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ECOLOGICAL SUCCESSION OF MACROBENTHOS IN DEEP- AND SHALLOW-WATER ENVIRONMENTS OF WESTERN LAKE ERIE: 1930-1974

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Abstract. Western Lake Erie suffered the loss of vast deep-water /8-10 m/ Hexagenia populations in 1953 due to pollution. Increased oxygen demand in the sediments and water column was unfavorable to Ephemeroptera and other "clean-water" organisms. A survey in 1974 showed that deep-water populations of Mollusca, Hirudinea and Gammarus were greatly affected and the benthic community had changed to an Oligochaete-Chironomid-Sphaeriid assebblage. However in the 0-2 m zone the benthic community was similar to that of 1930 with 8 taxa of Ephemeroptera including Baetis phoebus, Caenis sp. and Stenonema pulchellum. On the loose rocks near shore Ephemeroptera totalled 46/m^2, Trichoptera, 888/m^2 and Diptera, 274/m^2. Increased nutrient levels since 1930 promoted the growth of an abundant mat of Cladophora which sheltered a population of Gammarus at 118/m^2. These results suggest that oxygenation by wave action has kept the shallow-water fauna in good condition while deeper levels have suffered from anoxia so that western Lake Erie is no longer a "river-lake" as described by Dr. Henry van der Schalie.

Habitats, communities, abundance

The decline and loss of the great Hexagenia mayfly populations in western Lake Erie was discussed at the first International Conference on Ephemeroptera (Wood 1973). Prior to 1953 these mayflies were found over a wide area of western Lake Erie at numbers often exceeding 400/m^2 even at 10 m depth. Shelford and Boesel (1942) recognized several communities in the open lake benthos and regarded a Hexagenia-Oecetis community as probably climax. However, as Beeton (1965) and Carr and Hiltunen (1965) showed, pollution by mankind changed the course of ecological succession. Further studies of the deep-water benthos showed a continuous decline in the diversity of the fauna with an increased dominance of pollution-tolerant organisms (Cook and Johnson 1974, Britt et al. 1980). Further analysis of this trend is provided by revisiting the area of the 1951 - 1952 benthic survey (Wood 1963) using the same methods including enumeration of live and dead Unionidae.

Another purpose of the present study is to compare ecological succession between the deep- and shallow-water environments. The most obvious difference between these habitats would be the high oxygenation of shallow water in contrast to possible anoxic conditions in the hypolimnion. During the 1930's detailed studies of the shallow-water benthos of the Bass Islands were provided by Krecker and Lancaster (1933) and Shelford and Boesel (1942). With this work as a basis of comparison, the shallow-water benthos was intensively studied during the summer of 1974.

METHODS

Deep-water

The study area is located west of a line from Cedar Point to Point Pelee, at depths $\geq$ 8 m. During the summers of 1973 - 1974, 15 stations were sampled within this area, with 29 collections (Fig. 1). Samples were taken with a heavy drag-dredge with fixed jaws allowing an opening of 42 x 16 cm, with a collecting bag of 0.5 mm mesh. Results are presented as number per sample although it was previously estimated (Wood 1963) that one sample covered 0.16 m^2 if taken in soft bottom. Data from 1951 - 1952 included 153 samples within the study area. Additional samples were taken from outside this area and analyzed in 1951 - 1952 but these samples are not included in the present analysis. Sample locations are shown in Wood (1973). Most samples in both studies were collected in mud or mud-sand.

Shallow-water

Many qualitative and quantitative benthic samples were collected from 23 stations in the Bass Islands area (Fig.2) from May 28 to August 6, 1974. Shore substrates included sand, pebble, clay, flat shelving rock, boulders and flat and angular rubble. These substrates are described in Krecker and Lancaster (1933). These authors recognized the optimum substrate for most shore fauna as flat and angular rocks. In the present study this substrate was sampled intensively by lifting rocks out of the water and picking or washing off all animals. For a quantitative study 17 rocks were sampled and also measured on all sides with a ruler to determine the surface area (total area 2.0 m^2). Although this quantitative method is rough, it was comparable to methods used in the earlier studies.

Shelving rock was observed to note the presence of any fauna and was sampled by scraping with an aquarium net. Adult aquatic insects were collected by sweeping with an aerial net and by picking up adults attached to buildings or attracted to lights. A mercury vapor light trap was used in June, 1976.

The deeper near-shore habitat was sampled by use of a clam dredge 0.6 m in width, with a fine mesh nylon bag. This dredge was used 60 times to collect macrobenthos from 35 stat-

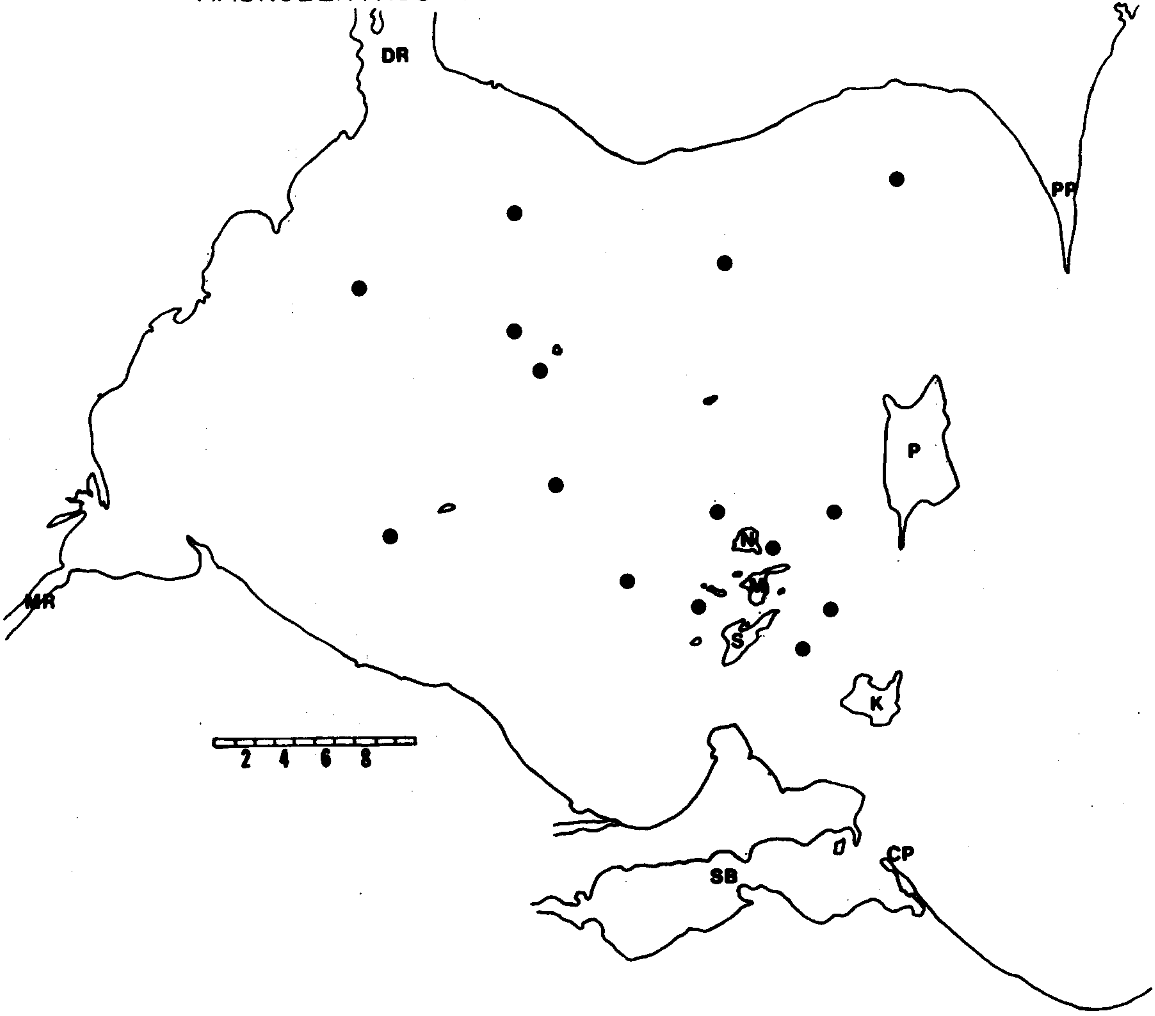

Fig. 1: Summer 1973-74 deepwater />8m/ macrobenthic sampling stations in the western basin of Lake Erie. CP, Cedar Point; DR, Detroit River; K, Kelleys Island; M, Middle Bass Island; MR, Monroe River; N, North Bass Island; P, Pelee Island; PP, Point Pelee; S, South Bass Island; SB, Sandusky Bay.

ions just offshore (Fig. 2) in depths ranging from 1 - 9 m. Substrates varied from mud and sand to rubble and bedrock.

RESULTS AND DISCUSSION

Deep-water

Data from each survey was reduced by a system of zonal averages and is presented as pie charts in Figs. 3 and 4. In these charts the area for the 1973 - 1974 pie is proportional to the abundance of the organisms relative to the area drawn for that organism for 1951 - 1952. A numerical summary of the data is also presented in Table 1. Comlete data is available on request from the senior author.

Insecta were represented by 4 taxa in the 1951 - 1952 survey (Fig. 3a, Table 1). Hexagenia mayfly nymphs 39.9/sample. were most abundant, followed by Chironomidae, 21.2/sample, and small numbers of the trichopteran, Oecetis and the deep-water corixid, Sigara lineata.

Fig. 2: Summer 1974 shore /0-1 m, circles/ and near-shore /1-9 m, triangles/ macrobenthic sampling stations. B, Ballast Island; M, Middle Bass Island; N, North Bass Island; South Bass Island.

Only Chironomidae were taken during 1973 - 1974, and these were identified to genus. Subfamily Chironominae included Chironomus, 79 % of the collections of Chironomidae, and Cryptochironomus, 1 %. Tanypodinae included Coelotanypus, 11 % and Procladius, 6 %. The predatory Tanypodinae were most abundant at the extreme western end of the basin while the detritivore, Chironomus, predominated in the central part of the basin.

Although no Hexagenia nymphs have been reported from the benthos of the western basin since 1965 (Britt et al., 1973) two species are present and may exist in shallows around the islands where substrate and oxygenation conditions are suitable. On July 28, 1974 a number of Hexagenia limbata subimagoes were attracted to the lights of a ship moored in Squaw Harbor, South Bass Island, and on July 7 - 8, 1975, W. L. Peters (pers. comm.) collected some Hexagenia rigida from the side of a building on South Bass Island.

Crustacea were represented in the samples only by Gammarus fasciatus (Fig. 3b, Table 1). It occurred widely across the western basin in 1951 - 1952 with an average of 13.2/sample. Only 0.08/sample were taken in 1973 - 1974. However, as will be shown later, their numbers increased in the shallows.

Hirudinea (Fig. 3c, Table 1) averaged 17.1/sample in 1951-1952 and included Erpobdella, two species of Helobdella, Glossiphonia complanata and Placobdella montifera. In 1973 - 1974 only 0.7/sample were taken and Placobdella was not found.

Although Oligochaeta were not recorded in either of the two surveys, a great abundance of Branchiura sowerbyi was noted in 1973 - 1974 and their egg cocoons clogged our screens. One sample was estimated to contain over 444,000 cocoons. Pliodzinskas (1978) surveyed the Oligochaetes during 1973 - 1975. He found four numerically co-dominant species: Limnodrilus hoffmeisteri Claparède, $96/m^2$; L. cervix Brinkhurst, $67/m^2$; L. maumeensis Brinkhurst and Cook, $35/m^2$; Branchiura sowerbyi, $34/m^2$. These numbers are calculated from his data and are gross underestimates as unidentified immatures amounted to $1068/m^2$. The average Oligochaete density in the western basin during 1973 - 1975, estimated from Pliodzinskas (1978) was $1333/m^2$ which corresponds to 213/sample in our survey, based on 0.16 m^2/sample.

Branchiura sowerbyi was not taken during 1951 - 1952. Britt et al. (1973) first collected this worm at the Bass Islands at 10 m depth in 1959. Hiltunen (1969) reported a few specimens taken in 1961 at four stations about 40 km west of the Bass Islands. Wolfert and Hiltunen (1968) found Branchiura to be common at 28 stations in Sandusky Bay in 1963. Veal and Osmond (1968) reported the worm at various stations across the western basin in 1967, and by the late 1970's specimens were collected in the southwestern corner of the central basin (Britt et al. 1980). Thus Branchiura sowerbyi gradually appeared in the western basin and by 1975 become a dominant member of the benthos. It is a large worm with an average wet weight of 152 mg/individual, compared to about 0.3 mg/individual for the other genera (Pliodzinskas 1978). Using the numerical density for Branchiura estimated above, this one worm had a biomass of at least 5.1 g/m^2. This is about half of the 9.6 g/m^2 biomass of Hexagenia estimated by Wood (1963).

Mollusca (Fig. 4, Table 1) included Unionidae, Gastropoda and Sphaeriidae. Unionidae were the most abundant component of the macrobenthos by wet weight (shell excluded) in 1951 - 1952 (Wood 1963). Fourteen species in 13 genera were collected both living and dead (Fig. 4a). A dead shell was defined as one in which the two valves were recovered opposed and intact. The length of time such a shell may persist in the sediments is not known, but an increase in the proportion of dead shells would signal a decline of the species. This was certainly true during the quarter century between the two surveys as the proportion of dead Unionid shells in the collections increased from 29 to 79 percent. Elliptio dilatata had 64 % dead shells in 1951 - 1952 and was not found alive in 1973 - 1974. Anodonta grandis had 36 % dead shells in 1951 - 1952 and 100 % dead in 1973 - 1974. Proptera alata had 40 % dead in 1951 - 1952 and 86 % dead in 1973 - 1974. Even Ligumia nasuta, the second most abundant clam in 1951 - 1952, leter showed 95 % dead shells. Lampsilis radiata siliquoidea, the most abundant Unionid at each time, increased in proportion of dead shells from 30% to 50% between the two surveys. In overall abundance total live Unionidae decreased from 1.69/sample in 1951 - 1952 to 0.59/sample in 1973 - 1974 in the open lake (Table 1).

During the summer of 1974, 60 clam dredgings were taken in the island area at locations shown in Fig. 2. A greater variety of living specimens were taken than in the open lake at the same time (Table 2). These included 8 living species. The nearshore habitat was evidently more favorable to these Mollusca than that of the open lake as the proportion of dead shells was 52 % in the former compared to 79 % in the latter area. Nearshore species, formerly taken live in the open lake, included Amblema costata, Fusconaia flava, Anodonta grandis, and Obliquaria reflexa. Shells of Leptodea fragilis are very buoyant when dead and several specimens were taken on shore at the Bass Islands.

Although dead shells were not collected for Gastropoda, the pie charts (Fig. 4c) show a severe decline in the number of living specimens between the two surveys. Numbers decreased from 26/sample to 0.9/sample (Table 1) and three genera, Helisoma, Elimia and Birgella were not taken in 1973 - 1974. Likewise Sphaeriidae (Fig. 4b and Table 1) descreased from 25.2 to 9.6/sample. Greatest losses were in Sphaerium corneum which decreased from 19.3 to 1.5/sample. However the group contains pollution-tolerant forms and has survived better than other Mollusca.

The present deep-water study shows a loss of the diversity of prior years and the development of a pollution-tolerant fauna dominated by Oligochaetes and Chironomidae. This trend is supported by a survey in 1978 (Bur 1982) in which the western basin deepwater benthos was found to contain 58.8 % Oligochaeta, 34.5 % Diptera, 3.3 % Pelecypoda, and 3.5% Nematoda (by volume of organism).

Shallow-water

The mayfly fauna (Table 3) fo the exposed shore (0 - 1 m depth) in 1974 closely ressembled that of the 1930's. Baetis phoebus, 39.5/m^2, Caenis sp., 12.5/m^2, and Stenonema pulchellum, 4.0/m^2, were the dominant mayflies in that zone during May 28 to August 6, 1974. Qualitative collections yielded three additional Heptageniidae species: Stenacron gildersleevei, Stenonema femoratum and Stenacron interpunctatum. The latter species was taken only occasionally in the 0 - 1 m zone but may be abundant in deeper water farther offshore since large numbers of imagoes were collected in swarms near the shoreline (imaginal collections July 3 - August 7, 1974; June 4 - 5, 1976). Lyman (1955) found that Stenacron interpunctatum was most abundant in water 1 - 2 m deep and much less numerous closer to shore in Douglas Lake, Michigan.

Ephemera simulans imagoes were collected on June 30 and July 7, 1974, and on June 4-5,1976 large numbers of final nymphal exuviae, subimagoes and imagoes were collected. We did not

Table 1. Number per sample of macrobenthos from western Lake Erie at depths 8 m, 1951-52 and 1973-74.

Taxon	1951-52	1973-74
Hexagenia	39.9	0
Chironomidae	21.2	31.7
Gammarus fasciatus	13.2	0.08
Hirudinea	17.1	0.7
Unionidae	1.69	0.59
Gastropoda	26	0.9
Sphaeriidae	25.2	9.6
Total	144	44

Table 2. Unionidae /live and dead/ collected from 60 dredgings in the near-shore zone /1-9 m/ of the Bass Islands, summer 1974.

Species	Live	Dead
Quadrula pustulosa /Lea/	1	-
Amblema costata /Rafinesque/	1	-
Fusconaia flava flava /Rafinesque/	2	-
Anodonta grandis grandis Say	2	-
Obliquaria reflexa Rafinesque	1	-
Proptera alata /Say/	1	4
Obovaria subrotunda /Rafinesque/	-	1
Leptodea fragilis /Rafinesque/	-	1
Ligumia nasuta /Say/	-	1
Ligumia recta /Lamarck/	-	1
Lampsilis radiata siliquoidea /Barnes/	3	3
Lampsilis ovata ventricosa /Barnes/	1	2
Total	12	13

collect any nymphs of *E. simulans* and an associated burrowing species, *Ephoron album* (Say), because we did not sample in gravel and sand shoal habitats in which Britt (1962) reported these species to be abundant at numerous locations along the shores of South Bass Island in 1948 - 1953. Because *E. album* emerges in late July until September, it is likely that we missed emerging adults. Barton and Hynes (pers. comm.) collected *E. album* along the north shore of the western basin of Lake Erie.

Imagoes of *Hexagenia rigida* and subimagoes of *H. limbata* were also taken as previously noted. However, the nymphal habitats of these species were not found during the present survey.

The mayfly fauna of the island area in 0 - 1 m in 1930 included *Caenis*, *Hexagenia* (?, on flat rubble), *Ameletus* and *Heptagenia* (Krecker and Lancaster 1933). In 1937 Shelford and Boesel (1942) reported *Stenonema femoratum* and *S. pulchellum* as the most abundant mayflies in the 0 - 1 m zone, however, *Baetis*, *Stenacron interpunctatum* and *Centroptilum* counts were probably greatly diluted because these data included the entire 0 - 8 m zone whereas these species are generally most abundant in very shallow water. *Baetis phoebus*, for example, was found to be very abundant at depths of 0 - 15 cm but rare at depths greated than 15 cm in Douglas Lake, Michigan (Lyman 1955).

The *Heptagenia* reported by Krecker and Lancaster (1933) probably includes our *Stenonema* and *Stenacron* species as these two genera were included in *Heptagenia* until Traver (1933) erected the genus *Stenonema* and Jensen (1974) erected *Stenacron* from several *Stenonema* species. However Barton and Hynes (pers. comm.) collected three species of Heptagenia along the Canadian shore of the western basin. Thus it is possible that Heptagenia has occurred and may still occur in the island region.

Although many of the same genera and species of mayflies still live around these islands they have been forced to adapt to great environmental changes. As a result of the cultural eutrophication of Lake Erie the green alga, *Cladophora glomerata* (Linné) has proliferated. Neil and Owen (1964) noted that *Cladophora* requires a firm, stable substrate for attachment, and growth occurs most abundantly on coarse gravel, boulders and bedrock along exposed shorelines where constant wave action prevents the accumulation of sediments. These habitats are now completely invaded by *Cladophora*. Meanwhile the more protected areas of the shoreline have suffered a loss of aquatic vascular plant species. Stuckey (1971) estimated that half of the vascular plant flora in the harbors between South Bass and Gibraltar Islands had been eliminated between 1898 surveys and 1970, and that only three of the original 40 species were common or abundant in 1970. We also did not find the shorezone beds of submerged and emerged macrophytes described by Krecker and Lancaster (1933). Krecker (1939) or Dennis (1938). Loss of the flora is attributed to high turbidity due to siltation from agricultural and other land development practices, and to direct human interference from dredging, building of retainer

Table 3. Macrobenthos of the shore /0-1 m/ and near-shore /1-9 m/ areas of the Bass Islands, summers 1974-76.

Taxon	#/m²[1]	Taxon	#/m²[1]
Ephemeroptera	/56.0/	Lepidoptera	
Baetis phoebus McDunnough	39.5	Paragyractis	0.5
Caenis	12.5	Odonata	
Stenonema pulchellum /Walsh/	4.0	Enallagma exsulans /Hagen/	
[2]S. femoratum /Say/		Hemiptera-Corixidae	
Stenacron interpunctatum /Say/		Diptera	/6.0/
S. gildersleevei/Traver/		Antocha	1.0
[3]Hexagenia limbata occulta Walker		Tipulidae	3.0
[3]H. rigida McDunnough		Empididae	
[3]Ephemera simulans Walker		Simuliidae	0.5
Trichoptera	/888.0/	Hemerodromia ?	
[4]Symphitopsyche recurvata /Banks/	610.5	uniden. larvae	1.5
Cheumatopsyche speciosa /Banks/	263.5	Diptera-Chironomidae	/277.0/
Neureclipsis	1.0	Cricotopus	216.5
Cyrnellus fraternus /Banks/		Psectrocladius	2.5
Polycentropus		Trichocladius	0.5
Ceraclea cancellata /Betten/,	10.5	Dicrotendipes	4.5
transversa /Hagen/,		Glyptotendipes	3.5
tarsipunctata /Vorhies/		Microtendipes	1.5
Oecetis	0.5	Parachironomus	1.0
Nectopsyche		Cryptochironomus	
Hydroptila	0.5	Polypedilum	14.0
Orthotrichia		Chironomus	
[5]Helicopsyche borealis /Hagen/		Pseudochironomus	0.5
Leptoceridae pupae	0.5	Rheotanytarsus	17.5
uniden. larvae	1.0	Tanytarsini	
Coleoptera	/9.0/	Procladius	
Stenelmis crenata /Say/ larvae	5.0	Tanypodinae	
adults	1.5	uniden. larvae	15.0
Macronychus glabratus Say		Amphipoda	
Lutrochus laticeps Casey	2.0	Gammarus fasciatus Say	113.5
Anchytarsus bicolor /Melsheimer/	0.5	Isopoda	
Ectopria nervosa /Melsheimer/		Asellus intermedius Forbes	3.0

Table 3 continued

A. racovitzai racovitzai Williams		Hydra	
Decapoda	1.0	Bryozoa	
Gastropoda	/2.5/	Hirudinea	
[6]Physella gyrina gyrina /Say/,	1.5	Erpobdella punctata punctata	0.5
integra integra /Haldeman/		/Leidy/	
[7]Fossaria	1.0	Helobdella	
[8]Elimia livescens livescens /Menke/		uniden.	0.5
Bithynia tentaculata /Linnaeus/		Oligochaeta	
Ferrissia		Nais pseudobtusa Piguet	
Gyraulus deflectus /Say/		N. bretscheri /Michaelsen/	
Valvata		N. elinguis Müller	
Pelecypoda		N. communis Piguet	
Sphaeriidae		N. variabilis Piguet	
Unionidae /see Table 2/		N. barbata Müller	
Platyhelminthes		Chaetogaster diaphanus /Grüithuisen/	
Dugesia tigrina /Girard/	33.9	Branchiura sowerbyi Beddard	
Hydracarina		Tubificidae	
Cnidaria			

[1]Counts from 17 rocks totalling 2.0 m^2 /all sides/, taxa without numbers are from qualitative collections.

[2,4,6-8]These taxa were formerly: 2, S. tripunctatum tripunctatum /Banks/; 4, Hydropsyche recurvata Banks; Physa gyrina Say, Physa integra Haldeman; 7, Lymnaea; 8, Goniobasis livescens /Menke/.

[3]Collected as subimagoes or imagoes.

[5]Only one empty case collected.

walls and docks, and recreational boating (Stuckey 1971, Taft and Kishler 1973). The very high water levels of 1973 - 1974 (see Farney and Bookhout 1982) probably caused further losses of macrophytes.

The effect of the Cladophora invasion on the mayfly populations is not known. Certainly decomposition of sloughed off filaments in late summer would be adverse. Loss of the macrophytes would affect such species as Centroptilum fragile McDunnough that occur only in areas with submerged plants (Lyman 1956). Shelford and Boesel (1942) reported Centroptilum but we did not find it.

Trichoptera were the most numerous insect group collected in shallow water during 1974 with a total of $888/m^2$ (Table 3). The dominant family was Hydropsychidae with the genera Symphitopsyche at $610.5/m^2$ and Cheumatopsyche at $263.5/m^2$. The former genus was dominant in the early part of the summer while the latter prevailed from July on. These Hydropsychidae caddisflies were often so abundant that the entire bottom and sides of rocks were covered with their retreats. Both species were also occasionaly collected off rocks dredged in deep water near shore.

The genus Ceraclea ($10.5/m^2$) was common near shore and was also taken at depths up to 7 m. C. cancellata and C. tarsipunctata were co-dominant in our collections together with a few larvae of the obligate sponge-eating species C. transversa. Although Marshall (1939) collected nine species of Ceraclea at light at Gibraltar Island in the summer and fall of 1937 (about 47 species of Trichoptera taken in all), Horwath (1964) and Resh and Unzicker (1975) found only four of those Ceraclea species at light. These data, together with our study, suggest a decline of species diversity within this interesting genus. Adverse changes in their environment include pollution, loss of macrophyte habitat, and a reduction of sponge populations, an important food for some species.(Resh et al. 1976). Obviously the alga Cladophora could have displaced sponges in many habitats.

Other Trichoptera from our study (Table 3) included Neureclipsis ($1.0/m^2$), common near shore, Oecetis, occasional in shallow and deep water, Cyrnellus and Polycentropus, generally collected off rocks 2 - 7 m deep. We also took two larvae of Nectopsyche, and in all 11 genera if we include one case of Helicopsyche borealis. Failing to sample sand and mud we may have missed Molanna which prefers that habitat (Wiggins 1977).

Hydropsychidae were also the dominant family of Trichoptera in the 1930's. Krecker and Lancaster (1933) found $155/m^2$ of Hydropsychidae on flat rubble in 1930 and Shelford and Boesel (1942) reported $70/m^2$ of Symphitopsyche in the 0 - 1 m zone and $0.2/m^2$ of Cheumatopsycne in the 0 - 8 m zone. Krecker and Lancaster (1933) also found Hydroptilidae, Leptoceridae, Helicopsyche and Rhyacophilidae to be common on certain substrates, and *Molanna* was also listed. Shelford and Boesel (1942) also reported Leptoceridae, *Helicopsyche* and *Molanna*. The Rhyacophilids collected by Krecker and Lancaster (1933) are likely *Ceraclea* according to Resh and Unzicker (1975).

Although it is difficult to make any precise comparisons between these various studies we can conclude that the Hydropsychidae have more than held their own over these years possibly due to pollution tolerance of some species. As with the Ephemeroptera a diversity of genera continues in the Trichoptera of these islands. Evidently some *Ceraclea* species have disappeared and the unusual *Helicopsyche borealis* seems in decline. We collected only one empty case while Barton and Hynes (pers. comm.) did not take it along the north shore of the western basin and considered it rare along the Canadian shore of Lake Erie.

Chironomidae were represented by over 10 genera in the 1974 survey (Table 3). The three most numerous were *Cricotopus*, 216.5/m^2, *Rheotanytarsus*, 17.5/m^2, and *Polypedilum* 14.0/m^2. *Cricotopus* were taken mostly on loose rocks from the 0 - 1 m zone and few were found on shelving rock. In contrast, in 1930 Chironomidae (presumably mostly *Cricotopus*) averaged 3133/m^2 on shelving rock, with much fewer numbers on flat rubble and block rubble (Krecker and Lancaster 1933). *Cricotopus* was also the numerically dominant in the shore zone in 1937 and averaged 1000/m^2 at 0 - 8 m depth (Shelford and Boesel 1942).

Other aquatic insects (Table 3) included 5 species of Coleoptera of which *Stenelmis crenata* was common to abundant and occurred in both shallow and deep locations. Tipulidae were the most common of the non-chironomid Diptera. Other collections included the moth larva, *Paragyractis*, two specimens of the damselfly nymph *Enallagma exsulans* and some Corixidae.

Crustacea taken in the shore zone in 1974 included *Gammarus fasciatus*, 113.5/m^2, two species of *Asellus* and the occasional crayfish. *Gammarus* occurred in large numbers wherever the alga, *Cladophora* occurred, both at shore and nearshore stations. Neil and Owen (1964) also reported large numbers of *Gammarus* on *Cladophora* and Barton and Hynes (1976) estimated peak densities of *G. fasciatus* at over 10,000/m^2 on *Cladophora*-covered substrates. This niche was much more restricted in the 1930's. Krecker and Lancaster (1933) reported *Cladophora* only along a narrow zone at the waterline, whereas today Cladophora is abundant on hard substrates from shore to well below several meters in depth. Consequently few *Gammarus* were reported in the 1930's.

Gastropoda (Table 3) were common in habitats protected from wave action. *Physella* spp., *Fossaria* spp. and *Elimia livescens livescens* were most abundant. The latter was the only snail regularly taken by dredge at offshore stations. *Bithynia tentaculata*, formerly abundant in deep water, was taken in some numbers at two North Bass Island stations. The present shore zone snail is much less diverse than that described by Dennis (1938) in the summer of 1927, primarily due to the loss or severe reduction of many of the macrophyte habitats. Ten of 15

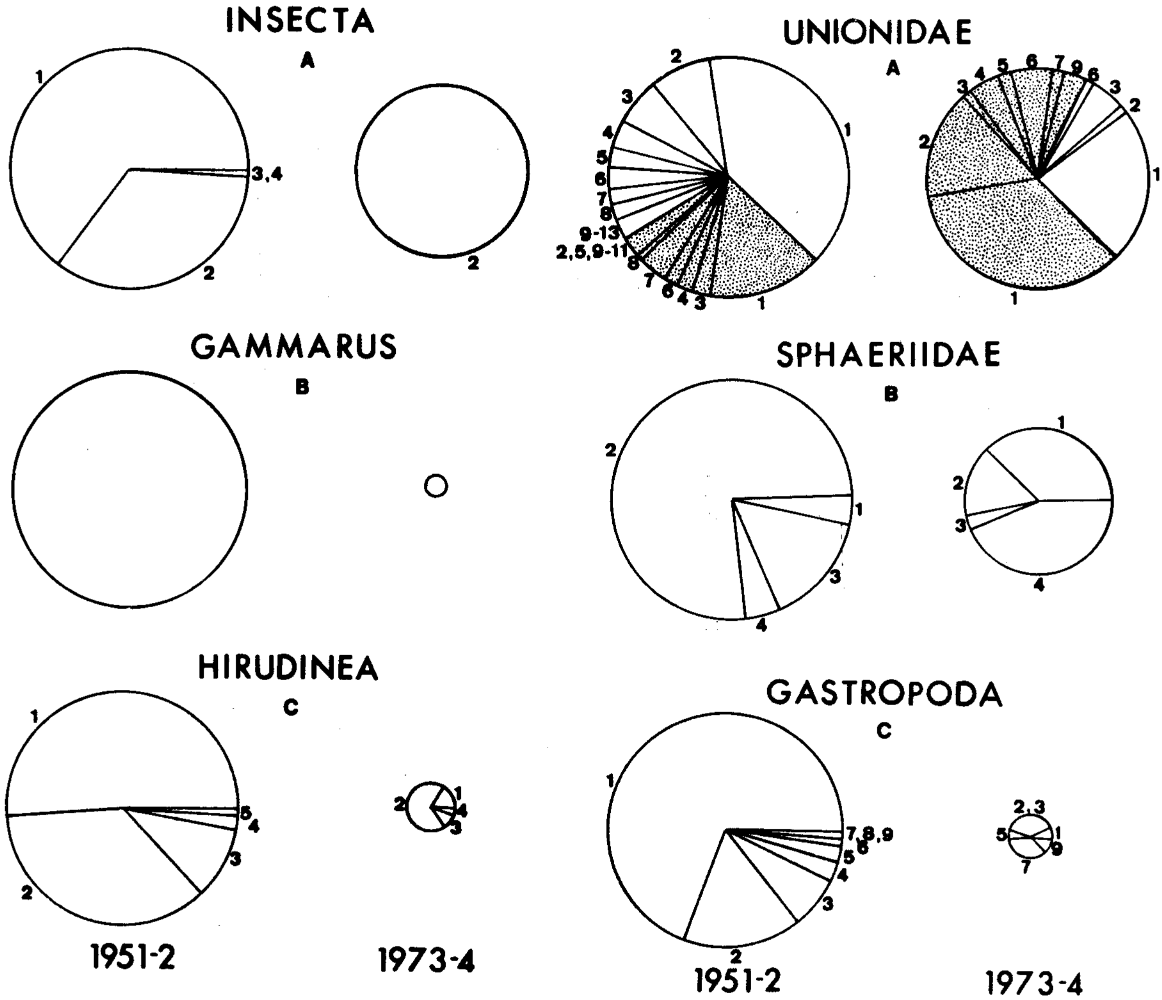

Fig. 3-4: Comparison of Insecta, *Gammarus* and Hirudinea populations from 1951-52 to 1973-74 based on number per sample. A: 1, *Hexagenia*; 2, Chironomidae; 3, *Oecetis*; 4, *Sigara lineata* /Forster/. B: *Gammarus fasciatus* Say. C: 1, *Erpobdella*; 2, *Helobdella stagnalis* /Linnaeus/; 3, *H. elongata* /Castle/; 4, *Glossiphonia complanata* Linnaeus; 5, *Placobdella montifera* Moore. Comparison of Unionidae, Sphaeriidae and Gastropoda populations from 1951-52 to 1973-74 based on number per sample. A /collected live, clear area; collected dead, stippled area/: 1, *Lamsilis radiata siliquoidea* /Barnes/ and *L. ovata ventricosa* /Barnes/; 2, *Ligumia nasuta* /Say/; 3, *Leptodea fragilis* /Rafinesque/; 4, *Anodonta grandis grandis* Say; 5, *Fusconaia flava flava* /Rafinesque/; 6, *Proptera alata* /Say/; 7, *Elliptio dilatata* /Rafinesque/; 8, *Truncilla donaciformis* /Lea/; 9, *Obovaria subrotunda* /Rafinesque/; 10, *Quadrula pustulosa* /Lea/; 11, *Amblema costata* Rafinesque; 12, *Obliquaria reflexa* Rafinesque; 13, *Pleurobema cordatum cordatum* /Rafinesque/. B: 1, *Musculium transversum* /Say/ /formerly *Sphaerium transversum* /Say/ /; 2, *Sphaerium corneum* /Linnaeus/; 3, *S. striatinum* /Lamarck/; 4, Pisidium spp. C: 1, *Bithynia tentaculata* /Linnaeus/; 2, *Valvata* spp.; 3, *Amnicola* spp.; 4, *Pleurocera acuta acuta* Rafinesque; 5, *Physella*; 6, *Helisoma* spp.; 7, *Campeloma decisum* /Say/; 8, *Birgella subglobosa* /Say/; 9, *Elimia livescens livescens* /Menke/ /formerly *Goniobasis livescens* /Menke/ /.

species collected by Dennis occurred on or were associated with aquatic vascular plants. Snails that occurred on rocks in 1927 were generally present in 1974.

A variety of other animals (Table 3) usually encountered in shallow water were taken in our survey although little attempt was made to quantify them. The leech, Erpobdella punctata was common amongst flat and angular rubble. The Oligochaete Nais was common and occasionally taken in great numbers. One specimen of the Tubificid, Branchiura sowerbyi was collected offshore. The planarian Dugesia tigrina was common in both shallow and deep water. The coelenterate, Hydra, was present in many collections as were water mites (Hydracarina). Gemmules of Bryozoa were often taken.

Although the same eutrophic water mass bathes both deep- and shallow-water habitats of Lake Erie they are infuenced by sediment-water interchange in the former and by air-water intercharge in the latter. The result for deep-water has been a drastic change in the fauna with great loss of diversity and dominance by Oligochaetes and Chironomidae. The very high biochemical oxygen demand of the sediments coupled with occasional periods of winds insufficient to mix and thereby replenish oxygen of the deep water has created the persistent periods of anoxia associated with these changes in the fauna (Carr et al. 1965, Herdendorf 1980). A single worm species, Branchiura sowerbyi, has filled most of the gap left by loss of the vast Hexagenia populations.

Oxygen levels in the shore zone continue to be favorable as a result of wave action and gas exchange across the air-water interface. Therefore the lotic-like macrobenthic fauna of the shore zone (0 - 1 m) has largely persisted since the 1930's despite greatly increased nutrient pollution levels. Apart from the influx of Gammarus fasciatus into the Cladophora beds, changes in the shallow-water fauna have been subtle and rather difficult to document. Hydropsychidae caddisflies, encouraged by higher nutrient levels, now outnumber the chironomid Cricotopus. Decline of macrophyte beds around the islands has caused problems for some mayfly, caddisfly and snail species. The Unionid populations have been affected but not as seriously as in the deep water.

Our study of the rocky shores of the Bass Islands compares well to the lotic-like fauna of the 0 - 2 zone of the Canadian wave-swept shores of Lake Erie studied by Barton and Hynes (pers. comm., 1976, 1978). However, because the substrate of the north shore of the western basin was predominately sand and gravel (Barton, pers. comm.) we found a much more diverse fauna on the more stable and optimal substrate of flat and angular rocks which are very common around the shores of the Bass Island region((contact Dr. Barton for a breakdown of their Lake Erie fauna into that of the three separate basins). Cones (1976) found the macrobenthos of Locust Point (located on the mid south shore of the western basin), where station depths ranged between 1 - 4.5 m, was dominated by oligochaetes and chironomids which were able to live in a shifting silt, sand, gravel substrate not condusive for the attachment of many of the organisms collected in our own study.

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