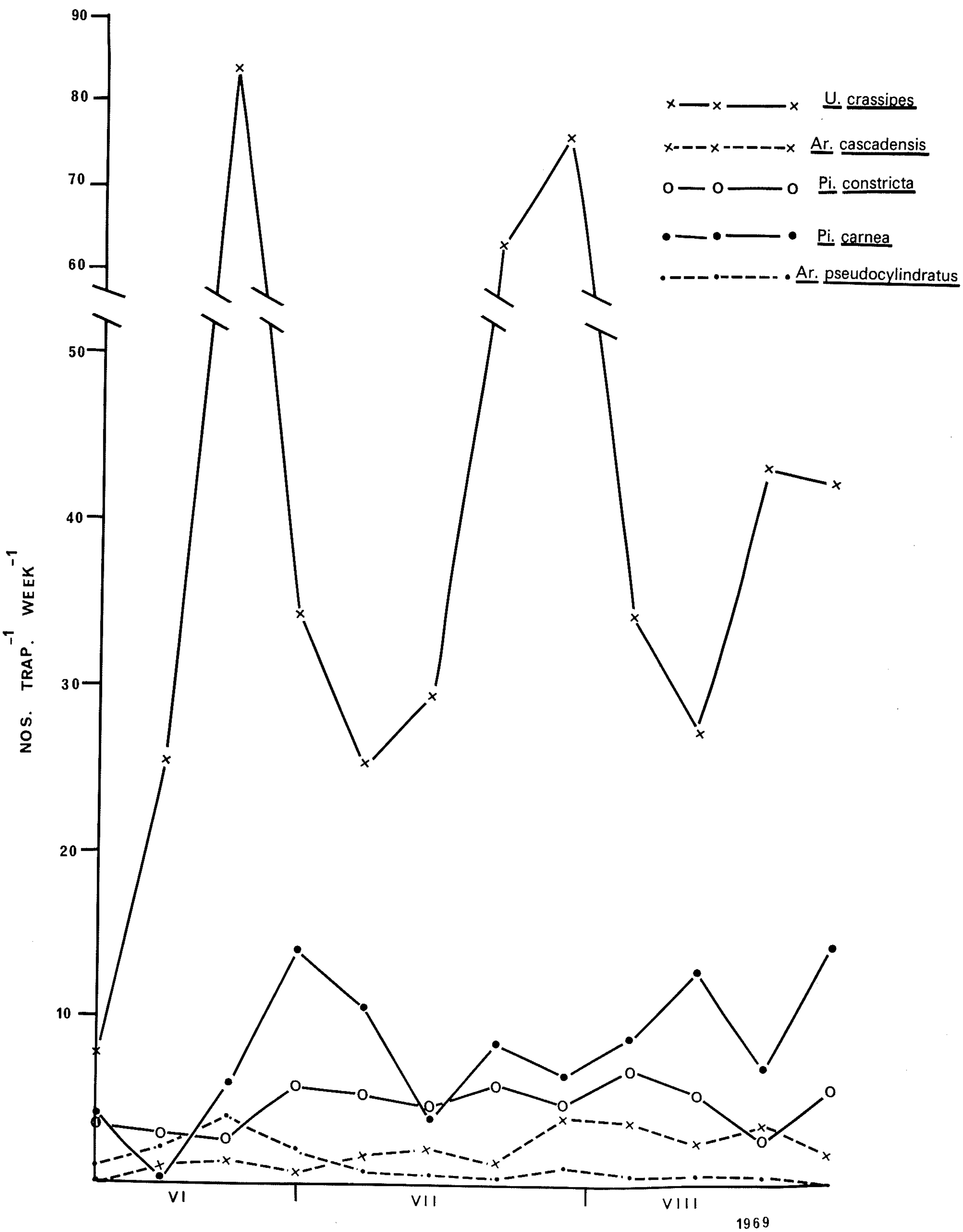
The thirteen most numerous species (Table 1) readily separated on the basis of season of greatest adult abundance as follows: (i) in spring; (ii) in early summer; (iii) in mid-summer; (iv) in late summer; and (v) in autumn (Table 2). Relevant data on nine other species (Piona interrupta, Neumania semicircularis, Limnesia maculata, Hydrochoreutes intermedius, Hydrodroma despiciens, Eylais extendens, Oxus connatus, Lebertia porosa and Piona conglobata) are included in this Table.

Fig. 26: Seasonal succession of mite species in 1966-7.



U. crassipes
Pi. constricta
Ar. pseudocylindratus
Fr. americana
NOS. TRAP$^{-1}$. WEEK$^{-1}$
60
50
40
30
20
15
10
5
VIII
IX
X
XI
XII
1966
III
IV
V
VI
VII
1967

Fig. 27: Seasonal succession in mite species in 1969.



90
80
70
60
50
40
30
20
10
NOS. TRAP.$^{-1}$ WEEK$^{-1}$
U. crassipes
Ar. cascadensis
Pi. constricta
Pi. carnea
Ar. pseudocylindratus
VI
VII
VIII
1969

Table 2: Seasonal preference, swimming ability, size and habitat preferences of some water mites from Marion Lake.

| Species | Swimming ability | Size (μ x 100) | Habitat | Depth |
|---|---|---|---|---|
| Late spring forms | | | | |
| E. extendens | Good | 50 | Macrophytes | under 1.5 m |
| Er. americana | Good | 8 | All | all |
| Hd. intermedius | Glider | 6 | Macrophytes | most under 2 m |
| Early summer forms | | | | |
| Le porosa | Climber | 20 | Macrophytes | 1.0-4.0 m |
| O. connatus | Good | 8 | Macrophytes (at north end) | up to 2.5 m |
| N. semicircularis | Glider | 14 | mid to south end | all |
| Pi. constricta | Excellent | 12 | all | all |
| Pi. debilis | Good | 9 | all | all |
| Mid-summer forms | | | | |
| Li. maculata | Excellent | 20 | Macrophytes | greater than 1.0 m |
| Pionopsis nov. sp. | Swimmer & walker | 5 | Macrophytes | all |
| Pi. variabilis | Excellent | 12 | More open areas | all |
| Pi. conglobata | Good | 8 | Macrophytes | 3.0-415 m |
| Fo. ovalis | Good | 3.2 | Macrophytes | all |
| Ar. pseudocylindr-atus | Swimmer & walker | 10 | Bottom | all |
| Late summer forms | | | | |
| U. crassipes | Glider | 14 | all | all |
| Pi. carnea | Excellent | 16 | open areas | all |
| Pi. interrupta | Good | 18 | Macrophytes | all |
| Ar. cascadensis | Swimmer & Walker | 10 | Bottom | all |
| Hy. despiciens | Climber | 20 | Macrophytes | up to 3.0 m |
| Autumn forms | | | | |
| U. gracilipalpis | Glider | 11 | all | all |
| Fo. borealis | Good | 4 | open mud (north end) | all |
| Ar. solifer | Walker | 16 | Macrophytes | all |

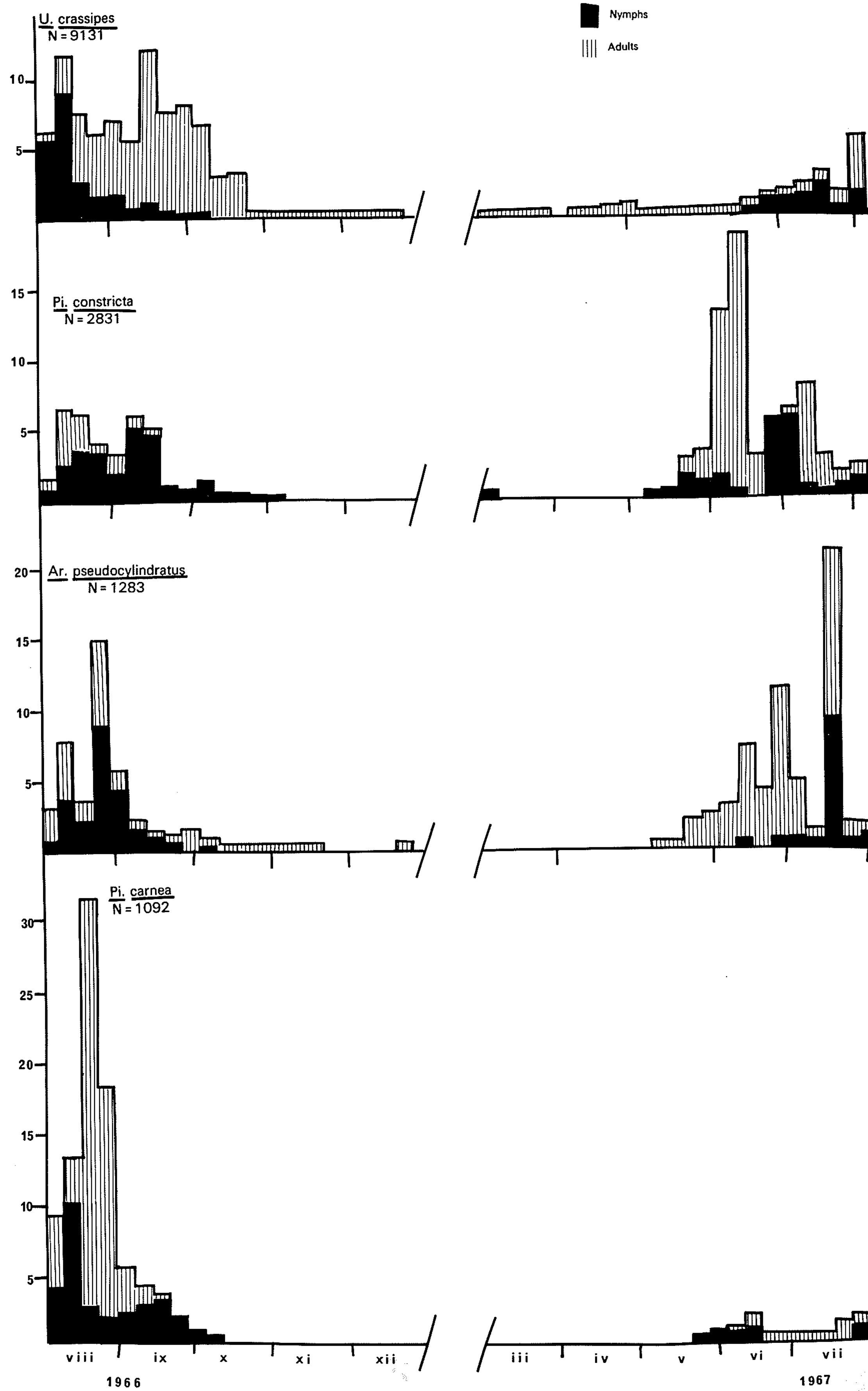
(Swimming ability classification follows that of Schwoerbel 1959)

Of the three spring forms, E. extendens was largest. It is an excellent swimmer preying on other mites, on insect larvae (especially Ephemeroptera and Chironomidae), and on Cladocera. It occurred in shallow water among emergent macrophytes. It reproduced in June. H. intermedius reproduced in late June and in July as did F. americana. The latter species occurred in low numbers at all depths from mid-April to October (fig. 28). The greatest adult:nymph ratio (5.9:1) was in August, 1966, with these nymphs becoming adults in September. In both 1967 and 1969 the numbers of F.americana were highest in June (figs. 28, 29). It probably overwintered as adults.

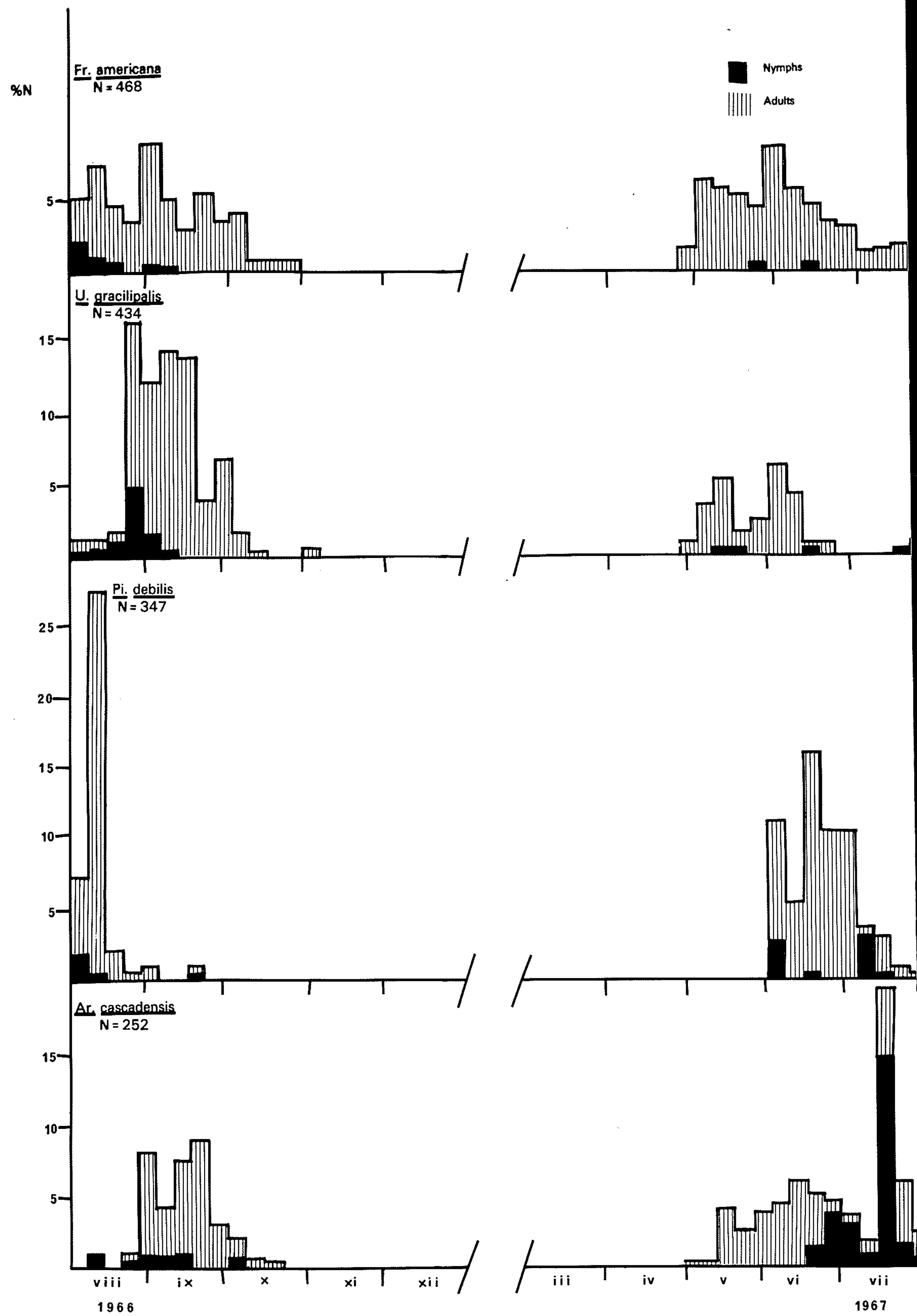
L. porosa was the largest of the early summer species. It fed on Sida crystallina and on Ephemeroptera nymphs. It was found near macrophytes where Sida and Ephemeroptera gather. Only P. constricta nymphs occurred from mid-October to early May 1967 (fig. 28). In late May, 1967, a big increase in adult numbers occurred. The pattern was similar in 1969 (fig. 29) with adults very numerous in June and early July and nymphs numerous in August. I found a nymphochrysallis of P. constricta on Ablabesmyia monilis on July 13, 1967. P. debilis peaked in August 1966 and in June and July 1967 and in June 1969 (fig. 28, 29). P. debilis overwintered as a nymph.

The mid-summer species L. maculata and P. conglobata

Fig. 28: Occurrence of most common
mite species in 1966-7.

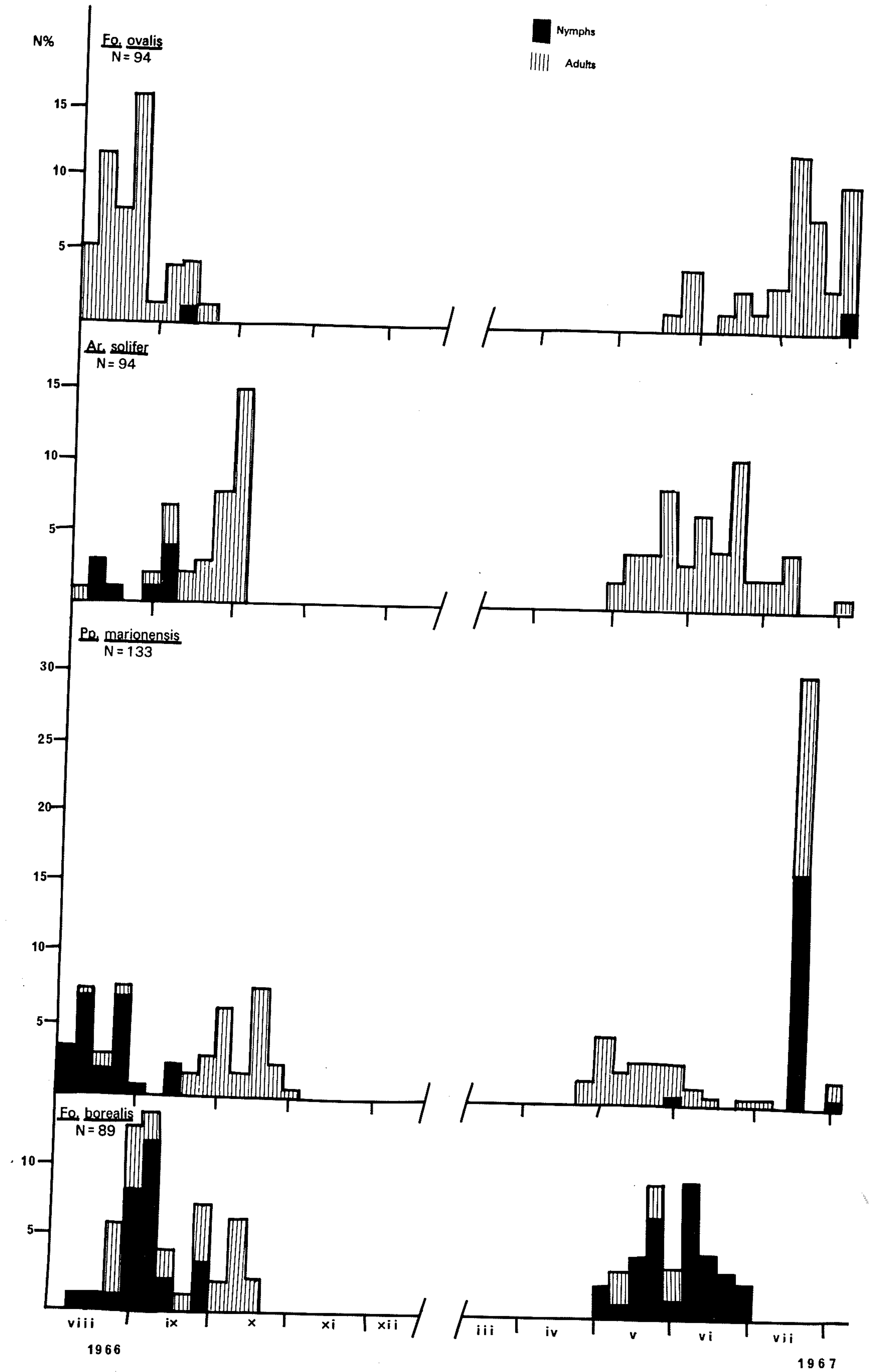


U. crassipes
N = 9131
Nymphs
Adults
Pi. constricta
N = 2831
Ar. pseudocylindratus
N = 1283
Pi. carnea
N = 1092
viii
ix
x
xi
xii
iii
iv
v
vi
vii
1966
1967



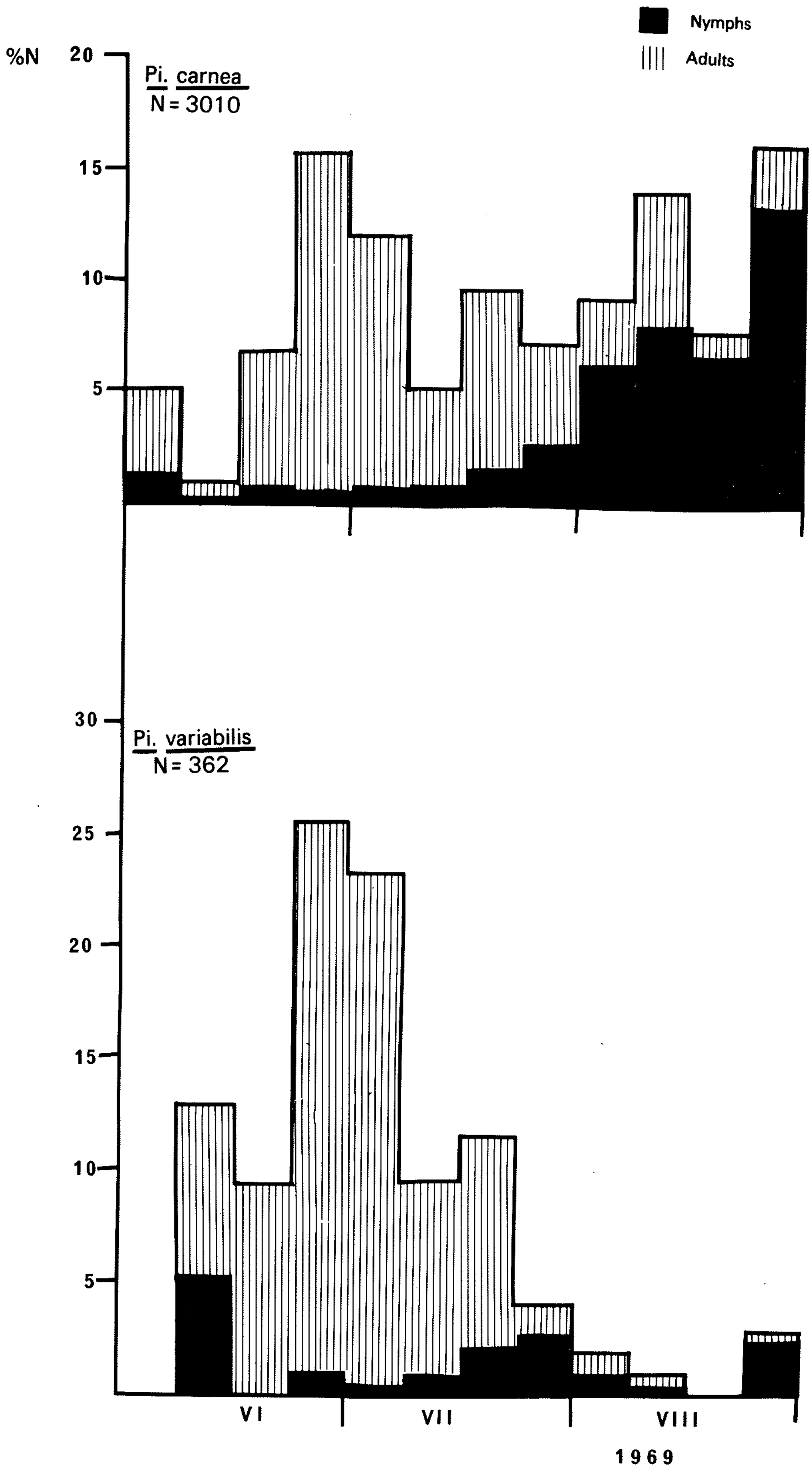
%N
Fr. americana
N = 468
Nymphs
Adults
5
U. gracilipalis
N = 434
15
10
5
Pi. debilis
N = 347
25
20
15
10
5
Ar. cascadensis
N = 252
15
10
5
viii
ix
x
xi
xii
iii
iv
v
vi
vii
1966
1967


975

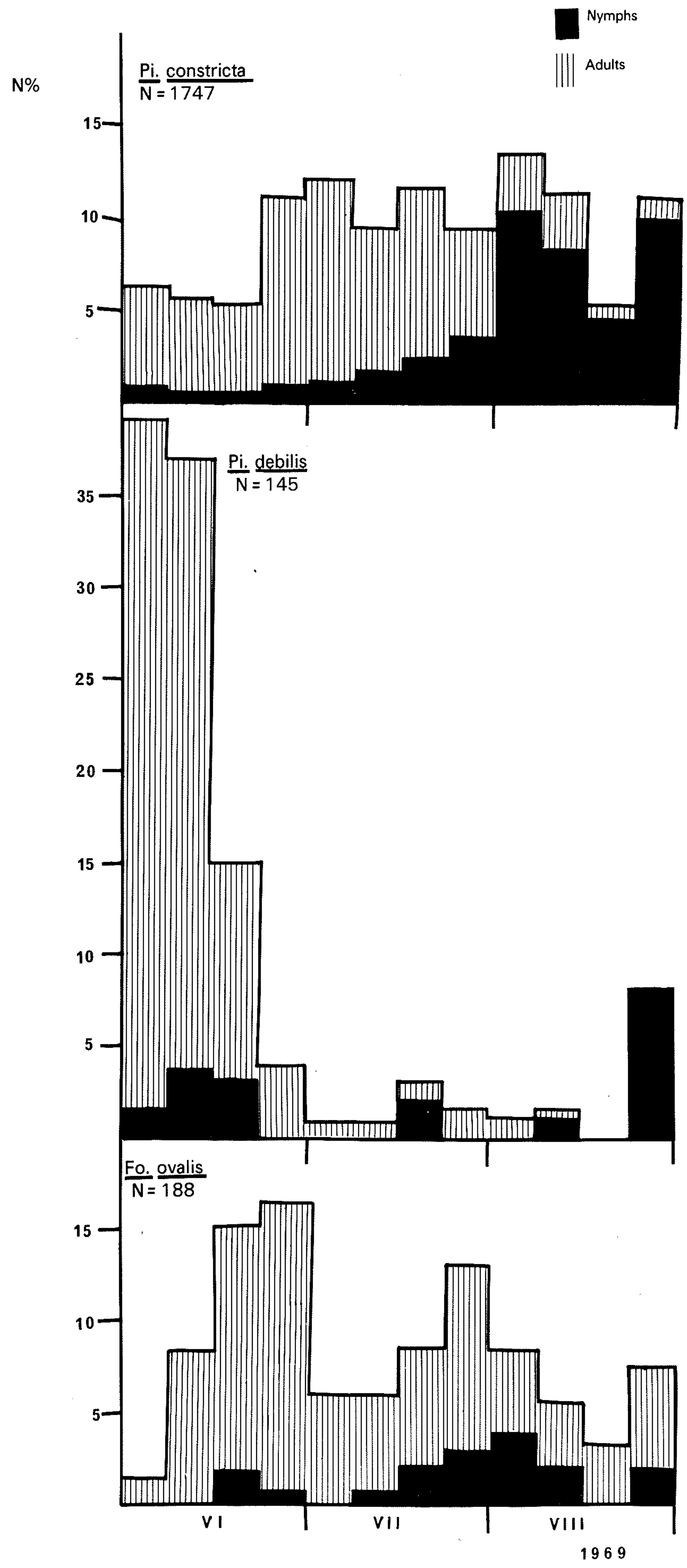


N%
Fo. ovalis
N = 94
Nymphs
Adults
15
10
5
Ar. solifer
N = 94
15
10
5
Pp. marionensis
N = 133
30
25
20
15
10
5
Fo. borealis
N = 89
10
5
viii
ix
x
xi
xii
iii
iv
v
vi
vii
1966
1967

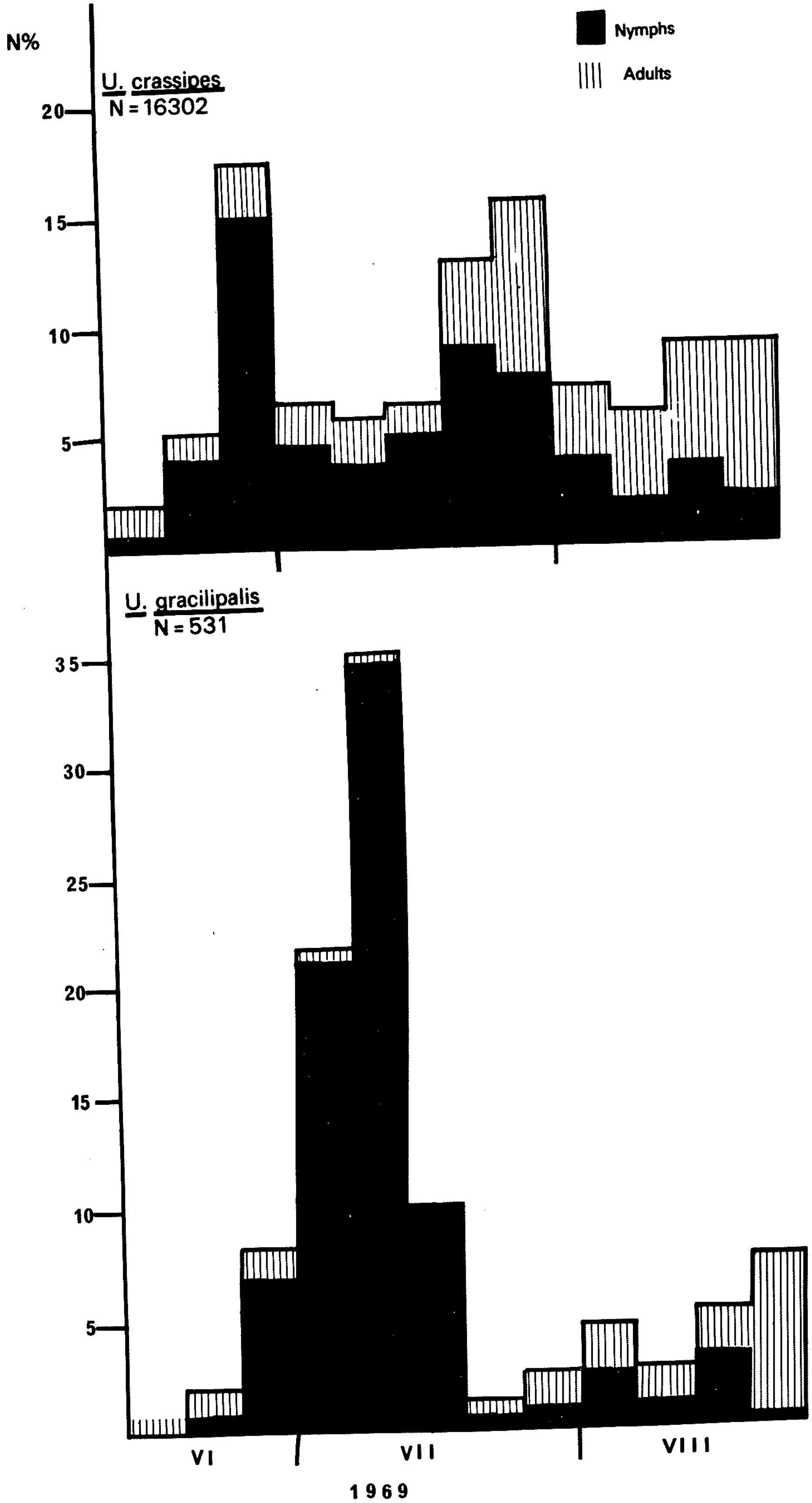
Fig. 29: Occurrence of the most common
mite species in 1969.


Nymphs
Adults
%N
20
15
10
5
Pi. carnea
N = 3010
30
25
20
15
10
5
Pi. variabilis
N = 362
VI
VII
VIII
1969

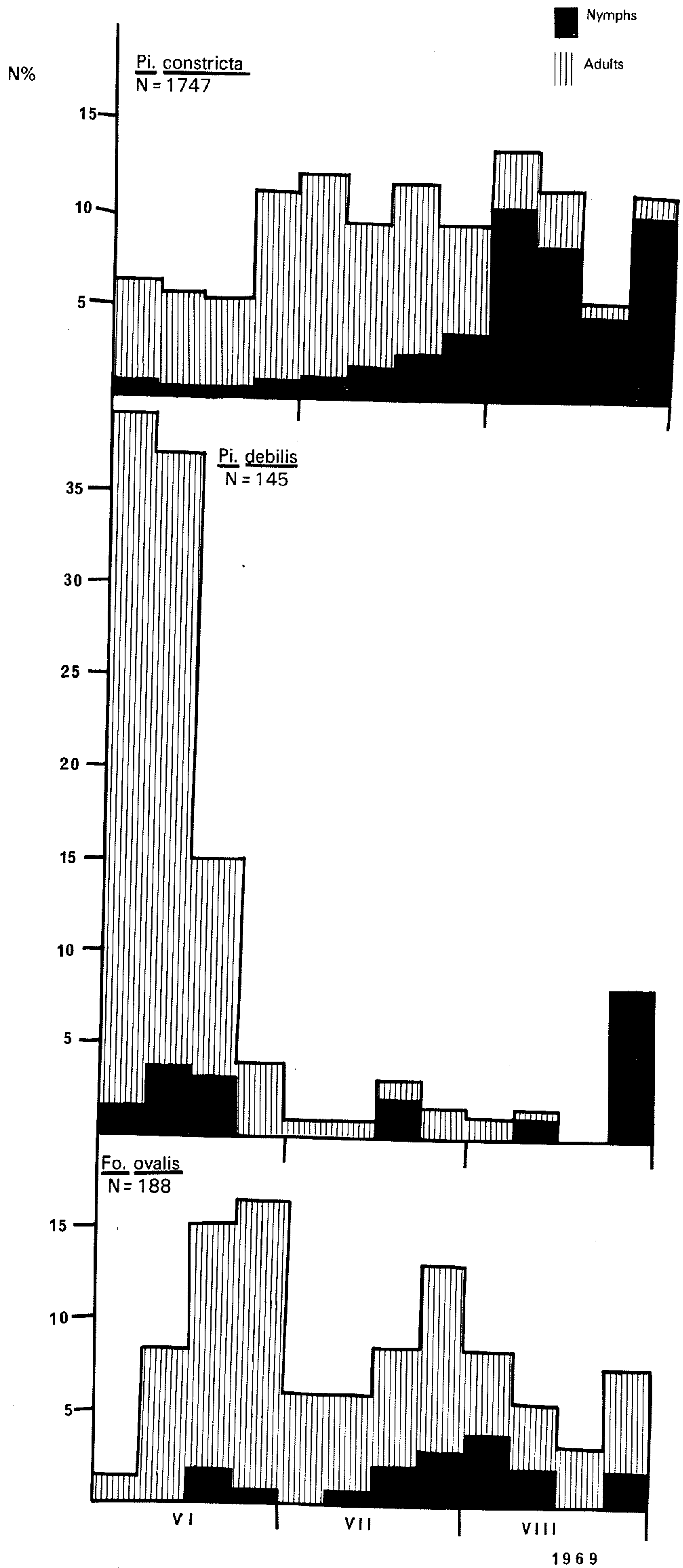
Ptt



Nymphs
Adults
N%
Pi. constricta
N = 1747
15
10
5
Pi. debilis
N = 145
35
30
25
20
15
10
5
Fo. ovalis
N = 188
15
10
5
VI
VII
VIII
1969



N%
Nymphs
Adults
U. crassipes
N = 16302
20
15
10
5
U. gracilipalis
N = 531
35
30
25
20
15
10
5
VI
VII
VIII
1969


Nymphs
Adults
N%
Pi. constricta
N = 1747
15
10
5
Pi. debilis
N = 145
35
30
25
20
15
10
5
Fo. ovalis
N = 188
15
10
5
VI
VII
VIII
1969

preferred the middle of the lake. Arrenurus pseudocylindratus adults peaked in numbers in June and in July (figs. 28, 29). Adults occurred in late December and in mid-February suggesting that these are the overwintering stage. In 1966-7 no specimens of P. variabilis occurred between late September and late May. In 1967 and in 1969 the greatest numbers of adults occurred in early July. 93% of the specimens found in Marion Lake occurred in 1969 (fig. 29). In both 1966-67 and in 1969 the greatest number of Forelia ovalis adults occurred in June and July (figs. 28, 29). The data available (fig. 28) suggested that Pionopsis nov. sp. overwintered as an adult.

The late summer species, Piona interrupta and Hydrodroma despiciens, showed marked preferences for macrophytes. The larvae of Unionicola crassipes remained free in the host sponge tissues. They moved about in the sponges in early June and in July. Eventually the larvae formed nymphochrysallids within which the nymphophans developed. The nymphs emerged after 46.2 days (range 40-53). They first appeared on the sponge in late June to early July and seemed to have a free-swimming stage at this time. The nymphs returned to the sponge after a short while and formed the teleiochrysallids within which the teleiophans developed. Adults emerged from this stage. The length of time between nymphs breaking out of the nymphoderma until they completed the metamorphosis into adults was 36.5 days (range 32-40) giving U. crassipes a total immature life from egg to newly emerged adult of 90.7

days (range 78-105). These adults appeared in late August, 1967 (fig. 28) and in July in 1969 (fig. 29). In all years rapid declines in numbers of nymphs were followed by rapid increases in numbers of adults. Evidence from the Hargrave Sampler Series suggested that the adults hibernated in the bottom during the winter. In 1966 adults of *P. carnea* peaked in mid-August after which they declined and nymphs became dominant (fig. 28). Only nymphs occurred in the lake from mid-September to mid-June 1967. The pattern was repeated during the summer of 1967 with the adults peaking in numbers in late July and early August. In 1969 the peak in numbers occurred in late July and early August (fig. 29). Two adults from the Hargrave Series on March 19, 1969, and on December 30, 1969, and a teleiochrysallis found on *Chara globularis* on April 24, 1967, suggested that the nymph may not be the only overwintering stage. *A. cascadensis* peaked in numbers of adults in September in 1966 and in August in 1967 (fig. 28). The adult peak was in July and August in 1969 (fig. 29).

The three autumn species showed marked differences in breeding periods (*U. gracilipalpis* in late spring and early summer; *A. solifer* in mid to late summer; and *F. borealis* in mid to late autumn). Nymphs of *U. gracilipalpis* were the dominant form in June and July (figs. 28, 29). By the end of July adults were dominant and they peaked in September. This species overwintered as adults in the bottom mud (based on two males recovered from the Hargrave Series in November and in December 1968). *F. borealis* adults peaked in October and in November 1966 (fig. 28). *A. solifer* nymphs only appeared from August to mid-September 1966 (fig. 28) and the adults peaked in September and October. The adult was the overwintering form. 96.7% of all specimens of *A. solifer* occurred in 1966-7.

## Overwintering

Water mites in Marion Lake overwinter in one of two ways. Either they enter a quiescent phase such as a teleiochrysallis or as a nymphochrysallis or they hibernate as adults in the bottom mud (Table 3). The low number of mites noted between late October and late May, especially in the December-March period (fig. 24) was presumably caused by mites entering their overwintering stage.

## Interspecific association

The Yates's corrected $\chi^2$ and the uncorrected $\chi^2$ matrices for the first division (n = 358) are shown in Tables 4 and 5. The species with the highest sum of $\chi^2$ and hence the greatest interaction with other species was *Arrenurus pseudocylindratus*. The first division was made on this species. The 358 samples were subdivided into those with *A. pseudocylindratus* and those without *A. pseudocylindratus* and the subsequent divisions worked out (fig. 30).

Table 3: Suggested overwintering stages for various mite species in Marion Lake.

| Species | | Overwintering stage |
|---|---|---|
| E. extendens | Teleiochrysallis | - hatches in spring as adult. |
| Hy. despiciens | Teleiochrysallis | - emerges as adult in May. |
| Fr. americana | Adults | - hibernating in mud. |
| Li. maculata | Adults | - hibernating in mud. |
| Genus Unionicola spp. | Adults | - hibernating in mud. |
| N. semicircularis | Adults | - ? hibernating in mud. |
| Pionopsis nov. sp. | Adults | - hibernating in mud. |
| Genus Piona spp. | Nymphochrysallis or as hibernating nymph in mud. | |
| Fo. ovalis | Adults | - hibernating in mud. |
| Fo. borealis | Larvae or as nymphochrysallis. | |
| Genus Arrenurus spp. | Adults | - in mud. |

(Data for this Table was collected in one of two ways - either by direct observations or by noting the last stage of the life cycle collected in late autumn and the first stage collected in the spring and early summer).

Fig. 30: Hierarchical chart for interspecific associations in mites of Marion Lake in 1969.

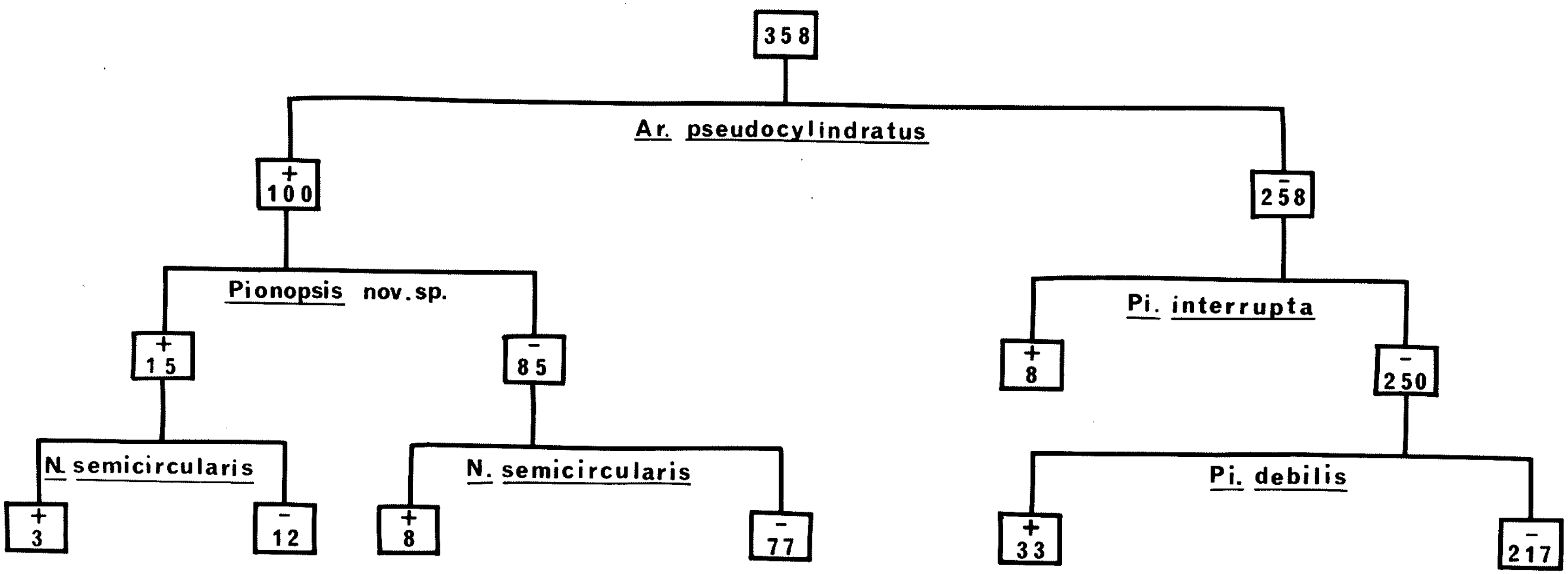

358
Ar. pseudocylindratus
+ 100
- 258
Pionopsis nov.sp.
+ 15
- 85
N. semicircularis
+ 3
- 12
N. semicircularis
+ 8
- 77
Pi. interrupta
+ 8
- 250
Pi. debilis
+ 33
- 217

Table 4: Values of Yates's corrected $\chi^2$ for association of water mite species in Marion Lake, 1969.

| | Fr. americana | Li. maculata | U. gracilipalpis | N. semicircularis | Hd. intermedius | Pionopsis nov. sp. | Pi. carnea | Pi. constricta | Pi. debilis | Pi. interrupta | Pi. variabilis | Fo. ovalis | Fo. borealis | Ar. cascadensis | Ar. pseudocylindratus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fr. americana | | | | | | | | | | | | | | | |
| Li. maculata | 0.106 | | | | | | | | | | | | | | |
| U. gracilipalpis | 0.940 | 0.144 | | | | | | | | | | | | | |
| N. semicircularis | 2.632 | 0.648 | 0.671 | | | | | | | | | | | | |
| Hd. intermedius | 1.354 | 2.698 | 0.022 | 0.810 | | | | | | | | | | | |
| Pionopsis nov. sp. | 0.849 | 2.698 | 4.270* | 1.831 | 0.003 | | | | | | | | | | |
| Pi. carnea | 0.558 | 0.106 | 0.617 | 0.265 | 0.968 | 0.109 | | | | | | | | | |
| Pi. constricta | 0.097 | 0.133 | 0.035 | 0.056 | 0.018 | 0.044 | 0.452 | | | | | | | | |
| Pi. debilis | 2.403 | 0.697 | 0.433 | 1.038 | 1.841 | 0.013 | 0.351 | 0.020 | | | | | | | |
| Pi. interrupta | 0.018 | 0.313 | 0.444 | 3.070 | 0.948 | 0.338 | 0.064 | 0.043 | 0.467 | | | | | | |
| Pi. variabilis | 6.439* | 0.173 | 2.440 | 0.534 | 0.125 | 1.139 | 0.008 | 0.003 | 0.034 | 1.134 | | | | | |
| Fo. ovalis | 0.001 | 0.020 | 0.985 | 6.076* | 0.212 | 4.630* | 1.153 | 0.003 | 0.002 | 2.528 | 4.949* | | | | |
| Fo. borealis | 0.003 | 0.888 | 0.132 | 0.201 | 0.492 | 0.049 | 0.000 | 0.005 | 0.878 | 0.155 | 0.155 | 0.210 | | | |
| Ar. cascadensis | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 | 0.401 | 0.029 | 0.404 | 0.002 | 0.300 | 0.447 | 1.591 | 0.384 | | |
| Ar. pseudocylindratus | 1.006 | 0.025 | 0.866 | 0.445 | 0.225 | 2.135 | 0.002 | 1.380 | 0.076 | 0.303 | 9.116* | 6.441* | 4.917* | 9.730* | |
| Hz. lacustris | 0.020 | 9.277* | 0.367 | 1.410 | 7.062* | 1.012 | 0.003 | 0.296 | 0.349 | 4.549* | 0.324 | 0.010 | 3.173 | 0.085 | 0.697 |

(* means significant value. Significant value underlined means positive association. )

Table 5: Uncorrected $\chi^2$ values for association between pairs of water mite species in Marion Lake in 1969.

| | Fr. americana | Li. maculata | U. gracilipalpis | N. semicircularis | Hd. intermedius | Pionopsis nov. sp. | Pi. carnea | Pi. constricta | Pi. debilis | Pi. interrupta | Pi. variabilis | Fo. ovalis | Fo. borealis | Ar. cascadensis | Ar. pseudocylindratus | Hz. lacustris |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fr. americana | | | | | | | | | | | | | | | | |
| Li. maculata | 0.725 | | | | | | | | | | | | | | | |
| U. gracilipalpis | 1.226 | 0.057 | | | | | | | | | | | | | | |
| N. semicircularis | 3.604 | 0.191 | 1.309 | | | | | | | | | | | | | |
| Hd. intermedius | 2.668 | 0.223 | 0.164 | 0.045 | | | | | | | | | | | | |
| Pionopsis nov.sp. | 1.384 | 2.024 | 5.600* | 3.825 | 1.161 | | | | | | | | | | | |
| Pi. carnea | 0.697 | 0.006 | 0.793 | 0.527 | 1.805 | 0.276 | | | | | | | | | | |
| Pi. constricta | 0.161 | 0.002 | 0.087 | 0.202 | 0.248 | 0.166 | 0.549 | | | | | | | | | |
| Pi. debilis | 3.100 | 0.012 | 0.819 | 2.297 | 4.853* | 0.118 | 0.568 | 0.092 | | | | | | | | |
| Pi. interrupta | 0.281 | 1.509 | 1.284 | 7.242* | 0.391 | 2.099 | 0.003 | 0.010 | 0.001 | | | | | | | |
| Pi. variabilis | 7.146* | 0.038 | 2.964 | 1.106 | 0.810 | 1.859 | 0.000 | 0.003 | 0.003 | 2.331 | | | | | | |
| Fo. ovalis | 0.032 | 0.280 | 1.365 | 7.942* | 1.127 | 6.140* | 1.412 | 0.030 | 0.049 | 4.403* | 5.752* | | | | | |
| Fo. borealis | 0.090 | 0.402 | 0.002 | 0.144 | 0.503 | 0.294 | 0.083 | 0.038 | 2.458 | 0.704 | 0.641 | 0.822 | | | | |
| Ar. cascadensis | 0.021 | 0.011 | 0.171 | 0.038 | 0.213 | 0.726 | 0.061 | 0.508 | 0.053 | 0.788 | 0.617 | 1.931 | 0.847 | | | |
| Ar. pseudocylindratus | 1.327 | 0.262 | 1.222 | 1.038 | 0.015 | 3.188 | 0.005 | 1.662 | 0.296 | 1.116 | 10.189* | 7.443* | 7.093* | 10.542* | | |
| Hz. lacustris | 0.363 | 0.089 | 2.192 | 0.324 | 0.111 | 0.380 | 0.265 | 0.001 | 0.559 | 0.156 | 2.053 | 0.722 | 0.201 | 0.119 | 0.012 | |
| Totals | 22.82 | 5.992 | 19.10 | 29.84 | 14.34 | 29.15 | 7.048 | 3.717 | 15.28 | 22.32 | 35.51 | 39.45 | 14.32 | 16.65 | 45.51 | 7.44 |

A significant difference between the mean temperatures of water for samples containing A. pseudocylindratus and the mean temperatures of water for samples without A. pseudocylindratus was found. The mean water temperature for samples containing A. pseudocylindratus was the higher of the two (Appendix G, test C-1). Significant differences in the mean water temperature for samples without A. pseudocylindratus and Pionopsis nov. sp. but containing Piona debilis and the mean temperature for samples lacking all three mite species were found (Appendix G, test C-2).

The samples containing P. debilis but not A. pseudocylindratus nor Pionopsis nov. sp. were found at a significantly different (i.e. greater) depth than were those without all three species (Appendix G, test d-1).

Egg production and egg-laying behaviour

The number of egg/female Unionicola crassipes remained high from April to early August when a marked decrease in numbers occurred (Table 6). The eggs were laid in the tissues of the fresh water sponge, Spongilla lacustris, found in Marion Lake. Sponge colour varied depending on how many eggs, nymphochrysallids, and/or teleiochrysallids of U. crassipes were present. In July and early August, sponges were pale green due, in part, to the large number of unionicolid developmental stages present ($30 . cm^{-2}$ of sponge). In May and in late August to early September, the living tissues of the sponge were bright green with relatively fewer mite development-

Table 6: Eggs and egg-laying patterns of the thirteen most common water mite species in Marion Lake.

| | Egg-bearing females | Most egg-bearers | Peak nos. eggs/female | Eggs laid in groups of | Egg colour | Egg size (in μ) |
|---|---|---|---|---|---|---|
| U. crassipes | mid-IV to early X | mid-IV to mid-VII | mid-IV to late V | 16 (5-24) | white-yellow | 151 (100-191) |
| Pi. carnea | VI to VIII | VII | late VII to early VIII | 15 (6-29) | red-orange | 215 (180-270) |
| Pi. constricta | late V to early X | early VIII | early VI to early VII | 12 (4-20) | yellow-red | 168.5 (148-240) |
| Ar. pseudocylindratus | V to VIII | V to VI | VI | 9 (3-13) | red | 158.2 (105-188) |
| U. gracilipalpis | mid-V to early VIII | VI | late VI | - | yellow-white | 145 (115-160) |
| Ar. cascadensis | V to early VII | VI | VI | 10 (6-14) | orange | 142.2 (80-160) |
| Pi. debilis | early VI to late VII | VI to VII | VII | 8 (4-14) | yellow-orange | 155 (127-260) |
| Fr. americana | mid-V to X | VI | early VI | 5 (3-9) | yellow | 163 (120-188) |
| Pi. variabilis | mid-VI to early VII | VII | VII | 12 (6-18) | red-orange | 160.5 (150-210) |
| Fo. ovalis | V to IX | VIII | VIII | 7 (4-21) | red | 164.5 (144-190) |
| Pionopsis nov. sp. | early V to X | VI | late V and VI | 2 (1-6) | red | 128 (115-143) |
| Fo. borealis | IX to XI | early XI | early XI | - | red | 171.2 (152-203) |
| Ar. solifer | V to VIII | early VII | early VII | 10 (6-15) | red | 184.5 (162-203) |

al stages present (10.cm$^{-2}$ of sponge). The late September sponges had a larger proportion of dead tissues which were brown and brittle. The eggs took a mean of 8 days to hatch (range 6-14) with an observed survival rate of eggs (i.e. the % hatching) in the sponge of 97.8% + 2%).

*Piona carnea* larvae crawled around within the egg capsule before they hatched (Table 7). A female which oviposited on June 13, 1969, lived until July 24. Failure to check her vial on June 24 (when the larvae hatched) and for several days afterwards resulted in the female eating her offspring. Egg-bearing females occurred from June to August (Table 6).

*P. constricta* larvae moved around within the egg capsule for two days prior to hatching (Table 7). The eggs laid in August (Table 6) probably became nymphs by September. Despite repeated attempts, female *U. gracilipalpis* could not be induced to lay their eggs (Table 6). Only one *P. interrupta* female oviposited in the laboratory, laying 38 eggs in all, none of which hatched. *Eylais extendens* females occurred in May and June. Females kept in the laboratory lived for 22 days after the first oviposition (June 19-July 11, 1969. The bright-red eggs were laid in groups of 34 (range 30-40). Eggs of *E. extendens* found May 26, 1967, hatched on June 12. By June 16, larvae parasitized *Gerris notabilis* in the rearing tank. Larvae formed nymphochrysallids on the host by June 25 and on July 20 the nymph appeared. This gave *E. extendens* a span of 55 days from egg to nymph. A second experiment,

Table 7: Egg development time for selected water mite species from Marion Lake.

| Species | Egg development time (days) | Nature of egg capsule |
|---|---|---|
| *U. crassipes* | 8 (range 6-14) | separate |
| *Pi. carnea* | 11 (range 8-14) | unpartitioned |
| *Pi. constricta* | 9 (range 6-12) | unpartitioned |
| *Ar. pseudocylindratus* | 10 (range 7-16) | partitioned |
| *Ar. cascadensis* | 7 (range 5-10) | partitioned |
| *Pi. debilis* | 10 (range 8-13) | partitioned |
| *Pi. variabilis* | 13 (range 7-19) | unpartitioned |
| *Fo. ovalis* | 10 (range 3-19) | unpartitioned |
| *Pionopsis* nov. sp. | 10 (range 9-13) | separate |
| *Ar. solifer* | 13 (range 6-21) | partitioned |
| *Pi. interrupta* | did not hatch | partitioned |
| *E. extendens* | 19.2 (range 16-21) | unpartitioned |

in 1969, gave the mean span as 58 days (range 53-63). As no adult mites of this species occurred in the lake after July 21, it is possible that the nymph forms the teleiochrysallis quickly and overwintered as such. The data available suggested that *E. extendens* was a late spring to early summer species (Tables 2 and 3).

Observations on the egg production and egg-laying behaviour of *Piona debilis*, *P. variabilis*, *Forelia*, *ovalis*, *F. borealis*, *Frontipoda americana*, *Pionopsis* nov. sp., *Arrenurus cascadensis*, *A. pseudocylindratus*, and *A. solifer*, were also made (Tables 6 and 7).

Observations on ovipositing females of *Piona carnea*, *P. constricta*, *P. debilis*, *P. variabilis*, *Pionopsis* nov. sp., *Forelia ovalis*, *Arrenurus cascadensis*, *A. pseudocylindratus*, and *A. solifer*, showed that egg-laying females did not lay all the eggs in a single oviposition, but rather spread the oviposition over several days. When males were kept in the vials with the females copulation took place several times during the protracted oviposition.

## Host-parasite relationships

A total of 12,875 insects (including 12,675 chironomids) from the Insect Emergence Trap Series were examined for mite larvae between April 10 and August 26, 1969. Few chironomids (131-1.03%) had mite larvae attached (Table 8). These were distributed on a monthly basis as follows:

Table 8: Host-parasite relationships formed by mites in Marion Lake.

| Host | | Mites | |
|---|---|---|---|
| Species | Peak | Species | Peak egg-bearing females |
| S. lacustris | v to viii | (U. crassipes | mid-vi to mid-vii |
| | | (U. gracilipalpis | late vi |
| En. boreale | v to vi | (Ar. cascadensis | v to vi |
| | | (Ar. pseudocylindratus | vii to viii |
| Ae. interrupta | vii | (Ar. cascadensis | v to vi |
| | | (Ar. solifer | v to vi |
| G. buenoi ) G. remiges ) G. incurvatus)- G. notabilis ) Lt. americana) | vi, vii | E. extendens | v, vi |
| C. modestus | mid-vii | (Pi. carnea | late vii to viii |
| | | (Pi. constricta | early vi to vii |
| C. anthracinus | v to vi | Pi. carnea | late vii to viii |
| Protanypus sp. A | mid-v | Pi. constricta | early vi to vii |
| Ta. verralli | vii | (Pi. carnea | late vii to viii |
| | | (Pi. variabilis | late vi to vii |
| Ta. lestagei | vi | Pi. constricta | early vi to vii |
| Ta. sp. B | | (Pi. carnea | late vii to viii |
| | | (Pi. constricta | early vi to vii |
| | | (Pi. variabilis | late vi to vii |
| | | (Fr. americana | vii |
| | | (N. semicircularis | vi to vii |
| Pe. sp. A | mid-v | (N. semicircularis | vi to vii |
| | | (Pionopsis nov. sp. | late v to vi |
| Po. bellus | late vii to viii | Ar. pseudocylindratus | late vii to viii |
| Po. denticulatus | late vii to viii | (Ar. pseudocylindratus | late vii to viii |
| | | (N. semicircularis | vi to vii |
| | | (Pi. carnea | late vii to viii |
| | | (Pi. constricta | early vi to vii |
| | | (Pi. debilis | vii |
| Ab. monilis | mid-viii | (Ar. pseudocylindratus | late vii to viii |
| | | (Pionopsis nov. sp. | late v to vi |
| | | (N. semicircularis | v and vi |
| | | (Fr. americana | vii |
| | | (Pi. constricta | early vi to vii |
| | | (Pi. variabilis | early vi to vii |

| Month | Number of chironomids examined | Number of chironomids with mite larvae | % parasitized |
|---|---|---|---|
| April | 255 | 0 | 0.0 |
| May | 6407 | 40 | 0.6 |
| June | 2791 | 28 | 1.0 |
| July | 1523 | 35 | 2.3 |
| August | 1699 | 28 | 1.6 |
| Total | 12675 | 131 | 1.03 |

Nine of 103 odonatan adults (8.7%) emerging from Marion Lake had mite larvae attached to them and 29 (11.9%) of 244 odonatan nymphs examined had mite larvae attached (Table 8). One emerging caddisfly had a mite larva attached to its wing. This specimen was lost before identification. Thirty-two (78%) of 41 gerrids examined had larvae and nymphochrysallids of Eylais extendens attached (Table 8). All the specimens of Lethocerus americanus found in the Marion Lake region during May and June 1969 had larvae and nymphochrysallids of E. extendens attached (Table 8).

Sparing (1959) reported Hydrodroma despiciens as parasitic on Chaoborus spp. (found in Marion Lake). I found no parasitized members of this genus emerging from the lake.

Specimens of the sponge (Spongilla lacustris) from Marion Lake had larvae, nymphochrysallids, and teleiochrysallids of Unionicola crassipes present in its tissues as well as nymphochrysallids and teleiochrysallids of U. gracilipalpis (Table 8). The number of sponges remained constant from June to early

August, 1969 ($1.58.m^{-2}$). The sponge tissues were at optimum condition during June and July after which they deteriorated rapidly.

Habitat preferences

Of the 32 species found in the bottom traps in 1966-1967, 24 were from traps set in Littoral I, 25 in Littoral II, and 20 in Sublittoral (Table 9). Similarly, of the 27 species trapped in 1969, 24 were in traps set in Littoral I, 25 in Littoral II, and 20 in Sublittoral (Table 9). Sorensen Index values for 1966-1967 and 1969 were:

| | | |
|---|---|---|
| 1966-1967: | Between Littoral I and Littoral II | - 78.4% |
| | Between Littoral I and Sublittoral | - 80.0% |
| | Between Littoral II and Sublittoral | - 84.4% |
| 1969 : | Between Littoral I and Littoral II | - 89.9% |
| | Between Littoral I and Sublittoral | - 77.3% |
| | Between Littoral II and Sublittoral | - 88.9% |

The high and uniform values of the Index showed that there was a great similarity of species composition of mites in different parts of the lake (Table 10).

Comparison of Littoral I, Littoral II, and Sublittoral results for 1966-1967 with 1969 values yielded high and uniform Sorensen Indices (Table 11) indicating stability in the composition of the mite fauna between 1966-1967 and 1969.

Several mite species exhibited preferences for one habitat type (Table 2). Some species (Piona carnea, P. variabilis and

Table 9: Species composition in the Littoral I, Littoral II, and Sublittoral during 1966-67 and 1969.

| | Littoral I | | Littoral II | | Sublittoral | |
|---|---|---|---|---|---|---|
| | 1966-7 | 1969 | 1966-7 | 1969 | 1966-7 | 1969 |
| *E. extendens* | x | x | x | | | |
| *Hy. despiciens* | x | x | x | x | x | |
| *Ps. orbicularis* | | | x | x | x | x |
| *Te. lundbladi* | | x | | x | | |
| *Sperchon* sp. | x | | | | | |
| *Le. porosa* | | | | x | x | x |
| *O. connatus* | x | x | | x | x | |
| *O. gnaphiscoides* | | | x | | | |
| *Fr. americana* | x | x | x | x | x | x |
| *Li. maculata* | x | x | x | x | x | x |
| *Hg. neootoporus* | x | | x | | x | |
| *At. glandulosus* | x | | | | | |
| *At. nodipalpis americanus* | x | x | | x | | |
| *U. crassipes* | x | x | x | x | x | x |
| *U. gracilipalpis* | x | x | x | x | x | x |
| *N. semicircularis* | x | x | | x | | x |
| *Hd. intermedius* | x | x | | x | | |
| *Ti. vernalis* | | x | | | | |
| *Pionopsis* nov. sp. | x | x | x | x | x | x |
| *Pa. leuckarti* | x | | | | x | |
| *Pi. carnea* | x | x | x | x | x | x |
| *Pi. constricta* | x | x | x | x | x | x |
| *Pi. debilis* | x | x | x | x | x | x |
| *Pi. interrupta* | x | x | x | x | x | x |
| *Pi. variabilis* | x | x | x | x | x | x |
| *Pi. conglobata* | x | | x | x | | x |
| *Fo. ovalis* | x | x | x | x | x | x |
| *Fo. borealis* | x | x | x | x | x | x |
| *M. orbicularis* | x | | | | | |
| *Ar. cascadensis* | x | x | x | x | x | x |
| *Ar. megalurus intermedius* | x | | | | x | |
| *Ar. pseudocylindratus* | x | x | x | x | x | x |
| *Ar. solifer* | x | x | x | x | x | x |
| *Hz. lacustris* | x | x | x | x | x | x |

Table 10: Number of species common to the three environments (Littoral I, Littoral II and Sublittoral) in 1966-7 and in 1969.

| 1966-7 | Littoral I | Littoral II | Sublittoral |
|---|---|---|---|
| Littoral I | 28 | | |
| Littoral II | 20 | 23 | |
| Sublittoral | 20 | 19 | 22 |
| **1969** | **Littoral I** | **Littoral II** | **Sublittoral** |
| Littoral I | 24 | | |
| Littoral II | 22 | 25 | |
| Sublittoral | 17 | 20 | 20 |

Table 11: Comparison of the Littoral I, Littoral II and Sublittoral for 1966-7 and 1969.

| | Number of Species common | Number of Species 1966-7 | Number of Species 1969 | Index (%) |
|---|---|---|---|---|
| Littoral I : 1966-7 v 1969 | 22 | 28 | 24 | 84.6 |
| Littoral II: 1966-7 v 1969 | 20 | 23 | 25 | 83.3 |
| Sublittoral: 1966-7 v 1969 | 17 | 22 | 20 | 77.3 |

*Forelia borealis*) occurred only over open mud, others (*Eylais extendens*, *Hydrodroma despiciens* and *Hydrochoreutes intermedius*) near emergent vegetation and still others (*Oxus connatus*, *Limnesia maculata* and *Piona conglobata*) near submergent vegetation. *Lebertia porosa*, *Forelia ovalis*, *Piona interrupta*, *Pionopsis* nov. sp., and *Arrenurus*?*solifer* were found mostly near macrophytes (both emergent and submergent). Many species (such as *Frontipoda americana*, *Unionicola crassipes*, *Unionicola gracilipalpis*, *Piona constricta*, *P. debilis*, *Arrenurus cascadensis* and *A. pseudocylindratus*) exhibited no particular habitat preference and were found in all habitats sampled.

Eighteen species occurred in the plankton of Marion Lake (Table 12). Three species (*Unionicola crassipes*, *Piona carnea* and *P. constricta*) made a significant contribution (99.4%) only occasionally. (*Piona carnea* and *P. constricta* were present in fairly high numbers however, their occurrence did not overlap significantly. *P.constricta* was more frequent in samples from May to July 15 (163:78). By July 22, the two species were present in almost equal numbers (69:61) and from July 29 on, *P. carnea* was more numerous (350:79).

## Vertebrate predators of mites

The stomach contents of four vertebrates present in the lake (*Salmo gairdneri*, *Oncorhynchus nerka*, *Taricha granulosa*, and *Ambystoma gracile*) were examined for water mites. Fourteen (8.6%) of the 163 stomachs of *S. gairdneri* had mites; 35 (9.85)

Table 12: Number and species of mites in the plankton of Marion Lake during 1966 (in order of frequency).

| Species | Number | % |
|---|---|---|
| *Unionicola crassipes* | 8712 | 90.1 |
| *Piona carnea* | 589 | 6.1 |
| *Piona constricta* | 319 | 3.3 |
| *Piona variabilis* | 10 | |
| *Arrenurus cascadensis* | 8 | |
| *Unionicola gracilipalpis* | 5 | |
| *Frontipoda americana* | 5 | |
| *Arrenurus solifer* | 4 | |
| *Pionopsis* nov. sp. | 3 | |
| *Piona interrupta* | 3 | |
| *Hydrozetes lacustris* | 3 | |
| *Hygrobates neooctoporus* | 2 | |
| *Neumania semicircularis* | 2 | |
| *Arrenurus pseudocylindratus* | 2 | |
| *Piona debilis* | 2 | |
| *Hydrochoreutes intermedius* | 2 | |
| *Hydrodroma despiciens* | 1 | |
| *Forelia ovalis* | 1 | |
| Unidentified larvae | 1 | |

of 359 stomachs of *O. nerka*; eight (6.3%) of the 128 stomachs of *T. granulosa* and five (4.6%) of the 109 stomachs of *A. gracile* had mites (Table 13).

## Invertebrate predators of mites

In the laboratory I observed large Anisoptera nymphs (*Aeshna interrupta*) seize water mites (*Piona carnea*, *P. constricta*, and *Unionicola crassipes*) and in some instances immediately reject them. *A. interrupta* ate all *U. crassipes* adults and nymphs offered and rejected most of the *P. carnea* offered. About 50% of the *P. constricta* were eaten and about 50% rejected. Pearlstone (pers. comm.) found mite remains (*Arrenurus cascadensis* and Piona spp.) in the gut contents of *Enallagma boreale* (Zygoptera) nymphs.

Table 13: Analysis of the water mites in the stomach contents of four vertebrates in Marion Lake

| | Number of stomachs | | | | | Number of mites | |
|---|---|---|---|---|---|---|---|
| | examined | with mites | with adults or nymphs only | with larvae only | with adults nymphs and larvae | adult and/or nymphs | larvae |
| *A. gracile* | 109 | 5 | 0 | 0 | 5 | 5 | 8 |
| *T. granulosa* | 128 | 8 | 7 | 1 | 0 | 8 | 16 |
| *S. gairdneri* | 163 | 14 | 4 | 9 | 1 | 7 | 16 |
| *O. nerka* | 339 | 35 | 18 | 12 | 5 | 55 | 106 |
| Totals | 739 | 62 | 29 | 22 | 11 | 75 | 146 |

*A. gracile*: three species (*Pr. constans*, *Fr. americana* and *Ar. cascadensis*).

*T. granulosa*: four species (*Pr. constans*, *U. crassipes*, *Ar. cascadensis* and *Ar. pseudocylindratus*).

*S. gairdneri*: four species (*Pr. constans*, *Li. maculata*, *Fo. borealis* and *Hz. lacustris*).

*O. nerka*: thirteen species (*Pr. constans*, *Hy. despiciens*, *Fr. americana*, *Li. maculata*, *At. nodipalpis americanus*, *Fo. ovalis*, *Pp. marionensis*, *U. crassipes*, *Ar. cascadensis*, *Ar. pseudocylindratus*, *Ar. solifer*, *Hz. lacustris* and *Ho. muscorum*).

## Discussion

Thirteen of the 38 species found were of frequent enough occurrence to be considered as 'common' (Table 1). Thirteen other species were 'rare residents'. Ten species (Pionacercus leuckarti, Attractides glandulosus, Teutonia lundbladi, Lebertia martisensis, Oxus gnaphiscoides, Pionopsis lutescens, Tiphys vernalis, Mideopsis orbicularis, Arrenurus megalurus intermedius and Sperchon sp.) were considered to be 'non-resident' or 'transient' species. Two species (Protzia constans and Homocaligus muscorum) occurred only in vertebrate stomachs so their exact status is problematic. P. constans lives under stones in streams (Marshall 1943a, Bergstrom 1953, Conroy 1968) and because of this may have been excluded from the sampling programme. H. muscorum lives in sphagnum moss (Habeeb 1962b, 1966b, Wood 1969) and so may also have been excluded from the sampling programme.

Young (1969) pointed out that the "abundance of a species depends on its ability to adjust to the prevailing chemical and physical conditions, success in competition and upon any host required for reproduction". Mitchell (1964) found that 25% of his species records of Arrenurus in Burt Pond were for individuals unable to reproduce because of unfavourable conditions for the parasitic phase of their life cycle (i.e. their hosts were absent). Young (1969) termed such mites as 'transient species' that were able to adjust to the environment but unable to reproduce for lack of host species. Thus a mite could be found in a lake, could survive for an extended period because it adjusted to the prevailing local conditions, but, if its larval host was absent, was unable to reproduce. It may have reached the lake attached to its host that was blown off course. This would explain the rare occurrence of some species in Marion Lake (e.g. Pionacercus leuckarti, Teutonia lundbladi, Oxus gnaphiscoides, Pionopsis lutescens, Tiphys vernalis and Arrenurus megalurus intermedius). While Lebertia porosa might be included in this group, I hesitate to do so as Lundblad (1924) found that the larvae of L. porosa developed directly into nymphs without a parasitic phase. Sparing (1959) however, found chironomids to be the larval hosts.

Some species found fairly frequently in Marion Lake may be unable to reproduce due to lack of a suitable host. Possible species in this category included Limnesia maculata, Hydrochoreutes intermedius, Hydrodroma despiciens, Piona conglobata, Oxus connatus, Hygrobates neooctoporus and Pseudohydryphantes orbicularis. Five species, known to be stream-dwelling forms, occurred in Marion Lake - all near the mouth of the inlet stream. They may have been washed into the lake by a heavy spate. These were Lebertia martisensis, Attractides glandulosus, A. nodipalpis americanus, Mideopsis orbicularis and Sperchon sp.

The number of species found in Marion Lake compared with the 41 species from Mikolajskie Lake (Pieczynski 1964), the range of 6-29 species from 41 lakes in the River Krutynia basin (Pieczynski 1963) and the range of 2-40 species in 60 lakes, bog-pools and ponds around Mecklenburg (Schieferdecker 1966).

The increase in adults noted in June 1967 (fig. 24) was probably due to the emergence of hibernating mites. In discussing a similar phenomenon for Mikolajskie Lake (Pieczynski 1964) said it was due to "immigration from other environments" (meaning from parts of the lake deeper than 5.5 m). It is unlikely that this is the cause in Marion Lake.

In winter the number of species and individuals declined in Marion Lake. From late October to early May an average of two species occurred in the lake on each collecting day (fig. 24) - furthermore few mites were captured. In explaining the drop in numbers of individuals and species Pieczynski (1964) noted that this coincided with the drop in water temperature below 14 C. The increase in numbers Pieczynski noted in June, he related to a rise in water temperature above 15 C. I found trap catches in 1966-1967 were related to changing water temperature but not in 1969. Efford (pers. comm.) pointed out that the reason for the low number of individuals and species in Marion Lake between October and May was probably explained by the high turnover rate the lake experienced in winter months. Hall (1964) noted that the rate of development of a population can be increased if, when there is a constant supply of food available at a moderately low temperature, the temperature is raised or if the amount of food is increased. In the spring when there are lots of nutrients available, the water temperature increased. As a result the phytoplankton productivity increased -

followed by an increase in the zooplanktonic herbivores - followed by an increase in the carnivores. McQueen (1970) noted such an increase for *Diaptomus oregonensis* and for rotifers. These two groups were food for *Cyclops bicuspidatus thomasi* which also showed an increase in numbers (McQueen 1969). Similar increases are noted for Ostracoda and for chironomids. The increase in mite numbers in late May and in June may simply be a response to the increased availability of food organisms.

Of the spring mite species, *Eylais extendens* adults were found by Crowell (1960) from April to mid-July (with four nymphs in late July). Conroy (1968 and unpublished data) reported nymphs from May to late June and adults from May to late July. Lundblad (1962, 1968) found adults from June to September with the greatest number in June and July. He found nymphs in May, June and July (with the greatest number in July). These results agreed with the Marion Lake findings and supported my contention that *E. extendens* is a late spring to early summer species.

The results from the early summer forms in Marion Lake (*Lebertia porosa*, *Neumania semicircularis* and *Piona constricta*) agreed with the results in the literature. Conroy (1968 and unpublished data) found only adult *P. constricta* from May to July in Manitoba, Saskatchewan and Alberta and only nymphs in August from Manitoba and Saskatchewan. Conroy (1968) found female *N. semicircularis* in early June in Saskatchewan and males and females in August in British Columbia. Adults were also found in late August in Saskatchewan (unpublished data from Prince Albert National Park). From this it would appear that in Marion Lake N. semicircularis overwintered as an adult, laid eggs in May and June, and the nymphs appeared from mid-June on. By mid-July the nymphs had become adults. Lundblad (1962, 1968) found adult Lebertia porosa from April to November with most occurring in July and August. He found nymphs in July and young adults in June, July and August. Conroy (1968 and unpublished data) found adults from June (most) to late August (but none in July) and nymphs in June and July (most). Lundblad's results suggested that L. porosa was a mid-summer form while the results of Conroy (1968 and unpublished) as well as those of the present study suggested that this species was an early summer form in Canada.

The mid-summer forms included Limnesia maculata, Piona variabilis and P. conglobata. Lundblad (1962, 1968) found P. variabilis nymphs in June and adults from May to October with most adults occurring in June and July. Viets (1930) found the species in April. Conroy (1968) found many males and females in June in Alberta, Saskatchewan and Manitoba. Limnesia maculata adults were found by Lundblad (1962, 1968) from February to October - with most in August. He found nymphs from May to October - with most in July. Lundblad (1927, 1968) stated L. maculata overwintered in a lethargic state as an adult. Conroy (1968) found adults from June to August and nymphs in July and August (most). Lundblad (1962, 1968) found adult P. conglobata from April to September with most in June. He found young males in May and June and young females from May to August. Conroy (1968 and unpublished data) found adults from May to August (with many nymphs in August) in Manitoba, Saskatchewan and Alberta. All of the above results confirmed the findings of the present survey that these three species were mid-summer species.

Late summer species in Marion Lake included Unionicola crassipes, Piona carnea and Hydrodroma despiciens. Lundblad (1962, 1968) found U. crassipes nymphs from May to August with one specimen in late October. He recorded the most nymphs in July. Adults were numerous in March and April, declined in numbers from May to July and showed a marked increase by early September. Conroy (1968 and unpublished data) found only adults in Saskatchewan in May; females and nymphs (ratio of adults:nymphs was 38:1) in June in Saskatchewan, Alberta and Manitoba; only nymphs in July while collections from Saskatchewan in late August had a ratio of 5:1 adults:nymphs. Lundblad (1927) found that U. crassipes overwintered in a lethargic state (probably as an adult). The results of the present study confirmed this. Results from other parts of Canada (Conroy 1968) together with those of Lundblad (1962, 1968) and of Sparing (1959) when compared to the Marion Lake results led me to the conclusion that U. crassipes had a similar life cycle in Northern Germany, Sweden and Canada. Lundblad (1962, 1968) found the largest number of P. carnea nymphs in July with a marked drop in numbers in August. The number of adults was highest in May, dropped in June and July, and by August a slight increase was noticed. Lundblad collected no P. carnea in September. Conroy (1968 and unpublished data) found only adult P. carnea in May and June, 16 adults and 89 nymphs in July and one adult and two nymphs in August. Sparing (1959) found P. carnea overwintering as nymphs while Walter (1922) found egg-bearing females under the ice in Pascuminer See in February - suggesting the overwintering stage to be the adult. The Marion Lake results suggesting that this was a late summer species contrasted with the above findings. In Marion Lake the nymph was the overwintering stage. Hydrodroma despiciens adults were found by Lundblad (1962, 1968) from February to October with most in July and August. He found nymphs most numerous in July and that the species overwintered as an adult. Conroy (1968 and unpublished data) found adults in May and June, adults and nymphs in July (all from British Columbia). Other collections by Conroy from Manitoba, Saskatchewan and Alberta in July and August followed the same pattern. All these findings agreed with the results of the Marion Lake study.

The autumn species in Marion Lake included U. gracilipalpis. Lundblad (1962, 1968) found adult U. gracilipalpis from May to October with the greatest number/collection in October. He found juveniles in August. The conclusion that U. gracilipalpis was a late summer to early autumn species in Marion Lake is supported by Lundblad's results.

The only other species found in Marion Lake about which seasonal data was available in the literature was Hygrobates neooctoporus. Modlin (1971) found nymphs of H. neooctoporus reached their greatest abundance in late July and early August. He found adult numbers peaked in October (when copulation was supposed to take place). What data were available from Marion Lake fitted the pattern described by Modlin.

Nymphs were the overwintering stages in Piona spp., but Limnesia maculata overwintered as adults (Lundblad 1927). Viets (1936) also reported nymphs as the overwintering stage for Piona spp., while both Sparing (1959) and Motas (1928) reported both adults and nymphs as overwintering forms. In Japan P. carnea overwintered as a nymph (Imamura 1954) and Crowell (1960) assumed that the adult was the overwintering stage for Piona rotunda and "for most species". Walter (1922) reported adult females in February in Pascuminer See and suggested that the adult was the overwintering stage. The present study finding that nymphs were the overwintering stages in Piona spp., contrasted with the claims of Walter, Motas and Sparing above and agreed with the results of Imamura and Lundblad.

Hutchinson (1959) found that even a relatively minor size difference between two species can be sufficient to ensure their survival and that interspecific size difference appeared to make species diversity more stable. He also stated that a seasonal difference in reproduction may also be needed if two species are to coexist. Brown and Wilson (1956) pointed out that if two normally allopatric species with comparable requirements became sympatric then character displacement must take place if both species are to survive. One species may become larger than the other. Hutchinson (1959) and Hutchinson and

MacArthur (1959) pointed out that small size permitted animals to become specialized in such a way as to be able to take advantage of even minor variations within the habitat. The small size of water mites ensures that they can adapt to changes in the microhabitat and thus maintain the stability of the species diversity in the lakes. I found (Appendix C, Table C-18) that the mite population in Marion Lake between 1966-1967 and 1969 had remained stable.

Differences in size, together with different preferences for food, habitat, and reproductive season will interact to reduce the interspecific competition in mites. The size differences between *Hydrochoreutes intermedius* and *Frontipoda americana* (1: 1.33) was close to the order of magnitude (1.3) suggested by Hutchinson (1959) "as an indication of the kind of difference necessary to permit two species to co-occur in different niches but at the same level of a food-web". In the early summer forms in Marion Lake, differences in size, swimming ability and habitats were noted. *Piona constricta* was the most numerous of these species. It was also one of the more abundant mites in the plankton (Table 12). The other early summer forms are not planktonic and therefore do not compete with *P. constricta.* The mid-summer species (Table 2) had differences in swimming ability, size and habitat preferences. *Pionopsis* nov. sp. occurred most frequently near macrophytes while *Arrenurus pseudocylindratus* showed no particular preference. *Pionopsis* nov. sp. bred in May and

June while A. pseudocylindratus bred in June and July. The autumn species (Table 2) also showed differences in size, breeding period and in larval hosts. The host of Forelia borealis is thought to be a chironomid; that of Unionicola gracilipalpis was uncertain (but was probably Spongilla lacustris); the hosts of Arrenurus solifer were Odonata (Aeshna interrupta and Zoniagrion sp.).

As there were two species of Unionicola, six species of Piona, two species of Forelia, and three species of Arrenurus found in Marion Lake, the question of intrageneric competition arose. The two species, U. crassipes and U. gracilipalpis used Spongilla lacustris to complete all or part of their life cycles. U. crassipes was the larger of the two (1.28 : 1) - a size difference in the correct order of magnitude (1.3 : 1) found by Hutchinson (1959) as sufficiently large for two species to coexist together. A second difference was that U. crassipes was the dominant water mite in the plankton while U. gracilipalpis was a rare planktonic form, preferring to live close to the lake bottom. During August and September, 1966, 5084 individuals of U. crassipes occurred in the plankton and 6086 in the bottom traps. During the same period, five U. gracilipalpis occurred in the plankton and 285 in the bottom traps. So, because U. gracilipalpis was non-planktonic, it further reduced competition with U. crassipes. The two species of Forelia (F. ovalis and F. borealis) presented many differences. The size ratio was 1.25:1.

F. borealis occurred in open mud conditions while F. ovalis occurred near macrophytes. F. ovalis reproduced in June and in July while F. borealis reproduced from late September to November. The six species of Piona (P. carnea, P. constricta, P. conglobata, P. debilis, P. interrupta, and P. variabilis) peaked in numbers of adults at three different times - P. constricta and P. debilis in early summer; P. conglobata and P. variabilis in mid-summer; and P. carnea and P. interrupta in late summer. P. constricta and P. debilis showed marked size differences (Table 2) and occurred in different habitats. P. conglobata and P. variabilis differed both in size and in habitat preferences. P. carnea and P. interrupta showed a size difference below that suggested by Hutchinson (1959) - 1 : 1.13, but which lay within what Hutchinson considered as an acceptable range. P. carnea was a common planktonic form while P. interrupta was an infrequent planktonic form. P. interrupta occurred mostly near macrophytes while P. carnea occurred in all habitats in Marion Lake. In Europe and in Japan, P. carnea is known to prefer more open conditions (Walter 1922, Motas 1928, Imamura 1954). Four species of Arrenurus occurred in Marion Lake. One of these (A. megalurus intermedius) occurred only once (July 29,1967). The other three species (A. cascadensis, A. pseudocylindratus and A. solifer) were frequently found. The two species of approximately the same size (A. cascadensis and A. pseudocylindratus) peaked at different times of the year (fig. 28) and showed preferences for different larval hosts (A. cascadensis on Odonata and

A. pseudocylindratus on chironomids principally and on Odonata). In the analysis for interspecific association (Table 4) strong negative associations were noted between the two mite species. A. solifer, the largest of the Arrenurids, parasitized Odonata and peaked in numbers in autumn. All three species were bottom dwellers with A. solifer occurring mostly near macrophytes. While a wide range of sizes were observed for water mites in Marion Lake, the cogeneric species adhered fairly closely to Hutchinson's (1959) ratio. If this ratio were not approached in cogeneric species, other differences were obvious that permitted them to co-occur.

Hutchinson (1959) suggested that there is an evolutionary tendency towards diversity, high efficiency and food chains of limited length. Diversity is limited in the first place by the amount of space an organism needs in which it can function properly. This is roughly proportional to the size of the organism. Diversity may also be limited by the basic concept behind Gause's Axiom. In order to set up a stable relationship, two sympatric species must differ from one another ecologically to some significant degree. The problem here lies in trying to estimate how much overlap will produce instability. Slobodkin (1961) suggested that the only way one can assess this is by making a direct anatomical comparison between the species involved. Among the Marion Lake mites, only two species, U. crassipes and U. gracilipalpis, were similar to each other anatomically. U. crassipes differed from U. gracilipalpis in two main anatomical respects - its palps are shorter and its legs, particularly the first pair, are thicker with a slightly different spine arrangement. Palpal lengths for U. gracilipalpis were: males, range 950-1050 μ ; females, range 1000-1350 μ . Palpal lengths for U. crassipes were: males, range 307-728 μ ; females, range 300-890 μ . In this instance there seemed to be minimal anatomical differences present which allow the two species to co-exist in Marion Lake. In other species, the anatomical differences suggest very little niche overlap. Piona carnea, P. constricta, P. debilis, P. interrupta, P. variabilis and P. conglobata differed from each other in size, in palpal shape, in genital plate structure, in the number and arrangement of the genital acetabula, in the leg structure (especially in the III-leg and IV-leg of the males), in the shape of the coxal plates and in their seasonal and habitat preferences. In the case of the genus Piona, the anatomical differences suggested a minimal overlapping of niches. In all other genera represented by more than one species, significant anatomical differences occurred. These, in themselves, ensured a certain stability to mite species diversity.

My observations on egg-laying behaviour supported the results of Uchida (1932) that the eggs were deposited either all at once or piecemeal over several days, I disagreed with Wesenberg-Lund (1939) that the eggs were always laid in one session. Sparing (1959) cited several examples of females in the Family Pionidae that laid their eggs in groups over a few days. Ellis-Adam and Davids (1970) observed Piona alpicola

Neuman) laying eggs periodically over an extended period, thus supporting the results of Uchida, Sparing and those of the present study.

Egg-production rates described for Marion Lake species were similar to those described for the same species in the literature (Arndt and Viets 1938, Walter 1922, Sokolow 1925, Soar and Williamson 1927, Motas 1928, Viets 1936, Wesenberg-Lund 1939, Sparing 1959, Pieczynski 1961b, and Conroy 1968 and unpublished data). Exceptions were that egg-bearing Piona carnea females first appeared in June in Marion Lake in contrast to the results of Walter (1922) who found egg-bearing female P. carnea under the ice in Pascuminer See in February. Viets (1936) reported that P. carnea paid eggs in groups of 16-70 in contrast to the Marion Lake results of 6-29 for P. carnea. The Marion Lake results agreed with those of Conroy (1968) for P. carnea. Crowell (1960) observed a female Eylais extendens ovipositing (while lying on her back). He reported that she died three days later. Conroy (1968) found adult E. extendens from early May to late July (with all females egg-bearing from June 12 on). Wesenberg-Lund (1939) said E. extendens laid eggs in groups of 10-20 (compared to 30-40 for Marion Lake). E. extendens females from Marion Lake survived for 22 days after oviposition (but laid no more eggs). This result with the observations of Ellis-Adam and Davids (1970) on Piona alpicola disagreed with Crowell's findings.

Various authors have described relationships between water mites and their larval hosts. For Unionicola crassipes, Sparing

(1959) noted four stages of the life cycle in *Spongilla lacustris* in July. These were: (i) teleiochrysallids (most numerous), (ii) in lesser numbers, small whitish eggs in groups of 10-20 (lacking an envelope), (iii) isolated, young free-living larvae (running over the sponge tissue); and (iv) a few nymphochrysallids. By mid-September, she observed no developing stages in the sponges except nymphochrysallids and teleiochrysallids. The sponges all died by November. The following year Sparing observed ovigerous females in March. The earliest eggs laid were in May; the earliest larvae appeared in early June; the nymphs began leaving the sponges by mid-July. Wesenberg-Lund (1918) noted that *U. crassipes* laid eggs in sponges in early May and that by late June larvae appeared. The above sets of results are almost identical to those from Marion Lake.

Sparing (1959) reported that *P. carnea* parasitized chironomids. Uchida (1932) gave the host as *Chironomus* spp. Sparing (1959) also reported chironomids as larval hosts for *P. variabilis* and *P. conglobata*. Munbhberg (1937) found the latter mite species parasitized *Ablabesmyia monilis*. No chironomids emerging from Marion Lake were parasitized by *P. conglobata* larvae.

Prasad and Cook (1972) described the larva of *U. gracilipalpis*. I was unable to separate the larva of this species from that of *U. crassipes* (p 29-30) though sponges isolated in vials yielded nymphs and adults of both species. I found no evidence to support my hypothesis that U.gracilipalpis laid eggs in S. lacustris. I have no doubt, however, that the mite needed the sponge to complete its life cycle.

Sparing (1959) gave chironomids as the host for Limnesia maculata and for Lebertia porosa. In the latter case Lundblad (1924) disagreed and said that the Lebertia larvae develop into nymphs without a parasitic phase. Modlin (1971) found Hygrobates neooctoporus larvae parasitic on the genus Metriocnemus sp. (Chironomidae). The larvae of the above three mites were not found on chironomids emerging from Marion Lake. Wesenberg-Lund (1939) and Sparing (1959) gave corixids as the larval hosts for Eylais extendens. Their findings contrasted with the present study and with the findings of Fernando and Galbraith (1970) who reported gerrids as the host insect.

The rate of parasitism of potential hosts in Marion Lake was low when compared to the results of other workers. Rohlf reported 147 chironomids out of 589 (25%) with one or more Arrenurus larvae on them (Sokal and Rohlf 1969, p 90). This rate is much higher than the Marion Lake results (1.03%). Mitchell (1968) found 98% of the damselfly, Cercion hieroglyphium Brauer, with Arrenurus larvae on them. Only 8.8% of the Odonata which emerged from Marion Lake had mite larvae attached. Mitchell's results were for a small pond with a high density of both mites and hosts. This meant that the chance of a mite larva successfully finding its host was high. In Marion Lake, the density of both Arrenurids and Odonatans was low and, as shown by Mitchell (1964, 1966 and 1969), these densities will greatly influence the probability of larval success.

Fernando and Galbraith (1970) found only "three of hundreds of gerrids infested with mites" though on one occasion (July 6, 1969) all gerrids examined were infested by Eylais extendens larvae. I found 78% of the gerrids in Marion Lake to be infested by E. extendens and 100% of the Lethocerus americanus were infested.

Out of several hundreds caught, only one caddisfly adult was parasitized by a mite larva (on the wing). This contrasted with the findings of Crowell (1967) who found that 18% of the caddis flies examined were parasitized by mites. Many workers found U. crassipes parasitic on sponges and on mussels (p 22). U. crassipes has a high probability of larval success since females laid eggs on sponges. The only undetermined element for U. crassipes is the probability of successful feeding off the hosts tissues. The high probability of larval success could be the reason for U. crassipes's dominance in the lake because once a female locates a sponge and deposits eggs, the probabilities of failure in succeeding stages are low.

It would appear that U. gracilipalpis also deposits eggs on sponges. If this were not so, then the lower numbers of U. gracilipalpis may simply be due to the failure of the larvae to find and/or to recognise the sponge and that when it does find the sponge all the best sites were taken by U. crassipes.

The larvae of all other mite species in Marion Lake had to actively seek their hosts, recognize them as such, attach themselves to the hosts, feed on the host, and drop off the host successfully. Because of the low rates of parasitism of potential hosts in Marion Lake, one may speculate that the effective overlap of mite and host in Marion Lake is low or there is some other limit to the populations and that all mite larvae find sufficient hosts without difficulty (i.e. there was a surplus of hosts).

Marion Lake water mites may follow Pennak's (1957) concept on species dominance in zooplankton communities. Pennak pointed out that in the great majority of limnetic communities there are, at any one time, only one numerically dominant copepod, one such cladoceran and one such rotifer. Moreover, he pointed out that these communities rarely contain more than one species of the same genus at the same time. He said it was a regular occurrence to find 80% or more of all limnetic copepods present to belong to a single species; 78% of all cladocerans and 64% of all rotifers to a single species. Table 12 shows that water mites follow this pattern with one numerically dominant species. The two Pionas followed this concept in that P. constricta was dominant in the plankton from late spring to mid-summer while P. carnea was dominant from mid to late summer (p. 93). Both U. crassipes and P. carnea were found in the plankton by other workers (Koenike 1896, Viets 1924 and Sokolow 1930). Sokolow found P. variabilis to be the most frequently occurring species in the plankton with U. crassipes much rarer.

Many workers have reported mites from the gut contents of vertebrate predators such as fish, turtles, birds, and amphibians. In most instances, mites make up less than 1% of the food organisms. Stankovitch (1921) however, found that mites made up 6.7% of the total number of organisms found in the gut contents of 100 cyprinid alevins. He added that mites are rarely observed in great numbers in gut contents - a point noted in the present study. Since only 62 of 739 stomachs examined (8.4%) had 75 adult and nymphal mites present, it was concluded that mites were unimportant items in the diets of the four vertebrates examined. As a percentage by weight of the food of the four predators they are less than 0.1%. While the number of mite larvae was high (148) relative to the number of adults and nymphs, it was concluded that they were probably on their insect hosts when the latter were consumed. The low number of adult and nymphal mites in predator stomachs from Marion Lake suggested that they, too, might have been eaten accidentally.

Motas (1928) reported large Aeshna nymphs (Odonata) eating the nymphs of Piona obturbans and Viets (1923) reported nymphs of Agrion eating mites. Pritchard (1964) reported 'Hydracarina' from the gut contents of Odonata nymphs such as Aeshna spp., Leucorrhina spp., Sympetrum sp., Libellula sp., and Cordulia sp. He thought that mites were probably eaten accidentally by the dragonflies. In many of my observations, the predatory behaviour of large *Aeshna interrupta* nymphs suggested a deliberate stalking of the mite prey rather than a random stroke at them. It may have been that the dragonflies were simply responding to the movement of the mites in the water. Some mites were immediately rejected by the dragonflies. *A. interrupta* ate all the *Unionicola crassipes* adults and nymphs that were offered to it, while it rejected most of the *Piona carnea* specimens offered. The Marion Lake results suggest a selection by the dragonflies of food organisms rather than the predators simply eating anything that came their way.

# REFERENCES


Arndt, W. and K. Viets 1938. Die biologischen (parasitologischen) zwischen Arachnoideen und Spongien. Z. Parasit., 10 (1):67-93.

Banks, N. 1919. The Acarina collected by the Canadian Arctic Expedition, 1913-1918. Rep. Canad. Arctic Exped. 1913-1918, 3: Insects: part H: Spiders, Mites, and Myriapods. Southern Party 1913-1916, Ottawa.

Bergstrom, D.W. 1953. Hydracarina from the Rocky Mountain Region. Trans. Amer. Microscop. Soc., 72: 157-162.

Brown, W. L., and E. O. Wilson 1956. Character displacement. Systm. Zool., 5: 49-64.

Conroy, J. C. 1968. The Water Mites of Western Canada. Nat. Mus. Canada, Bull. # 223: Contrib. Zool. IV: 23-42.

Conroy, J. C. 1973. A New Method for Trapping Water Mites in the Benthos of a Lake. Proc. III International Congr. Acarology, Prague 1971, pp 151-157.

Cook, D. R. 1954. Preliminary List of the Arrenuri of Michigan. Part II - the subgenus Megaluracarus. Trans. Amer. Microscop. Soc., 73: 367-380.

Cook, D. R. 1955. Preliminary Studies of the Hydracarina of Michigan. The Sub-family Foreliinae Viets (Acarina: Pionidae). Annals Ent. Soc. Amer., 48: 299-307.

Cook, D. R. 1956. Preliminary Studies of the Tiphysinae of the United States (Acarina: Pionidae). Annals Ent. Soc. Amer., 49: 263-274.

Cook, D. R. 1960. Water mites of the genus Piona in the United States (Acarina: Pionidae). Annals Ent. Soc. Amer., 53: 35-60.

Cook, D. R. 1970. North American Species of the Genus Hydrochoreutes (Acarina: Pionidae). Mich. Ent., 3: 108-117.

Cribbins, J. M. 1959. Hydracarina of Sanctuary Lake: A preliminary survey. Proc. Pennsylvania Acad. Sci., 33: 226-235.

Cronholm, M. 1946. "Uber die Hydracarinen der Aneboden Seen. Meddel. fran Lunds. Univ. limnolog. Inst., VI: 1-58.

Crowell, R. M. 1957. The Taxonomy, Distribution, and Developmental Stages of Water Mites collected in Central and North-central Ohio. Unpubl. diss., Ohio State University.

Crowell, R. M. 1960. The taxonomy,distribution and developmental stages of Ohio water mites. Bull. Ohio Biological Survey N.S., 2, 1: 1-77.

Crowell, R. M. 1961. Catalogue of the Distribution and Ecological Relationships of North American Hydracarina. Canad. Ent., 93 (5): 321-359.

Crowell, R.M. 1967. The immature instars of Albia caerulea (Acarina: Axonopsidae), a water mite parasitizing caddisflies (Trichoptera). Canad. Ent., 99: 730-734.

Davies, G. S. 1970. Productivity of Macrophytes in Marion Lake, British Columbia. J. Fish. Res. Bd., Canada, 27: 71-81.

Efford, I. E. 1967. Temporal and spatial differences in phytoplankton productivity in Marion Lake, British Columbia. J. Fish. Res. Bd., Canada, 24: 2283-2307.

Ellis-Adam, A. C., and C. Davids 1970. Oviposition and post-embryonic development of the water mite Piona alpicola (Neuman 1880). Netherlands J. Zool., 20 (1): 122-137.

Elton, C. S. 1923. On the colours of water mites. Proc. Zool. Soc. Lond., (1922): 1231-1239.

Fernando, C. H., and D. Galbraith 1970. A heavy infestation of gerrids (Hemiptera-Heteroptera) by water mites (Acarina: Limnocharidae). Can. J. Zool., 48: 592-594.

Habeeb, H. 1950. Three interesting water mites. Le Naturaliste Canadien, 77: 112-117.

Habeeb, H. 1953a. North American Hydrachnellae, Acari. I-V. Leaflets of Acadian Biology, 1: 1-16.

Habeeb, H. 1953b. North American Hydrachnellae, Acari. VI. Le Naturaliste Canadien, 80: 274-276.

Habeeb, H. 1954a. North American Hydrachnellae, Acari. IX-XVI. Leaflets of Acadian Biology, 2: 1-14.

Habeeb, H. 1954b. North American Hydrachnellae, Acari. XVII. Leaflets of Acadian Biology, 3: 1-4.

Habeeb, H. 1954c. North American Hydrachnellae, Acari. XVIII-XXV. Leaflets of Acadian Biology, 4: 1-8.

Habeeb, H. 1955a. North American Hydrachnellae, Acari. VII-VIII. Le Naturaliste Canadien, 82: 49-62.

Habeeb, H. 1955b. North American Hydrachnellae, Acari. XXVI-XXVII. Leaflets of Acadian Biology, _5_: 1-4.

Habeeb, H. 1955c. North American Hydrachnellae, Acari. XXIX-XXXI. Leaflets of Acadian Biology, _6_: 1-4.

Habeeb, H. 1955d. North American Hydrachnellae, Acari. XXXII-XXXIV. Leaflets of Acadian Biology, _7_: 1-4.

Habeeb, H. 1955e. North American Hydrachnellae. XXXV-XXXVI. Leaflets of Acadian Biology, _8_: 1-4.

Habeeb, H. 1956a. North American Hydrachnellae, Acari. XXXVII. Leaflets of Acadian Biology, _9_: 1-2.

Habeeb, H. 1956b. North American Hydrachnellae, Acari. XXXVIII. Leaflets of Acadian Biology, _10_: 1-2.

Habeeb, H. 1956c. Notes on water mites. I. Leaflets of Acadian Biology, _11_: 1-2.

Habeeb, H. 1956d. North American Hydrachnellae. XXXIX-XLI. Leaflets of Acadian Biology, _12_: 1-4.

Habeeb, H. 1957a. Some water mites from Baffin Island. Leaflets of Acadian Biology, _13_: 1-2.

Habeeb, H. 1957b. A revision of three Torrenticolae. Leaflets of Acadian Biology, _14_: 1-2.

Habeeb, H. 1957c. New Hydrachnellae from North Carolina. Leaflets of Acadian Biology, _15_: 1-8.

Habeeb, H. 1957d. Über _Nautarachna karl-vietsi_ Habeeb 1956. Abh. naturw. Ver. Bremen, _35_ (1): 51-52.

Habeeb, H. 1957e. North American Hydrachnellae. XLII-XLVII. Leaflets of Acadian Biology, _16_: 1-8.

Habeeb, H. 1958a. North American Hydrachnellae. XLVIII-L. Leaflets of Acadian Biology, _17_: 1-2.

Habeeb, H. 1958b. New mites from New Brunswick. Leaflets of Acadian Biology, _18_: 1-4.

Habeeb, H. 1959. New Hydrachnellae chiefly from California. Leaflets of Acadian Biology, _19_: 1-6.

Habeeb, H. 1960. Two new Hydrachnellae from New York. Leaflets of Acadian Biology, 21: 1-2.

Habeeb, H. 1961. A new species of Torrenticola and Icones. Leaflets of Acadian Biology, 24: 1-6.

Habeeb, H. 1962. A new species of Homocaligus (Acarina: Raphignathidae). Leaflets of Acadian Biology, 27: 1-4.

Habeeb, H. 1965. A new species of Limnocares and other things. Leaflets of Acadian Biology, 39: 1-4.

Habeeb, H. 1966. New genera in the Stigmaeidae, Acarina. Leaflets of Acadian Biology, 42: 1-2.

Habeeb, H. 1968a. A new species of Attractides and other things. Leaflets of Acadian Biology, 45: 1-4.

Habeeb, H. 1968b. To Anne and Daniel Fraser. Leaflets of Acadian Biology, 46: 1-4.

Habeeb, H. 1968c. To my students at Auburn Community College or my substitute for a faculty lecture. Leaflets of Acadian Biology, 48: 1-4.

Habeeb, H. 1968d. Some new North American species of Lebertia. Leaflets of Acadian Biology, 49: 1-4.

Habeeb, H. 1968e. Lebertia piscator and Sperchonopsis ancarmata, new water mites. Leaflets of Acadian Biology, 50: 1-4.

Habeeb, H. 1969. Notes on water mites. II. Leaflets of Acadian Biology, 51: 1-2.

Halbert, J. N. 1911. Acarinida. i - Hydracarina. Proc. R. Irish Acad., 31 (39i): 1-44, 3 plates (The Clare Island Survey).

Hall, D. J. 1964. An experimental approach to the dynamics of a natural population of Daphnia galatea mendota. Ecology, 45: 94-112.

Hamilton, A. L. 1965. An analysis of a fresh-water benthic community with special reference to the Chironomidae. Ph. D. Thesis, The University of British Columbia, 216 pp., unpubl. Ms.

Hargrave, B. T. 1969. Epibenthic algal production and community respiration in the sediments of Marion Lake. J. Fish. Res. Bd., Canada, 26: 2003-2026.

Hoff, C. 1944. A preliminary study of the Hydracarina of Reelfoot Lake, Tennessee. J. Tenn. Acad. Sci., 19: 234-239.

Hutchinson, G. E. 1959. Homage to Santa Rosalia or why are there so many kinds of animals ? Amer. Nat., 93: 145-159.

Hutchinson, G. E., and R. MacArthur 1959. A theoretical ecological model of size distributions among species of animals. Amer. Nat., 93: 117-126.

Imamura, T. 1953. Water mites from Gifu Prefecture. Jour. Fac. Sci., Hokkaido Univ., Ser. VI: Zool., 11: 412-471.

Imamura, T. 1954. On a water mite, Piona (Piona) carnea (Koch), found in the Ozegahara moor. Scient. Research Ozegahara moor, Tokyo. (709-713), Contrib. 136, Otsu Hydrobiol. Stat., Univ. Kyoto.

Keiding, J. 1948. Acarina, Mites. in KAJ BERG - 'Biological Studies on the River Susaa'. Fol. Limnol. Scandin., Kobenhavn., 4: 79-107.

Koenike, F. 1895. Nordamericanische Hydrachniden. Abh. naturw. Ver. Bremen, 13: 167-226.

Koenike, F. 1896. Holsteinische Hydrachniden. Forschber. biol. Stat. Plön, 4 (6): 207-247.

Koenike, F. 1909. Acarina, Milben. in A. BRAUER - 'Die Süsswasser-fauna Deutschlands'. Jena, 12: 13-184.

Koenike, F. 1912. A revision of my 'Nordamericanische Hydrachniden'. Trans. Canad. Inst., Toronto, 9: 281-296.

Lanciani, C. C. 1970. Resource partitioning in species of the water mite genus Eylais. Ecology, 51: 338-342.

Lambert, J. W., and W. T. Williams 1962. Multivariate methods in plant ecology. IV - Nodal analysis. J. Ecol., 50: 775-802.

Lambert, J. W., and W. T. Williams 1966. Multivariate methods in plant ecology. VI - Comparison of information analysis and association analysis. J. Ecol., 54: 635-664.

Lavers, C. H. 1945. The species of Arrenurus of the state of Washington. Trans. Amer. Microscop. Soc., 64: 228-264.

Lundblad, O. 1924. Neue Hydracarinen aus Schwedens I. Ent. Tidskr., 45: 67-72.

Lundblad, O. 1927. Die Hydracarinen Schwedens I. Zool. bidrag. Uppsala, 11: 181-540.

Lundblad, O. 1934. Die nordamericanischen Arten der Gattung Hydrachna. Ark. Zool., 28A(A): 1-44.

Lundblad, O. 1956. Zur Kenntnis sud- und mitteleuropaischer Hydrachnellen. Ark. Zool., 10 (1): 1-306.

Lundblad, O. 1962. Die Hydracarinen Schwedens II. Ark. Zool., 14 (1): 1-634.

Lundblad, O. 1968. Die Hydracarinen Schwedens III. Ark. Zool., 21 (1): 1-633.

Maglio, C. 1924. Idracarini. in RINA MONTI - 'La Limnologia del Lario'. Ministero Economia Nazionale, Roma. 75-124, 20 figs.

Marshall, R. 1903. Ten species of Arrenuri belonging to the subgenus Megalurus Thon. Trans. Wisc. Acad. Sci., 14: 145-172.

Marshall, R. 1908. The Arrhenuri of the United States. Trans. Amer. Microscop. Soc., 28: 85-140.

Marshall, R. 1910. New studies of the Arrhenuri. Trans. Amer. Microscop. Soc., 29: 97-110.

Marshall, R. 1912. Some American Lebertia. Trans. Amer. Microscop. Soc., 31: 225-230.

Marshall, R. 1914. Some new American water mites. Trans. Wisc. Acad. Sci., 17: 1300-1304.

Marshall, R. 1921. New species and collections of Arrhenuri. Trans. Amer. Microscop. Soc., 40: 168-176.

Marshall, R. 1922a. A preliminary report on the vertical distribution of water mites in Green Lake, Wisconsin. Trans. Ill. State Acad. Sci., 15: 200-201.

Marshall, R. 1922b. New American water mites of the genus Neumania. Trans. Wisc. Acad. Sci., 20: 205-213.

Marshall, R. 1924. Water mites from Alaska and the Canadian Northwest. Trans. Amer. Microscop. Soc., 43: 236-255.

Marshall, R. 1926. Water mites from the Okobojii region. Univ. Iowa Stud. Nat. Hist., 11: 28-35.

Marshall, R. 1927a. Collecting water mites in Cuba. Trans. Ill. State Acad. Sci., 19: 197-199.

Marshall, R. 1927b. Water mites from Cuba. Trans. Amer. Microscop. Soc., 46: 61-65.

Marshall, R. 1927c. Hydracarina of the Douglas Lake region. Trans. Amer. Microscop. Soc., 46: 268-285.

Marshall, R. 1929a. The water mites of Lake Wawasee. Proc. Indiana Acad. Sci., 38: 315-320.

Marshall, R. 1929b. Canadian Hydracarina. Univ. Toronto Studies, Biol. Ser., No. 33 (Publ. Ont. Fish. Res. Lab., #39), 57-93.

Marshall, R. 1930a. Water mites of the Jordan Lake region. Trans. Wisc. Acad. Sci., 25: 245-253.

Marshall, R. 1930b. Hydracarina from Glacier National Park. Trans. Amer. Microscop. Soc., 49: 342-345.

Marshall, R. 1932. Preliminary list of the Hydracarina of Wisconsin, Part II. Trans. Wisc. Acad. Sci., 27: 339-357.

Marshall, R. 1931. Preliminary list of the Hydracarina of Wisconsin, Part I: The red mites. Trans. Wisc. Acad. Sci., 26: 311-319.

Marshall, R. 1933a. Water mites from Wyoming as fish food. Trans. Amer. Microscop. Soc., 52: 34-41.

Marshall, R. 1933b. Preliminary list of the Hydracarina of Wisconsin. Part III. Trans. Wisc. Acad. Sci., 28: 37-61.

Marshall, R. 1935. Preliminary list of the Hydracarina of Wisconsin. Part IV. Trans. Wisc. Acad. Sci., 29: 273-297.

Marshall, R. 1937. Preliminary list of the Hydracarina of Wisconsin. Part V. Trans. Wisc. Acad. Sci., 30: 225-251.

Marshall, R. 1940a. On the occurrence of water mites in the food of turtles. Amer. Midl. Nat., 24: 361-364.

Marshall, R. 1940b. Preliminarl list of the Hydracarina of Wisconsin. Part VI. Trans. Wisc. Acad. Sci., 32: 135-165.

Marshall, R. 1943a. Hydracarina from California. Part 1. Trans. Amer. Microscop. Soc., 62: 306-324.

Marshall, R. 1943b. Hydracarina from California. Part 2. Trans. Amer. Microscop. Soc., 62: 404-415.

Marshall, R. 1946. Preliminary list of the Hydracarina of Wisconsin. Revision of Part I. Trans. Wisc. Acad. Sci., 36: 349-373.

McCauley, V. J. 1969. The food and feeding of some common herbivorous chironomids in Marion Lake. in I. E. EFFORD: 'Marion Lake Project, 1968-69'. I. B. P. Canada, unpublished preliminary report, 57 pp.

McCauley, V. J. 1970. Studies on the ecology of certain Chironomidae in Marion Lake. - in I. E. EFFORD: 'Marion Lake Project, 1969-70'. I. B. P. Canada, unpublished preliminary report, 82 pp.

McCauley, V. J. 1971. The life histories and trophic relations of Chironomidae. - in I. E. EFFORD: 'Marion Lake Project, 1970-1971'. I. B. P. Canada, unpublished preliminary report, 93 pp.

McCauley, V. J. 1972. Ecology of the Chironomidae. - in I. E. EFFORD: 'Marion Lake Project, 1971-72'. I. B. P. Canada, unpublished preliminary report, 90 pp.

McQueen, D. J. 1969. Reduction of zooplankton standing stocks by predacious Cyclops bicuspidatus thomasi in Marion Lake, British Columbia. J. Fish. Res. Bd., Canada, 26: 1605-1618.

McQueen, D. J. 1970. Grazing rates and food selection in Diaptomus oregonensis (Copepoda) from Marion Lake, British Columbia. J. Fish. Res. Bd., Canada, 27: 13-20.

Miller, A. E. 1925. An introductory study of the Acarina, or mites, of Ohio. Bull. Ohio Agric. Exper. Stat., # 386, 85-172.

Mitchell, R. 1955. Anatomy, life history, and evolution of the mites parasitizing fresh-water mussels. Mus. Zoology Univ. of Michigan, Misc. Publ., #89, v + 28 pp.

Mitchell, R. 1957. On the mites parasitizing Anodonta (Unionidae: Mollusca). J. Parasit., 43 (1): 101-104.

Mitchell, R. 1959. Life histories and larval behaviour of arrenurid water mites parasitizing Odonata. J. N. Y. Entomol. Soc., 67: 1-12.

Mitchell, R. 1961. Behaviour of the larvae of Arrenurus fissicornis Marshall, a water mite parasitic on dragonflies. Anim. Behav., 9: 220-224.

Mitchell, R. 1964. A study of sympatry in the water mite genus Arrenurus (Family Arrenuridae). Ecology, 45 (3): 546-558.

Mitchell, R. 1965. Population regulation of a water mite parasitic on unionid mussels. J. Parasit., 51: 990-996.

Mitchell, R. 1966. Ecological aspects of sympatry in water mites. Proc. Jap. Soc. Syst. Zool., 2: 28-31.

Mitchell, R. 1967a. Host exploitation of two closely related water mites. Evolution, 21 (1): 59-75.

Mitchell, R. 1967b. Terms used for Marine and Freshwater Acari. 2nd International Congress on Acarology, Unpubl. Ms.

Mitchell, R. 1968. Site selection by larval water mites parasitic on the damselfly Cercion hieroglyphicum Brauer. Ecology, 49 (1): 40-47.

Mitchell, R. 1969. A model accounting for sympatry in water mites. Amer. Nat,, 101: 331-346.

Mitchell, R., and G. W. Pitchford. 1954. On mites parasitizing Anodonta in England. J. Conchology, 23 (11): 365-370.

Mitchell, R., and J. L. Wilson 1965. New species of water mites (Unionicola) from Tennessee unionid mussels. J. Tenn. Acad. Sci., 40 (3): 104-106.

Modlin, R. F. 1970. Hygrobates neooctoporus: Description of larva, nymph and adult. Trans. Amer. Microscop. Soc., 89 (2): 288-295.

Modlin, R. F. 1971. Contributions to the life cycle and ecology of the water mite, Hygrobates neooctoporus Marshall 1924 (Hygrobatidae, Acari). Amer. Midl. Nat., 85: 54-62.

Morgan, N. C., A. B. Waddell, and W. B. Hall 1963. A comparison of the catches of emerging insects in floating box and submerged funnel traps. J. Anim. Ecol., 32: 203-219.

Motas, C. 1928. Contribution a la conaissance des Hydracariens français particulierement du Sud-Est de la France. Trav. Labor. Hydrobiol. Pisc. Univ. Grenoble, 20: 1-373.

Müller, O. F. 1776. Zoologiae Danicae prodromus, seu animalium Daniae et Norvegiae indigenarum characteres, nomina, et synonyma imprimis popularium. Havniae, 32 + 282 pp.

Munchberg, P. 1935. Zur Kenntnis des parasitimus der Larven der Hydracarinen - Unterfam. der Pionae, nebst. beschriebung der Larven zweier Arten. Abh. Ber. Grenzmark Ges. Schneidermuhl, 10: 97-106.

Munchberg, P. 1937. Über den Parasitimus der Wassermilbenlarven an Luftinsekten. Dtsch. Entomol. Zschr., 1937 (1-2): 19-34.

Munchberg, P. 1951. Ein zweiter Beitrag über die in den USA, eine odonatenparasitische Larvenphase aufweisenden Arrenurus-Arten (Ordnung: Hydracarina). Arch. Hydrobiol., 45 (3): 378-388.

Munchberg, P. 1952. Über Fortpflanzung, Leberweise und Korperbau von Arrenurus planus Marshall. Zool. Jahrbuch, (Syst.), 81: 27-46.

Munchberg, P. 1953. Vierter Beitrag zur Kenntnis der im nord-amerikanischen Raume an Odonaten parasitierenden Arrenurus-Arten (Ordnung: Hydracarina). Zool. Jahrbuch., (Syst.), 82: 47-57.

Munchberg, P. 1954. Zur Kenntnis der an Culiciden (Diptera) schmarotzenden Arrenurus-Larven (Hydracarina), sowie über die bedeutung dieser Parasiten fur Wirt und Mensch. Z. f. Parasitenkunde, 16: 298-312.

Newell, I. M. 1945. Hydrozetes Berlese (Acari, Oribatoidea): The occurrence of the genus in North America and the phenomenon of levitation. Trans. Conn. Acad. Sci., 36: 253-275.

Newell, I. M. 1959. 'Acari', in W. T. EDMONDSON (ed.): 'Ward and Whipple's - Freshwater Biology'. Chapter 42: pp 1080-1116. J. Wiley & Sons, New York.

Patterson, C. G. 1970. Water mites (Hydracarina) as predators of chironomid larvae (Insecta: Diptera). Can. J. Zool., 48: 610-614.

Pennak, R. W. 1953. Freshwater invertebrates of the United States. Ronald Press, New York, ix + 769 pp. (Chapter 23: Hydracarina, pp 470-487).

Pennak, R. W. 1957. Species composition of the limnetic zooplankton communities. Limnol. Oceanogr., 2: 222-232.

Pennak, R. W. 1958. Regional lake typology in northern Colorado, U. S. A. Verhandl. internat. Ver. Limnol., 13: 264-283.

Pieczynski, E. 1960a. Formation of groupings of water mites (Hydracarina) in different environments in Lake Wilkus. Ekol. Polska, Ser. A, 8: 169-198.

Pieczynski, E. 1960b. Types of settlement of water mites (Hydracarina) of the littoral zone of Lake Wilkus. Ekol. Polska, Ser. B, 6: 339-346.

Pieczynski, E. 1961a. The trap method of capturing water mites (Hydracarina). Ekol. Polska, Ser. B, 7: 111-115.

Pieczynski, E. 1961b. Numbers, sex ratio, and fecundity of several species of water mites (Hydracarina) of Mikolajskie Lake. Ekol. Polska, Ser. A, 9: 219-227.

Pieczynski, E. 1963. Some regularities in the occurrence of water mites (Hydracarina) in the littoral of 41 lakes in the River Krutynia basin and the Mikolajskie district. Ekol. Polska, Ser. A, 11: 143-157.

Pieczynski, E. 1964. Analysis of numbers, activity, and distribution of water mites (Hydracarina) and of some other aquatic invertebrates in the lake littoral and sublittoral. Ekol. Polska, Ser. A, 12: 691-735.

Pieczynski, E. 1965. Effect of the size of traps and their exposure time on the catches of aquatic invertebrates, chiefly water mites (Hydracarina). Bull. de l'Acad. Pol. des Sciences, Cl. II, 13 (10): 577-581.

Pieczynski, E. 1969. The trap method for ecological studies on water mites (Hydracarina) in lakes. Proc. 2nd Intl. Congress Acarology, 1967, 103-106.

Piersig, G. R. 1896-1899. Deutschlands Hydrachniden. Zoologica 1896-1899, 19 (22): 7 + 601 pp.

Prasad, V., and D. R. Cook 1972. Water mite larvae. Mem. Amer. Entomol. Inst., 18: ii + 326 pp.

Pritchard, G. 1964. The prey of dragonfly larvae (Odonata-Anisoptera) in ponds in Northern Alberta. Can. J. Zool., 42: 785-800.

Pritchard, G., and T. G. Leischner. 1973. The life history and feeding habits of Sialis cornuta Ross in a series of abandoned beaver ponds (Insecta: Megaloptera). Can. J. Zool., 51: 121-131.

Schrieferdecker, H. 1966. Die Hydrachnellae des Naturschutzgebietes "Ostufer der Muritz" in Mecklenberg. Beitrag. Entomol., 16 (5/6): 721-758.

Schwoerbel, J. S. 1959. Ökologische und tiergeographische Untersuchungen über die Milben (Acari: Hydrachnellae) der Quellen und Bäche des sudlichen Schwartzwaldes und seiner Randgebiete. Arch. Hydrobiol., Suppl., 24 (3/4): 385-546.

Scott, J. W. 1927. A study of trout food in the Medicine Bow National Forest. Ecol. Soc. Amer., Nashville, Tennessee.

Soar, C. D. 1900. British freshwater mites. Sci. Gossip, 6: 363-365.

Soar, C. D., and W. Williamson 1925. The British Hydracarina. The Ray Society, Vol. I, 266 pp, plates 1-20.

Soar, C. D., and W. Williamson 1927. The British Hydracarina. The Ray Society, Vol. II, 263 pp, plates 21-40.

Soar, C. D., and W. Williamson 1929. The British Hydracarina. The Ray Society, Vol. III, 232 pp, plates 41-60.

Sokal, R. J., and F. J. Rohlf 1969. Biometry - The Principles and Practices of Statistics in Biological Research. xxi + 776 pp., W. H. Freeman & Co., San Francisco.

Sokolow, I. 1925. Untersuchungen über die Eiablage und den Laich der Hydrachniden. II. Zsch. Morphol. Okol. Tiere, 4: 301-332.

Sokolow, I. 1930. Die Hydracarinen von Russisch-Karelien. Zool. Jahrbuch, (Syst.), 59: 139-232.

Sparing, I. 1959. Die Larven der Hydrachnellae, ihre parasitische Entwicklung und ihre Systematik. Parasit. Schrift., 10: 1-168.

Stankovitch, S. 1921. Etude sur la morphologie et la nutrition des alevins des cyprinides. Bull. Soc. Scient. Isere, Grenoble, 42: 31-312.

Thor, Sig 1925. Über die Phylogenie und Systematik der Acarina, mit Beitragen zur ersten Entwicklungsgeschicte einzelner Gruppen. IV. - Beitrage zur Ontogenie der Acarina. Nyt. Mag. Naturv., 62: 123-162.

Uchida, T. 1932. Some ecological observations on water mites. J. Fac. Sci. Hokkaido Univ., Sapporo, (s. 6), Zool., 1 (4): 143-165.

Viets, Karl 1923. Hydracarina, Wassermilben - in P. SCHULTZE: 'Biologie der Tiere Deutschlands'. Borntraeger, Berlin, 21: 29-52.

Viets, Karl 1924. Die Hydracarinen der norddeutschen, besonders der holsteinischen Seen (Versuch einer Oekologia der See Hydracarinen). Archiv. f. Hydrobiol., Suppl. IV (1): 71-179.

Viets, Karl 1928. Wassermilben, Hydracarina. - in BROHMER, EHRMANN, ULMER: 'Die Tierwelt Mitteleuropas', Leipzig 3 (4): 57 pp, 135 figs.

Viets, Karl 1930. Quantitative Untersuchungen über die Hydracarinen der norddeutschen Seen. Archiv. f. Hydrobiol., 22: 1-71.

Viets, Karl 1936. Wassermilben oder Hydracarina. - in F. DAHL: 'Tierwelt Deutschlands', Jena, 31 and 32: 584 pp.

Viets, Karl 1955. Die Milben des Susswassers und des Meeres. Part 1, 476 pp, Jena.

Viets, Karl 1956. Die Milben des Susswassers und des Meeres. Parts 2 and 3, 870 pp, Jena.

Viets, Karl, and H. P. Plate 1954. Die oekologischen (parasitologischen) Beziehungen zwischen Wassermilben (Hydrachnellae, Acari) und Susswassermollusken. Zach. angew. Entomol., 35 (4): 459-494.

Viets, Karl, and K. O. Viets 1960. Wassermilben, Hydracarina. - in BROHMER, EHRMANN, ULMER: 'Die Tierwelt Mitteleuropas', Leipzig, 3 (4): 44 pp (Revision of VIETS 1928).

Viets, K. O. 1955. Wassermilbenaus nord Bayern. Abhandl. Bayer. Akad. Wiss., Neue Folge, 73: 1-106.

Walter, C. 1922. Die Hydracarinen der Alpengewasser. Denkschr. d. Schweizer Naturforsch. Ges., 58 (2): 11 + pp 60-251.

Wesenberg-Lund, C. 1918. Contributions to the knowledge of the post-embryonal development of the Hydracarina. Vid. Medd. Dansk. Naturhist. Foren., 70: 5-57.

Wesenberg-Lund, C. 1939. Biologie der Susswassertiere. Wirbellose Tiere. Deutsche Ausgabe Besorgt von O. STORCH. Wien, (J. Springer), 11 + 817 pp.

Williams, W. T., and J. W. Lambert 1959. Multivariate methods in plant ecology. I - Association analysis in plant communities. J. Ecol., 47: 83-101.

Williams, W. T., and J. W. Lambert 1960. Multivariate methods in plant ecology. II - The use of an electronic digital computer for association analysis. J. Ecol., 48: 689-710.

Williams, W. T., and J. W. Lambert 1961. Multivariate methods in plant ecology. III - Inverse association analysis. J. Ecol., 49 : 717-729.

Williams, W. T., J. W. Lambert, and G. N. Lance 1966. Multivariate methods in plant ecology. V - Similarity anaylsis and information analysis. J. Ecol., 53: 427-445.

Wolcott, R. H. 1898. New American species of the genus Atax (Fabr.) Bruz. Zool. Bull., 1: 279-285.

Wolcott, R. H. 1899. On the North American species of the genus Atax (Fabr.) Bruz. Trans. Amer. Microscop. Soc., 20: 193-259.

Wolcott, R. H. 1902. The North American species of Curvipes. Trans. Amer. Microscop. Soc., 23: 201-256.

Wolcott, R. H. 1903. The North American species of Limnesia. Trans. Amer. Microscop. Soc., 24: 85-107.

Wolcott, R. H. 1905. A review of the genera of the water mites. Stud. Zool. Labor. Nebraska, #66, Trans. Amer. Microscop. Soc., 26: 161-243.

Wolcott, R. H. 1918. The water mites (Hydracarina). - in WARD and WHIPPLE'S : 'Freshwater Biology'. Chapter 26: pp851-875. John Wiley & Sons, New York.

Wood, T. G. 1969. The Homocaligidae, a new family of mites (Acari: Raphignathoidea) including a description of a new species from Malaya and the British Solomon Islands. Acarologia, 11 (4): 711-729.

Young, W. C. 1969. Ecological distribution of Hydracarina in North Central Colorado. Amer. Midl. Nat., 82: 367-401.

Zschokke, F. 1911. Die Tiefseefauna der Seen Mitteleuropas, Eine geographischefaunistische Studie. Intern. Rev. Hydrobiol. Hydrogr., Monogr., und Abh., 4: 246 pp, 2 maps.

APPENDIX A: Complete systematic classification of the water mites of Marion Lake.

PHYLUM : ARTHROPODA

SUBPHYLUM : CHELICERATA

CLASS : ARACHNIDA

SUBCLASS : LATIGASTRA

SUPERORDER : EPECTINATA

ORDER : ACARI

SUBORDER : TROMBIDIFORMES

SUPERCOHORT : PROSTIGMATA

COHORT : PARASITENGONA

SUPERFAMILY : LIMNOCHARAE

Family : Eylaidae

Genus : Eylais Latreille 1796

Species : extendens (Muller 1776)

SUPERFAMILY : HYDRPHANTAE

Family : Protziidae

Genus : Protzia Piersig 1896

Subgenus : Calonyx Walter 1907

Species: constans (Marshall 1943b).

Family : Hydrodromidae

Genus : Hydrodroma Koch 1837

Species : despiciens (Muller 1776) sensu stricta

SUPERFAMILY : LEBERTIAE

Family : Pseudohydryphantidae

Genus : Pseudohydrphantes Viets 1907

Species : orbicularis Marshall 1929b.

Family : Teutonidae

Genus : Teutonia Koenike 1889

Species : lundbladi Habeeb 1955c

Family : Sperchonidae

Genus : Sperchon Kramer 1877

Species : Not determined.

Family : Lebertiidae

Genus : Lebertia Neuman 1880

Species : martisensis Marshall 1943

Subgenus : Pilolebertia Thor 1900

Species : porosa (Thor 1900) sensu stricta

Family : Oxidae

Genus : Oxus Kramer 1877

Species : connatus Marshall 1929b

Species : gnaphiscoides Habeeb 1955d

Genus : Frontipoda Koenike 1891

Species : americana Marshall 1914

SUPERFAMILY : PIONAE

Family : Limnesiidae

Genus : Limnesia Koch 1836

Species : maculata (Muller 1776) sensu stricta

Family : Hygrobatidae

Genus : Hygrobates Koch 1837

Subgenus : Tetrabates Thor 1922

Species : neooctoporus (Marshall 1926)

Genus : Attractides Koch 1837

Species : glandulosus (Walter 1918)

Species : nodipalpis (Thor 1899)

Subspecies : americanus (Marshall 1943b)

Family : Unionioolidae

Genus : Unionicola Haldeman 1822 sensu stricta

Species : crassipes (Muller 1776) sensu stricta

Species : gracilipalpis (Viets 1908) sensu stricta

Genus : Neumania Lebert 1879

Species : semicircularis Marshall 1922

Family : Pionidae

Genus : Hydrochoreutes Koch 1837

Species : intermedius Cook 1956

Genus : Tiphys Koch 1836

Subgenus : Acercopsis Viets 1926

Species : vernalis (Habeeb 1954d)

Genus : Pionopsis Piersig 1894

Subgenus : Pionopsis sensu stricta

Species : lutescens (Hermann 1804)

Subgenus : Neotiphys (Habeeb 1956a)

Species : Nov. sp.

Genus : Pionacercus Piersig 1894

Species : leuckarti Piersig 1894

Genus : Piona Koch 1842

Subgenus : Piona sensu stricta

Species : carnea (Koch 1836)

Species : constricta (Wolcott 1902)

Species : debilis (Wolcott 1902)

Species : interrupta Marshall 1929b

Subgenus : Tetrapiona Viets 1926

Species : variabilis (Koch 1836)

Subgenus : Dispersipiona Viets 1926

Species : conglobata (Koch 1836) sensu stricta

Genus : Forelia (Haller 1882)

Subgenus : Forelia sensu stricta

Species : ovalis Marshall 1929b

Subgenus : Madawaska Habeeb 1954a

Species : borealis (Habeeb 1954a)

SUPERFAMILY : MIDEOSPAE

Family : Mideopsidae

Genus : Mideopsis Neuman 1880 sensu stricta

Species : orbicularis (Muller 1776)

SUPERFAMILY : ARRENURAE

Family : Arrenuridae

Genus : Arrenurus Duges 1834

Subgenus : Arrenurus sensu stricta

Species : cascadensis Lavers 1945

Subgenus : Megaluracarus Viets 1911

Species : megalurus (Marshall 1903)

Subspecies : intermedius (Marshall 1940b)

Species : pseudocylindratus (Piersig 1904)

Species : solifer (Marshall 1908)

SUPERFAMILY : RAPHIGNATHOIDEA

Family : Homocaligidae

Genus : *Homocaligus* Berlese 1910

Subgenus : *Paludocaligus* Habeeb 1966

Species : *muscorum* Habeeb 1962

SUPERFAMILY : ORIBATAE

Family : Oribatae

Genus : *Hydrozetes* Berlese 1902

Species : *lacustris* (Michael 1882)

This classification follows that of Viets (1956) and of Newell (1959).

APPENDIX B: Zoogeographic distribution of the mite species found in Marion Lake. Species arranged in systematic order after Viets (1956).

| | Palaearctic | Nearctic | Neotropical | Ethiopian | Oriental | Australian |
|---|---|---|---|---|---|---|
| E. extendens | x | x | | | | |
| Pr. constans | | x | | | | |
| Hy. despiciens | x | x | x | x | x | x |
| Ps. orbicularis | | x | | | | |
| Te. lundbladi | | x | | | | |
| Sperchon sp. | | x | | | | |
| Le. martisensis | | x | | | | |
| Le. porosa | x | x | | | | |
| O. connatus | | x | | | | |
| O. gnaphiscoides | | x | | | | |
| Fr. americana | | x | | | | |
| Li. maculata | x | x | | x | | |
| Hg. neooctoporus | | x | | | | |
| At. nodipalpis americanus | | x | | | | |
| At. glandulosus | x | x | | | | |
| U. crassipes | x | x | x | x | x | |
| U. gracilipalpis | x | x | | | | |
| N. semicircularis | | x | | | | |
| Hd. intermedius | | x | | | | |
| Ti. vernalis | | x | | | | |
| Ps. lutescens | x | x | | | | |
| Pionopsis nov. sp. | | x | | | | |
| Pa. leuckarti | x | x | | | | |
| Pi. carnea | x | x | | | | |
| Pi. constricta | | x | | | | |
| Pi. debilis | | x | | | | |
| Pi. interrupta | | x | | | | |
| Pi. variabilis | x | x | | | | |
| Pi. conglobata | x | x | | | | |
| Fo. ovalis | | x | | | | |
| Fo. borealis | | x | | | | |
| M. orbicularis | x | x | x | | | |
| Ar. cascadensis | | x | | | | |
| Ar. megalurus intermedius | | x | x | | | |
| Ar. pseudocylindratus | | x | | | | |
| Ar. solifer | | x | | | | |
| Ho. muscorum | | x | | | | |
| Hz. lacustris | x | x | | | | |
| Total | 14 | 38 | 4 | 3 | 2 | 1 |

APPENDIX C: Examination of the sampling methods used in Marion Lake.

## Introduction

Because the life styles of mite species differ - some are bottom dwellers, some planktonic, some shallow-water forms, some deep-water forms, some live near macrophytes - no one trapping method will give the true numerical and species compositions for the mite fauna in a lake. Several sampling methods were used (pp 12-16, above) and the overall mite species list for Marion Lake determined (Table 2, p. 87). This Appendix presents the results of comparisons made between the different sampling methods used during the present study. There is no way of assessing the true species composition. However, based on the results below I think that the Conroy Trap (Conroy 1973) is the best method for sampling water mites both in numbers of individuals and of species caught.

## Results

Comparison of sampling methods

Thirty-two species were caught in Conroy bottom traps in 1966-1967, 27 in bottom traps in 1969, 17 in insect emergence traps in 1966-1967, 26 in insect emergence traps in 1969, 18 in plankton hauls in 1966, six in pump samples, 11 in Pieczynski traps, eight in net sweeps, five in cylinder traps, five in Hargrave samples and 13 in stomach contents (Table C-1).

TABLE C-1: Water mite species caught by the various sampling methods used in Marion Lake.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *U. crassipes* | + | + | + | + | + | + | + | + | + | + | + |
| *Pi. carnea* | + | + | + | + | + | + | + | + | + | + | |
| *Pi. constricta* | + | + | + | + | + | + | + | + | + | | |
| *Ar. pseudocylindratus* | + | + | + | + | + | + | + | | | + | + |
| *U. gracilipalpis* | + | + | + | + | + | | | | | + | |
| *Ar. cascadensis* | + | + | + | + | + | | + | + | + | | + |
| *Pi. debilis* | + | + | + | + | + | | + | + | | | |
| *Fr. americana* | + | + | + | + | + | | | | | | + |
| *Pi. variabilis* | + | + | | + | + | | | | | | |
| *Fo. ovalis* | + | + | | + | + | | | + | | | + |
| *Pionopsis* nov. sp. | + | + | + | + | + | + | + | | | | + |
| *Fo. borealis* | + | + | | + | | | | | | | |
| *Ar. solifer* | + | + | + | + | + | | | | | | + |
| *Pi. interrupta* | + | + | | + | + | | + | | | | |
| *N. semicircularis* | + | + | | + | + | | | | | | |
| *Hz. lacustris* | + | + | + | + | + | + | + | | | | + |
| *Li. maculata* | + | + | + | + | | | | + | | | + |
| *Hd. intermedius* | + | + | | + | + | | | | | | |
| *Hy. despiciens* | + | + | + | + | + | | | | | + | + |
| *Pi. conglobata* | + | + | + | + | | | + | | | | |
| *E. extendens* | + | + | | + | | | | + | + | | |
| *At. nodipalpis americanus* | + | + | | + | | | | | | | + |
| *O. connatus* | + | + | + | + | | | | | | | |
| *Hg. neooctoporus* | + | | + | | + | | | | | | |
| *Le. porosa* | + | + | | + | | | | | | | |
| *Ps. orbicularis* | + | + | | | | | | | | | |
| *Pr. constans* | | | | | | | | | | | + |
| *Pa. leuckarti* | + | | + | + | | | | | | | |
| *At. glandulosus* | + | | | | | | | | | | |
| *Ho. muscorum* | | | | | | | | | | | + |
| *Te. lundbladi* | | + | | | | | | | | | |
| *Le. martisensis* | | + | | | | | + | | | | |
| *O. gnaphiscoides* | + | | | | | | | | | | |
| *Pp. lutescens* | | | | + | | | | | | | |
| *Ti. vernalis* | | + | | | | | | | | | |
| *M. orbicularis* | + | | | | | | | | | | |
| *Ar. megalurus intermedius* | + | | | | | | | | | | |
| *Sperchon* sp. | + | | | | | | | | | | |
| Unidentified larvae | + | + | + | + | + | + | | | | | + |
| Total number of species | 32 | 27 | 17 | 26 | 18 | 6 | 11 | 8 | 5 | 5 | 13 |

1 = Bottom traps 1966-7; 2=Bottom traps 1969; 3=Insect Emergence traps 1966-7; 4=Insect Emergence traps 1969; 5=Plankton 1966; 6=Pump samples 1966; 7=Pieczynski traps 1966; 8=Net sweeps 1969; 9=Cylinder samples 1969; 10-Hargrave sampler 1968-69; 11=Stomach contents 1964-69.

+ Means species present.

Pieczynski traps were used from June 13 to August 15, 1966 (Table C-2). When these traps were compared with insect emergence traps, two main differences were noted: a greater variety of species in emergence traps (including all but two species found in Pieczynski traps), and a greater number of mites.$m^{-2}$ in the emergence traps (Table C-3).

The Hargrave sampler gave disappointing results with a total of 40 mites in 320 samples or 5.5 mites.$m^{-2}$ (Table C-4). Catches made on June 20, 1969, July 18, 1969, and August 20, 1969, when both Hargrave sampler and Conroy bottom traps were used, were compared (Table C-5). A disparity in the number of mites.$m^{-2}$ was noted.

Only five species occurred in the cylinder traps (Table C-6). A total of 89 mites were obtained in 50 cylinder samples.

Table C-6: Catches of mites in cylinder traps in 1969.

| | 18-vi-1969 | | 21-vii-1969 | | 20-viii-1969 | |
|---|---|---|---|---|---|---|
| | Mites/ day | Mites.$m^{-2}$ | Mites/ day | Mites.$m^{-2}$ | Mites/ day | Mites.$m^{-2}$ |
| *Pi. carnea* | 19 | 43.2 | 8 | 24.2 | 16 | 48.5 |
| *Pi. constricta* | 6 | 13.6 | 2 | 6.1 | 10 | 30.3 |
| *U. crassipes* | 5 | 11.2 | 7 | 21.2 | 8 | 24.2 |
| *E. extendens* | 1 | 2.3 | 0 | | 0 | |
| *Ar. cascadensis* | 0 | | 1 | 3.0 | 6 | 18.2 |
| Totals | 31 | | 18 | | 40 | |
| Number of samples | 20 | | 15 | | 15 | |

Table C-2: Number of mites found in Pieczynski traps in 1966.

a = number of mites in ten traps.

b = number of mites.$m^{-2}$.$day^{-1}$.

| | | 15-vi-1966 | 17-vi-1966 | 21-vi-1966 | 24-vi-1966 | 4-vii-1966 | 11-vii-1966 | 21-vii-1966 | 29-vii-1966 | 4-viii-1966 | 11-viii-1966 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U. crassipes | a | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 3 |
| | b | - | - | - | - | - | 1.1 | - | - | - | 2.3 | |
| Pi. constricta | a | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 |
| | b | - | - | 2 | - | 0.8 | 1.1 | - | - | - | - | |
| Ar. pseudocylindratus | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 |
| | b | - | - | - | - | - | - | - | - | - | 5.7 | |
| Ar. cascadensis | a | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 5 |
| | b | - | 4 | - | - | - | 2.3 | - | 1 | 1.3 | - | |
| Pi. debilis | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 |
| | b | - | - | - | - | - | - | - | - | - | 8 | |
| Pionopsis nov. sp. | a | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 6 |
| | b | - | 12 | 4 | - | - | - | - | - | 1.3 | - | |
| Ar. solifer | a | 0 | 0 | 0 | 0 | 5 | 6 | 5 | 0 | 1 | 1 | 18 |
| | b | - | - | - | - | 4 | 6.9 | 10 | - | 1.3 | 1.1 | |
| Pi. interrupta | a | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | b | - | - | 2 | - | - | - | - | - | - | - | |
| Pi. conglobata | a | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | b | - | 4 | - | - | - | - | - | - | - | - | |
| Hz. lacustris | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | b | - | - | - | - | - | - | - | - | - | 1.1 | |
| Le. martisensis | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | b | - | - | - | - | - | - | - | 1 | - | - | |
| Totals | a | 0 | 5 | 4 | 0 | 6 | 10 | 5 | 2 | 3 | 16 | |
| | b | - | 20 | 8 | - | 4.8 | 11.4 | 10 | 2 | 3.9 | 18.2 | |

Table C-3: Pieczynski trap catches compared to insect emergence trap catches in 1966 (results expressed as mites.m$^{-2}$).

a = Pieczynski trap results
b = Insect emergence trap results

| Date | | U. crassipes | Pi. carnea | Pi. constricta | Ar. pseudocylindratus | U. gracilipalpis | Ar. cascadensis | Pi. debilis | Fr. americana | Pionopsis nov. sp. | Ar. solifer | Pi. interrupta | Hz. lacustris | Li. maculata | Hy. despiciens | Pi. conglobata | O. connatus | Hg. neooctoporus | Pa. leuckarti | Le. martisensis | Unidentified larvae | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-vi | a | - | - | - | - | - | - | - | - | 16 | - | 8 | - | - | - | - | - | - | - | - | - | 24 |
| | b | 6 | 49 | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 58 |
| 24-vi | a | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | b | 5 | 20 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 27 |
| 4-vii | a | - | - | 8 | - | - | - | - | - | - | 40 | - | - | - | - | - | - | - | - | - | - | 48 |
| | b | 4 | 79 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 85 |
| 11-vii | a | 8 | - | 8 | - | - | 16 | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | 80 |
| | b | 9 | 17 | 6 | - | - | - | 6 | 2 | 1 | - | - | 1 | - | 1 | - | - | - | 2 | - | 29 | 74 |
| 21-vii | a | - | - | - | - | - | - | - | - | - | 40 | - | - | - | - | - | - | - | - | - | - | 40 |
| | b | 40 | 553 | 30 | 2 | - | 8 | 5 | 15 | 1 | - | - | 1 | - | - | 1 | 1 | - | - | - | 22 | 679 |
| 29-vii | a | - | - | - | - | - | 8 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 9 |
| | b | 6 | 49 | 7 | - | 5 | 7 | 6 | 7 | - | 1 | - | 1 | 1 | - | - | - | - | - | - | 2 | 92 |
| 4-viii | a | - | - | - | - | - | 8 | - | - | 8 | 8 | - | - | - | - | - | - | - | - | - | - | 24 |
| | b | 19 | 12 | 10 | - | - | 4 | 2 | 6 | - | - | - | - | - | 1 | - | - | 1 | - | - | 1 | 56 |
| 11-viii | a | 16 | - | - | 40 | - | - | 56 | - | - | 8 | - | - | - | - | - | - | - | - | - | 8 | 128 |
| | b | 4 | 1 | 7 | - | - | 1 | 1 | - | - | - | - | 1 | - | 1 | - | - | - | - | - | 9 | 25 |

Totals (as mites.m$^{-2}$): a = 353
b = 1096

Table C-4: Hargrave sampler catches, 1968-69.

a = number of mites in 20 catches.
b = number of mites.$m^{-2}$.

| | *U. crassipes* | | *Pi. carnea* | | *Ar. pseudocylindratus* | | *U. gracilipalpis* | | *Hy. despiciens* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b | a | b |
| 16- ix -1968 | 4 | 8.9 | | | | | | | | |
| 14- xi -1968 | 1 | 2.2 | | | | | 1 | 2.2 | | |
| 8- xii-1968 | 1 | 2.2 | | | | | 1 | 2.2 | 1 | 2.2 |
| 23- i -1969 | 2 | 4.4 | | | | | | | | |
| 20- ii-1969 | 1 | 2.2 | | | | | | | | |
| 19- iii-1969 | 2 | 4.4 | 1 | 2.2 | | | | | | |
| 17- iv -1969 | 5 | 11.1 | | | | | | | | |
| 16- v -1969 | 4 | 8.9 | | | | | | | | |
| 20- vi -1969 | 1 | 2.2 | | | | | | | | |
| 18- vii-1969 | 1 | 2.2 | | | | | | | | |
| 21-viii-1969 | 2 | 4.4 | | | | | | | | |
| 18- ix -1969 | 1 | 2.2 | | | | | | | | |
| 30- xii-1969 | 7 | 15.6 | 3 | 6.7 | 1 | 2.2 | | | | |
| Totals : | 32 | | 4 | | 1 | | 2 | | 1 | |

Table C-5: Catches made using Conroy bottom traps compared to catches made using Hargrave samplers (results expressed as mites.$m^{-2}$).

| | 20-vi-1969 | | 18-vii-1969 | | 21-viii-1969 | |
|---|---|---|---|---|---|---|
| | C.T. | H.S. | C.T. | H.S. | C.T. | H.S. |
| *U. crassipes* | 1019.0 | 2.2 | 659.0 | 2.2 | 296.0 | 4.4 |
| *Pi. carnea* | 25.0 | - | 117.0 | - | 86.0 | - |
| *Pi. constricta* | 32.0 | - | 67.0 | - | 56.0 | - |
| *Ar. pseudocylindratus* | 9.0 | - | 1.0 | - | - | - |
| *U. gracilipalpis* | 14.0 | - | 2.0 | - | 6.0 | - |
| *Ar. cascadensis* | 14.0 | - | 5.0 | - | 26.0 | - |
| *Pi. debilis* | 24.0 | - | 4.0 | - | - | - |
| *Fr. americana* | 18.0 | - | 14.0 | - | 4.0 | - |
| *Pi. variabilis* | 4.0 | - | 16.0 | - | - | - |
| *Fo. ovalis* | 6.0 | - | 7.0 | - | 7.0 | - |
| *Pionopsis* nov. sp. | - | - | 2.0 | - | 11.0 | - |
| *Fo. borealis* | - | - | - | - | 1.0 | - |
| *N. semicircularis* | - | - | 3.0 | - | - | - |
| *Li. maculata* | - | - | - | - | 1.0 | - |
| *E. extendens* | 1.0 | - | - | - | - | - |
| *At. nodipalpis americanus* | - | - | 1.0 | - | - | - |
| Unidentified larvae | 8.0 | - | - | - | - | - |
| Totals | 1174.0 | 2.2 | 898.0 | 2.2 | 494.0 | 4.4 |

Net Sweep samples yielded only eight species (Table C-7). When net sweeps, cylinder traps, and Conroy bottom traps were compared (Table C-8), I noted that net sweeps caught eight species, cylinders five species and bottom traps 17 species on the same day. One species (Eylais extendens) occurred in both net sweeps and cylinders but not in bottom traps while 11 species occurred in bottom traps but not in either of the other methods (Table C-8).

Six species were found in the pump samples (Table C-9). The pump samples were compared with plankton hauls and bottom traps on days when the three methods coincided (Table C-10). All species recorded in pump samples occurred in bottom traps on the same day. Five species (Forelia ovalis on August 5, Arrenurus cascadensis and A. solifer on August 24, Piona interrupta on September 1, and P. variabilis on September 20) were in the plankton but not in bottom traps on the same day (although all five species occurred regularly in bottom traps). Comparisons between plankton hauls and bottom traps on the same day showed bottom traps consistently caught more species (Table C-11).

## Statistical Tests

Pump samples (Table C-9) were compared with plankton hauls (Table C-12). There was a difference in the number of species caught (six in pump, 18 in plankton) and with two exceptions (Pionopsis nov. sp. on July 29, 1966, and Hydrozetes lacustris on August 29, 1966), all species in pump samples were

Table C-7: Catches of mites in net sweeps, 1969.

a = number of mites in 40 sweeps
b = number of mites.$m^{-3}$.

| | 18-vi | | 9-vii | | 21-vii | | 20-viii | |
|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b |
| U. crassipes | 1 | 0.1 | 4 | 0.4 | 3 | 0.3 | 7 | 0.7 |
| Pi. carnea | 88 | 8.8 | 67 | 6.7 | 92 | 9.2 | 73 | 7.3 |
| Pi. constricta | 31 | 3.1 | 47 | 4.7 | 23 | 2.3 | 37 | 2.3 |
| Ar. cascadensis | 4 | 0.4 | 0 | -- | 0 | -- | 0 | -- |
| Pi. debilis | 4 | 0.4 | 2 | 0.2 | 4 | 0.4 | 0 | -- |
| Fo. ovalis | 1 | 0.1 | 0 | -- | 0 | -- | 0 | -- |
| Li. maculata | 0 | -- | 1 | 0.1 | 0 | -- | 0 | -- |
| E. extendens | 0 | -- | 2 | 0.2 | 5 | 0.5 | 0 | -- |
| Totals | 129 | | 123 | | 127 | | 117 | |
| Number of sweeps | 40 | | 40 | | 40 | | 40 | |

Table C-8: Comparisons of numbers of mites caught in Conroy traps, in cylinder samples and in net sweeps (expressed as numbers of mites.day$^{-1}$.

| | 18-vi-1969 | | | 9-vii-1969 | | | 21-vii-1969 | | | 20-viii-1969 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conroy | Cylinder | Net | Conroy | Cylinder | Net | Conroy | Cylinder | Net | Conroy | Cylinder | Net |
| U. crassipes | 802 | 5 | 1 | 606 | - | 4 | 472 | 7 | 3 | 296 | 8 | 7 |
| Pi. carnea | 11 | 19 | 88 | 19 | - | 67 | 69 | 8 | 92 | 86 | 16 | 73 |
| Pi. constricta | 35 | 6 | 31 | 39 | - | 47 | 34 | 2 | 23 | 56 | 10 | 37 |
| Ar. pseudocylindratus | 58 | - | - | 8 | - | - | 3 | - | - | - | - | - |
| U. gracilipalpis | 3 | - | - | 52 | - | - | - | - | - | - | - | - |
| Ar. cascadensis | 12 | - | 4 | 27 | - | - | 13 | 1 | - | 26 | 6 | - |
| Pi. debilis | 15 | - | 4 | - | - | 2 | 2 | - | 4 | - | - | - |
| Fr. americana | 26 | - | - | 13 | - | - | 12 | - | - | 4 | - | - |
| Pi. variabilis | 6 | - | - | 8 | - | - | 6 | - | - | - | - | - |
| Fo. ovalis | 15 | - | 1 | 2 | - | - | 2 | - | - | 7 | - | - |
| Pionopsis nov. sp. | 1 | - | - | - | - | - | - | - | - | 11 | - | - |
| Fo. borealis | - | - | - | - | - | - | - | - | - | 1 | - | - |
| Ar. solifer | - | - | - | 1 | - | - | - | - | - | - | - | - |
| N. semicircularis | - | - | - | 2 | - | - | - | - | - | - | - | - |
| Li. maculata | - | - | - | 1 | - | 1 | - | - | - | 1 | - | - |
| Hd. intermedius | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Hy. despiciens | - | - | - | - | - | - | 1 | - | - | - | - | - |
| E. extendens | - | 1 | - | - | - | 2 | - | - | 5 | - | - | - |
| Te. lundbladi | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Unidentified larvae | 26 | - | - | 1 | - | - | 2 | - | - | - | - | - |
| Totals | 1012 | 31 | 129 | 779 | - | 123 | 616 | 18 | 127 | 488 | 40 | 117 |

Table C-9: Mites.m$^{-3}$ in the pump samples in 1966.

| | *U. crassipes* | *Pi. carnea* | *Pi. constricta* | *Ar. pseudocylindratus* | *Pionopsis nov. sp.* | *Hz. lacustris* |
|---|---|---|---|---|---|---|
| 11- v -1966 | | | | | | |
| 16- v -1966 | 1.3 | | | | | |
| 19- v -1966 | | | | | | |
| 26- v -1966 | 1.3 | | | | | |
| 5 - vi -1966 | 7.5 | | 1.3 | | | |
| 15- vi -1966 | 3.8 | | | | | |
| 23- vi -1966 | 10.0 | | 2.5 | | | |
| 30- vi -1966 | 5.0 | | | | | |
| 7- vii-1966 | 3.8 | | | | | |
| 15- vii-1966 | 15.0 | 1.3 | 15.0 | | | |
| 22- vii-1966 | 12.5 | 3.8 | 5.0 | | | |
| 29- vii-1966 | 23.8 | | 2.5 | | 1.3 | |
| 5-viii-1966 | 33.8 | 8.8 | 3.8 | | | |
| 12-viii-1966 | 27.5 | 2.5 | | | | |
| 24-viii-1966 | 2.5 | 2.5 | | | | |
| 29-viii-1966 | 15.0 | | 2.5 | | | 2.5 |
| 1- ix -1966 | 27.5 | | | | | |
| 12- ix -1966 | 7.5 | | 5.0 | | | |
| 15- ix -1966 | 10.0 | | | | | |
| 20- ix -1966 | | | | 2.5 | | |

Table C-10: Comparison of numbers of mites caught in pump samples (PS), in plankton hauls (PH), and in Conroy bottom traps (CT).

| Date | | U. crassipes | Pi. carnea | Pi. constricta | Ar. pseudocylindratus | U. gracilipalpis | Ar. cascadensis | Pi. debilis | Fr. americana | Pi. variabilis | Fo. ovalis | Pionopsis nov. sp. | Fo. borealis | Ar. solifer | Pi. interrupta | Hz. lacustris | Li. maculata | Hd. intermedius | Hy. despiciens | O. connatus | Hg. neooctoporus | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-viii | PS | 27 | 7 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 37 |
| | PH | 720 | 122 | 17 | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | 861 |
| | CT | 266 | 19 | 21 | 16 | - | - | 14 | 7 | - | - | 6 | - | 1 | - | 1 | - | - | - | - | - | 351 |
| 24-viii | PS | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 |
| | PH | 892 | 60 | 8 | - | - | 4 | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | 968 |
| | CT | 183 | 62 | 28 | 149 | 1 | - | - | 2 | - | 3 | 2 | - | - | 2 | 1 | - | - | - | 1 | 2 | 436 |
| 29-viii | PS | 12 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 |
| | PH | 312 | 12 | 8 | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 336 |
| | CT | 474 | 33 | 65 | 67 | 39 | 16 | 3 | 29 | - | 1 | - | 5 | 1 | 6 | 2 | - | - | 1 | - | - | 742 |
| 1- ix | PS | 22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 22 |
| | PH | 836 | 13 | - | 1 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 851 |
| | CT | 199 | 30 | 39 | 16 | 32 | 7 | - | 12 | - | - | 2 | 7 | 1 | - | - | - | 1 | 1 | - | - | 347 |
| 12- ix | PS | 6 | - | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10 |
| | PH | 24 | 24 | 8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 56 |
| | CT | 481 | 22 | 102 | 7 | 36 | 11 | 1 | 4 | - | 2 | - | - | 2 | 1 | 1 | 1 | - | - | - | - | 671 |
| 20- ix | PS | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| | PH | 820 | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - | 824 |
| | CT | 321 | 14 | 24 | 6 | 36 | 20 | - | 5 | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 428 |

Totals: Pump samples - 89; Plankton hauls - 3869; Conroy traps 2975.

Table C-11: Comparison of species composition of catches in plankton hauls and in Conroy bottom traps made on the same day.

| Date | Bottom traps only | Plankton hauls only | Common to both | Total number of species |
|---|---|---|---|---|
| 5-viii-1966 | 4 | 1 | 4 | 9 |
| 24-viii-1966 | 8 | 2 | 3 | 13 |
| 29-viii-1966 | 9 | 0 | 4 | 13 |
| 1- ix -1966 | 9 | 1 | 3 | 13 |
| 12- ix -1966 | 9 | 0 | 3 | 12 |
| 20- ix -1966 | 8 | 1 | 1 | 10 |

Table C-12: Mites.m$^{-3}$ in plankton hauls from Marion Lake in 1966.

| | U. crassipes | Pi. carnea | Pi. constricta | Ar. pseudocylindratus | U. gracilipalpis | Ar. cascadensis | Pi. debilis | Fr. americana | Pi. variabilis | Fo. ovalis | Pionopsis nov. sp. | Ar. solifer | Pi. interrupta | N. semicircularis | Hz. lacustris | Hd. intermedius | Hy. despiciens | Hg. neooctoporus | Unidentified larvae |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26- v | 3.5 | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5- vi | 12.8 | 0.4 | 0.1 | + | - | - | - | - | + | - | - | - | - | + | + | + | - | - | - |
| 15- vi | 6.9 | 0.2 | 0.4 | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |
| 23- vi | 9.8 | - | 0.2 | - | - | - | 0.1 | - | 0.1 | - | + | - | + | - | - | - | - | - | - |
| 30- vi | 9.5 | 0.1 | 0.1 | - | - | - | - | - | - | - | + | - | + | - | - | + | - | - | - |
| 7- vii | 1.5 | + | 0.3 | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | + |
| 15- vii | 12.3 | 0.9 | 2.7 | - | + | + | - | + | - | - | - | - | - | - | - | - | - | - | - |
| 22- vii | 9.3 | 1.6 | 1.8 | - | - | + | - | + | - | - | - | - | - | - | + | - | - | - | - |
| 28- vii | 13.3 | 5.8 | 1.6 | - | - | 0.1 | + | 0.1 | - | - | - | - | - | - | - | - | - | 0.1 | - |
| 5-viii | 18.3 | 3.1 | 0.4 | - | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - |
| 24-viii | 22.7 | 1.5 | 0.2 | - | - | 0.1 | - | - | - | - | - | + | - | - | - | - | - | - | - |
| 29-viii | 7.9 | 0.3 | 0.2 | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1- ix | 21.3 | 0.3 | - | + | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - |
| 12- ix | 0.6 | 0.6 | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20- ix | 20.9 | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| 27- ix | 11.3 | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4- x | 26.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

(+ means present in very low numbers).

in plankton hauls on the same day. A $\chi^2$ test compared pump samples, plankton hauls and Pieczynski traps (Tables C-13 and C-14,a) to see if these methods caught the same mite species in the same proportion. A significant difference at (P = 0.01) was noted. I suspected that the three methods did not catch the same mite species in the same proportions.

A highly significant difference in the proportions of the species caught by pump samples, plankton hauls and Conroy bottom traps (Table C-14,b) was noted. A second series of tests found that bottom traps and pump samples caught different proportions of mites from plankton hauls - with no significant difference noted between the pump samples and Conroy bottom samples (Table C-14, c, d,and e).

Net sweeps and cylinder samples were taken in 1969. I checked to see if the three methods sampled the same species in the same proportions. A significant difference in the proportions of species caught occurred. Bottom traps caught higher proportions of mite species than either of the other methods (Table C-14, g and h) and net sweeps caught higher proportions of mite species than did cylinder traps (Table C-14, i).

Tests on Conroy bottom traps

Tests on Conroy bottom traps included observations to see if mites entered the traps as they were lowered to the bottom; to see if mites escaped as the traps were raised; and to determine the optimum height the traps should be set above the mud-water interface.

The traps were lowered to the bottom and raised immediately. This was repeated 53 times. No mites were found in the traps. I concluded that mites probably did not enter the traps as they were lowered into

Table C-13: Comparisons of numbers of mites caught in pump samples (PS), in plankton hauls (PH), and in Pieczynski traps (PT) in 1966.

| | | U. crassipes | Pi. carnea | Pi. constricta | Ar. pseudocylindratus | U. gracilipalpis | Ar. cascadensis | Pi. debilis | Fr. americana | Pi. variabilis | Fo. ovalis | Pionopsis nov. sp. | Ar. solifer | Pi. interrupta | N. semicircularis | Pi. conglobata | Hg. neooctoporus | Le. martisensis | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16-vi | PS | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| | PH | 270 | 6 | 14 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 291 |
| | PT | - | - | - | - | - | 1 | - | - | - | - | 3 | - | - | - | 1 | - | - | 5 |
| 22-vi | PS | 8 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10 |
| | PH | 385 | - | 8 | - | - | - | 2 | - | 4 | - | 1 | - | 1 | - | - | - | - | 401 |
| | PT | - | - | 1 | - | - | - | - | - | - | - | 2 | - | 1 | - | - | - | - | 4 |
| 7-vii | PS | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| | PH | 86 | 1 | 11 | 1 | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 100 |
| | PT | - | - | 1 | - | - | - | - | - | - | - | - | 5 | - | - | - | - | - | 6 |
| 15-vii | PS | 12 | 1 | 12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 25 |
| | PH | 481 | 35 | 102 | - | 1 | 1 | - | 1 | - | - | - | - | - | - | - | - | - | 621 |
| | PT | 1 | - | 1 | - | - | 2 | - | - | - | - | - | 6 | - | - | - | - | - | 10 |
| 22-vii | PS | 10 | 3 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 17 |
| | PH | 366 | 61 | 69 | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | 498 |
| | PT | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | - | 5 |
| 27-vii | PS | 19 | - | 2 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 22 |
| | PH | 521 | 228 | 62 | - | - | 2 | - | 2 | 1 | - | - | - | - | - | - | 2 | - | 818 |
| | PT | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 2 |
| 5-viii | PS | 27 | 7 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 37 |
| | PH | 720 | 122 | 17 | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | 861 |
| | PT | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | - | - | - | - | - | 3 |

Totals: Pump samples - 117; Plankton hauls - 3590; Pieczynski traps - 35

Table C-14: Tests comparing the different sampling methods.

The null hypothesis tested in each case was: The methods under consideration caught equal ratios of all mite species.

(a) <u>Pump samples, plankton hauls, Pieczynski traps</u>

$\chi^2_{0.05,\ 7\ df} = 14.067$ $\chi^2_{calc} = 38.03$***. I rejected the null hypothesis.

(b) <u>Pump samples, plankton hauls, Conroy bottom traps</u>

$\chi^2_{0.05,\ 8\ df} = 15.507$ $\chi^2_{calc} = 224.9$***. I rejected the null hypothesis.

(c) <u>Pump samples vs plankton hauls</u>

$\chi^2_{0.05,\ 5\ df} = 11.07$ $\chi^2_{calc} = 21.07$***. I rejected the null hypothesis.

(d) <u>Pump samples vs Conroy bottom traps</u>

$\chi^2_{0.05,\ 5\ df} = 11.07$ $\chi^2_{calc} = 2.044$ NS I accepted the null hypothesis.

(e) <u>Plankton hauls vs Conroy bottom traps</u>

$\chi^2_{0.05,\ 5\ df} = 11.07$ $\chi^2_{calc} = 224.68$*** I rejected the null hypothesis.

(f) <u>Conroy bottom traps, net sweeps, cylinder samples</u>

$\chi^2_{0.05,\ 13\ df} = 22.362$ $\chi^2_{calc} = 1216.5$**** I rejected the null hypothesis.

(g) <u>Conroy bottom traps vs cylinder samples</u>

$\chi^2_{0.05,\ 7\ df} = 14.067$ $\chi^2_{calc} = 194.3$*** I rejected the null hypothesis.

(h) <u>Conroy bottom traps vs net sweeps</u>

$\chi^2_{0.05,\ 9\ df} = 16.919$ $\chi^2_{calc} = 1174.7$***

I rejected the null hypothesis.

(i) <u>Cylinder samples vs net sweeps</u>

$\chi^2_{0.05,\ 7\ df} = 14.067$ $\chi^2_{calc} = 74.52$***

I rejected the null hypothesis.

position. It is probable that the mites swam away from the trap as it sank slowly to the bottom. I tested to see if mites left the trap as they were raised to the surface. Twenty-five mites (mostly *Piona carnea*, *P. constricta* and *Unionicola crassipes*) were placed in the collecting jar and the trap lowered into position. A piece of muslin tied over the mouth of the large funnel prevented any mites entering the trap during the experiment. The trap remained on the bottom for five minutes then it was brought to the surface and the number of mites remaining in the collecting jar checked. The test was repeated 100 times. Only one mite left the jar during the test. I concluded that few, if any, mites were lost from the traps as they were raised. All the above tests were in water 4.5 m deep to allow the longest time for the traps to sink or to be raised.

To determine the optimum height to set the traps above the mud-water interface, two tests were applied: 1) number of mites in traps set at 45 cms above the interface was compared with those set at 10 cms above the interface, and 2) number of mites in traps set at 10 cms was compared with the number of mites in traps set at 5 cms (Table C-15). I found a significant difference between numbers caught in traps set at 10 cms and numbers caught at 45 cms with the traps set at 10 cms catching more mites. No significant difference in numbers caught between traps set at 5 cms and traps set at 10 cms occurred.

A test to see if length of time a trap was in the lake affected the efficiency of the trap showed that there was no reason to suppose that the effectiveness of the traps dropped with the length of time in the lake

(Table C-16).

A 24-hour sampling series to check mite activity at different times of the day was carried out in August 1969, with the ten bottom traps changed every four hours over a period of 96 hours (Table C-17).

I compared the 1966-1967 bottom trap data with the 1969 bottom trap data to see if the results for the two years gave a similar picture of the mite population in Marion Lake. Using the Wilcoxon Two Sample test, the numbers caught for each species in 1966-1967 were compared to the numbers caught for each species in 1969 and the results was found to be non-significant (Table C-18). I concluded that there was no difference between the numbers of each species caught for the two years and that the two sets of data applied to the same mite population.

Mite activity

During the week of October 8-14, 1966, the number of mites.$trap^{-1}$ was 14 in contrast to 33.5/trap the week before. Water temperature (at 1.0m) was 9.0 C on October 14 while it had been 14.5 C the week before. During the week of June 7, 1967, the catch.$trap^{-1}$ was 10.5 mite while in the week of June 14 the number.$trap^{-1}$ rose to 30. The water temperature (at 1 m) on both days was 14 C. By June 21, the number.$trap^{-1}$ reached 39.5 - the water temperature was 20 C. On July 7, 1969, 17.6 mites.$trap^{-1}$ occurred at 14 C. On July 9, 87.9 mites.$trap^{-1}$ were found at 16 C and on July 11, 36.8 mites.$trap^{-1}$ occurred at 15.5 C.

Table C-15: Tests for optimum height of traps above the mud-water interface.

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(1) Traps set at 10 cms vs traps set at 45 cms.

$H_o$ : Traps set at 45 cms and traps set at 10 cms catch the same number of mites.

$H_1$ : Traps set at 45 cms and 10 cms do not catch the same number of mites.

$n_1$ (at 10 cms) = 35; $x_1$ = 2207.5; $\bar{x}_1$ = 63.1; $S_1$ = 30.9

$n_2$ (at 45 cms) = 35; $x_2$ = 1349.6; $\bar{x}_2$ = 38.6; $S_2$ = 18.0

$t_{0.05,\ 66\ df} = 1.98$ $t_{calc} = -4.06$***

I rejected the null hypothesis and suspected that traps set at 10 cms caught more mites than those set at 45 cms.

(2) Traps set at 10 cms vs traps set at 5 cms.

$H_o$ : Traps set at 10 cms and traps set at 5 cms catch the same number of mites.

$H_1$ : Traps set at 10 cms and at 5 cms do not catch the same number of mites.

$n_1$ (at 10 cms) = 22; $S_1$ = 59.5; $S_d$ = 49.1; $\bar{x}_1$ = 68.96

$n_2$ (at 5 cms) = 22; $S_2$ = 41.4; $\bar{d}$ = 39.5; $\bar{x}_2$ = 66.64

$t_{0.05,\ 40\ df}$ 2.002 $t_{calc}$ = 0.804 N.S.

I had no reason to suspect that the number of mites caught in traps set at 10 cms and at 5 cms differed.

---

Table C-16: Length of time a trap was in the lake vs. the number of mites.day$^{-1}$.

| | | |
|---|---|---|
| Traps 1-10 : | 4 days in the lake - average 43.3mites.trap$^{-1}$. | |
| Traps 11-20: | day 1-2 | 10.6 mites.trap$^{-1}$ |
| | day 2-3 | 10.0 mites.trap$^{-1}$ |
| | day 3-4 | 9.8 mites.trap$^{-1}$ |
| | day 4-5 | 11.1 mites.trap$^{-1}$ |
| | Total | 41.5 mites.trap$^{-1}$ |
| Traps 21-30: | 4 days in the lake - average 46.0 mites.trap$^{-1}$. | |
| Traps 31-40: | day 1-2 | 12.4 mites.trap$^{-1}$ |
| | day 2-3 | 11.4 " " |
| | day 3-4 | 11.4 " " |
| | day 4-5 | 11.6 " " |
| | Total | 46.8 mites.trap$^{-1}$. |

(Note: Traps 1-10 were in the lake from July 25-29, 1969. Traps 11-20 were changed every day in this period.

Traps 21-30 were in the lake from August 16-20, 1969. Traps 31-40 were changed each day in this period.)

Table C-17: Number of each species caught in the daylight and in the nighttime in ten bottom traps during the period August 16-20, 1969.

| | Day (6 AM - 8 PM) | Night (8 PM - 6 AM) |
|---|---|---|
| U. crassipes | 88 | 496 |
| Ar. cascadensis | 51 | 10 |
| Pi. constricta | 24 | 67 |
| Pi. carnea | 20 | 137 |
| Pionopsis nov. sp. | 11 | 0 |
| Fo. ovalis | 10 | 0 |
| U. gracilipalpis | 4 | 0 |
| Fr. americana | 4 | 0 |
| Fo. borealis | 1 | 0 |
| Li. maculata | 1 | 0 |

Table C-18: Comparison between 1966-1967 Bottom Trap data and 1969 Bottom Trap data.

| Species | 1966-1967 | | 1969 | |
|---|---|---|---|---|
| | Number | Rank | Number | Rank |
| U. crassipes | 9130 | 2 | 16302 | 1 |
| Pi. constricta | 2831 | 4 | 1747 | 5 |
| Ar. pseudocylindratus | 1263 | 6 | 337 | 15 |
| Pi. carnea | 1092 | 7 | 3010 | 3 |
| U. gracilipalpis | 434 | 11 | 531 | 9 |
| Fr. americana | 468 | 10 | 342 | 14 |
| Pi. debilis | 347 | 13 | 145 | 18 |
| Ar. cascadensis | 252 | 16 | 763 | 8 |
| Pionopsis nov. sp. | 133 | 19 | 57 | 23 |
| Fo. ovalis | 94 | 20½ | 188 | 17 |
| Ar. solifer | 94 | 20½ | 3 | 44½ |
| Fo. borealis | 89 | 22 | 35 | 26 |
| Pi. variabilis | 41 | 24 | 362 | 12 |
| Pi. interrupta | 27 | 27 | 15 | 29 |
| Li. maculata | 16 | 28 | 8 | 35 |
| Hy. despiciens | 10 | 31 | 2 | 49½ |
| Hg. neooctoporus | 9 | 32 | - | |
| Le. porosa | 7 | 34 | 2 | 49½ |
| Ps. orbicularis | 6 | 36½ | 3 | 44½ |
| O. connatus | 6 | 36½ | 3 | 44½ |
| At. nodipalpis americanus | 6 | 36½ | 2 | 49½ |
| Hd. intermedius | 6 | 36½ | 11 | 30 |
| Hz. lacustris | 5 | 39½ | 4 | 41½ |
| At. glandulosus | 4 | 41½ | - | |
| Pa. leuckarti | 3 | 44½ | - | |
| E. extendens | 2 | 49½ | 1 | 53 |
| Pi. conglobata | 2 | 49½ | 5 | 39½ |
| O. gnaphiscoides | 1 | 53 | - | |
| N. semicircularis | 1 | 53 | 37 | 25 |
| M. orbicularis | 1 | 53 | - | |
| Ar. megalurus intermedius | 1 | 53 | - | |
| Sperchon sp. | 1 | 53 | - | |
| Te. lundbladi | - | | 1 | 53 |
| Ti. vernalis | - | | 1 | 53 |

$n_2$ ranks = 786.5 Wilcoxon statistic = 455.5

t(0.05, infinity) = 1.96 $t_s$ = 0.001 NS.

A periodic decline of mite catches occurred even though the water temperature was relatively constant. These declines appeared to be correlated to weather conditions - for example, in August 1969:

| Sampling day | Weather | Number of mites/trap |
| --- | --- | --- |
| August 8 : | Rain | 22.8 $mites.trap^{-1}.day^{-1}$ |
| 10 : | Cloudy, bright sunny intervals | 33.1 $mites.trap^{-1}.day^{-1}$ |
| 12 : | Rain | 19.6 $mites.trap^{-1}.day^{-1}$ |
| 14 : | Sunny | 37.8 $mites.trap^{-1}.day^{-1}$ |
| 16 : | Cloudy, dull, some sunny periods | 26.9 $mites.trap^{-1}.day^{-1}$ |

The four most numerous mite species on each of the above sampling days were *Unionicola crassipes*, *Piona carnea*, *P. constricta* and *Arrenurus pseudocylindratus*. Because these four species contributed over 98% of all mites caught in this period and because the trap method used depended on the activity of the mites, I concluded that prevailing weather conditions affected water mite activity.

Discussion

Pieczynski (1961a) reported large numbers of mites from his traps ($45.trap^{-1}.day^{-1}$) compared to my results ($0.1$ to $0.3$ $mites.trap^{-1}.day^{-1}$). I found fewer mite species in Pieczynski traps than in insect emergence traps over the same period (Table C-3). Two species, Lebertia martisensis and Piona interrupta, occurred in Pieczynski traps but not in insect emergence traps on the same day. Only one specimen of L. martisensis was found in Marion Lake, while P. interrupta occurred frequently in the emergence traps on other occasions. Eleven species occurred in insect emergence traps but not in Pieczynski traps. An apparent bias by Pieczynski traps both for and against certain species was noted. Three of the most frequently found species in other sampling methods (Unionicola gracilipalpis, Piona carnea and Frontipoda americana) never occurred in Pieczynski traps. Unionicola crassipes and Piona constricta rarely occurred in Pieczynski traps, while two less frequently found species, Arrenurus solifer and Piona debilis, often occurred in Pieczynski traps. I concluded that Pieczynski traps did not offer an equal opportunity for all species to be caught. Pieczynski (1965) noted that in oligotrophic conditions one should use his traps in a large series of at least 100 traps to minimize standard error applying to catches. He warned that with a large series, however, there was a corresponding increase in experimental error. He (op. cit.) discussed the effect of size of traps and the effect of length of exposure on the catches of mites. He decided that his traps should be rather large as well as uniform in size. By large he meant $176.7$ $cm^2$ (compared to $1000$ $cm^2$

for Conroy traps). He found (1965) that the length of time a trap was in the lake had little effect on the yield and that the numbers.trap$^{-1}$.day$^{-1}$ in traps changed daily were virtually the same as the numbers in traps left in for three or four days. He also noted the same order of species dominance in both sets of traps. Results from Marion Lake were similar.

I rejected the Hargrave sampler on three grounds - 1) the low number of individuals (40 in 320 samples); 2) the low number of species (five); and 3) because mites with good vision and/or swimming ability could swim away from this sampler as it was lowered into position. Only mites actually in the mud would be caught.

The extremely low number of mite species in net sweeps and cylinder samples and the differences in proportions of those species actually present suggested that these methods did not offer equal opportunity to be caught to all species in the lake. Common species (such as Frontipoda americana, Unionicola gracilipalpis, Piona variabilis, Forelia borealis and Arrenurus pseudocylindratus) were absent from collections made by either of these two methods. A 24-hour bottom trap series from Marion Lake showed that some species showed preferences for daylight activity while others were more active at night (Table C-17). These diurnal differences in activity explain the poor results from the net sweeps and cylinders as these collections were made in daylight. A bias may occur while net sweeps or cylinder samples are taken. This showed up particularly in the net sweeps which showed greater numbers of Eylais extendens than any other method. A search for specimens of E. extendens as breeding stock with the aid of several 'assistants' yielded a total of 16 individuals during the summer of 1969. This low number emphasized the bias of the net sweeps in recording seven individuals. Because of this the net sweeps and cylinders were used only as a means of obtaining relative estimates of free-swimming mites in the lake at the time of sampling.

When plankton hauls, pump samples and bottom traps were compared to see if they caught the same species in the same proportions, plankton hauls were found to catch a larger proportion of the mites than either of the other methods (Table 14, b, c, d, and e). Examination of Table C-10 showed that 18 species present in Conroy bottom traps were absent from pump samples and 11 species in Conroy bottom traps were absent from the plankton. Six species occurred in the pump samples - all were present in Conroy trap samples on the same day and, with one exception (20-ix-1966), all were in the plankton as well. More species occurred in the Conroy traps than in the plankton on each sampling date (Table C-10). Five species found in the plankton were not in Conroy trap samples on the same date (although all occurred frequently in the Conroy traps on other occasions) while 51 species occurred in Conroy traps but not in the plankton.

No differences in the proportions of mite species found in Conroy traps and in pump samples occurred but a disparity in the number of species recorded by each method was noted (Table C-10, C-14,d). From August 5 to September 20, 1966, six species occurred in pump samples and 22 in Conroy traps. It is concluded that pump samples and plankton hauls did not offer equal opportunity to be caught to all species found in Conroy traps. Plankton hauls are not going to sample the crawlers on the bottom or on vegetation.

Conroy traps indicated a more diverse population of water mites in Marion Lake than did any (or all) of the other methods tested (Table C-1). I recorded 34 species from Conroy traps, two (Protzia constans and Homocaligus muscorum) in stomach contents, one (Pionopsis lutescens) in insect emergence traps and one (Lebertia martisensis) in Pieczynski traps, for a total of 38 species from Marion Lake (Table C-1, Table 1). When one remembers that the insect emergence traps consisted of the 'catching unit' of the Conroy traps, the difference between the various sampling methods is further emphasized. All other methods combined yielded 23 mite species as opposed to 35 species from Conroy traps and insect emergence traps.

The efficiency of a trap depends on its design and how it affects the behaviour of the animals it is trapping. Morgan et al. (1963) pointed out that there were two main losses of efficiency for this kind of trap: 1) the danger of the cone-type trap being swamped by waves (not a consideration in the present instance), and 2) the shading effect of the trap itself on ascending mites. The Conroy traps were cleaned every four days to prevent the growth of algae on the cone. This kept the shading effect to a minimum. Morgan et al. (op. cit.) pointed out that it was probably only those animals ascending near the edges of the cone that could take successful avoiding action: the larger the area of the cone, the smaller was this edge-effect relative to the size of catch. Since the size of trap used (35.8 cms in diameter, 0.1 $m^2$) was the largest possible that could be made from available vinyl plastic sheets, it met the edge-effect requirement. Larger cones would be unstable in water and heavier plastic would be required. Since heavier plastic is (a) harder to work and (b) more likely to break, extra support would be required - thus increasing the shading effect.

Walter (1922), Lundblad (1927) and Motas (1928) commented on the fact that seasonal changes in water temperature influenced the degree of activity of mites in lakes. Uchida (1932) observed a marked decrease in mite activity on dull, cloudy days, in bad weather and at night, while he observed that mites swim actively on fine days. Walter's, Lundblad's, and Motas's observations may account for the seasonal variations in the number of mites caught in Conroy traps while Uchida's observations may account for changes in catch in the absence of water temperature changes.

Conroy bottom traps caught more mite species than did any other method and except for plankton hauls Conroy traps caught more individuals than any other method. I decided that the Conroy bottom trap was the sampling method which best reflected the mite species composition in Marion Lake and that this trapping method gave thebest opportunity for most species in the lake to be caught. The other trapping methods helped determine the true species composition picture. A disadvantage of the Conroy trap was the requirement that the mites came to the trap as these traps were dependent on mite activity at any given time. I decided that the Conroy Bottom Trap was sufficiently unbiased that my results and the conclusions drawn from them are valid. I based this conclusion on the facts that 1) planktonic mites occurred in the bottom traps - the dominant forms in the plankton (Table 12) - U. crassipes, P. carnea and P. constricta - were dominant forms in the bottom traps at the same time; 2) Lebertia porosa, Hydrodroma despiciens and Arrenurus solifer are known to be poor swimmers, yet all were found regularly in Conroy trap samples (A. solifer was thirteenth most frequently found mite).

APPENDIX D: Water temperature in Marion Lake during 1966-7 and 1969.

The water temperatures in Marion Lake were taken at irregular intervals during 1966-7. These temperatures were taken at 1.0 m. The results are in fig. D-1.

The water temperatures were taken three times a week during the 1969 sampling period. They were taken at six depths (0.5 m, 1.0 m, 2.0 m, 3.0 m, 4.0 m and 4.5 m). The results are in fig. D-2.

D-1 Mean weekly water temperatures at a depth of 1.0 m during 1966-7.

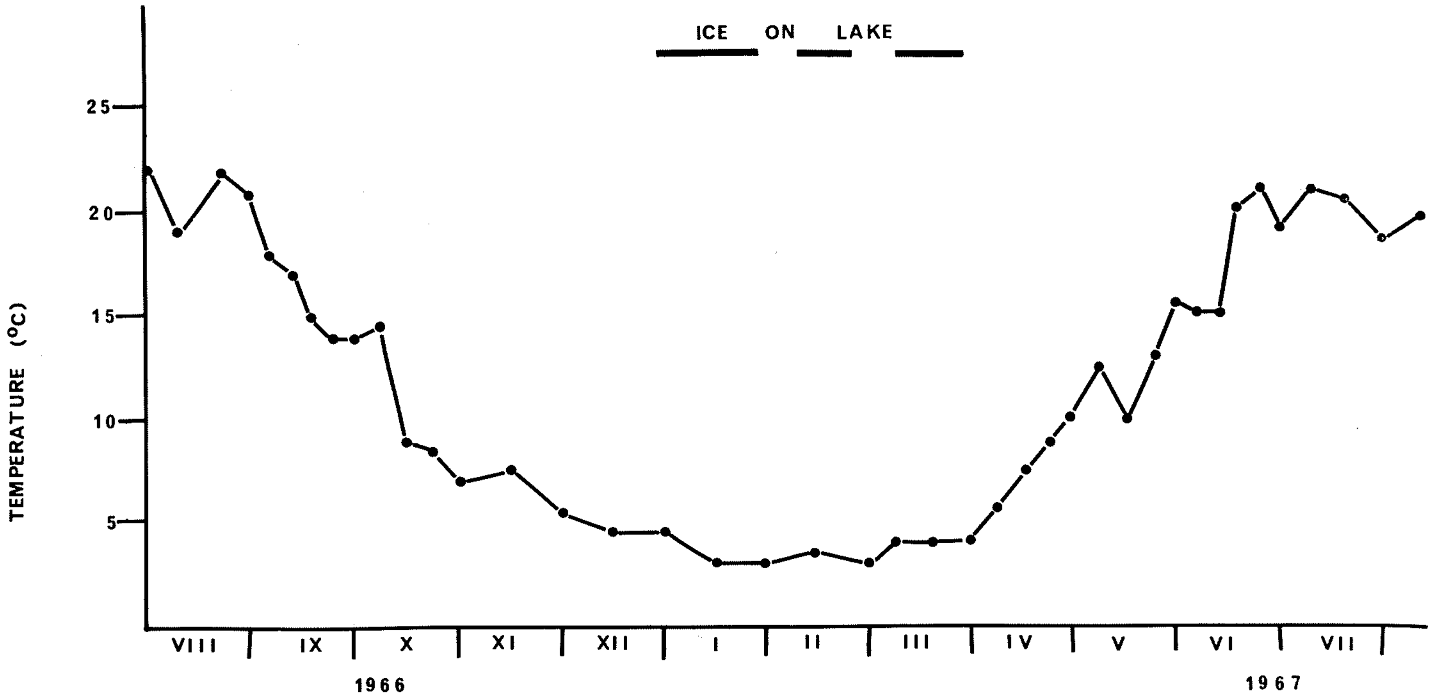
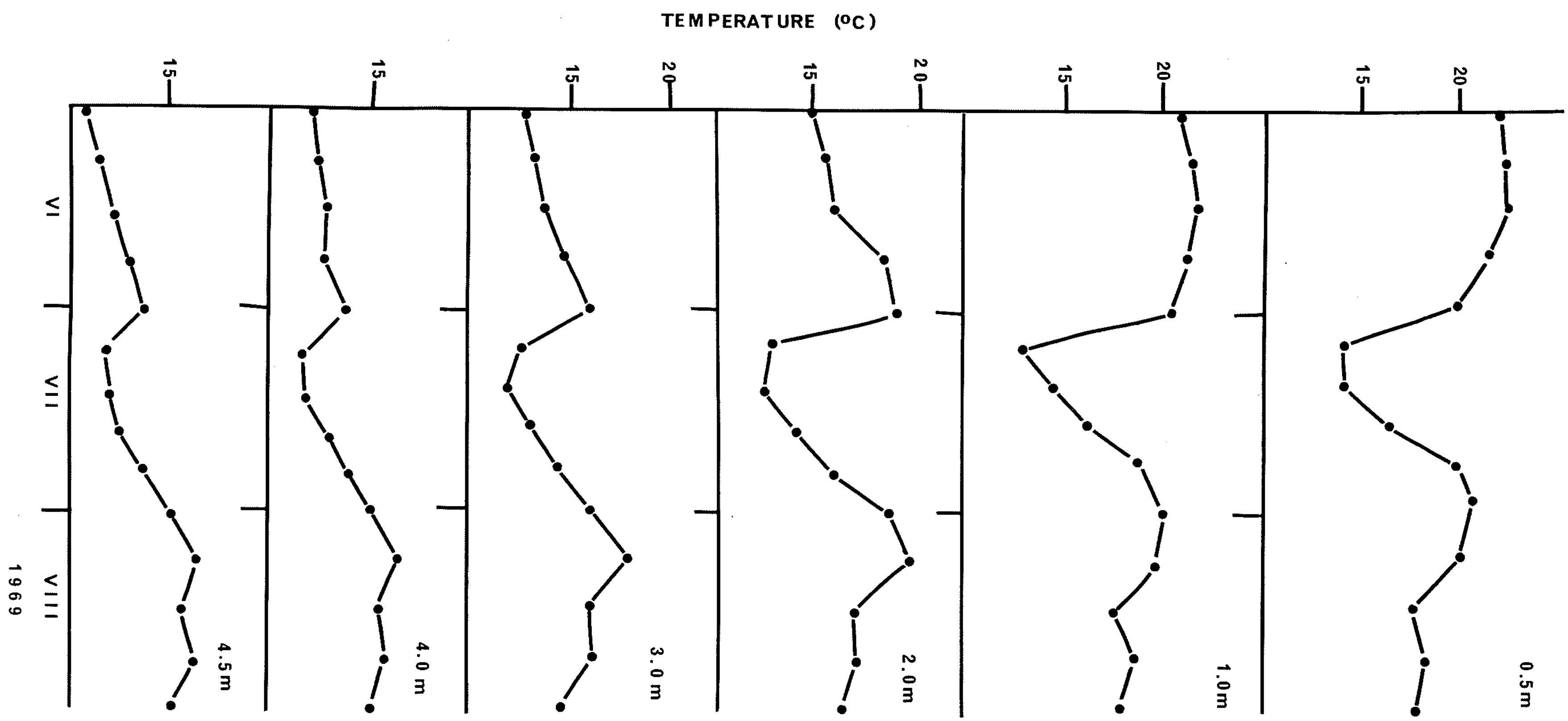

ICE ON LAKE
25
20
15
10
5
TEMPERATURE (°C)
VIII
IX
X
XI
XII
I
II
III
IV
V
VI
VII
1966
1967

Fig. D-2: Mean weekly water temperatures at the depths indicated during the summer of 1969.


TEMPERATURE (°C)
15
20
VI
VII
VIII
1969
0.5m
1.0m
2.0m
3.0m
4.0m
4.5m

APPENDIX E: Water Mite Food

The principal food organisms for water mites in Marion Lake were small chironomids, Cladocera (especially *Sida crystallina* (Muller) and *Chydorus sphaericus* (Muller) ), Ostracoda, Copepoda (*Diaptomus oregonensis* Lilljeborg and *Cyclops bicuspidatus thomasi* Forbes), Ephemeroptera nymphs, Nematoda, dead insects and even other water mites (Table E-1).

I observed *Limnesia maculata* eating *Unionicola crassipes* and *Piona* spp. Another *L. maculata* ate a *Hydrodroma despiciens* that appeared to be dead. Other *L. maculata* specimens were observed swimming around with small pionids in their palps. *Eylais extendens* ate several *Piona* spp., and both *Piona carnea* and P. ate the same unidentified water mite nymph.

When I examined the data on food organisms in Marion Lake I concluded that there was an abundant supply of food available to the mites.

Table E-1: Food of water mites in Marion Lake.

| Prey | Predator | |
|---|---|---|
| Ostracoda | Arrenurus spp., Fr. americana, Oxus spp. | Pi. debilis, Pi. variabilis, |
| Cladocera | | |
| Chydorus sphaericus<br>Sida crystallina | Pi. carnea, Pi. constricta, Pi. interrupta, E. extendens, | Unionicola spp., N. semicircularis, Hd. intermedius, Arrenurus spp. * |
| Copepoda<br>Diaptomus oregonensis,<br>Cyclops bicuspidatus thomasi,<br>Harpactacoids | Unionicola spp., Pi. carnea, Pi. constricta, Pionopsis spp., | Arrenurus spp., N. semicircularis, Hd. intermedius, Oxus spp. |
| Other mites - living | Li. maculata, Pi. carnea, | E. extendens, Pi. interrupta |
| - dead | Hy. despiciens* | |
| Dead insects, etc. | Hy. despiciens* | |
| Chironomids | Li. maculata, Le. porosa, Piona spp. | N. semicircularis, Unionicola spp., |
| Ephemeroptera | Le. porosa, | E. extendens * |
| Nematoda | Arrenurus spp. * | |
| Detritus | Le. porosa * | |

(* after Motas 1928).

Other workers findings

Motas (1928), Uchida (1932) and Wesenberg-Lund (1939) listed Copepoda, Cladocera, Ostracoda, Chironomidae and small Ephemeroptera as the principal food organisms for mites. Motas (1928) reported that certain *Lebertia* were detritus feeders and all three authors reported cannibalistic tendencies among the genera *Eylais*, *Piona* and *Limnesia*. Patterson (1970) reported *P. carnea* and *L. undulata* (Muller) as predacious on a number of species of chironomid. He found that these mites preyed on chironomids at an average rate of 0.86 larvae.mite$^{-1}$.48 hr$^{-1}$. He also found that in the natural environment the mites fed at least every few days.

Motas (1928) said *Lebertia porosa* was a detritus feeder. I found one male with an Ephemeroptera nymph in its palps. I later observed the same individual feeding on a *Sida crystallina*. In Marion Lake I found *L. porosa* in close association with macrophytes where *Sida* tended to congregate.

APPENDIX F: Coding for generic names used in the various tables in the text. In all the tables in this study the generic names have been coded as follows:-

| | | | |
|---|---|---|---|
| Eylais | to E. | Piona | to Pi. |
| Protzia | to Pr. | Forelia | to Fo. |
| Hydrodroma | to Hy. | Mideopsis | to M. |
| Pseudohydryphantes | to Ps. | Arrenurus | to Ar. |
| Teutonia | to Te. | Homocaligus | to Ho. |
| Lebertia | to Le. | Hydrozetes | to Hz. |
| Oxus | to O. | Spongilla | to S. |
| Frontipoda | to Fr. | Enallagma | to En. |
| Limnesia | to Li. | Aeshna | to Ae. |
| Hygrobates | to Hg. | Gerris | to G. |
| Attractides | to At. | Lethocerus | to Lt. |
| Unionicola | to U. | Chironomus | to C. |
| Neumania | to N. | Tanytarsus | to Ta. |
| Hydrochoreutes | to Hd. | Psectrocladius | to Pe. |
| Tiphys | to Ti. | Procladius | to Po. |
| Pionopsis | to Pp. | Ablabesmyia | to Ab. |
| Pionacercus | to Pa. | | |

The following generic names were not shortened in the tables: Sperchon, Zoniagrion, and Protanypus.

APPENDIX G: Statistical Tests Usage

A) Tests for correlation between palp size and length of CP III and CP IV in both sexes of *Unionicola crassipes*.

Test a-1: Males

$H_o: \beta = 0$

$H_1: \beta \neq 0$

$t(0.05,\ 435\ df) = 1.96$

$t_{calc.} = 3.58$ ***

Test a-2: Females

$H_o: \beta = 0$

$H_1: \beta \neq 0$

$t_{(0.05,\ 374\ df)} = 1.96$

$t_{calc.} = 21.79$ ***

I concluded that there was a strong correlation between palp size and the size of CP III and CP IV in *Unionicola crassipes* males and females.

B) Tests for correlation between water temperature and number of mites/trap.

Test b-1: 1966-1967 data

x = number of mites, y = temperature (in C)

$n = 41$, $x = 530.5$, $x^2 = 8575.25$. $xy = 16501.75$

$y = 919.9$, $y^2 = 4449.01$

$b_{yx} = 2.688$ $S_b = 0.414$ $r_{xy} = 0.721$

i - $H_o: \rho = 0$

$H_1: \rho \neq 0$

critical $r_{xy\,(0.05,\ 39)} = 0.301$

$r_{xy\,(calc.)} = 0.721$ * (This is greater than $r_{xy}$ (crit) ).

I rejected the null hypothesis and suspected that there was a correlation between water temperature and numbers of mites/trap in 1966-1967.

ii - $H_o: \beta = 0$

$H_1: \beta \neq 0$

$t_{(0.001.\ 39\ df)} = 3.551$

$t_s = 6.5$ ***

I rejected the null hypothesis and suspected that this did not come from a population with a regression coefficient of 0.

Test b-2: 1969 (summer) data

$n = 144$ $x = 2323.75$ $x^2 = 38348.4375$ $xy = 149085.6825$

$y = 9245.33$ $y^2 = 866164.159$

$b_{yx} = 0.1267$ $S_b = 1.503$ $r_{xy} = -\ 0.007$

i): $H_o: \rho = 0$

$H_1: \rho \neq 0$

$r_{xy}$ (0.05, 142 df) $= 0.165$

$r_{calc.} = -\ 0.007$ N.S.

I accepted the null hypothesis.

ii): $H_o$ : $\beta = 0$

$H_1$ : $\beta \neq 0$

$t_{(0.05,\ 142\ df)} = 1.96$

$t_s = -0.084$ N.S.

I accepted the null hypothesis.

C. Analyses of variance tests on mean differences in water temperature for samples taken in 1969.

Test C-1: Samples with *Arrenurus pseudocylindratus* compared to samples without *A. pseudocylindratus*.

Samples with *A. pseudocylindratus*

$n = 100 \quad s_1^2 = 8.152$

Samples without *A. pseudocylindratus*

$n = 258 \quad s_2^2 = 5.742$

$F_{(0.05;\ 100,\ 258)} = 1.3$

$F_{calc.} = 1.42$***

I rejected the null hypothesis.

Test C-2: Samples with *Piona debilis* but without both *A. pseudocylindratus* and *Pionopsis marionensis*

compared to

samples without *P. debilis*, *A. pseudocylindratus* and *P. marionensis*

Samples with *P. debilis*

$n = 33 \quad s_1^2 = 7.876$

Samples without *P. debilis*

$n = 217 \quad s_2^2 = 4.993$

$F_{(0.05;\ 33,\ 217)} = 1.44$

$F_{calc.} = 1.58$*

I rejected the null hypothesis.

D) Analysis of variance tests on mean differences in water depth for samples taken in 1969.

$H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 \neq \mu_2$

Samples with *P. debilis*, but without *A. pseudocylindratus* and *P. marionensis*

compared to

samples without all three species.

Samples with *P. debilis*

$n = 33 \quad s_1^2 = 1.04$

Samples without *P. debilis*

$n = 217 \quad s_2^2 = 1.82$

$F_{(0.05;\ 33,\ 217)} = 1.58$

$F_{calc.} = 1.75$*

I rejected the null hypothesis.