DECLINE OF *HEXAGENIA* (EPHEMEROPTERA) NYMPHS IN WESTERN LAKE ERIE

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INTRODUCTION

The western end of Lake Erie formerly produced large numbers of *Hexagenia* mayflies belonging to two species, *Hexagenia limbata occulta* (WALKER) and *Hexagenia rigida* McDUNNOUGH (CHANDLER, 1963). During July of some years dense swarms were observed over the islands of South Bass, Rattlesnake, Middle Bass and Gibraltar. These swarms were so thick as to appear like clouds of smoke weaving up and down over the tree tops (LYMAN, 1944). This study deals with a history of these mayflies in the western basin of Lake Erie from the time they were first described in 1929 (WRIGHT, 1955) to the present when the great swarms are absent and the nymphal populations are less than $1/m^2$ (CARR and HILTUNEN, 1965).

THE HABITAT

The western basin of Lake Erie is separated from the remainder of the lake by a chain of islands. Considering that part of the lake west of a line from the tip of Point Pelee to the tip of Cedar Point, the western basin has an average depth of 7.4 meters and a surface area of 3.276×10^9 m^2.

Formerly the western basin was well oxygenated at all depths. WRIGHT (1955) reported that in 1929 the chemistry of the surface and bottom water was nearly the same. In three seasons of study only one case of nearly total depletion of oxygen in the bottom water occurred. CHANDLER (1940) reported that thermocline formation was an irregular and temporary phenomenon and that on most dates the temperature did not very more than 2 C from surface to bottom. Likewise CHANDLER found that dissolved oxygen was nearly uniform from surface to bottom. Variation with depth did not exceed 2 ppm. CHANDLER concluded that this part of Lake Erie ressembles a sublittoral zone with respect to thermal and chemical conditions, and that water circulates from surface to bottom throughout most of the year, due to currents and wind action. This results in an abundance of typically shallow-water communities.

SHELFORD and BOESEL (1942) recognized communities at depths of 10 meters characterized as *Pleurocera-Lampsilis* and as *Hexagenia-Oecetis* communities. Studies by WRIGHT (1955) and WOOD (1953) also showed the great variety of typically sublittoral fauna in this part of Lake Erie. The naiad fauna was so varied and extensive that VAN DER SCHALIE (1950) referred to western Lake Erie as a «river-lake».

Unfortunately man's activities have created many undesirable changes in this habitat. BEETON (1965) documented many of the chemical changes in the Great Lakes and showed that Lake Erie has undergone accelerated eutrophication, particularily during the past 30 years.

Beeton (1966) stated that the oxygen demand of the water and sediments has increased greatly in western Lake Erie, and that only five days of thermal stratification were now necessary for the dissolved oxygen content to drop below 3 ppm, whereas 28 days were required in 1953.

Populations of Nymphs

The location of sampling stations and abundance of nymphs as number per square meter during 1951-52 is shown in Fig. 1. These data were originally published as wet weight of

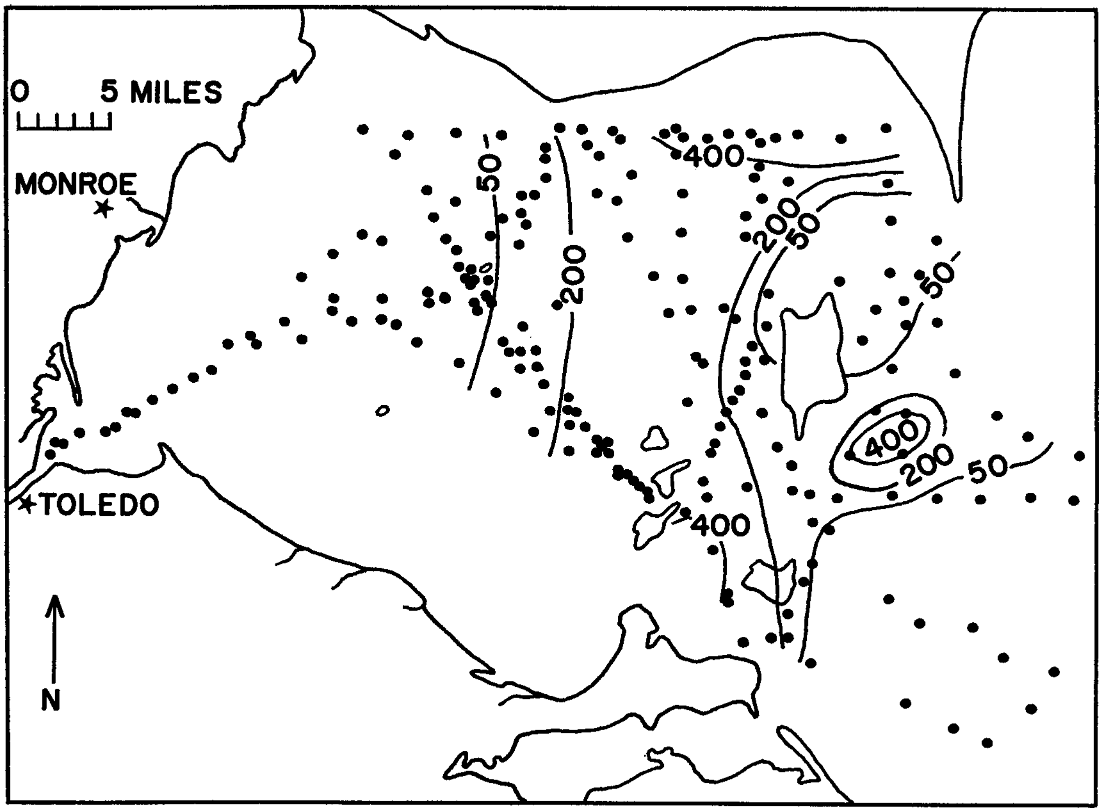

Figure 1. Western Lake Erie, showing location of sampling stations (black dots) and isopleths of abundance/m² of *Hexagenia* during 1951-52.

nymphs per unit volume of sediment (Wood, 1963). Subsequently Carr and Hiltunen (1965) presented maps showing the number of nymphs in western Lake Erie during 1930 and 1961. The present map allows full comparison between these three surveys.

As an aid to discussion, western Lake Erie may be divided into two regions by a line drawn through West Sister and Middle Sister Islands (the two small islands adjacent to the $50/m^2$ isopleth in Fig. 1). These will be called the western section and the island section. The smaller western section receives the discharge of the Detroit, Raisin and Maumee Rivers. The larger eastern section contains the major islands and receives the discharge of the Sandusky River.

Western Section

The western section was sampled during 1929-30 and 67 yielded an average of samples of 114 nymphs/m^2 (calculated from Wright, 1955). During 1951-52 the author took 36 bottom samples from this area and found 19 nymphs/m^2. This shows a loss of 66 percent of the *Hexagenia* during 1929 to 1952. However the earlier data was biased by inclusion of many samples from polluted river mouths. In the «open lake area» of Wright (1955) an average of 394/m^2 of nymphs was obtained in 1929-30, but only 35/m^2 during 1951-52. This open lake area includes the above western section but excludes the territory within 5 to 10 miles of the Ohio and Michigan shores. These adjusted statistics show a loss of 90 percent of the nymphs in the western section during 1929 to 1952.

One sample is excluded from these averages for 1951-52. This sample, taken October 29, 1951, at a distance of 8 miles from Monroe, Michigan, contained 749/m^2 of nymphs. These were largely first year specimens with an average weight of 5 mg, as compared to the 40 mg average wet weight for all nymphs collected. This sample was clearly in a region of low abundance by weight as shown in the gravimetric map (Wood, 1963). Sample variations were averaged out by drawing lines of equal abundance on the map (Fig. 1). These isopleths were drawn at population levels of 50, 200 and 400/m^2 to correspond to the maps shown by Carr and Hiltunen (1965). These authors show that, in 1930, the 50, 200 and 400/m^2 isopleths were located 6, 8 and 17 km distance respectively from Monroe, Michigan. However, in Fig.1, the 50/m^2 isopleth is 29 km from Monroe, Michigan, the 200/m^2 isopleth is 35 km away and the 400/m^2 isopleth is 47 km away. These isopleths seem to have moved eastward at an average rate of 1.2 km/year during this 20 year period.

Island Section

In the island section (east of a line drawn from Middle Sister to West Sister Islands) 12 samples in 1929-30 yielded 369/m^2 of nymphs (Wright, 1955). This value compares favorably to data by Chandler (1963) who found 350/m^2 im the island area during 1941-47. The survey of 1951-52 yielded over 200/m^2 (Fig. 1). Evidently *Hexagenia* populations in this part of Lake Erie were not much changed from earlier levels as late as 1952.

The Catastrophic Calm

Natural catastophies generally result from unusual releases of the powers of nature. However western Lake Erie suffered from the withholding of such powers. During the late summer of 1953 a period of unusual calm weather prevailed, the lake became thermally stratified, and dissolved oxygen became depleted in the hypolimnion (Britt, 1955a). Oxygen concentrations as low as 0.7 ppm, were found near the bottom. The calm prevailed during a period of 13 days and Britt found that many of the nymphs were killed over that time, presumably from lack of oxygen. Samples taken in the island area where Chandler had studied yielded 465/m^2 of nymphs (all dead) on September 5, 1953, and a negative sample on September 16. Although samples taken in 1954 seemed to show a recovery of the population in the form of small, first-year nymphs (Britt, 1955b), these never became established. Carr and Hiltunen (1965) showed isopleths of less than 10/m^2 in the open lake area. In the island area Britt (1963) reported that the *Hexagenia* populations had been reduced to the point of becoming extinct. Present reports indicate that the genus is now restricted to certain mainland shoal areas.

Discussion

A similar loss of *Hexagenia* nymphal populations occurred in Green Bay, Lake Michigan (Howmiller and Beeton, 1970). These workers reported that *Hexagenia*, once present in nuisance proportions, and still present in 1952, had apparently disappeared from Green Bay by 1969. They concluded that eutrophication and pollution were responsible for this loss.

Phi median	Trask sorting factor																					
	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.5	4.0	4.5	5.0+
0-1					0.0								0.02							0.0	0.35	1.42
1-2	0.0	0.15		0.01	0.0												0.01					
2-3	0.08	0.01	0.56			0.12																0.44
3-4				0.10	0.05	0.92	1.50	2.32											0.24			0.38
4-5								0.05									0.03			1.42	1.26	1.93
5.1																	0.13					
5.2																						
5.3																					0.67	
5.4																				0.03		
5.5																				1.44		
5.6															0.48							
5.7																				1.48	0.29	
5.8																					0.20	
5.9																				0.37	0.01	
6.0																			5.67			
6.1																						
6.2																1.17		1.02				
6.3																	1.86	5.71	1.87	0.51		
6.4									1.61										0.13	0.01		
6.5																						
6.6																		7.86	1.72		0.79	
6.7																6.09	1.83					
6.8						0.81								3.82	5.50	5.96		5.60			1.39	
6.9															4.23							
7.0													4.76		2.22				0.01			
7.1																						1.51
7.2																6.66	1.13					
7.3												0.30	0.78	1.25		0.0						
7.4											0.54	0.99		0.51		1.71	2.17		0.32			
7.5							1.98						2.70									
7.6										0.64												
7.7								0.01			0.72		0.15				0.18		0.07			
7.8							0.15		1.27			7.18	0.0			0.02			0.01	0.90		
7.9						0.55	0.33	0.78			2.46											
8.0			0.0		1.38	0.04	0.18	1.04	1.13											1.19		
8.1			0.01	0.27	0.85	0.17	0.87	0.12		0.40	0.42				0.28							
8.2	0.06		0.28	0.06	0.31	0.40	0.34	0.0	1.55		0.20											

Table 1. Distribution of *Hexagenia* nymphs in gm/m^2 of wet weight, in relation to the Phi median and to the Trask sorting factor. (Unnumbered squares were not sampled.)

In Lake Erie the percentage of organic matter in the over-dried sediments was taken as a measure of organic pollution during the 1951-52 survey (WOOD, 1963). On this basis samples containing greater than 4 percent organic matter contained few or no nymphs. It seems significant that the most highly organic sediments occurred in the open lake area discussed above. However the most homogenous sediments were also the most highly organic thus it was not possible to state whether organic pollution or inability to form burrows was a limiting factor. CHANDLER (1963) found the greatest populations on sediments that contained sand, silt and clay in a 20 : 40 : 40 ratio. This observation was supported in the present survey.

The distribution according to sediment type is shown in Table 1, in which the weight of *Hexagenia* nymphs in gm/m^2 is listed according to both the phi median (ϕ) and to the Trask sorting factor (Tr) of the sediment. These statistics have the following meaning. The phi median is such that the average particle size equals $2^{-\phi}$. For example, if the average particle diameter equals 8ϕ the sediment is a clay of average particle size $1/2^8 = 1/256$ mm. The Trask sorting factor equals 2 raised to the power of the phi quartile deviation. This becomes a measure of the homogeneity of the sediment — Tr 1.3 refers to a very homogeneous sediment; Tr. 5.0 refers to a very heterogeneous sediment.

Evidently, from Table 1, the nymphs did not occur to any extent in the most homogeneous sediments (Tr $<$ 1.6). However sizeable populations (over 1 gm/m^2) occurred in a variety of sediment types from sand (—1ϕ to 4ϕ), silt (4ϕ to 8ϕ) and clay ($>$8ϕ). The greatest populations centered at about 6.8ϕ and 2.7 Tr. Although it was not possible to sample all types of sediment it is evident that these burrowing nymphs are adaptable to a wide variety of conditions.

VERDUIN (1963) suggested a gradual eutrophication of Lake Erie during 1945-1962, with many of the changes occurring rather sharply between 1949 and 1953. Sources of nitrate and phosphate in southeast Michigan were identified by HARLOW (1966). These produced levels of nutrients in the western section sufficient to trigger algal blooms during 1964-65. As the major sources were municipal wastes it can be assumed that these conditions have been building up for many years (W*ood*, 1968). Evidently the *Hexagenia* populations in Lake Erie were endangered before 1953. The oxygen catastrophe and *Hexagenia* kill was primarily damaging in that it provided lebensraum for pollution-tolerant organisms. It was then inevitable that *Hexagenia* would be displaced.

Based on a standing crop of 9.6 gm/m^2 during 1951-52 (WOOD, 1963) the loss to the ecosystem amounted to 70 million pounds, wet weight. BRITT(1962) showed that mayfly nymphs were an important source of fish-food in Lake Erie. Loss of this food resource is most likely correlated with the concurrent loss of 15 million pounds each of walleye and bluepike in the annual Lake Erie fishery.

RÉSUMÉ

Déclin de *Hexagenia* (Ephemeroptera) dans la section ouest du lac Erié

Les larves d'*Hexagenia* des espèces *H. limbata occulta* (WALKER) et *H. rigida* MCDUNNOUGH ont diminué en effectif de 90 % entre les années 1930 et 1952 dans la moitié ouest du lac Erié. Dans la partie comportant des îles les populations sont restées abondantes pendant cette période jusqu'à la catastrophe de 1953 conduisant à une déficience en oxygène. A la fin de l'été 1953, à cause d'un temps exceptionnelement calme, le lac s'est stratifié thermiquement et il en est résulté une déficience en oxygène dissoute dans le hypolimnion. De nombreuses larves ont été tuées en une période de 13 jours apparemment par manque d'oxygène. Probablement la compétition d'autres organismes en même temps qu' un effet accru d'eutrophication a empêché le retour des *Hexagenia.* La perte pour le benthos s'est élevé à 70 millions de livres en poids humide.

Zusammenfassung

Das Abnehmen der *Hexagenia* (Ephemeroptera) im westlichen Eriesee

Die Anzahl der *Hexagenia* Nymphen von der Art *H. limbata occulta* (Walker) und *H. rigida* McDunnough haben zwischen den Jahren 1930 und 1952 in der westlichen Hälfte des Eriesees zirka 90 Prozent abgenommen. In den Inselgegenden waren die Populationen während dieser Periode und bis zur Sauerstoffmangelkatastrophe von 1953 auf hoher Stufe. Während des Spätsommers von 1953 herrschte eine Periode von ungewöhnlich ruhigem Wetters; der See war thermal stratifiziert und aufgelöster Sauerstoff war im Hypolimnion aufgebraucht. Viele Nymphen wurden in einer 13-tätigen Zeitspanne durch offensichtlichen Sauerstoffmangel getötet. Vermutliche Konkurrenz bei anderen Organismen, zusammen mit den zunehmenden Effekten von Eutrophication, hat die Wiederaufbildung der *Hexagenia* verhindert. Verlust an den Benthos stellte eine stehende Ernte von 70 Millionen Pfund, nasses Gewicht, dar.

Discussion

B. Russev : Wie sind die quantitativen Untersuchungen gemacht?

K. Wood : I used a drag type dredge and I measured the number of mayflies per unit volume of sediment. This was an unusual method but I found that it corresponded quite well to other surveys in which the Eckman dredge was used.

B. Russev : Wieviele verschiedene Kubikmeter wurden gesammelt?

K. Wood : I used a drag and it contained a bag of nylon marquisette. It collected an average of 20 liters of sediment in each haul. This method was used primarily because I wanted to collect the Mollusca so I needed to cover a large volume of sediment to get the Mollusca.

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