

ORIGIN AND DISPERSAL OF THE ALEWIFE, *ALOSA*
PSEUDOHARENGUS, AND THE GIZZARD SHAD, *DOROSOMA*
CEPEDIANUM, IN THE GREAT LAKES

ROBERT RUSH MILLER

Museum of Zoology, University of Michigan
Ann Arbor, Michigan

ABSTRACT

It is possible that the alewife is native to Lake Ontario and the gizzard shad to Lake Erie, although conclusive evidence for this is lacking. There appear to be no records of the alewife from Lake Ontario prior to 1873, after the lake had been stocked with American shad. That species may still occur in Lake Ontario occasionally. A tabular comparison of these species is given to facilitate identification. The alewife is referred to the genus *Alosa* (rather than *Pomolobus*) because no reliable characteristics are available to distinguish the species of these two groups.

Wilmot recorded a herring-like fish (not the American shad) from Lake Ontario about 1837 which probably was the gizzard shad, though it may have been the alewife. The first record of gizzard shad in Lake Ontario is for 1913, but the species was reported from Lake Erie in 1848, 18 years after the completion of the first canal to connect Lake Erie and the Ohio River. It is hypothesized that the gizzard shad entered Lake Erie in pre-Columbian times during a warm-dry period.

A chronological record of the appearance of alewives in the upper Great Lakes shows the first specimen reported from Lake Erie was taken in 1931, Lake Huron 1933, Lake Michigan 1949, and Lake Superior 1954; actual dates of first appearance in each lake are unknown, but the species obviously moved from Lake Erie to the other lakes via Detroit River and Lake St. Clair. The alewife did not become abundant in Lake Erie or Lake Huron until around 1950 or in Lake Michigan until about 1956; it is widely distributed but not yet abundant in Lake Superior. The phenomenal increase in abundance and spreading of the alewife may be correlated with the upset in population balance by the sea lamprey; catch statistics for the alewife and shallow water cisco (*Coregonus artedii*) from South Bay, Lake Huron, suggest a direct or indirect causal relationship during 1954-1956.

The gizzard shad does not occur north of lower New York Harbor (and there only rarely) on the Atlantic slope, although it has been reported from New Brunswick, where it was probably misidentified for the alewife. Its inland range has been extended by canal connections and perhaps it reached Lake Erie in this way; it definitely entered Lake Michigan through the Chicago River canal. A reference in 1874 to the "saw-belly" from the Great Lakes undoubtedly represents the gizzard shad, also known by that name. The species has evidently spread to Lake Ontario and the vicinity of Quebec by moving through the Welland Canal, and to Lake Huron via the Detroit River and Lake St. Clair. The first specimen known to be taken in Lake Michigan was caught on October 13, 1953, west of Muskegon, Michigan; another was taken near Gary, Indiana, on November 2, 1953. The gizzard shad has not been reported from Lake Superior where cold, deep water may prohibit its establishment. It has on occasion gained some commercial importance in Lakes Erie and Huron, where

31,600 pounds valued at \$930 were taken in 1949. The gizzard shad may have been aided in expanding northward by the warming climatic trend of the past half century.

The two species, particularly the alewife, are steadily increasing in abundance and methods of utilizing this new resource should be devised.

INTRODUCTION

Three species of the herring family, Clupeidae, which is predominantly marine, have been reported from the Great Lakes drainage. The American shad, *Alosa sapidissima* Wilson, has been listed as native to Lake Ontario (e.g., by Hubbs and Lagler, 1947, p. 34), although others claim that it first appeared there when planted by the U.S. Fish Commission in the 1870's (Smith, 1892, pp. 193-194; Evermann and Kendall, 1902, p. 213). The species was last recorded from Lake Ontario in 1931, but it occurs in the lower Ottawa River and stragglers may occasionally reach the lake (Radforth, 1944, pp. 94-95). As detailed below, the alewife, *Alosa pseudoharengus* (Wilson), may have penetrated the Great Lakes drainage from the St. Lawrence River as far as Lake Ontario. It has been able to surmount the barrier of Niagara Falls by passing through the Welland Canal into Lake Erie, from which it has spread throughout the Great Lakes. The gizzard shad, *Dorosoma cepedianum* (LeSueur), probably entered the Great Lakes drainage naturally from the Mississippi River basin via Lake Erie and then moved eastward into Lake Ontario. Its recent occurrence in Lake Michigan, on the other hand, seems clearly the result of immigration through the Chicago River canal; it is unknown in Lake Superior or in the northern parts of Lake Huron and Lake Michigan.

Because fishery biologists and others have difficulty in distinguishing these three species, some of the distinctive external characters are indicated (Table 1) in order to facilitate identification, particularly of young fish. Leim (1924, p. 227, figs. 28-31) gave additional characters that distinguish shad from alewives, including photographs of early life-history stages. An adult gizzard shad (unless injured) is easily recognized by the greatly lengthened last dorsal ray, as well as by the small, inferior mouth and deep body. The position of the dorsal fin, relative length of the anal fin, and comparative size of the upper jaw provide field characters for distinguishing smaller specimens of the three species. Vertebral counts do not overlap between the alewife and the shad or between the gizzard shad and the shad. As Graham (1956, p. 20) has shown, populations of the alewife from Lake Ontario have fewer vertebrae than do those of Atlantic coastal streams.

TABLE 1.—Comparison between three species of herrings reported from the Great Lakes drainage

Character	American shad ¹	Alewife ²	Gizzard shad ³
Last ray of dorsal fin . . .	Not modified	Not modified	Modified into a long filament (inconspicuous or absent in young)
Origin of dorsal fin	Well before insertion of pelvic fins	Well before insertion of pelvic fins	Over or behind insertion of pelvic fins
Anal fin	Relatively short, with 18-24 rays	Short, with 15-20 rays	Relatively long, with 25-36 rays
Ventral scutes	Typically 22 + 16 = 38 (range, 34-39)	Typically 19 + 14 = 33 (range, 32-37)	Typically 18 + 12 = 30 (range, 27-32)
Longitudinal scale rows	52-64	45-54	52-70
Vertebrae (including hypural)	52-60	47-50	48-51
Upper jaw	Long, slender, its tip reaching posteriorly to middle of pupil in young (25 mm. T.L.) and to beyond eye in adult; no notch	Shorter and wider, its tip reaching to front of pupil in young and to rear of pupil in adult; no notch	Short and moderately wide, its tip scarcely reaching front of eye in young and front of pupil in adult; a slight notch (indentation) along ventral margin in young, becoming a deep notch in adult
Lower jaw	Strong, longer than upper jaw, not fitting into notch in upper jaw	Strong, projecting beyond upper jaw, not fitting into notch in upper jaw	Relatively weak, equal to (young) or shorter than upper jaw, fitting into notch in upper jaw
Mouth	Terminal	Terminal	Subterminal to inferior
Gillrakers	Long, slender, about 25-75 on lower limb in young to adult	Long, slender, about 20-40 on lower limb in young to adult	Very long, fine, close-set, about 90-275 on lower limb in young to adult

¹Vertebral counts taken from Vladykov and Wallace (1938); number of anal rays in part from Leim (1924, p. 224); gillraker counts approximated from Hildebrand and Schroeder (1928, p. 94).

²Counts original, based on Great Lakes and Ontario material only, except for gillraker number which is modified from Hildebrand and Schroeder (1928, p. 89). Leim (1924, p. 206) recorded a variation of 46 to 51 vertebrae in Atlantic Coast alewives.

³All counts taken from Miller (1950) except number of gillrakers, which is original.

ALEWIFE

The scientific name of the alewife is generally given as *Pomolobus pseudoharengus* (Wilson). However, Hildebrand and Schroeder (1928, p. 93) indicated that *Pomolobus* and *Alosa* are scarcely distinct and Bailey, Winn and Smith (1954, p. 118) gave further reasons why it seems best to unite them. No clear-cut morphological characters have been proposed to distinguish as a group the species usually placed in *Pomolobus* from those assigned to *Alosa*. Moreover, the name *Pomolobus* probably rests on uncertain nomenclatural grounds, for it may be questioned seriously whether Rafinesque's description of *P. chrysochloris* (type species of *Pomolobus*) is based on this genus and species or on the Ohio shad, *Alosa alabamiae obiensis* Evermann (S. F. Hildebrand, unpublished manuscript on the Clupeidae of the Western North Atlantic). Use of *Alosa*, the older of the two generic names, therefore seems preferable.

There is no conclusive evidence that the alewife occurs naturally in Lake Ontario. Bean (1884, p. 589) and others believed it was introduced there by mistake in the 1870's when shad were planted by the U.S. Fish Commission. This has been denied (see Smith, 1892, p. 188), but evidence for nativity is weak since there appear to be neither specimens nor records of the species from Lake Ontario prior to 1873. The possibility that alewives did reach this lake from the St. Lawrence River should not be dismissed, however. Radforth (1944, p. 96) felt that they may have entered Lake Ontario during the invasion of the Champlain Sea, in the later stages of the glacial history of the Great Lakes. Toner (1934) pointed out that its presence in certain lakes whose outlets pass over barrier falls in Frontenac and Leeds counties, eastern Ontario, disproves the claim that the alewife was planted in Lake Ontario. Possibly the species reached its limits of toleration in Lake Ontario and in favorable seasons was able to establish sizable populations which were decimated during inimical years, when presumably only the hardiest individuals persisted. Since around 1890, the alewife has intermittently appeared in Lake Ontario in almost incredible numbers, as noted during periodic summer die-offs (Graham, 1956, p. 21). Whether such comparative abundance reflects recency of introduction is problematical.

The historical appearance of the alewife in the upper Great Lakes, as evidenced by captures known to the author, is given in chronological order (Table 2). The first specimen was taken in Lake Erie in 1931, in Lake Huron in 1933, in Lake Michigan in 1949 and in Lake Superior in 1954. This clearly establishes the sequence of its invasion of these lakes but the dates of first appearance in each lake are not known. As Dr. M. B. Trautman pointed out (*in litt.*), there must have been thousands of alewives in Lake Erie in 1931 before one could be caught in a net. Nevertheless, the species apparently did not really become abundant there until about 1950, although commercial fishermen caught alewives infrequently, in Ohio waters, after 1940, and there were similar reports from the Cana-

TABLE 2.—*Spread of the alewife in the upper Great Lakes*

Date	Locality	Remarks ¹
Sept. 23, 1931	L. Erie, at E. end off Nanticoke, Ont.	Adult, 7¾ in. long (Dymond, 1932).
Mar. 28, 1933	L. Huron, 12 mi. E. of Outer Duck Id., Ont.	Adult, from about 70 fathoms; others reported (MacKay, 1934).
April 15, 1935	L. Huron, 40 mi. from Rogers City, Mich.	Adult, 188 mm. S. L., from 70 fathoms; UMMZ No. 109109 (Van Oosten, 1935).
Dec. 26-31, 1940	L. Erie, off South Bass Id., Ohio	Adult, 9 in. T. L. taken in gillnet by K. H. Doan (Trautman, 1957).
Dec. 27, 1942	L. Erie, near Vermillion and Lorain, Ohio	Two adults taken in gillnet by fishermen (Trautman, 1957).
May 5, 1949	L. Michigan, W. of S. Manitou Id., Mich.	Adult, 176 mm. S. L., from 60 fathoms, Charles Anderson; UMMZ No. 157215.
Mar. 20, 1951 ²	L. Michigan, off Whitehall, 14 mi. SW. of Montague, Mich.	Adult, 197 mm. S. L., from 60 fathoms, James Grover; UMMZ No. 160969 (see <i>The Fisherman</i> , Vol. 19, No. 5, 1951, p. 6).
Mar. 12, 1952	L. Michigan, 10 mi. ENE. of Milwaukee, Wisc.	Adult, 177 mm. S. L., Frank Miller; UMMZ No. 162861.
July 13, 1953	L. Erie, on beach W. of Colchester, Ont.	Young-of-the-year taken with gizzard shad (Langlois, 1954, p. 207).
July 14, 1953	L. Erie, South Bass Id., Ohio	Young-of-the year (Langlois, 1954, p. 207).
Dec. 22, 1953 ³	L. Michigan, 12 mi. WNW. of South Haven, Mich.	Adults, 180 and 188 mm. S. L., from 32 fathoms, Chris Jensen; UMMZ No. 166514.
Sept. 25, 1954	L. Superior, off Pendill's Cr., Chippewa Co., Mich.	Adult, 168 mm. S. L., Robert Gordon; UMMZ No. 167872.
Nov., 1954	L. Superior, Chequamegon Bay, off Long Id., Wisc.	Adult, 164 mm. S. L., obtained by Russell Daly; UMMZ No. 167945.
June 1 & 14, 1955	L. Superior, Whitefish Bay, about 1 mi. N. of mouth of Tahquamenon R., Mich.	Adults, 162 and 175 mm. S. L., from pound net, Ernest L. Pomeroy.
June 3, 1955	L. Huron drainage: Ocqueoc R. Weir near Rogers City, Mich.	Adults, 179 and 182 mm. S. L., Albert E. Hall, Jr.; UMMZ No. 169062.
June 10, 1955	L. Superior, Whitefish Bay, Mich.	Adult, 197 mm. S. L., sent in by L. R. Anderson.
June 11, 1955	L. Michigan, East Bay of Grand Traverse Bay, Mich.	19 juveniles, 55-76 mm. S. L., bait dealer for Stanley Lieveense; UMMZ No. 170945.
Sept. 14, 1955	L. Huron, along shore in the Les Cheneaux Channels, Mackinac Co., Mich.	Fingerlings, about 2 in. T. L., bait dealer; ident. by L. R. Anderson.
Oct. 17 and Nov. 12, 1955	L. Superior, Gros Cap area near Sault St. Marie, Ont.	Adult male (210 mm. T. L.) and adult female (273 mm. T. L.), ident. by K. H. Loftus and W. B. Scott; ROM No. 18157 (male).
Feb. 13, 1956	L. Superior, off Two Harbors, Minn.	Adult from herring net, Adolph Ojard; ident. by John G. Hale and Samuel Eddy.

TABLE 2—Continued

Date	Locality	Remarks ¹
March, 1956	L. Superior, off Knife R., Minn.	Adult taken by Ivar Pederson; ident. by John G. Hale.
June 6, 1956	L. Superior, at mouth of Blind Sucker R., Luce Co., Mich.	Adult, 9½ in. long, caught by George McGary; 2 other adults also taken. Ident. by L. R. Anderson.
July 31, 1956	L. Superior, Split Rock R. area, Minn.	Adult, 161 mm. S. L., from herring net, Ragnivald Sve.
Aug. 31, 1956	L. Superior, off Shaganance Id. (near entrance to Black Bay), Ont.	Adult male, 166 mm. S. L., taken by Melville Gerow; ident. by R. A. Ryder.
Sept. 10, 1956 ²	L. Michigan, East Bay of Grand Traverse Bay at O-at-ka Beach, Mich.	341 postlarvae to young, 19-40 mm. S. L., taken in minnow seine for Stanley Lievense; UMMZ No. 171308.
Nov. 5, 1956	L. Superior, Keweenaw Bay, 1 mi. off town of same name, Mich.	Adult, 181 mm. S. L., from surface gillnet over 17 fathoms, taken by Uno Weideman.

¹Abbreviations are: S.L. standard length; T.L., total length; UMMZ, University of Michigan Museum of Zoology; ROM, Royal Ontario Museum.

²Approximate date.

³On April 24, May 10, and Oct. 20, 1954, 3 more adults were taken in 32-50 fathoms by Mr. Jensen from the same general area; UMMZ No. 167702.

dian waters of Lake Erie. "After 1950 the young and adults [alewives] were sufficiently numerous so that they were distributed rather regularly throughout Lake Erie. In December, 1954, they clogged the gill and fyke nets in the vicinity of Conneaut, Ohio, following a bad storm" (Trautman, *in litt.*, Dec. 20, 1956). This information is supported by Dr. W. B. Scott who wrote (*in litt.*, March 5, 1954) that ". . . in the last four or five years the alewife has definitely increased in numbers in Lake Erie." The Welland Canal has been available for this highly migratory species since 1829, and yet we have no knowledge of its occurrence in Lake Erie until 1931 (or of the equally migratory sea lamprey before 1921).

The rather sensational increase in abundance and spread of the alewife during the past decade has probably resulted from a number of changes particularly favorable to this species. Important modifications in the complex interrelationships of the native fauna have been brought about by the sea lamprey, *Petromyzon marinus*, and these disturbances may have influenced the change in alewife abundance. We do not yet have, however, sufficient biological information to be able to draw conclusions on this problem. The lake herring and alewife may compete for food and space at some stage in their life cycles since the adults rely heavily on animal

plankton. Locally, as at South Bay (Table 3), Saginaw Bay and Green Bay (information from Stanford H. Smith), the alewife populations have recently increased greatly while the lake herring stocks have decreased. Possibly, newly metamorphosed lampreys migrating across these bays to deeper water have helped to reduce the lake herrings; or, the decrease (particularly noteworthy in these bays in 1954, 1955, and 1956) may be a result of normal population fluctuation. That it has occurred simultaneously in the three bays, however, suggests some degree of causal relationship, direct or indirect, between the alewife, lake herring and lamprey (and possibly other species).

The alewife is now abundant in many parts of Lake Huron and Lake Michigan. During the period May 6, 1954, to March 10, 1955, when the U. S. Fish and Wildlife Service research vessel M/V CISCO made thirteen cruises in the southern part of Lake Michigan (mostly south of a line joining Milwaukee and Grand Haven, but north to a line joining Manitowoc and Ludington), no alewives were caught. On the other hand, during nine similar cruises in the northern half of Lake Michigan, over the period May 10 to November 12, 1955, 21 alewives were taken from 10 stations. Nevertheless, by late 1953 the alewife had moved as far southward in Lake Michigan as the vicinity of South Haven (Table 2, item 11). Moreover, in a memorandum dated January 2, 1957, Max A. Hunt (District Fisheries Supervisor, Plainwell, Michigan) reported that "Commercial fishermen, fishing out of Saugatuck, report the alewife is being caught in their "chub" nets in up to 43 fathoms of water. There have been 200-300 fish taken in a single lift. The fishermen are complaining about the alewife fouling their nets." Saugatuck is about 20 miles north of South Haven and well within the southern half of Lake Michigan.

The author is indebted to Leonard S. Joeris for the following information on the alewife in the Green Bay area of Lake Michigan. The first indication of spawning was noted in October, 1953, when two or three schools of small alewives were present in the carp-holding ponds near Duck Creek, Wisconsin (at the southern tip of Green Bay). Additional reliable reports of schools of young were received in the early fall of 1954 and

TABLE 3.—*Catch of alewife and lake herring in South Bay, Lake Huron, Ontario* (all fish taken in 1½ inch mesh five-pound nets fished in same location)

Year	Pounds alewife	Pounds herring	Number of lifts
1951.....	0.2 (1 fish)	36,018	175
1952.....	1.0 (5 fish)	14,119	163
1953.....	6.0 (51 fish)	12,625	65
1954.....	2,316	8,731	97
1955.....	16,302	4,841	86
1956 ¹	22,428	3,476	93

¹Figures for 1956 are provisional, subject to checking, but final figures could vary only a few pounds from those given.

1955. The number of adults has increased yearly from a single individual in 1952 to common occurrence by 1955 in all herring pound nets—yet not in sufficient numbers to cause difficulty for the fishermen. By the spring of 1956, however, fishermen in the Ellison Bay and Gills Rock area (on the eastern side of Green Bay) were becoming quite concerned by the continuing increase of the alewife. A steady increase in numbers has also occurred for the gillnet fishery along the northern part of Green Bay and Lake Michigan.

Alewives are now abundant in the Saginaw Bay area of Lake Huron. For example, during operations of the CISCO over the period May 3 to October 25, 1953, 6 of 9 cruises caught this species. While trawling in a very shallow area near the southwest end of the Bay, about 6,000 alewives, 1.5 to 3.0 inches long, were taken in a 35-foot trawl in one 5-minute bottom tow, and 8,500 were caught in a 5-minute tow just off the bottom. Over 50 percent of all fishes caught in trawling operations by the CISCO were alewives (information from Stanford H. Smith).

Records up to the fall of 1956 suggest that the alewife may not yet have established itself in numbers in Lake Superior although it has rapidly dispersed there. The CISCO ran nine cruises on the lake during May 3 to October 25, 1953, and took no alewives, although their nets were fished in some of the regions from which the species was obtained soon thereafter (Table 2.)

Van Oosten (1935) felt that the alewife probably entered Lake Huron through Georgian Bay directly from Lake Ontario via the Trent River-Trent Canal-Lake Simcoe-Severn River waterway, rather than by way of the Detroit River and Lake St. Clair, since the species had not been reported from the last two areas. In response to my query regarding this possibility, Dr. W. B. Scott wrote (Jan. 2, 1957) that there are no records of this species (or of *Petromyzon*, *Osmerus* or *Anguilla*) from Lake Simcoe, or any other major portion of the waterway, even though the habitat there seems to be excellent for all of these fishes. The proposed route is a very involved, even tortuous one, and the water flows through hydroelectric plants at two marine railways at the western end of the system. Failure to take alewives in Detroit River is not surprising, since organized collecting there (as by the Michigan Institute for Fisheries Research) has been carried out chiefly in shallower waters than those which the alewife habitually seeks. Radforth (1944, pp. 95-96) also concluded that the alewife reached Lake Huron via the Detroit River and Lake St. Clair.

It seems evident that the alewife will become increasingly abundant in the Great Lakes and that utilization of this new resource should be encouraged. The species may well establish itself, by distribution in bait¹ buckets, in such inland lakes as Crystal Lake, Benzie County, Michigan.

¹On July 6, 1956, an alewife 139 mm. S.L. was taken by I. A. Rodeheffer and J. K. Day in Mullet Lake, Cheboygan Co., Michigan (specimen in UMMZ collection).

According to Robert Heffner, bait dealer from Beulah, it occurs nearby in Betsie River, near Frankfort, and at the mouth of Platte River; he has observed dense schools of alewives at sizes up to 4 inches at Frankfort. Although they do not survive well when collected in large numbers, a few do live and it is difficult to sort them all out from bait species. Alewives have been used in Lake Ontario as a ready source of cheap food as well as for fertilizer, and on the Atlantic coast they are marketed fresh, smoked or pickled.

GIZZARD SHAD

Discussion regarding the northern limit of this species, both for the Atlantic seaboard and for the Great Lakes-St. Lawrence basins, has been frequently published. Early errors in range statements and evidently in identification have led to subsequent confusion. Some of the controversy, however, also hinges on the question of whether *Dorosoma* is native in the Great Lakes drainage.

At least as early as the 1870's, Gill (1873, p. 811) erred by including Cape Cod in the distribution of this species. Subsequently, Jordan and Gilbert (1883, p. 271) and others perpetuated the error. The author has been unable to discover the basis for listing Cape Cod as the northern limit of the gizzard shad on the Atlantic seaboard, but the locality has persisted in the literature almost to the present (e.g., see Vladykov, 1945, p. 36). *D. cepedianum* is uncommon north of latitude 40° N. in New Jersey and southeastern Pennsylvania, and reaches its northern coastal limit in New York Harbor, usually called the Lower Bay or Sandy Hook Bay (Breder and Nigrelli, 1934, p. 194; Breder, 1938, pp. 23, 28). Halkett (1913, p. 46) stated that this species has been recorded from St. John River, Fredericton, New Brunswick, and this formed the basis of the inclusion of New Brunswick in the range of *Dorosoma cepedianum* by Hubbs and Lagler (1947, p. 34) and by Radforth (1944, p. 58). As pointed out by Vladykov (*op. cit.*), the New Brunswick record is based upon the remarks of an unknown author, who, in a review of Nash's Check List of the Fishes of Ontario, wrote of *D. cepedianum*: ". . . it is a native Canadian fish, and was recorded by the late Edward Jack on the St. John River, at Fredericton, N. B. . . ." The St. John River is a tributary of the Bay of Fundy and its mouth lies more than 500 miles northeast of the northernmost known coastal limit of *Dorosoma*. This record is therefore unacceptable; the fish thought to have been a gizzard shad very likely was the alewife, which occurs as far north as Newfoundland and has been confused with the gizzard shad.

Kirtland (1850, p. 2) appears to have been the first to suggest that *Dorosoma* entered the Great Lakes (i.e., Lake Erie) via canal connections, and this belief has been variously accepted and restated by subsequent authors during the succeeding century. The problem is complicated by the

very different physical conditions of Lake Michigan and Lake Erie, the only two of the Great Lakes which offered direct access to the gizzard shad in glacial or postglacial times. More than a dozen species, representing three families, show a distributional pattern in Michigan that clearly indicates penetration from the south into southeastern Michigan. These fishes invaded the Lake Erie basin by utilizing the former outlet (now Maumee River) of the glacial precursor of Lake Erie, or by way of other natural connections across the very low divide between that basin and the Mississippi River system. Yet not one of these species is known from the adjacent drainage of Lake Michigan. It seems evident that the colder, deeper water of that lake has served as an effective barrier to these fishes, as it evidently has, until very recently, to the gizzard shad. Thus, although this species was reported by Nelson (1876, p. 44) from the Chicago River canal and Lake Michigan, there is no objective evidence to show that the gizzard shad established itself in the lake by migration from the Illinois River until recent years. There are no specimens of this species from the southern tip of Lake Michigan in the Chicago Natural History Museum (or any other collection), and Forbes and Richardson (1919, Map 8) gave no records nearer Lake Michigan than the junction of Fox and Illinois Rivers in La Salle County, Illinois; furthermore, Gerking (1945, Map 8) did not find it in the Lake Michigan drainage of Indiana.

Whether *Dorosoma* is native to Lake Erie cannot be proved conclusively because, to the author's knowledge, there are neither specimens nor records of gizzard shad from this lake prior to the completion in 1830 of the first canal connecting the Ohio River with Lake Erie. The first specimens of *Dorosoma* to be reported from the Great Lakes were four fish recorded by Kirtland (*loc. cit.*) in November, 1848, from near the mouth of the Cuyahoga River at Cleveland. He was certain that this species did not occur in Lake Erie or its tributaries in 1840, and believed the specimens captured in 1848 represented recent invaders from the south. Kirtland was perhaps overimpressed by the winterkill of many gizzard shad during a hard freeze in the Dayton Canal, since he cited this as evidence that *Dorosoma* "was a native of a warmer climate." He was also impressed with the failure of fishermen to recognize the gizzard shad near Cincinnati much before 1840 and with their stated belief that it was an emigrant from the south. Klippert (in Jordan, 1882, pp. 870-871) also believed that the gizzard shad was not native to Lake Erie; he wrote that "before the construction of the Ohio Canal it was not found anywhere north of the divide, or water shed between the lake [Erie] and the Ohio River." According to Jordan (*op. cit.*, p. 742), Mr John H. Klippert was "a close observer and excellent amateur ichthyologist."

In November, 1877, Samuel Wilmot (1879) collected a specimen of *D. cepedianum* from Sarnia, Ontario, at the southern tip of Lake Huron. It was identified by Baird as *Dorosoma cepedianum heterurum* and the author has verified that it is a gizzard shad (USNM No. 20836). In transmitting

this specimen, Wilmot wrote that "Fish very similar in appearance to this one have been known in Lake Ontario and other of our waters for many years; I recollect them forty years ago." This would have been about 1837. Wilmot was a pioneer fish culturist and supervisor of the Canadian salmon hatchery at Newcastle on Lake Ontario (Milner, 1874, pp. 25, 58, 228, 231), and he surely knew the American shad; his testimony strongly suggests that the gizzard shad inhabited the Lake Ontario basin as early as 1837, although it is possible that the species he referred to may have been the alewife. The first published record of the gizzard shad in Lake Ontario that I have noted is for 1913, when Nash reported the species to be very rare (see Dymond, Hart and Pritchard, 1929, p. 14). Since it is now known from an actual specimen that *Dorosoma* occurred in Lake Huron in the 1870's, it seems obvious that the reference by Milner (1874, p. 36) to the "saw-belly," identified as *Pomolobus chrysochloris* Rafinesque, actually represents one of the early records of *Dorosoma cepedianum* from the Great Lakes (which lake was not specified). This conclusion was first expressed by Hubbs and Lagler (1947, footnote, p. 34).

Although the possibility that *Dorosoma* first entered Lake Erie through canals cannot be ruled out, it is perhaps more plausible to regard this species as a postglacial migrant into Lake Erie. This view is favored by Trautman (1957). On the northern fringe of its range *Dorosoma* is near the limit of its thermal tolerance, forging northward during a series of favorable years and then, under adverse conditions, becoming almost eliminated (see, for example, Cox, 1896, p. 610). When numbers are killed and fishermen see the species for the first time, they fail to recognize it and conclude that it is a recent invader from a more southern clime. Dr. Trautman wrote me that this has happened innumerable times in Ohio since Kirtland's day. Perhaps the gizzard shad gained access to Lake Erie during a warm-dry period in pre-Columbian times and then, with the return to present conditions, it retreated but left relict populations. *Dorosoma* is favored to establish outlying colonies because spawning adults enter small streams or ditches, provided they are of low gradient, and the young are later abundant there. In early historic time, there were many places along the divide between the Ohio and Lake Erie watersheds (e.g., the close approach of the Maumee and Wabash drainages near Ft. Wayne, (Indiana) where *Dorosoma* could readily have crossed from one drainage to the other. It is also possible, as Gerking (1945, p. 33) suggested, that the gizzard shad may have entered the glacial precursor of Lake Erie through the Ft. Wayne outlet (Maumee River), but this view seems less acceptable because *Dorosoma* does not appear to be adapted to very cold water, such as prevailed during the melting of the continental glaciers in the evolution of the Great Lakes. The species occurs in the Great Lakes drainage of Indiana only in the Maumee River system (Gerking, *op. cit.*, Map 8). There appears to be no need for nor support of the hypothesis (Radforth, *loc. cit.*) that *Dorosoma* utilized the Mohawk-Hudson glacial

outlet (or the Chicago-Ubly outlet) to enter Ontario; if it utilized glacial waterways at all, the Maumee outlet seems to be the only possible one that it might have entered. Vladykov (*op. cit.*) concluded that this species reached the environs of Quebec by descending the St. Lawrence River from the Great Lakes.

Thus the gizzard shad, as perhaps with the alewife in Lake Ontario, apparently neared the limit of its tolerance in Lake Erie. Its increase and spread in the lower Lakes may well reflect the known warming climatic trend (Baum and Havens, 1956) or may be a response to changing biotic conditions of the Great Lakes in recent decades—or both phenomena may be operative. That the species has entered canals and thus extended its range seems well founded (e.g., see Wright, 1918, p. 544; Greeley, 1928, p. 95).

The first valid records (based on identified, preserved specimens) of *Dorosoma cepedianum* from Lake Michigan are the following: UMMZ No. 165645, an adult, 255 mm. S. L., taken by the McNab brothers, on October 13, 1953, in a trap net in 14 feet of water about 1 mile south of the channel connecting Lake Michigan and Muskegon Lake, west of Muskegon, Michigan. A second specimen, an immature female in poor condition identified by the author and then discarded, was obtained by D. C. Erlandson from a pound net set in 25 feet of water, on November 2, 1953, off Miller, 5 miles east of Gary, Indiana. The evidence clearly points to a southern origin for these stocks, since no specimens have been reported in the northern half of Lake Michigan or in northwestern Lake Huron. *Dorosoma* has thus gradually extended its range into Lake Huron by emigration from Lake Erie and into Lake Michigan through the Chicago River Canal. The gizzard shad has not been reported from Lake Superior, where low temperature and the absence of shallow water may preclude its establishment.

This species has had a long history of fluctuating abundance in Lake Erie but it evidently has rather recently established itself in numbers in certain parts of Lake Huron. For example, Bensley (1915) did not record it from Georgian Bay, and when Walter Koelz collected a specimen there late in 1919 (UMMZ No. 55632), fishermen informed him that the gizzard shad had rather recently appeared and that all those taken were small. Today the species is fairly common in suitable parts of Georgian Bay. It was so abundant in Detroit River and Lake St. Clair in the fall of 1932 that unemployed persons caught them for food with dipnets and hook and line. By October 7, 1933, the gizzard shad had moved inland up the Saginaw River drainage as far as Pine River at St. Louis, Gratiot Co., Michigan (UMMZ No. 101607, 1 adult); this is one of the few records of its occurrence well inland from the Great Lakes and populations have not established themselves at appreciable distances inland. An attempt was made to establish the species in Whitmore Lake, Washtenaw and Livingston Counties, Michigan, in August, 1935, when the Michigan Institute for Fisheries Research stocked 124 individuals (1.5 to 15.0 inches S. L.)

from Lake St. Mary's, Ohio. It is estimated that 100 adult shad survived after one week, but if so, successful reproduction did not occur and the introduction failed (IFR Report No. 315; see also Cooper and Schafer, 1954).

Abundance in lakes Erie and Huron since about 1940 is indicated by the commercial catch statistics (U. S. Fish and Wildlife Service and Michigan Department of Conservation) which show that a total of approximately 116,000 pounds valued at \$2,300 were taken during the period from 1942 to 1954. The largest catch for a single year, 31,600 pounds valued at \$930, was taken in 1949. Occasionally, sudden mortality of vast numbers (similar to that of the alewife in Lake Ontario) creates a public nuisance, as it did at Erie, Pennsylvania, during January-February, 1953. (This and other aspects of the biology of the gizzard shad are summarized by me in a paper to be published by the U. S. Fish and Wildlife Service entitled: "The clupeid fishes of the subfamily Dorosomatinae, with special reference to the gizzard shad, *Dorosoma cepedianum*.")

The gizzard shad is not as widespread in the Great Lakes as the alewife, probably because its preferred habitat is less extensive, and, except locally, it is not likely to attain or exceed the population size of that species. It has been utilized in the Great Lakes as a source of food for trout, swine and cattle, as fertilizer, and it has been steamed and pressed for oil.

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