Herring Family—Clupeidae

Three species of herrings in two genera are known from Wisconsin. In the United States and Canada 27 species in 9 genera are known (Robins et al. 1980).

The herring family contains many important marine species (e.g., herrings, shads, menhadens, and sardines), several of which are anadromous and enter fresh water to spawn. These fishes occur throughout the seas of the world, except for Antarctic waters. Among these are a few which have abandoned the marine phase of their existence. A few species live permanently in fresh water. Economically, the order Clupeiformes is an important group of fishes, and in terms of money value probably the most valuable in the world.

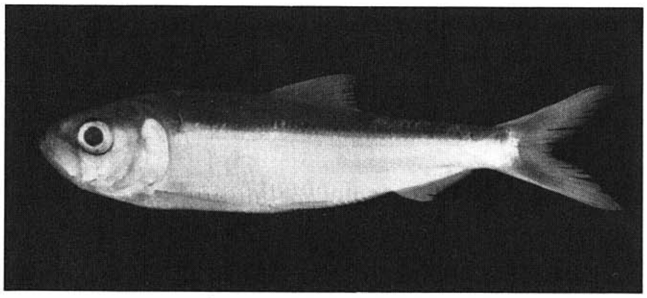
The herrings possess a row of modified scales, called scutes, along the midventral edge of the belly; these scales form a distinct sawtooth margin. All species have a transparent eye covering (adipose eyelid) with a vertical slit. All have the pelvic axillary process.

The herrings are spring spawners and the anadromous species crowd into streams in spectacular runs. Presumably, the eggs are deposited at random, and no care is given to them or to the newly hatched young.

Alewife

Alosa pseudoharengus (Wilson). *Alosa*—Saxon *Allis*, old name of the European shad, *Alosa alosa*; *pseudo*—false, *harengus*—herring.

Other common names: ellwife, sawbelly, sawbelly shad, shad, golden shad, branch herring, big-eyed herring, river herring, spring herring.



Adult 180 mm, L. Michigan (Door Co.), 3 July 1963

DESCRIPTION

Body oblong, strongly compressed laterally, depth into SL 3.0–3.7. Length 150–180 mm. Head length into SL 3.5–4.3. Mouth large, maxillary reaching below middle of eye; lower jaw projecting beyond upper jaw. Jaw teeth small, weak, and few. Gill rakers on lower limb of the first arch 41–44; upper limb of first gill arch about half the length of lower limb. Scales cycloid; lateral line absent; lateral series scales 42–50. Dorsal fin usually 13–14 rays, last ray not lengthened beyond the fin; dorsal fin insertion directly over or slightly in advance of pelvic fin insertion. Anal fin rays usually 17–18. Caudal fin deeply forked. Chromosomes 2n = 48 (Mayers and Roberts 1969).

Back gray-green or brownish green becoming silvery on sides and belly. Cheek silver. Single dark "shoulder" spot in most individuals. Adults with dark, longitudinal lines along scales above midline.

Larvae separable from gizzard shad larvae by ratio of snout to vent length/SL; values for alewife larvae 3.5–19.5 mm SL range from 0.82 to 0.74 (Lam and Roff 1977).

Possible hybrid *Alosa pseudoharengus* × *Alosa aestivalis* (Vincent 1960).

DISTRIBUTION, STATUS, AND HABITAT

The alewife reached the upper Great Lakes via the Welland Canal (bypass of Niagara Falls). It was first recorded from Lake Erie in 1931 and from Lake Huron in 1933. It appeared in Lake Michigan in 1949, had dispersed throughout most of the lake by 1953 (Miller 1957), and had become common throughout the lake by 1957. In the late 1950s and early 1960s the population increase was explosive. In Lake Superior it was first reported in 1953, and its numbers appear to be increasing there (McLain et al. 1965).

Movement of alewives into new areas occurred after high-water conditions, and the resultant increased current and high levels in the connecting canals and rivers may have served as a stimulus to the anadromous habits of this species (Graham 1954).

The alewife was observed running into Kangaroo Lake (Door County) and up the Pigeon River system in Sheboygan and Manitowoc counties, apparently establishing a permanent population in Pigeon Lake (L. Kernen, pers. comm.). It has been reported in East Twin River (Manitowoc County), Sheboygan River (Sheboygan County), Sauk Creek (Ozaukee County), and Milwaukee River (Milwaukee County). In Lake Superior it rarely occurs in tributary streams (McLain et al. 1965).

The alewife is abundant in Lake Michigan and common in Lake Superior. In Lake Michigan it constitutes 70–90% of the fish weight, and by sheer weight of numbers has dominated the fishery of the lake.

The present system in Lake Michigan—in which a single species, the alewife, makes up a major share of the forage fish of the lake—is not stable. According to S. H. Smith (1968a), the instability is accentuated because the alewife is highly sensitive and not well adapted to its life in fresh water. Its abundance has fluctuated widely in the other Great Lakes where it has already reached its peak. Causes of these fluctuations are not known and cannot be anticipated. Overfishing or overpredation during the low cycle of a fluctuation could cause the alewife population to collapse. It seems unlikely that the alewife can persist at its present level of abundance in Lake Michigan; a drop to a population level somewhat less than the present level may be expected.

In Lake Michigan the alewife inhabits all levels over all bottom types. It avoids cold water, and during the winter searches out the warmest areas—at the bottom in the deep portions of the lake. The cold water of Lake Superior may have deterred establishment of a substantial population there (S. H. Smith 1972).

BIOLOGY

Spawning occurs from June to August. In 1965 spawning in the harbor areas of Lake Michigan extended from the end of June to the first part of August, with the peak occurring during the first 2 weeks

Range of the alewife
- ● Specimens examined
- ▲ Wisconsin Fish Distribution Study (1974–75)
- ○ Literature and reports

of July (Norden 1967a). The majority of spawning alewives were in age groups II and III (158–172 mm); the females produced from 11,000 to 22,000 eggs, compared to the 60,000–100,000 eggs in the larger marine alewife (Graham 1954). Norden noted some ripe individuals, mostly males, of age group I, but no age-0 fish were in spawning condition. In mature fish the testes made up about 5% of total body weight, the ovaries 10%.

In Lake Michigan, 5,000–6,000 spawning fish have been seen in schools 4.5–6 m (15–20 ft) diam (Threinen 1958). While on their inshore migration, they come into shallow water at night and remain offshore during the day.

In Lake Ontario spawning occurred at temperatures of 13–16°C (55–60°F). But temperatures during the spawning period may vary considerably, and L. Wells (pers. comm.) reported that, although during the same period of time alewives are found in water with temperatures ranging from 5°C (41°F) or less to 20°C (68°F) or more, most are found in water warmer than 8°C (46.4°F). Alewives tend to avoid temperatures greater than 22°C (71.6°F), but in some spawning streams they must occasionally endure temperatures of 25°C (77°F) or more. In the Milwaukee Harbor during July and August, Norden (1967b) collected developing eggs and larvae at surface water temperatures ranging from 17.5 to 21.1°C (63.5–70°F).

Spawning was observed by Edsall (1964) on the Kalamazoo River, Michigan, about 3.2 km (2 mi) upstream from Lake Michigan. Observations were made off a 24-m (80-ft) dock where the water depth was 3 m (10 ft). The spawning act involves two or more fish which swim rapidly with sides touching in a tight circle 20–30 cm (8–12 in) diam spiraling upward from the depths. The act terminates after one or two circles have been completed at the surface. The spawners then swim rapidly downward and out of sight. Spawning was first observed late in the afternoon (1700 hr) and reached a peak at 0200 hr, when spawning could be heard clearly. (The termination of the spawning act involves considerable splashing.) According to Odell (1934), there seems to be no preferred type of bottom.

Spawning itself has been thought to be a factor in alewife die-offs, but dead or dying alewives are seldom seen in areas where spawning is taking place (S. H. Smith 1968a). Norden (1967a) suggested that perhaps alewives spawn but once.

In Lake Michigan alewives, the eggs are pale yellow and about 1 mm diam (Norden 1967b). Newly hatched larvae average 3.8 mm TL; the yolk-sac is absorbed 3 days later when the larvae average 5.1 mm. Larvae 19.1 mm long begin to develop adult features, and at 35 mm (1.4 in) their body form closely resembles that of the adult. Instructions for distinguishing alewife larvae from those of trout, cisco, smelt, and gizzard shad are provided by Norden.

The smallest individual containing food (copepods) was 5.9 mm long (Norden 1968). Cladocerans first appeared in the digestive tracts of 9.5-mm larvae. Cladocerans and copepods generally constitute over 75% of the total number of organisms consumed, with *Cyclops* and *Bosmina* contributing a high percentage of the plankton eaten.

According to Threinen (1958), eggs kept in the laboratory at 13.3–15.6°C (56–60°F) in running water and at 15.6–23.3°C (60–74°F) in standing water hatch in 81–132 hours. Hatching begins in 2 days and is completed at the end of 6 days at 15.6°C (60°F).

Norden (1968) noted that attempts to rear larval alewives in the laboratory failed, death occurring after the absorption of the yolk-sac, about 3 days after hatching. Heinrich (1977) overcame this problem by presenting a mixture of wild zooplankton (mostly copepod nauplii, cyclopoid copepodites, and the cladoceran *Bosmina longirostris*, ranging in maximum dimension from 0.2 to 0.9 mm) twice each day, beginning the day of hatching. The fry are both phototropic and pelagic (Threinen 1958).

Morsell and Norden (1968) found that zooplankton predominate in the stomachs of fish taken from the shore zone (0–1.2 m depth) of Lake Michigan, Milwaukee Harbor, and Green Bay; whereas *Pontoporeia*, a deepwater amphipod, predominates in the littoral (9–30-m depths) and profundal zones (depths greater than 30 m). As the lengths of the alewives increase, a progressively greater proportion of *Pontoporeia* is found. *Limnocalanus macrurus* is the dominant zooplankton in the food of alewives caught in the winter, whereas *Cyclops bicuspidatus* and *Diaptomus* sp. dominate during the other seasons. *Mysis relicta* contribute a small portion of the profundal and littoral diet for those alewives longer than 139 mm (5.5 in). Tendipedid larvae and pupae are found in alewives from all zones but are important only in the shore zone, where they contribute 58.5% of the dry weight of the stomach contents of fish in the 60–119-mm (2.4–4.7-in) size group. Filamentous algae, mostly *Cladophora*, often constitute more than 50% of the volume of stomach contents from fish taken in the shore zone of Lake Michigan and Green Bay, probably ingested incidentally to feeding on zooplankton. A few gastropods are found in alewives in the littoral zone, indicating that alewives feed on the bottom to some extent.

Gannon (1976) suggested that positive selection of *Daphnia* by alewives probably takes place in southern Green Bay, although this was not indicated in electivity indices. Laboratory studies reveal the *Daphnia* are digested most rapidly by alewives and, therefore, are under-represented in stomach contents relative to other plankton species.

Fish eggs were found by Morsell and Norden (1968) in the stomachs of 46.2% of spawning alewives and were presumed to be alewife eggs. Larger eggs from another species of fish were also found in a few stomachs of alewives collected from the littoral zone. According to Edsall (1964), during intensive spawning activity, there is considerable egg predation from both nonspawning and spawning alewives as eggs are being released during the spawning act. In addition to the alewife eggs, stomachs of the larger alewives were tightly packed with scales (probably from spottail shiners). Edsall concluded that, although large alewives may feed only lightly on alewife eggs, small alewives appear to be very effective egg consumers.

From scales and otoliths, Norden (1967a) determined ages of more than 2,000 specimens from the Milwaukee area of Lake Michigan. During the first year of life 55.7% of the total length was reached; the second year, 24.5%; the third year, 11.2%; the fourth year, 8.6%. Growth by year was: 0, about 95 mm (3.7 in); I, 139 mm (5.5 in); II, 158 mm (6.2 in); III, 172 mm (6.8 in). After alewives attain their third annulus, additional annuli are crowded and difficult to read. Norden noted that errors in aging fish having more than three annuli are apt to be greatly magnified.

A 27 June die-off sample from Sturgeon Bay provided Brown (1968) with the following age and growth (mm) values:

	II	III	IV	V	All ages
Males	135	152	166	164	154
Females	132	154	166	180	163

Preliminary studies show that males mature earlier, are recruited at a younger age to the bottom stocks and to the spawning population, and die earlier than females. Most of the age-I fish taken on 1 June 1967 by trawl in Lake Michigan off Sturgeon Bay were between 70 and 99 mm (2.8 and 3.9 in) long.

Alewives from all four inland Great Lakes are considerably smaller than the anadromous form (occasionally 360 mm) along the Atlantic Coast. According to Norden (1967a), average length of the largest alewives from Lake Michigan was 193 mm (7.6 in), while in Massachusetts spawning alewives averaged 270 mm (10.6 in). Four individuals taken off Algoma in Lake Michigan (UWSP 035) averaged 230 mm (9.1 in); four individuals taken off northern Bayfield County in Lake Superior (UWSP 2260) averaged 246 mm (9.7 in).

Threinen (1958) noted that few alewives live beyond 5 or 6 years; Van Oosten (1932) reported that they will reach an age of 8 years.

In Lake Michigan the alewife has become the dominant fish species (S. H. Smith 1968a, 1968b). In the winter, adult alewives live in the deepest water, while in the spring and fall they pass through the nearshore mid-depths. In the summer, the alewives crowd the shore. All year the young alewives can be found in the central mid-depths of the lake, where they spend their first 2 years. At one time or another during the year all zones of the lake are dominated by vast swarms of alewives competing with and often eliminating the stocks of native fishes.

Norden observed the aggressive nature of the alewife in captivity with other species of fish. When feed is introduced into the aquarium, the alewives swarm into the food and consume it while the other species move off to one side and don't feed (*Milwaukee Journal* 12 March 1972).

One aspect of its behavior which distresses man is its dying, a biological endpoint over which the alewife has little control. Brown (1968:2) stated:

> The classic population explosion, which crested in the southern and central basins of the lake in 1966 . . . was accompanied by progressively heavier spring and summer dieoffs and was climaxed by a massive mortality in June and early July 1967. The 1967 dieoff was in progress by the first week of June and reached its greatest intensity by the third week, when huge windrows of fish were deposited by wind and waves on beaches in Michigan, Indiana, Illinois and Wisconsin.

In Wisconsin the mortality extended in Lake Michigan up to Sturgeon Bay and in Green Bay along the east shore. About 70% of the alewives in Lake Michigan died during the 1967 die-off (Wells and McLain 1972).

The alewife encounters sharp changes in water temperature between the deep, cold waters of the Great Lakes and the shallow, warmer waters inshore and in the tributaries. That the fish perhaps cannot adapt to severe temperature changes is one of the most plausible explanations suggested for the mortalities. Hoar (1952) suggested that fish may lose osmotic control in warm water because of an exhausted thyroid mechanism, possibly related to low levels of iodine in fresh water.

In some studies, alewives have been observed to die when subjected to temperatures below 3.4°C (38°F) and this lack of tolerance for cold is undoubtedly why in midwinter they must seek the deepest areas of lakes where the water is warmest—usually 3.9°C (39°F) (S. H. Smith 1968a). The fact that deep water in the Great Lakes can become colder than this during severe winters may explain why alewives sometimes start to die in the deepest waters in midwinter. Midwinter die-offs tend to go unnoticed because the fish remain on the bottom and do not wash ashore.

Adult alewives from Lake Michigan acclimated to 20°C (68°F) had an estimated upper incipient (beginning) lethal temperature of 24.5°C (76.1°F) (Otto et al. 1976). Young-of-year alewives acclimated to the same temperature were tolerant to temperatures 6°C higher than adults. The ultimate lower lethal temperature for this species is about 3°C (37°F).

IMPORTANCE AND MANAGEMENT

The prolific alewife has wrought profound changes in the fish population structure in the upper Great Lakes, particularly in Lake Michigan. The following detrimental effects are often mentioned: (1) It has reduced other species of fish in the lake, including the perch, herring, chubs, and minnows, by competing with the young of those species for plankton as food and actually preying on the young of other fishes (S. H. Smith 1972). (2) The die-offs litter the beaches. (3) The fish clog intakes of power plants and municipal water filtration plants. In addition, they have small commercial value, although they constitute over 80% of the fish biomass in Lake Michigan. As S. H. Smith (1968a:12) has stated:

> An upset of the entire fishery ecology of Lake Michigan was already well underway in 1949 when the sea lamprey was consuming the last vestiges of the lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*)—the only abundant and widely distributed predators of the lake. Absence of large predators left the way wide open for a small and prolific species such as the alewife. Under this condition the alewife increased with almost unbelievable swiftness. In 1960 alewives represented about 8 per cent of the poundage of fish taken in experimental trawls in Lake Michigan; by 1966 they represented over 80 per cent. When undergoing its increase the alewives have reduced or replaced all of the previously very abundant species of the lake, and upset completely a very productive and stable multi-species balance that had existed since the glaciers retreated from the Great Lakes thousands of years ago.

However, the alewife also confers some benefits: (1) It is an excellent forage fish for high-value sport and commercial species such as salmon, steelhead, and lake trout. Biologists estimate that coho salmon are now consuming 36–45 million kg (80–100 million lb) of alewives each year, which amounts to less than 5% of the alewives in Lake Michigan (Downs 1974). (2) It is currently being harvested and converted into fish meal, which is primarily used to feed poultry. It does not find a market as mink feed, although Wisconsin leads the nation in mink production and 30% of the mink's diet is fish meal; because of the high levels of PCBs (polychlorinated biphenyls) in Great Lakes fish, mink ranchers use Canadian fish meal. (3) Its use as food for humans is being studied by University of Wisconsin food scientists, who are suggesting alewife hors d'oeuvres, alewife fish sticks, and "sardines." D. Stuiber (L. Berman, *Milwaukee Journal*, 7 October 1975) describes the alewife as tasting somewhat like a sardine (with the same nutritional content), but because it is a freshwater fish, it is softer. Larger alewives, though full of small bones, may be a valuable food fish for man and can be consumed fresh, as well as dry salted, pickled, and smoked.

Poff (1974:6) summarized the commercial importance of this species:

> Since 1970 the trend has been to stable production of alewives in these waters. Each year since 1966 the commercial harvest has been in excess of 18,000,000 pounds. This is phenomenal when one considers that production was negligible prior to 1956.
>
> A major harvest occurs in the areas bordering Pensaukee and Green Bay and off the ports of Manitowoc, Two Rivers and Milwaukee in Lake Michigan proper.

In 1974, the 18 million kg of alewives harvested were valued at $525,120. They amounted to 1,360 kilotons of fish meal, about 3% of the total United States production. Hardly 2% of the estimated 1 billion kg of alewives in Lake Michigan is being harvested and converted into fish meal.

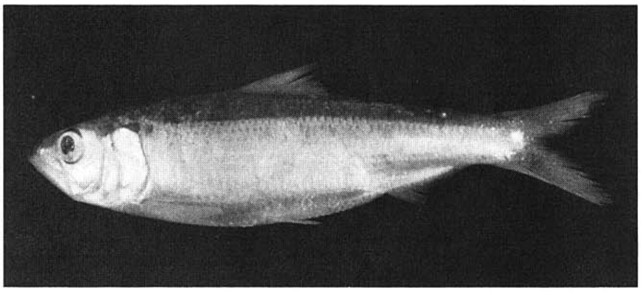
The catch is split nearly equally between trawlers and pound netters. Much of it is carried to a firm at Oconto, where, every day during the height of the fishing season between May and December, an estimated 91,000–136,000 kg of alewives are processed into cat food and fertilizer (L. Berman, *Milwaukee Journal*, 7 October 1975).

The introduction of this species into East Coast water-supply reservoirs suffering from plankton blooms and other distasteful problems has resulted in a number of successes. The plankton blooms which were clogging pipes and filters disappeared, and the alewife exhibited remarkable growth. Such biological control of plankton blooms appears to be more effective than the conventional treatment with copper sulfate. Although the alewife introduction program is still in the experimental stages, it is dispelling certain erroneous impressions that the fish is nothing more than a pest (Worthington 1976).

Skipjack Herring

Alosa chrysochloris (Rafinesque). *Alosa*—Saxon *Allis*, old name of the European shad, *Alosa alosa*; *chrysochloris*—gold-green.

Other common names: skipjack, blue herring, golden shad, river shad, river herring, shad.



Immature 106 mm, Wabash R. (Posey Co.), Indiana, 7 Sept. 1966

DESCRIPTION

Body oblong, strongly compressed laterally, depth into SL 3.4–4.0. Length 300–400 mm. Head length into SL 3.6–4.0. Mouth large, reaching below eye; lower jaw projecting beyond upper jaw. Upper and lower jaw teeth present at all ages; tongue with small teeth in 2–4 rows. Gill rakers on lower limb of first arch 20–30. Scales cycloid; lateral line absent; lateral series scales 53–60. Dorsal fin usually 17 rays, last ray not lengthened beyond the fin; dorsal fin insertion directly over or slightly in advance of pelvic fin insertion; anal fin rays about 18. Caudal fin deeply forked.

Back bluish or greenish, sides silvery with golden reflections, belly silvery. Row of vague, dusky "shoulder" spots, absent in some individuals. Scales of back with dusky bases.

DISTRIBUTION, STATUS, AND HABITAT

All Wisconsin records are from the mainstem of the Mississippi River and the St. Croix River below St. Croix Falls where the skipjack herring reaches the northern limit of its distribution. Greene (1935) examined collections from the following places: St. Croix River above the railroad bridge at Hudson (St. Croix County) (UMMZ 78081, 20 August 1928); St. Croix River at Hudson (St. Croix County); Lake Pepin at Rest Island, Minnesota (opposite Pepin County); slough of Mississippi River 3.2 km (2 mi) north of Victory (Vernon County) (UMMZ 78194, 22 August 1928). Greene had reports from Lake Pepin at Lake City, Minnesota (opposite Pepin County); Lake Pepin at Maiden Rock (Pierce County); Mississippi River at Fountain City (Buffalo County); Mississippi River at Wyalusing (Grant County); Mississippi River at Genoa (Vernon County).

Additional records: UWZM 678 (2) Lake Pepin at Lake City (Wabasha County, Minnesota) August 1904; UWZM 706 (1) St. Croix River at Hudson (St. Croix County) 25 July 1908; UWZM 794 (12) Lake Pepin at Lake City (Wabasha County, Minnesota) August 1904; MPM 689 (2) Mississippi River at Wyalusing (Grant County) 23 July 1911; MPM 599 Lake Pepin at Maiden Rock (Pierce County) 2 August 1910.

The skipjack herring is rare in South Dakota (Miller 1972) and threatened in Iowa (Roosa 1977). No recent records are available from Wisconsin waters and this species, once abundant, is extirpated (Wis. Dep. Nat. Resour. Endangered Species Com. 1975, Les 1979).

A chronology of the status of skipjack herring in the upper Mississippi River follows:

1903–1904—Wagner (1908:34): "I was never able to hook one in Lake Pepin, but while fishing for black bass in the swift waters of the Mississippi several miles below the lake, I was forced to abandon minnows as bait, as the skipjack took all of them."

1911–1913—Eddy and Underhill (1974:145–146): "Between 1911 and 1913 many specimens from Lake Pepin were forwarded to the United States Bureau of Fisheries Laboratory at Fairport, Iowa. These included both adults and young, which indicated that they must have spawned somewhere in that vicinity."

1914–1916—Coker (1930:168): "There is no question that during the three years immediately following the construction of the dam there was a decided decline in numbers of fish appearing at Keokuk and in numbers taken in Lake Pepin. The records of collections in Lake Pepin by our seining crew for the years 1914, 1915, and 1916 were as follows: 4,189 in 1914, 2,288 in 1915, and 42 in 1916. These observations led us to suppose that the fish were rapidly decreasing in numbers in the upper part of the river."

1926—Coker (1930:168): "In August, 1926, the author witnessed several seine hauls in Lake Pepin, in each of which one or two river herring were taken. . . . It was the testimony of several commercial fishermen that 'the herring were coming back.'"

1950—Eddy and Underhill (1974:146): "In about 1950 a few specimens were reported from the Mississippi River on the Wisconsin side below Prairie du Chien, but no Minnesota specimens have been reported since those of Surber at Big Stone Lake (headwaters of the Minnesota River) in 1920."

1975—Moyle (1975:26) noted that the skipjack her-

Range of the skipjack herring
○ Greene (1935)

ring is rare or extirpated in Minnesota: "It was once common in the Mississippi River as far upstream as Minneapolis, in the Lower St. Croix, and in the Minnesota River to its headwaters in Big Stone Lake. It has not been reported in recent years."

Today the skipjack herring is largely gone from the upper Mississippi River. P. W. Smith et al. (1971) noted that it is moderately common on the Mississippi River near the mouth of the Ohio River (southern tip of Illinois) and occasionally as far upstream as Pool 15 (environs of Muscatine, Iowa).

The skipjack herring inhabits the open waters of large rivers, and early in the year it often congregates in large numbers in the swift currents below dams and in the vicinity of wing dams. Occasionally it becomes an inhabitant of large river lakes. According to Trautman (1957) it appears to avoid turbid waters.

Undoubtedly one problem associated with the decline of the skipjack herring on the upper Mississippi River was its inability either to negotiate dams during the early spring migrations or to use canals bypassing the dams. Records show that great numbers of herring accumulated beneath the fastwater reaches below dams, but there is little evidence that many of the fish managed to get upstream either over or around the dams. Furthermore, nothing is known about how much unimpeded water is necessary to meet successful living and spawning requirements for this species, particularly near the northern limits of its range.

BIOLOGY

Little is known about the spawning habits of this species. At Keokuk, Iowa, fish in spawning condition were observed from the end of April through the beginning of July (Coker 1930). Although Coker was unsuccessful in determining the particular place and time of spawning, he concluded that the fish do not spawn in large aggregations, that during the spawning operations they are not readily captured by ordinary methods of fishing, and that spawning ends soon after the first of July. Fish full of roe were taken by Coker on 29 April 1914 at the very beginning of the run. Eggs and milt were exuded when pressure was applied. In 1915, eggs 0.8 mm diam were found on 24 May; 1.1 mm diam, 5 June. Milt issuing on pressure was first noted 23 June.

In Kentucky, young-of-year on 8 July were 21–30 mm SL and not completely covered with scales (Clay 1975). In Ohio, young-of-year during August were 25–102 mm (1–4 in) long and in October, 127–203 mm (5–8 in); adults, 305–406 mm (12–16 in) long, weighed 227–567 g (8–20 oz), and the largest specimen, 533 mm (21 in) long, weighed 1.59 kg (3 lb 8 oz) (Trautman 1957).

According to Harlan and Speaker (1956), the skipjack herring reaches a length of 254–305 mm (10–12 in) at maturity.

The skipjack feeds on plankton, small insect larvae, and small fishes (Eddy and Underhill 1975). In about 150 skipjack herring examined, approximately one-third were empty; a little more than one-third contained fish, chiefly minnows, with some mooneyes, gizzard shad, and others not determinable; and less than one-third contained insects and larvae, principally mayflies, some caddisflies, and others (Coker 1930).

Trautman (1957:179) described communal feeding:

> The species fed in large, swiftly swimming schools which forced the huge schools of emerald and mimic shiners to crowd together near the water's surface. Once the minnows were closely crowded together the skipjack dashed in among them, forcing the minnows to rise to the water's surface where they could be captured readily.

In pursuing its prey, the skipjack will itself frequently swim clear of the water. It is this phenomenon, recorded by many observers, that has given the fish the name "skipjack." In Lake Pepin Wagner (1908:34) noted: "Its peculiar habit of leaping out of the water while pursuing its prey is apparent here, especially at dusk, when the splashing of many specimens is almost continuous until long after dark."

The skipjack's movements are so swift that the eye can seldom follow them even in very clear water, as Eddy and Underhill (1974) noted, and its coloration also helps to obscure its movements.

In the Wabash River, Gammon (1973) noted that these fish actively avoided thermal inputs from an electrical power plant, all of which were warmer than 25.5°C (77.9°F).

IMPORTANCE AND MANAGEMENT

At one time the skipjack herring represented a very distinct economic asset because it helped perpetuate the ebony shell clam (*Fusconaia ebena*), which was regarded as the most valuable of all the pearly mussels of the Mississippi basin (Coker 1930). This clam was abundant in all the larger waters of strong current and yielded a shell of the best quality for buttons. The reproduction of the ebony shell clam, so far as all evidence goes, is accomplished largely through the parasitism of its young (glochidia) upon skipjack herring. Infection of the skipjack by larval mussels is heavy: one study showed 1,895 to 3,740 in a single fish, with a large number of fish infected (Baker 1928). By 1926, however, Coker found that the clam was a vanishing species in the upper river, and in 1929 not a living specimen of that species of clam could be found in Lake Pepin; there were only old shells (Eddy and Underhill 1974). Apparently only very old individuals are now to be found in the upper Mississippi River: a large, old specimen (103 mm) was obtained near Prairie du Chien in 1975 (Mathiak 1979).

The skipjack herring is also host to the glochidia of the mollusks *Megalonaias gigantea*, *Elliptio crassidens*, and *Anodonta grandis* (Hart and Fuller 1974).

The skipjack herring is criticized as being too bony to be of much value as a food fish and as lacking good flavor and food value. But no one faults it for its fighting qualities at the end of a line. Coker (1930:165–166) noted:

> . . . Its liveliness and vigor make it one of the gamiest fishes in the river, so that it affords real sport to the angler who fishes with live bait in swift water as about the ends of wing dams. An insight into its habits was had by the author and an aide as they fished for herring in the swift waters below the chute alongside the lock. The fish played about the boat in great numbers, darting through the water, leaping from the surface, taking the line and making the reels spin busily, only to release themselves when a strain was put upon the line. After a time it was found that the fish were taking the spindle-shaped lead in the mouth rather than the baited hook. The very swiftness of the fish prevented an earlier discovery of the trouble. With the leads removed from the lines and the bait kept close at the surface, the fish were caught in fair numbers.

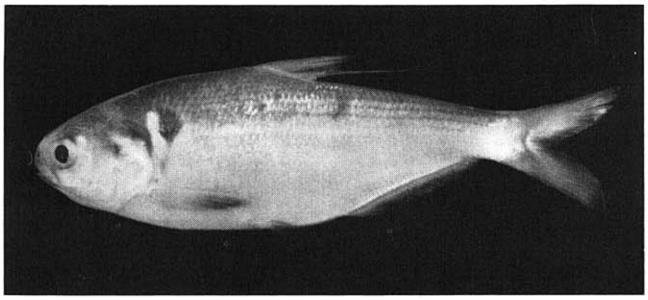
The oil present in its flesh is said by fishermen to be very attractive to catfishes, and many skipjacks are caught specifically for use as jug or trotline bait (Pflieger 1975).

With the present state of knowledge, it is doubtful that any program geared to reestablishing this species will meet with success. Initially, research should be devoted to determining its life cycle and its special needs, if any, for successful propagation.

Gizzard Shad

Dorosoma cepedianum (Lesueur). *Dorosoma*—lance body; *cepedianum*—after Lacepède, naturalist and compiler of *Histoire Naturelle des Poissons* (*Natural History of the Fishes*).

Other common names: eastern gizzard shad, shad, hickory shad, mud shad, jack shad, sawbelly, hairy back, flatfish, skipjack, Norwegian herring.



Yearling 197 mm, Mississippi R. (Jackson Co.), Illinois, 1 July 1969

DESCRIPTION

Body oblong, deep, strongly compressed laterally, depth into SL 2.5–3.1. Length 270–350 mm. Head length into SL 3.2–4.0. Snout rounded, overhanging the ventral mouth; lower jaw short, fitting into upper jaw; maxillary reaching below anterior margin of eye. Jaw teeth and teeth on tongue absent (minute teeth on upper jaw in larval young, but soon lost). Gill rakers on lower limb of first arch about 190; upper and lower limbs of first gill arch subequal. Scales cycloid; lateral line absent; lateral series scales 52–70. Dorsal fin usually 10–12 rays, the last ray greatly prolonged beyond the fin (short or nonexistent in young); dorsal fin insertion slightly behind pelvic fin insertion; anal fin rays 27–34. Caudal fin deeply forked.

Back and upper sides silvery blue, grading into silvery and white on lower sides and belly. Shoulder spot prominent on young-of-year, becoming faint and disappearing early in second year of life.

Larvae separable from alewife larvae by ratio of snout to vent length/SL, values ranging 0.87–0.81 for gizzard shad larvae 3.5–19.5 mm SL (Lam and Roff 1977).

DISTRIBUTION, STATUS, AND HABITAT

The gizzard shad occurs in the Mississippi River and Lake Michigan drainage basins. It has not been reported from the Lake Superior drainage. In the Mississippi system, it is present in the St. Croix River upstream to St. Croix Falls Dam, the lower stretches of the Chippewa–Red Cedar rivers, and the Wisconsin River at least as far upstream as Portage (Columbia County). In the Lake Michigan drainage it is found in the upper and lower Fox River and in Lake Winnebago.

Although Miller (1957) presents a case for the gizzard shad's entry into Lake Michigan through the Chicago River canal, it is also probable that the Fox-Wisconsin canal at Portage (Columbia County) may have been another dispersal route. B. Moes (pers. comm.) noted that he had seen this species in Green Bay as early as 1953.

Priegel (1967a) reported it as abundant in the upper portions of the upper Fox River. It is uncommon to common in the lower third of Green Bay and rare in protected harbors along Lake Michigan. The numbers of the gizzard shad taken by the commercial fisheries in the Mississippi River have not warranted listing this species in the catch.

Although appearing in sizable numbers in some Wisconsin waters, this species has not reached pest levels. Populations appear to fluctuate greatly, undoubtedly because of the limiting effects of the low winter temperatures. Any trend, however, which warms the water (e.g., industrial hotwater effluent) may enable carryover of breeding stock through severe winters. The establishment and spread of this species in recent years in Lake Michigan may be supported by such artificial warm spots in harbors and industrial bays. At present the gizzard shad is secure in Wisconsin; it functions as a forage fish, and is an interesting part of Wisconsin's fish population.

It inhabits large rivers, reservoirs, lakes, swamps, bays, sloughs, and similar quiet open waters, from clear to very silty. Although it occurs in the relatively strong current of the upper Mississippi River, it prefers quieter waters and swarms in the sluggish lower parts of that river (Miller 1960). It is essentially an openwater species, usually living at or near the surface.

If the oxygen supply is adequate, the species may descend to depths of 33 m (108 ft), as in the Norris Reservoir in Tennessee (Miller 1960). In Green Bay during the summer and fall the gizzard shad is caught in pound, fyke, or gill nets set at 2–8 m (7–26 ft). In Lake Michigan, gizzard shad are generally caught within 1.6 km (1 mi) of shore and at depths of 6–13 m (20–43 ft) (L. Wells, pers. comm.).

BIOLOGY

In southern Wisconsin spawning occurs from late April and early May to early August. The adults may ascend smaller streams or ditches to spawn and the young are later abundant in such places if the gra-

Range of the gizzard shad
● Specimens examined
▲ Wisconsin Fish Distribution Study (1974–75)
○ Literature and reports
◯ Greene (1935)

dient is sufficiently low (Miller 1960). Most populations inhabiting the warm-to-temperate waters of the United States spawn at 10–21°C (50–70°F).

According to Bodola (1966), only a few precocious male and female gizzard shad attain sexual maturity at age I. Almost all males and a good percentage of females mature at age II, and only rarely are age-III shad immature. Egg production is highest in the age-II fish, averaging 378,990 per individual.

During spawning the female is flanked on each side by males (Langlois 1954). Miller (1960:376) described the process:

> A group of males and females swimming near the surface begin to roll and tumble about each other in a mass, the eggs and sperm being ejected during this activity. The sticky eggs slowly sink to the bottom or drift with the current, readily becoming attached to any object they may contact.

The eggs, 0.75 mm diam, adhere to submerged aquatic plants and stones. Most spawning occurs at night.

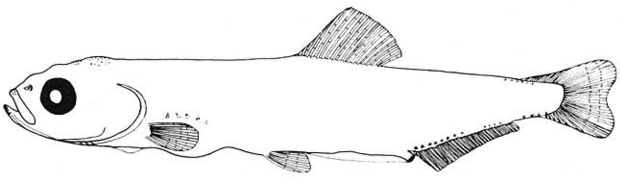
Spawning sites for the gizzard shad from Green Bay or Lake Michigan are unknown, but it is likely that they may be similar to those described by Bodola (1966) for western Lake Erie. He observed shad spawning at 19.5°C (67°F) or more over a sandy, rocky bar in 0.6–1.2 m (2–4 ft) of water. After spawning, the fish returned to deeper water. That Green Bay shad probably spawn in rivers is indicated by capture of this species from the lower Fox River at De Pere (Brown County).

Not all mature eggs, according to observations of Bodola (1966), are expelled at the same time. Eggs which are not mature are held over for the next year, and those which develop to the spawning stage too late to be expelled are resorbed.

The eggs hatch into larvae 3.5 mm long after 95 hours at 16.1°C or 36 hours at 26.7°C. The movements of the newly hatched gizzard shad were an upward swimming and a downward settling—in each direction the head is foremost (Bodola 1966). This behavior continues for 3 or 4 days. On the fourth day the fry begin to swim horizontally as well as upward and downward. Their mode of swimming at this age, observed (in a petri dish) under a dissecting microscope, is largely by the pectoral fins which "vibrated seemingly with the rapidity of the wings of a bee in flight." Walburg (1976) noted that the larvae are weak swimmers for at least several weeks after hatching.

Young shad observed in an aquarium congregated on the lighted side. They began feeding about the fifth day and during the fifth or sixth day after hatching, green algae were recognized through the thin gut wall. By the 10th day they attained a length of slightly more than 6 mm (Bodola 1966).

A 22-mm young-of-year was seined from the Mississippi River (Crawford County) on 5 August 1976 (Wis. Fish Distrib. Study).



Gizzard shad 22 mm TL, Mississippi R. (Crawford Co.) 5 Aug. 1976 (drawing by D. Becker)

The annulus of the gizzard shad scale is a valid year mark and is laid down in May to July, a little later in the older fish than in the younger (Bodola 1966). Shad lengths remain practically constant from November until the time of annulus formation.

Christenson and Smith (1965) captured 716 gizzard shad from a backwater area of the Mississippi River near Fountain City (Buffalo County), ranging from 279 to 404 mm (11–15.9 in) TL. These fish were probably ages II–IV. A shad (UWSP 5427) from the Minnesota River (Hennepin County, Minnesota), 392 mm and 943 g (15.4 in and 2.1 lb), is clearly age IV. A 483-mm and 1.47-kg (19-in and 3.25-lb) gizzard shad was caught from Lake Michigan in February 1979. Shad in western Lake Erie (Bodola 1966) showed the following growth:

SL at End of Year of Life (mm)

	1	2	3	4	5
Males	141	273	313	343	349
Females	140	285	335	364	386

Bodola found three fish of age VI, the oldest taken. Patriarche (1953) reported an age-X fish from Lake Wappapello, Missouri.

Trautman (1957) reported an unusually large fish 521 mm and 1.6 kg (20.5 in and 3 lb 7oz). In Wisconsin a 483-mm, 1.5-kg (19-in, 3-lb 4-oz) fish was caught from Lake Michigan in February 1979.

The earliest food of the gizzard shad appears to be protozoans (Bodola 1966). At about 20 mm, shad feed almost wholly on the smaller zooplankton. After the fish grow to 30 mm, the digestive tract contains increasing percentages of phytoplankton. Bodola (p. 421) noted that the gizzard shad are filter feeders:

> . . . They filter the water of whatever particulate matter it contains. Shad captured in open waters contained mostly free-floating phytoplankton; those captured among the attached plants, such as *Cladophora*, *Myriophyllum*, and *Cera-*

Growth of the Gizzard Shad in Wisconsin

Date	Age Class	No. of Fish	TL (mm) Avg	Range	Calculated TL at Annulus	Location	UWSP No.
10 July	0	13	53	39–67		Mississippi R. (Grant Co.)	032
13 July	0	24	36	25–55		Green R. (Grant Co.)	027
13 July	0	39	40	28–73		Wisconsin R. (Grant Co.)	026
17 July	0	20	54	38–82		Wisconsin R. (Grant Co.)	028
13 Sept.	0	3	116	103–132		Buffalo R. (Buffalo Co.)	3214
19 Sept.	0	7	117	99–127		Mississippi R. (Grant Co.)	3216
20 Sept.	0	5	122	108–140		Wisconsin R. (Columbia Co.)	3125
21 Sept.	0	18	46	34–73[a]		Mississippi R. (Houston Co., Minn.)	3315
23 Sept.	0	4	122	116–129		St. Croix R. (Pierce Co.)	4410
24 Sept.	0	3	138	133–142		Mississippi R. (Grant Co.)	1465
24 Sept.	0	12	147	115–166		Wisconsin R. (Grant Co.)	1509
11 Oct.	0	10	140	120–160		Mississippi R. (Houston Co., Minn.)	3180
2 May	I	16	141	124–161	(Annulus not yet deposited)	Mississippi R. (LaCrosse Co.)	1836
May–Aug.	I	4	176	167–186	120	Green Bay (Oconto Co.)	2473
June–Sept.	I	1	174		121	Green Bay (Brown Co.)	2391
June–Sept.	II	1	281		I–118; II–272	Green Bay (Brown Co.)	2391
June–Sept.	II	1	296		I–110; II–283	Green Bay (Door Co.)	2479
6–13 June	II	1	276		I–104; II–235	Green Bay (Oconto Co.)	2403

[a]Late spawning—probably beginning Aug.

tophyllum, ingested Cladocera, Copepoda, Rotifera, and small aquatic insect larvae; those captured in very turbid waters were filled largely with mud. That they do, however, add to their diet from the bottom debris is evidenced by the presence in the gizzard of sand particles of diameters in excess of 0.25 mm. This size of sand is not held in suspension even when the water is highly turbid. . . . The taking of sand when food is plentiful suggests its use as an aid in grinding by the gizzard—or that it may have been taken accidentally along with food.

Depending on their abundance in the water in which the fish are feeding, zooplankton or phytoplankton may predominate in the gut. Bodola noted that by the time the food reaches the intestine it has been macerated and partially digested so that it resembles mud. This fact may explain the frequently heard statement that shad eat mud.

The gizzard becomes evident in the 22.5-mm stage (Bodola 1966). In the adult it becomes a short, thick-walled muscular structure like the gizzard of a fowl; the intestine is long and much convoluted, with numerous folds on its inner surface and hundreds of pyloric caeca externally (Miller 1960). The presence of sand in the gut when ingested food is plentiful and its absence in winter when the gut is empty suggest that it may be taken as an aid in grinding the food in the gizzard. In the gizzard, algal and zooplankton items are always somewhat broken up.

Gizzard shad frequently travel in schools close to the surface. When they are surprised they will skip over the surface of the water, a habit that has caused fishermen in some places to give them the name "skipjack" (Eddy and Underhill 1974). Bodola (1966) noted that young gizzard shad are found in shallow water and the older fish in deeper water; the very oldest are captured only during the spawning season.

Severe winters limit the northern distribution of the gizzard shad. Gasaway (1970) observed large numbers of dead young-of-year shad frozen in the ice during the winters from 1954 to 1957; few survived the cold. Clark (1969) summarized temperature data for the gizzard shad as follows: preferred field temperature, 22.8–23.9°C (73–75°F); satisfactory growth, 33.9°C (93°F); upper lethal limit, 36.1°C (97°F). In White River and Ipalco Discharge, Indiana, the gizzard shad was captured at a temperature as high as 37.5°C (99.5°F) (Proffitt and Benda 1971). Clark noted that temperatures well below the lethal limit may be in the stress range. Miller (1960) stated that the species is particularly attracted by warm water flowing from industrial plants. In the Wabash River in Indiana, however, Gammon (1973) found that gizzard shad selected the coolest thermal region available, ranging from 22.2 to 28.9°C (72–84°F), and that they tended to avoid the warmer regions.

IMPORTANCE AND MANAGEMENT

The gizzard shad is host to the glochidia of the mollusks *Megalonaias gigantea*, *Elliptio dilatata*, *Anodonta grandis*, and *Arcidens confragosa* (Hart and Fuller 1974).

In the East, the gizzard shad has been taken on hooks baited with angleworm, small minnow, or even an artificial fly, but the few caught from Wisconsin waters are undoubtedly taken incidentally while fishing for other species.

Generally the gizzard shad is considered a poor bait fish, since the young are fragile and die quickly. But they have at times been gathered in large numbers for bait (*Milwaukee Journal*, January 1948):

Durand, Wis.—Fishermen along the Chippewa River are interested in the appearance of large schools of gizzard shad. Gathering bait in unfrozen parts of the river, fishermen have been surprised at how quickly they can fill their bait cans. The shad have come up the river from Lake Pepin and the Mississippi, where they are reported to have increased by the millions.

Along with the shad come flocks of seagulls to feed on them. For a time the taking of shad was prohibited but the ban has been lifted to permit bait fishermen to take them. They cannot, however, be used in any other waters than the Chippewa River.

The gizzard shad is not esteemed as food by man because of its soft, rather tasteless flesh and numerous fine bones. In the past, however, there has been a limited market for this species where a cheap fish was sought (Miller 1960). According to reports in the literature, it has also been used as hog, cattle, and trout food, and has been converted to fertilizer.

Young gizzard shad are important forage fish for sport and predator fishes. Hubbs (1934) spoke of them as "the most efficient biologically of all the forage fishes" because they are the short and efficient link in the food chain that directly connects basic plant life with sport fishes. Young-of-year about 51–127 mm (2–5 in) long form a major part of the diet of at least 17 important sport fishes (Miller 1960), and in some parts of the country the periodic mortality of the gizzard shad provides an important source of food for numerous species of waterfowl and wading birds.

Bodola (1966) reported that in Lake Erie the value of the gizzard shad as a forage fish is outweighed by the nuisance created when heavy mortality occurs and by the inconvenience caused to fishermen in whose nets they become entangled.

In some parts of its range, as in the East and the South, the gizzard shad has reached pest numbers; in some states reduction of the shad population is part of the fish management program. Under certain conditions in warm, shallow bodies of water that have a soft mud bottom, high turbidity, and relatively few predators, shad populations can explode and create problems (Hubbs 1934). Miller (1960) observed that under optimum conditions the gizzard shad is likely to get out of control, even if numbers of predator sport fishes are present, and this is particularly true if the species is not native to such waters.

The role of the gizzard shad in the ecology of fish populations is difficult to assess. Its value as a link in the food chain is not to be questioned. On the other hand, no use other than forage has been developed for shad, and their rapid growth soon makes them too large to be threatened by most predatory fish (Bodola 1966). Shad tend to overpopulate many waters to a degree that seems detrimental to other species.

In experimental gill nets fished in Lake Pepin during October 1965, when a total of 1,541 fish of 24 species were collected, the gizzard shad was the fourth most abundant species, constituting 8.2% of the catch.