J. Great Lakes Res. 17(4):517-521
Internat. Assoc. Great Lakes Res., 1991

BURROWING MAYFLY NYMPHS IN WESTERN LAKE ERIE, 1942-1944

Bruce A. Manny
National Fisheries Research Center-Great Lakes
U.S. Fish and Wildlife Service
1451 Green Road
Ann Arbor, Michigan 48105

ABSTRACT. These data, collected during 1942-1944 by Dr. David C. Chandler, describe the density, biomass, and growth of a now extinct population of burrowing mayfly nymphs (primarily Hexagenia limbata) *that lived in the sediments of western Lake Erie near South Bass Island. The growth dynamics of this population have not previously been documented. Female nymphs grew faster than males and were about 4 mm longer than males at emergence each year. Significantly fewer nymphs were collected in 1943 than in 1942 or 1944. Before they were extinguished by low dissolved oxygen in 1953, mayfly nymphs were abundant (about 350 weighing 10 wet g m^{-2}) near this island and throughout most of western Lake Erie. The western basin once supported a biomass of 9.6 t · km^{-2} or at least 17,600 metric tonnes of mayfly nymphs. If burrowing mayflies recolonize the sediments of western Lake Erie, these data could be used to assess the extent of their recovery.*
INDEX WORDS: Ephemeroptera, Hexagenia, *Great Lakes, density, biomass, growth.*

INTRODUCTION

Western Lake Erie once supported large numbers of burrowing mayflies (Shelford and Boesel 1942, Wright 1955) that were important as food for yellow perch, freshwater drum, and channel catfish (Ewers 1933, Price 1963). By 1953, cultural eutrophication caused low dissolved oxygen near the bottom of western Lake Erie that extinguished this mayfly population (Britt 1955a, b; Beeton 1961, 1969; Verduin 1963; Carr and Hiltunen 1965). As indicators of ecosystem health, burrowing mayflies are of current interest because their abundance reflects recovery from eutrophication in Lake Erie and other waters of moderate productivity (Reynoldson *et al.* 1989, Edwards and Ryder 1990).

In 1942-1944, Dr. David D. Chandler collected, but never published, these data on burrowing mayfly nymphs in western Lake Erie. An abstract based on these data states that this mayfly population consisted on 75% *Hexagenia limbata occulta* (Walker) and 25% *Hexagenia rigida* McDunnough (Chandler 1963). This abstract has been cited to illustrate historic changes in western Lake Erie (Wood 1973, Reynoldson *et al.* 1989). With Dr. Chandler's permission, I present these data.

METHODS

Burrowing mayfly nymphs were collected with a Petersen grab (surface area of sample = 0.074 m^2) in water about 9 m deep, one to three times a month from January 1942 to September 1944, at one station mid-way between Rattlesnake Island and South Bass Island (41°40'00"N, 82°50'30"W) in western Lake Erie (Fig. 1; D.C. Chandler, Gainsville, Florida, personal communication, 1988). Sediments were washed through a No. 40 screen (0.425 mm openings); residues retained on the screen were preserved in 10% formalin (N.W. Britt, Bradenton, Florida, personal communication, 1988). The biomass of burrowing mayfly nymphs sorted from these residues was expressed as wet weight of nymphs in grams per square meter of lake bottom; their total body lengths were measured to the nearest 0.1 mm. Nymphs were identified and sexed by Dr. F. Earle Lyman at the Stone Laboratory of Ohio State University near South Bass Island following Spieth (1941).

Only Figure 2 was provided to me by Dr. Chandler; the original data could not be found. To compare among years, I derived density values, biomass values, and sampling dates (Table 1) by inspection of Figure 2. I tested the significance of mean differences among my derived values with

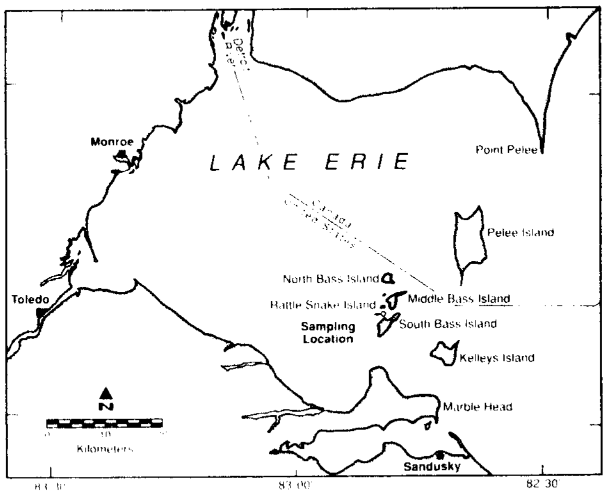

FIG. 1. The island area of western Lake Erie, once inhabited by this burrowing mayfly population.

Student's t at $p \leq 0.05$ (Steel and Torrie 1960). Lengths, weights, and densities of the nymphs were not corrected for preservative effects, sampler efficiency, or screen mesh size (cf. Reynoldson *et al.* 1989).

RESULTS AND DISCUSSION

The density of burrowing mayfly nymphs (mean ± one standard error) was significantly higher in 1942 (437 ± 34) and 1944 (379 ± 46) than in 1943 (202 ± 21; Fig. 2). During that period of time, the mean density of mayfly nymphs in the island area of western Lake Erie was about 350 m^{-2} (Britt 1955b, Chandler 1963). This value slightly exceeds the mean density of a burrowing mayfly population in a Kansas reservoir south and west of Lake Erie (320 m^{-2}; Horst 1976) and may represent the

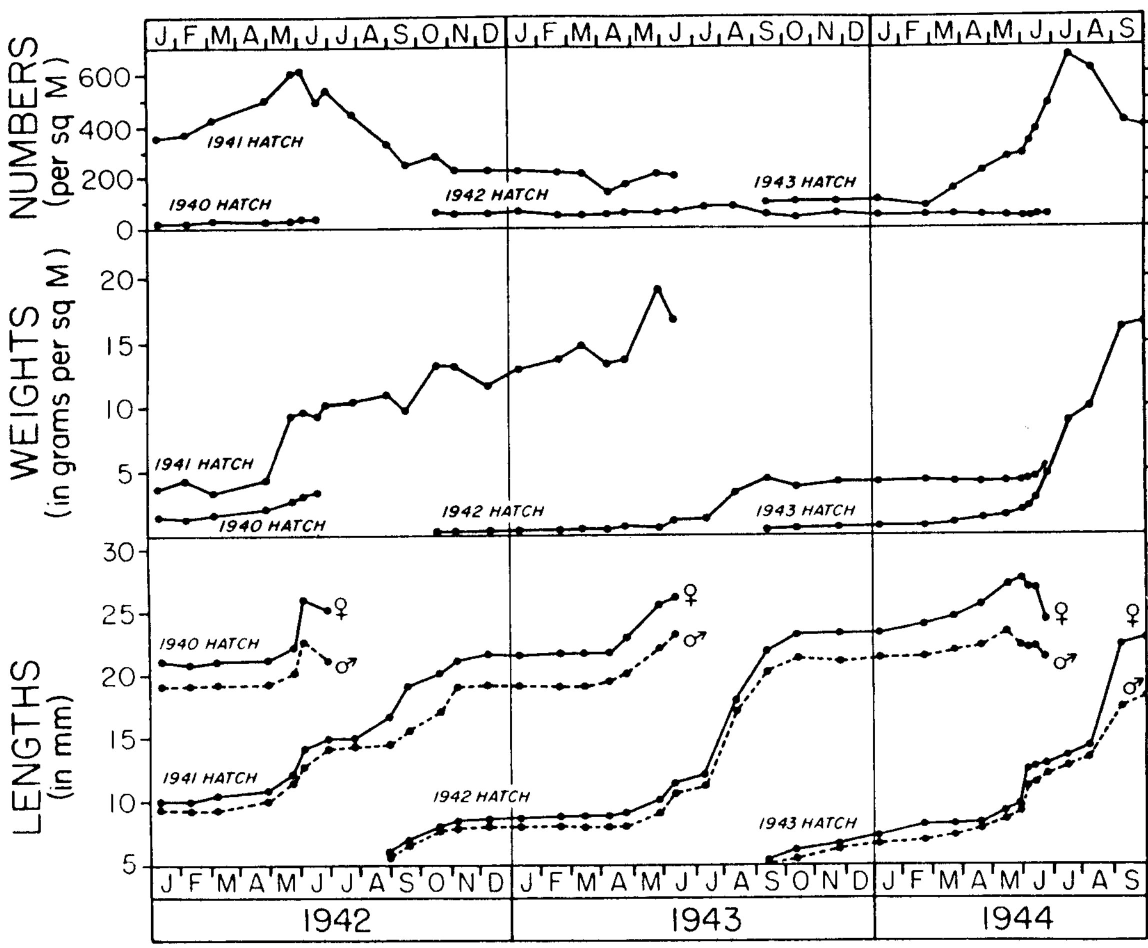

FIG. 2. Density, biomass, and size structure of the burrowing mayfly population in the island area of western Lake Erie, 1942–1944 (Courtesy of Dr. David C. Chandler).

TABLE 1. Sampling dates, nymphal biomass (g m⁻²), and nymphal density (no. m⁻²) during 1942–1944 in western Lake Erie, derived by inspection of Figure 2, including mean values ($\bar{x}$) ± one standard error (Se) for each year.

	Biomass			Density		
Date	Lower line	Upper line	Total	Lower line	Upper line	Total
1942						
12 Jan.	1.5	3.5	5.0	20	375	395
07 Feb.	1.4	4.5	5.9	25	385	410
04 Mar.	2.0	3.0	5.0	30	425	455
29 Apr.	2.5	4.5	7.0	28	500	528
20 May	2.9	9.6	12.5	30	608	638
01 Jun.	3.0	9.9	12.9	35	615	650
17 Jun.	3.4	9.4	12.8	40	495	535
30 Jun.		10.2	10.2		540	540
23 Jul.		10.3	10.3		450	450
31 Aug.		11.2	11.2		325	325
17 Sep.		9.9	9.9		260	260
18 Oct.	0.2	13.5	13.7	70	295	365
06 Nov.	0.2	13.5	13.7	65	220	285
09 Dec.	0.3	12.0	12.3	70	215	285
$\bar{x}$			10.2			437
Se			0.8			34
1943						
12 Jan.	0.4	13.0	13.4	75	210	285
19 Feb.	0.4	14.0	14.4	50	205	255
14 Mar.	0.5	15.0	15.5	50	202	252
07 Apr.	0.5	13.5	14.0	55	145	200
22 Apr.	0.8	14.0	14.8	65	180	245
29 May	0.8	19.0	19.8	70	205	275
13 Jun.	1.1	17.0	18.1	80	200	280
07 Jul.		1.1	1.1		90	90
14 Aug.		3.1	3.1		95	95
13 Sep.	0.5	4.1	4.6	55	100	155
13 Oct.	0.6	3.9	4.5	35	100	135
24 Nov.	0.6	4.0	4.6	60	100	160
$\bar{x}$			10.6			202
Se			1.9			21
1944						
03 Jan.	0.7	4.0	4.7	45	105	150
23 Feb.	0.7	4.2	4.9	50	90	140
21 Mar.	0.8	4.1	4.9	55	160	215
19 Apr.	1.1	4.0	5.1	55	215	270
14 May	2.0	4.0	6.0	45	290	335
29 May	2.5	4.0	6.5	40	299	339
02 Jun.	3.0	4.1	7.1	40	345	385
13 Jun.	3.5	4.5	8.0	50	390	440
18 Jun.	4.9	5.1	10.0	50	490	540
14 Jul.		9.0	9.0		680	680
06 Aug.		10.0	10.0		615	615
07 Sep.		16.5	16.5		415	415
30 Sep.		17.0	17.0		400	400
$\bar{x}$			8.4			379
Se			1.1			46
1942-44						
$\bar{x}$			9.7			345
Se			0.8			25

maximum mean density of burrowing mayfly populations at this latitude (Riklik and Momot 1982). Chandler (1963) noted that large and small *Hexagenia* nymphs coexisted in the sediments of western Lake Erie (Fig. 2) and concluded that such nymphs required 2 years to mature. Lacking the actual data needed for length frequency analysis of the nymphs, I could not verify this conclusion. The population may have possessed both 1- and 2-year life cycles (cf. Hudson and Swanson 1972). Adult mayflies emerged in early July in large numbers (cf. Goodrich 1916, Burns 1985). Small (5 mm) nymphs were found in bottom sediments in August or September. Because eggs from adults of this population usually hatched in about 30 d (Britt 1955b) and 45–90 d elapsed between adult emergence and the capture of small nymphs (Fig. 2), nymphs < 5 mm long may have been rinsed with sediments from the sample residues.

The sex of burrowing mayfly nymphs less than 15 mm in length cannot be accurately determined (P.L. Hudson, U.S. Fish and Wildlife Service, Ann Arbor, Michigan, personal communication, 1990). Hence, the sex of nymphs < 15 mm long in Figure 2 is questionable. Female nymphs grew faster than males and were about 4 mm longer than males at emergence each year (Fig. 2). Both female and male nymphs were longer than 21 mm at emergence. In June, female nymphs were about 2 mm longer in 1944 than in 1942 or 1943; male nymphs were 1.5 mm longer in 1943 than in 1942 or 1944. Lacking how many nymphs there were of each sex, I could not determine the sex ratio of this population.

Inspection of Figure 2 indicates that nymphs grew in length from June to September most rapidly in 1943, more slowly in 1944, and slowest in 1942. Conversely, nymphs increased in weight most rapidly in 1944, more slowly in 1942, and slowest in 1943.

The mean nymphal biomass of this population increased during each year and reached a maximum of 19.8 wet g m⁻² in May of 1943 (Fig. 2; Table 1). From 1942 to 1944, biomass was not significantly different each year, averaging 9.7 ± 0.8 wet g m⁻² (Table 1). This average biomass was not significantly different from that of the burrowing mayfly population throughout western Lake Erie during 1951–1952 (9.6 wet g m⁻²; Wood 1963). Converted to dry weight (1.4 g m⁻²; cf. Hudson and Swanson 1972), this biomass was significantly higher than the average biomass of seven other burrowing mayfly populations in North America

(0.63 ± 0.26 g m^{-2}; Riklik and Momot 1982). Compared with other *Hexagenia* populations in the Great Lakes basin, the population in western Lake Erie in 1942 had the highest biomass (Rasmussen 1988: Fig. 2).

Prior to 1953, this *Hexagenia* population in western Lake Erie was, geographically, perhaps the largest ever recorded. *Hexagenia limbata* is abundant only in eastern and central North America (Edmunds *et al.* 1976, Rasmussen 1988). Within that region, Lake Erie is one of the largest lakes (Herdendorf 1982) and its western basin (area = 3,680 km^2; Burns 1985) meets all habitat requirements of burrowing mayflies (Hunt 1953, Rasmussen 1988). For example, western Lake Erie is shallow (mean depth, 7.6 m); it is constantly supplied with large amounts of organic matter from the Detroit River (Edwards *et al.* 1989); and most of its bottom surficial sediments are soft mud and clay (Thomas *et al.* 1976, Burns 1985). Prior to 1953, *Hexagenia* nymphs were as numerous throughout the open lake area of western Lake Erie as they were around South Bass Island but were less numerous around the mouths of the three major tributaries to the basin (Shelford and Boesel 1942, Wright 1955). By extrapolating the mean *Hexagenia* biomass in the open lake area in 1951 (9.6 g m^{-2}; Wood 1963) over half the area of western Lake Erie (1,840 km^2), I calculated that the basin supported a total biomass of 9.6 t · km^{-2}, or at least 17,660 wet metric tonnes of mayfly nymphs before 1953. This high biomass represented a benthic food chain that provided abundant energy for fish production.

The density of *Hexagenia limbata* nymphs may be a suitable objective for measuring the recovery of naturally mesotrophic Great Lakes waters from eutrophication (Reynoldson *et al.* 1989, Edwards and Ryder 1990). The *H. limbata* population has recovered somewhat in the Detroit River from a maximum of 40 nymphs m^{-2} in 1968 to an average of 94 m^{-2} in 1985 (Thornley 1985, Schloesser *et al.* 1991) and small numbers of *H. limbata* nymphs (1–15 m^{-2}) were discovered in 1982 in western Lake Erie around the mouths of the three major tributaries (Manny *et al.* 1991). In 1930, the average density of *Hexagenia* nymphs around these tributaries was 123 m^{-2} in the Maumee River area, 15 m^{-2} in the Raisin River area, and 32 m^{-2} in the Detroit River area (Carr and Hiltunen 1965). As evidence accumulates that *Hexagenia* nymphs are recolonizing western Lake Erie, these historic data may be useful in assessing the recovery of burrowing mayflies and the habitat quality of their bottom substrates.

ACKNOWLEDGMENTS

I thank Dr. D. C. Chandler for generously providing Figure 2, Dr. N. W. Britt for some details about methods used to collect the data, Eileen Bartels for library assistance, Marilyn Murphy for typing the manuscript, and D. R. Barton, D. C. Chandler, J. E. Gannon, P. L. Hudson, D. M. Pugh, E. J. Rockell, D. W. Schloesser, J. M. Selgeby, and D. A. Wilcox for reviewing the manuscript. Contribution 775 of the National Fisheries Research Center-Great Lakes, U.S. Fish and Wildlife Service.

REFERENCES

Beeton, A. M. 1961. Environmental changes in Lake Erie. *Trans. Am. Fish. Soc.* 90:153–159.

________ . 1969. Changes in the environment and biota of the Great Lakes. In *Eutrophication: Causes, Consequences, Correctives*, pp. 150–187. Washington, D.C.: Natl. Acad. Sci.

Britt, N. W. 1955a. Stratification in western Lake Erie in summer of 1953: Effects on the *Hexagenia* (Ephemeroptera) population. *Ecology* 36:239–244.

________ . 1955b. *Hexagenia* (Ephemeroptera) population recovery in western Lake Erie following the 1953 catastrophe. *Ecology* 36:520–522.

Burns, N. M. 1985. *Erie, the lake that survived.* Totawa, New Jersey: Rowman and Allenheld.

Carr, J. F., and Hiltunen, J. K. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. *Limnol. Oceanogr.* 10:551–569.

Chandler, D. C. 1963. Burrowing mayfly nymphs in western Lake Erie previous to 1947. (Abstract). In *Proceedings of the Sixth Conf. Great Lakes Res.*, p. 267. Internat. Assoc. Great Lakes Res.

Edmunds, G. F., Jr., Jensen, S. L., and Berner, L. 1976. *The mayflies of North and Central America.* Minneapolis: Univ. Minnesota Press.

Edwards, C. J., and Ryder, R. A. 1990. *Biological surrogates of mesotrophic ecosystem health in the Laurentian Great Lakes.* Report to Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario

________ , Hudson, P. L. Duffy, W. G., Nepszy, S. J., McNabb, C. D., Haas, R. C., Liston, C. R., Manny, B. A., and Busch, W. N., 1989. Hydrological, morphometrical, and biological characteristics of the connecting rivers of the International Great Lakes: a review, pp. 240–264. *In* D.P. Dodge [ed.] *Proceedings of the International Large River Symposium.* Can. Spec. Publ. Fish. Aquat. Sci. 106.

Ewers, L. A. 1933. Summary report of Crustacea used as food by the fishes of the western end of Lake Erie. *Trans. Am. Fish. Soc.* 63:379–390.

Goodrich, C. 1916. A trip to islands in Lake Erie. *Annals Carnegie Mus.* 10:527–531.

Herdendorf, C. E. 1982. Large lakes of the world. *J. Great Lakes Res.* 8:379–412.

Horst, T. J. 1976. Population dynamics of the burrowing mayfly *Hexagenia limbata*. *Ecology* 57:199–204.

Hudson, P. L., and Swanson, G. A. 1972. Production and standing crop of *Hexagenia* in a large reservoir. Studies in the natural sciences. Vol. 1, No. 4. Nat. Sci. Res. Inst., Portales, New Mexico.

Hunt, B. P. 1953. The life history and economic importance of a burrowing mayfly (*Hexagenia limbata*) in southern Michigan lakes. *Mich. Dep. Cons. Bull. Inst. Fish. Res.* 4:1–151.

Manny, B. A., Hiltunen, J. K., Schloesser, D. W., and Judd, J. H. 1991. Changes in the bottom fauna of western Lake Erie from 1961 to 1982. U.S. Fish. Wildl. Serv., Natl. Fish Res. Cent.—Great Lakes, Ann Arbor, Mich. Unpubl. MS.

Price, J. W. 1963. A study of food habits of some Lake Erie fish. *Bull. Ohio Biol. Survey* 2:1–89.

Rasmussen, J. B. 1988. Habitat requirements of burrowing mayflies (Ephemeridae:*Hexagenia*) in lakes, with special reference to the effects of eutrophication. *J. N. Am. Benthol. Soc.* 7:51–64.

Reynoldson, T. B., Schloesser, D. W., and Manny, B. A. 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes waters. *J. Great Lakes Res.* 15:669–686.

Riklik, L., and Momot, W. T. 1982. Production ecology of *Hexagenia limbata* in Savanne Lake, Ontario. *Can. J. Zool.* 60:2317–2323.

Schloesser, D. W., Edsall, T. A., Manny, B. A., and Nichols, S. J. 1991. Distribution of *Hexagenia* nymphs and visible oil in sediments of the upper Great lakes connecting channels. *Hydrobiologia* 219:345–352.

Shelford, V. E., and Boesel, M. W. 1942. Bottom animal communities of the island area of western Lake Erie in the summer of 1937. *Ohio J. Sci.* 42:179–190.

Spieth, H. T. 1941. Taxonomic studies on the Ephemeroptera II. The genus *Hexagenia*. *Am. Midland Natur.* 26:233–280.

Steel, R. G. D., and Torrie, J. H. 1960. *Principles and procedures of statistics.* New York: McGraw-Hill.

Thomas, R. L., Jaquet, J.-M., Kemp, A. L. W., and Lewis, C. F. M. 1976. Surficial sediments of Lake Erie. *J. Fish. Res. Board Can.* 33:385–403.

Thornley, S. 1985. Macrozoobenthos of the Detroit and St. Clair rivers with comparisons to neighboring waters *J. Great Lakes Res.* 11:290–296.

Verduin, J. 1963. Changes in western Lake Erie during the period 1948–1962. *Verh. Internat. Verein. Limnol.* 15:639–644.

Wood, K. G. 1963. The bottom fauna of western Lake Erie, 1951–52. In *Proceedings of the Sixth Conf. Great Lakes Res.*, pp. 258–265. Internat. Assoc. Great Lakes Res.

________. 1973. Decline of *Hexagenia* (Ephemeroptera) nymphs in western Lake Erie. In *Proceedings of the First Internat. Conf. Ephemeroptera*, W. L. Peters and J. C. Peters (eds.), pp. 26–32. Leiden, Netherlands: E.J. Brill.

Wright, S. 1955. *Limnological survey of western Lake Erie.* U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish., No. 139.