Sunfish Family—Centrarchidae

Eleven species of centrarchids in four genera are known from Wisconsin. In the United States and Canada, 32 species in 9 genera are known. According to Miller (1959), the Centrarchidae probably arose from some specialized serranid progenitor which invaded fresh water during or before the Eocene period. The hypothetical primitive centrarchid probably was a free-swimming inhabitant of lowland waters, with a shape and size comparable to that of *Ambloplites*. From the distribution of present species and of species and genera known only as fossils, it would appear that the centrarchid center of origin was located in the Mississippi Valley (Branson and Moore 1962). By the beginning of the Pleistocene many of the extant genera, and some that disappeared before the close of that period, were in existence.

The sunfishes are typically spiny-rayed fishes, with 6–13 spines in the anterior dorsal fin, and 3–9 spines in the anterior part of the anal fin. The spinous and soft-rayed dorsal fins are generally joined as one fin. The fish are for the most part deep bodied and strongly compressed laterally. Fine teeth appear in brushlike bands on both the upper and lower jaws, and the lower pharyngeal arches broaden into pads bearing conical or molarlike teeth ("throat-teeth"). The swim bladder is isolated from the esophagus (physoclistous condition). The pectoral fins are moderately high on the body, and the pelvic fins are located almost directly below them and slightly posteriorly. The caudal fin is notched or slightly forked.

All sunfish species tend to be nest builders, although occasionally some species use the nests of other fishes that have already spawned.

The male generally builds the nest, cares for the eggs and young, and often is quite vicious in his protective role.

Hybridization, especially within the genus *Lepomis*, is common in many of our waters, especially in the southern sector of Wisconsin. This occurs when spawning fish of several species are unduly crowded, or when there is a great scarcity of one species coupled with the abundance of another, or when the individuals of the sparse species seem to have difficulty in finding their proper mates (Hubbs 1955). Hybrids have also been produced by placing male individuals of one species into a pond with females of another (Childers 1967). There seems to be a general agreement among ichthyologists who study centrarchids that behavioral isolation is probably the most important type of isolating mechanism in this group (Gerald 1971). That is, behavioral patterns which are specific to only one species are used to keep the different sunfishes separated from one another, especially during the critical spawning period. This conclusion has come about largely through the process of elimination, however, and the actual cues used by sunfish are still largely unknown. Auditory communication is only one of several types of cues used by fish.

The sunfishes are among the most colorful and attractive of our fishes and the bass species of the family are important game fish, avidly sought after by a large body of fishermen. The total production of the members of the sunfish family is astounding. In Wisconsin, they are among the most common of our fishes, and they furnish the bulk of the fish coming to creel. They are standby fishes for a shore lunch, or for that easy meal when the larger game fishes are not biting. Because of their popularity, the sunfishes have been widely stocked in Wisconsin.

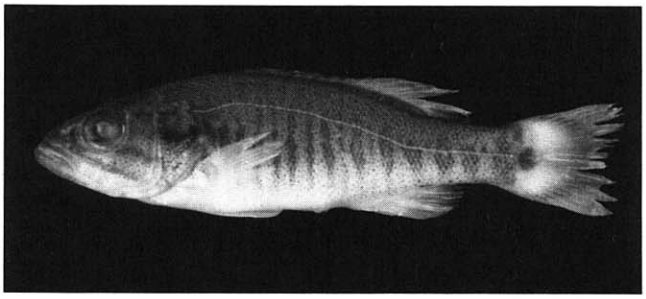
Unfortunately, because they are prolific and hardy, sunfishes also present a serious and difficult fish management problem. Many waters produce millions of stunted sunfish, to the dismay of fishermen and biologists. Consequently, size and bag limits have largely been removed in Wisconsin, and fishermen are encouraged to increase their harvest.

"Panfish cannot be accumulated or stockpiled for future use. What man does not utilize, nature will eliminate" (Snow 1960:14).

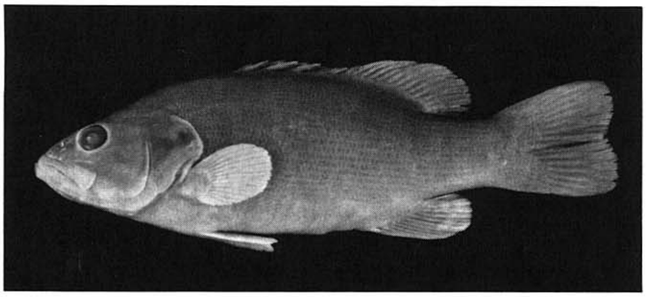
Smallmouth Bass

Micropterus dolomieui Lacepède. *Micropterus*—small fin; *dolomieui*—after M. Dolomieu, a French mineralogist and friend of Lacepède, for whom dolomite was named.

Other common names: northern smallmouth bass, smallmouth black bass, smallmouth, bronzeback, Oswego bass, black bass, yellow bass, brown bass, green bass, redeyed bass, redeye, white or mountain trout.



Immature 45 mm, Wisconsin R. (Juneau Co.), 26 June 1977



Subadult 166 mm, L. Winnebago (Winnebago Co.?), 18–21 Aug. 1960

Adult (living) (Wisconsin DNR photo)

DESCRIPTION

Body slender to robust, slightly compressed laterally, oval in cross section. Length 233–349 mm (9.1–13.7 in). TL = 1.23 SL. Depth into TL 3.7–4.8. Head length into TL 3.2–3.9. Mouth moderately large, slightly oblique. Upper jaw reaching from middle to posterior edge of eye but never beyond; lower jaw slightly longer than upper jaw; conical, pointed teeth in brushlike pads on upper and lower jaws; lower pharyngeal arches narrow, with numerous fine teeth. Gill rakers on first gill arch long, straight, pointed. Dorsal fins 2, but joined and appear as 1; first dorsal fin with 10 spines, second with 13–15 soft rays. Anal fin with 3 spines, 10–11 soft rays; pelvic fin thoracic, with 1 spine and 5 rays; pectoral fin short and rounded, when laid forward across cheek not reaching eye; caudal fin moderately forked. Scales ctenoid, in lateral line 69–80; lateral line complete. Chromosomes 2n = 46 (W. LeGrande, pers. comm.).

Back and head brown, or yellow-brown, or olive to green; sides lighter; belly light yellow to white. Most scales on sides with bronze reflections. Vertical bars faint, 9–16 (generally more numerous and prominent in young), not fused into a lateral band. Usually 3 dark streaks on each side of head, radiating backward from snout and eye; dark opercle spot about size of pupil of eye. Eye usually red or orange. Fins lightly pigmented, caudal fin in adults with darker edge; in young, caudal fin strikingly marked with yellow at base, pronounced dark crescent band through middle, and a whitish edge.

Breeding male darkens to blackish on back and sides; breeding female has intensified colors.

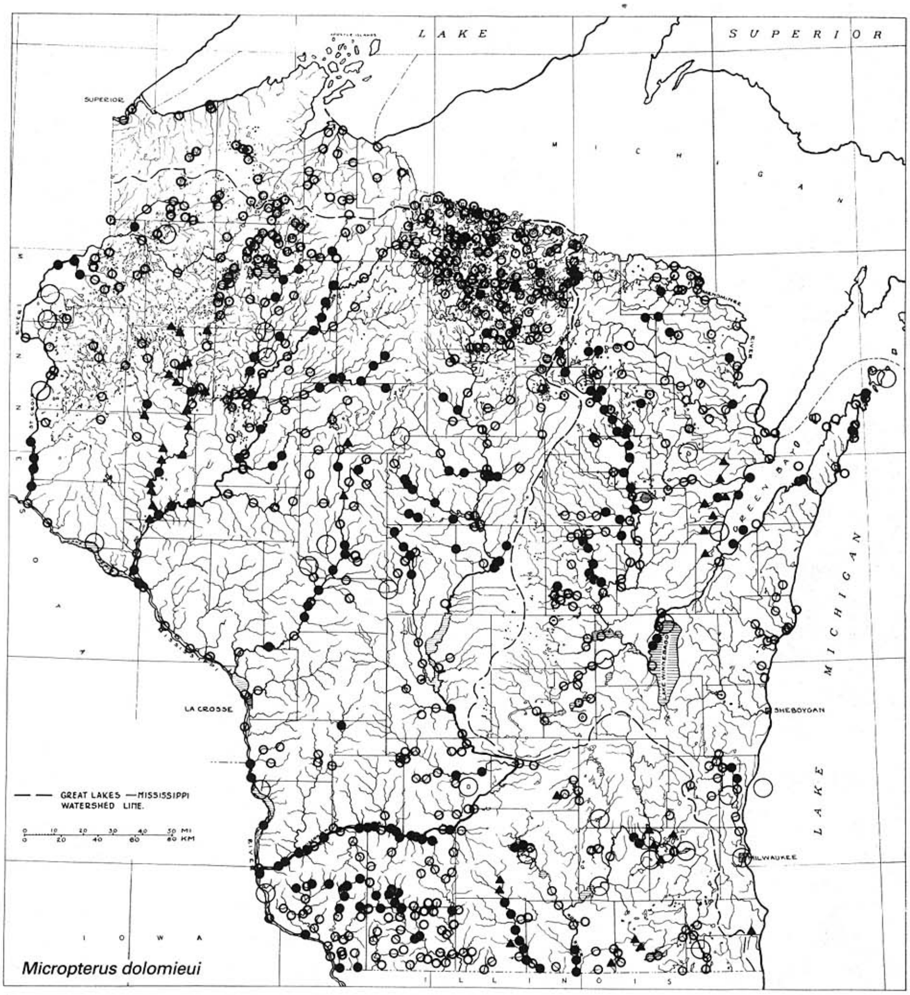
Hybrids: Smallmouth bass × spotted bass (Scott and Crossman 1973). Artificial smallmouth bass × largemouth bass (Schwartz 1972, *Sports Afield* June 1977:147–148).

DISTRIBUTION, STATUS, AND HABITAT

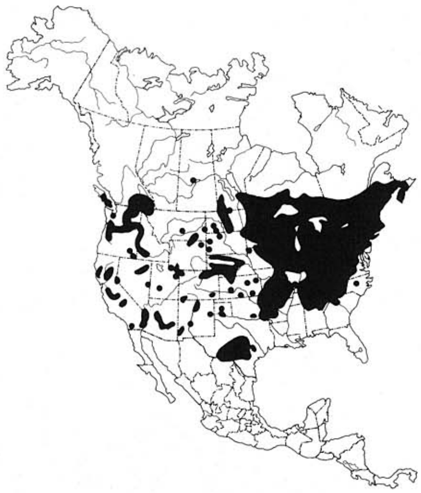
In Wisconsin, the smallmouth bass occurs in all drainage basins. It seems probable that it was quite generally dispersed in early postglacial time, and was distributed over the state approximately as it is at present before any introductions were made (Greene 1935). Over 5,650 km (3,500 mi) of smallmouth bass streams are listed for Wisconsin (Wis. Dep. Nat. Resour. 1968b).

Originally the smallmouth bass ranged from northern Minnesota to Lake Nipissing (Ontario) and Quebec, with a relict population from the Nipigon River (Ontario) south to the Tennessee River drainage of Alabama and to eastern Oklahoma (Hubbs and Lagler 1964). A range map was prepared by Hubbs and Bailey (1938). The smallmouth bass has been extensively introduced in American waters, in the waters of most European countries, and in the waters of Guam, Hawaii, Hong Kong, Japan, and Vietnam (Robbins and MacCrimmon 1974).

The smallmouth bass is common in medium to



Micropterus dolomieui



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

large streams and in large, clearwater lakes throughout Wisconsin. In Lake Winnebago, it is abundant along the north and east shores (Priegel 1967a). In Waukesha County, it was reported from 10 of 40 lakes sampled (Poff and Threinen 1963). It is common in upper Green Bay of Lake Michigan and in Chequamegon Bay of Lake Superior. Fair numbers are present in moderate to swift currents along the rocky banks of the lower Wisconsin River, and numerous young-of-year have been captured from eddies along Wisconsin River sand banks (Becker 1966). The streams draining into the Wisconsin River north of the east-west highland ridge traversing Grant and Iowa counties contain few or no smallmouth bass; south of the ridge the streams, including those less than 3 m wide, contain substantial populations of smallmouth bass. The smallmouth bass is uncommon on the Mississippi River, where "much of the favored habitat . . . has been altered or destroyed since the inception of the 9-foot navigational channel. The species now appears to be quite spotty" (R. Nord, pers. comm.). This species is uncommon at barriers in the mouths of tributaries of Lake Superior (McLain et al. 1965).

Smallmouth bass are less abundant in Wisconsin today than they were formerly. In the Fox River (Green Lake County), they were once so abundant that local farmers near Princeton netted them for hog food (Fassbender et al. 1970). In Lake Wingra (Dane County), during the 1936 carp seining, smallmouth bass were present in fair abundance (Noland 1951); however, none were reported in the 1944 carp seining, and the species is no longer listed from that lake (Churchill 1976). The smallmouth bass was common in the Rock River between Hustisford and Watertown (Dodge County) until about 1940, but it has become rare in that River since then (H. Neuenschwander, pers. comm.). Smallmouth bass fishing at most points along the Great Lakes shoreline is no longer of the excellent quality described for earlier years (Borgeson and Tody 1967).

The distribution of smallmouth bass in Wisconsin is typical of the distribution of a glacial lake species. In the northern part of the state it is found in both lakes and streams, but southward it is more common in swift, clear streams and rivers than in lakes. It prefers cool, flowing streams, and large, clear lakes over rocky and sandy bottoms. Lakes over 6.1 m (20 ft) deep, with rooted aquatic vegetation and clean, gravel shores provide the optimum habitat. In Lake Michigan, the smallmouth bass is confined to shoal waters of protected bays. It commonly avoids sluggish or muddy water.

In Wisconsin, the smallmouth bass was encountered most frequently in clear to slightly turbid, shallow water, over substrates of sand (27% frequency), gravel (23%), rubble (15%), boulders (14%), mud (11%), silt (7%), clay (3%), bedrock (1%), and detritus (1%). It was taken from lakes and streams with various currents: riffles 42%, pools 46%, and sloughs 13%, and with varying widths: 1.0–3.0 m (2%), 3.1–6.0 m (16%), 6.1–12.0 m (13%), 12.1–24.0 m (29%), 24.1–50.0 m (23%), and more than 50 m (16%). In lakes, the smallmouth bass seeks out rock ledges and rocky bottoms, but may also be found along weedy shorelines. It often occurs in streams containing trout, but typically inhabits the warmer water sections below trout water. Many streams hold trout in the headwaters and grade into smallmouth bass near the mouth.

BIOLOGY

Excellent summaries of the life history of the smallmouth bass are provided by Coble (1975) and Hubbs and Bailey (1938).

In reviewing water temperatures related to smallmouth bass spawning and nest building, Cleary (1956) noted that temperature thresholds are variable. Although commonly reported as spawning at water temperatures of 16.7–17.8°C (62–64°F), smallmouths have been found spawning at 11.7°C (53°F). In southern Wisconsin, the smallmouth bass spawns from the middle of May through June, when the water temperature ranges between 12.8 and 23.9°C (55 and 75°F). In Lake Geneva, Mraz (1960) noted nest construction at minimum water temperatures of 15–16.1°C (59–61°F), but females did not appear. In the Door County area of Lake Michigan (Wiegert 1966), some smallmouths spawned in sheltered shallow bays as early as 20 May when the water temperature rose above 15.6°C (60°F); other smallmouths caught on exposed reefs and shorelines had not yet spawned in late July. In the St. Croix River, spawning occurred as early as 11 May and as late as 7 June (Kuehn et al. 1961).

In Clear Lake (Oneida County), nesting activity was observed at 18°C (64.4°F), and spawning occurred at 19°C (66.2°F) (Marinac 1976); however, activity ceased when the water temperature fell to 16°C (60.8°F) in early June, and resumed when the temperature rose to 18°C (64.4°F) in the third week of June.

In the Red Cedar River (Dunn County), there was some evidence of upstream movement by smallmouth bass in the spawning period (Paragamian 1973). C. Brynildson (1957) stated that two factors adversely affected the success of smallmouth spawning in streams: a sudden drop in the water temperature, and the siltation of nests during floods. Mraz (1964d) reported that when the water temperature dropped from 18.3°C (64.9°F) to 7.2°C (45°F), the males deserted the nests, but first apparently fanned silt over the eggs. A few days later, after the water temperature again rose to 18.3°C (64.9°F), the males reappeared and cleared the nests of silt, and fresh egg deposits were found. None of these nestings were successful, however, as both old and new eggs were lost to a fungus infection.

In lakes, smallmouth bass nests are more common and are built earlier on the west and north shorelines, where the water temperatures are usually higher and the shores are best protected from prevailing winds (Mraz 1964d). Nests are constructed on gravel, preferably beside a natural or an artificial obstruction such as a stone crib, log, oil drum, large boulder, or stump. Concrete blocks placed in Lake Geneva (Walworth County) were accepted as nesting locations, and frequently two nests were found on either side of one block.

In Lake Michigan, most smallmouth nests were observed at water depths of 0.4–1.5 m on gravel and rubble; fewer nests were built on sand and bedrock with overlying gravel (Wiegert 1966). In Lake Geneva (Mraz 1960, 1964d), most of the smallmouth nests were located in 2.4–3.7 m of water, although some were more than 6 m below the surface.

Most nest building takes place in the early morning. A male apparently builds several "practice nests" until he finally settles on one as suitable (Mraz 1964d, Cleary 1956). Nest construction requires from 4 to 48 hr or more (Hubbs and Bailey 1938). After selecting a satisfactory nest site, the male begins construction by assuming a nearly vertical position in the water, head up, and sweeping vigorously with his tail. Silt, sand, and small stones settle at the periphery of the nest, which in diameter is about twice the length of the male. With his mouth he may remove large objects, and he roots and overturns the bottom material, especially in the center of the nest. Mraz (1964d) noted that he has never found a smallmouth nest that could be described as other than a perfect nest: a large, perfectly circular, clean gravel structure.

When the nest has been constructed, the smallmouth bass male awaits a female. When a female appears, the male makes short rushes at her. The female may be driven into the nest repeatedly, and may remain in the nest a little longer each time (Breder and Rosen 1966). As the female moves into the nest, the male on the periphery turns on his side with the fully distended dorsal spines pointing toward her. This may be a threat signal, and is similar to behavior exhibited by the threespine stickleback as the female enters a stickleback nest.

When the female is ready to spawn, there is a marked change in her appearance. The dark mottlings on her body become prominent as the background color pales. Breder and Rosen, quoting J. Reighard, described behavior in the nest (1966:408):

> . . . The two fish lie side by side on the bottom. The female is turned partly on her side so that her median plane forms an angle of about 45° with the plane of the horizon. The male remains upright with his head just back of the pectoral of the female or opposite it! The male is quiet during the process while the female exhibits certain peculiar fin movements. The eggs are emitted at periods when the female is with the male in the nest.

Reighard noted four such periods of 4–6 seconds each, which were separated by periods of about 30 seconds. The female that he observed remained in the nest with the male for 2 hours and 20 minutes. When she departed the male pursued her, but he returned to care for the eggs, which had adhered to the bottom stones of the nest.

A female smallmouth bass may spawn in more than one nest. Ordinarily, a male spawns with only one female at a time, but one male is known to have spawned with two females in the same nest at the same time; the females alternated egg-laying periods, and both females left the nest at about the same time after their eggs had been laid (Breder and Rosen 1966).

The male smallmouth bass protects the nest against intruders of his own and other species; however, Latta (1963) reported that the common shiner had spawned in smallmouth nests in eastern Lake Michigan. Mraz (1964d) observed the total loss of many smallmouth bass nests due to predation by minnows, bluegills, pumpkinseeds, and green sunfish. Their method of operation was simple (p. 8):

> . . . One lead fish approaches the nest or school and the male leaves to chase the fish away. At once, the remainder dart in and feed, then dart away at the male's return. This is repeated until the nest or school is cleaned up or the group of predators decide to leave.

The number of smallmouth bass eggs per nest varies from 2,000 to 10,000 (Wis. Dep. Nat. Resour. 1968b). The eggs and newly hatched fry are vulnerable to floods. If the nest is destroyed, renesting may occur—a habit which is a distinct advantage when earlier nesting has not been successful (Nord 1967). Kuehn et al. (1961) observed one nest which survived a 2-m rise in the water level.

The fecundity of three smallmouth bass females, ages IV and V, from Lake Geneva, which were 335, 406, and 414 mm TL was 4,896, 5,402, and 5,364 eggs respectively (Mraz 1960). The eggs of smallmouth bass average 2.2 (1.8–2.5) mm diam (Fish 1932, Latta 1963, Meyer 1970), and are deposited in the center of the nest (Mraz 1964d).

Hatching time for this species ranges from 9.5 days at a water temperature of 12.8°C (55°F) to 2.25 days at 23.9°C (75°F) (Emig 1966b). According to Mraz (1964d), if spawning occurs during a rapid water temperature rise which levels off at about 23–25°C (73–77°F), the eggs may hatch in 48 hr or less. Developing smallmouth bass embryos were subjected to a temperature rise from 11.7 to 25°C (53 to 77°F) with zero mortality (Webster 1945).

Fish (1932) described and illustrated the 8.8-, 9.5-, 10-, and 19-mm stages of the smallmouth bass. Meyer (1970) illustrated the 10.2-mm (12-day), 15.6-mm (49-day), and 24.0-mm (66-day) stages. A series of early developmental stages through 24 days is depicted by Hubbs and Bailey (1938). The approximate length of smallmouths when all fin rays are formed is 10.7–11.0 mm, and larvae about 24 mm long develop distinctive, dark, vertical patches along the lateral line. After the smallmouth fry have taken on a dark pigmentation, they are readily visible. Smallmouth nests then look as if tar has been poured into them, hence the term "black fry." The young bass remain in this stage for 2–4 days, after which the dark pigmentation disappears, the yolk-sac is absorbed, and the school is ready to move away from the nest (Mraz 1964d). Young smallmouth bass may remain in the nest for 6–15 days, after which they rise in a school above the nest. The male herds them together as they weave about, in the fashion of cichlid fishes (Breder and Rosen 1966).

The young are usually protected by the male from 2 to 9 days, but at times he guards them for as long as 28 days, even after they have become widely dispersed in the shallow water near shore (Hubbs and Bailey 1938). The smallmouth bass thus cares for its young for a longer time than other sunfishes do, with the exception of the largemouth bass.

Pflieger (1966) stated that there seemed to be a marked reduction in the abundance of smallmouth fry within the first few days after they left the nests, suggesting that mortality was high at that time. Wiegert (1966) observed predation on smallmouth bass fry by minnows and small perch in the Sawyer Harbor area (Door County) during the 1964 season. In Missouri (Pflieger 1966), a marauding bluegill consumed 39 smallmouth bass fry after the male smallmouth bass was frightened away. On one occasion Pflieger saw smallmouth fry produced during the first nesting period feeding on fry from the second nesting.

In southern Wisconsin (Grant, Richland and Lafayette counties), young-of-year smallmouth bass averaged 26 mm long in June, 55 mm in July, and 69 mm in August and September (S. Krause, pers. comm.).

Annulus formation occurs in late June and early July, and there is no difference in the growth rates of the sexes. Coble (1967a) determined that the total yearly growth of age-III to age-V smallmouth bass in South Bay, Lake Huron, was directly related to the mean surface water temperature for the period July through September. However, bass from Lake Opeongo, Ontario, and older bass from Lake Opeongo and South Bay showed no relationship between growth and surface water temperatures.

The weights at the annuli of the Red Cedar River population shown in the table below were: 0.01, 0.09, 0.29, 0.52, 0.84, 1.02, 1.17, and 1.35 kg (Paragamian and Coble 1975). Smallmouth bass from Lake Geneva weighed 0.45 kg at 318 mm long; they weighed 0.91 kg at 406 mm, and 1.36 kg at 470 mm (Mraz 1960). In eastern Lake Michigan, the K_{SL} of smallmouth bass ranged from 2.53 to 3.35 for fish 165–470 mm long; the condition generally increased with the size of the fish (Latta 1963). Smallmouth bass, 100–259 mm SL, from Muskellunge Lake (Vilas County) had K_{SL} values of 2.04–2.56 (Bennett 1938).

The age at maturity for smallmouth bass is 3–4 years (Nord 1967). Some Lake Geneva smallmouth bass mature at 3 years of age, or at about 279 mm (11 in) (Mraz 1960). In Lake Michigan, the fastest growing male smallmouth bass reached sexual maturity at 3 years (259 mm), and the fastest growing female reached maturity at 4 years (325 mm); all males were mature at 5 years (avg TL 277 mm), and all females, at 7 years (avg TL 361 mm) (Latta 1963).

A 4.1-kg (9-lb 1-oz) smallmouth bass was taken 21 June 1950 from Indian Lake (Oneida County).

Young smallmouth bass begin their carnivorous existence as they rise from the nest. Before the yolksac is fully absorbed, they feed actively on minute midge larvae, *Daphnia*, or other small crustacea (Moore 1922). Unlike adult bass, which do most of their feeding during the early morning and early evening, the young bass feed throughout the day, and perhaps also at night (Hubbs and Bailey 1938). By the time the smallmouth bass are 38 mm (1.5 in) long, insects and small fishes make up the bulk of their food, and at about 76 mm (3 in) they begin to feed on small crayfishes. Fishes of suitable size and of almost any species living in the same waters—including perch, sunfishes, minnows, darters, sculpins, suckers, catfishes, sticklebacks, and young bass—are eaten by smallmouth bass, and form a large part of the diet of all juvenile and adult smallmouths. Usually dead food is rejected, but when the food supply is insufficient dead animals are eaten. The smallmouth has needlelike teeth which grab and hold the prey so that it may be swallowed whole.

In the Red Cedar River (Dunn County), young-of-year smallmouths and one yearling had eaten primarily aquatic insects, including larval and adult *Hydropsyche* and larval mayflies (Paragamian 1973). In smallmouth bass more than 162 mm long, crayfish, fish, and aquatic insects had been eaten, in that order of importance; the fish food included the smallmouth bass, white bass, bluegill, and logperch. In smallmouth bass 135–329 mm long from the Plover River (Portage County), fish was the most important food item (48% occurrence), followed by crayfish

Age and Growth (TL in mm) of the Smallmouth Bass in Wisconsin

Location	1	2	3	4	5	6	7	8	9	10	11	12	13	Source
L. Michigan and Green Bay (Door Co.)	79	160	234	264	302	333	381	404	414	445	432	470	505	Wiegert (1966)
19 lakes & 1 stream, Northern Wisconsin	61	135	208	269	318	358	388	424	447	465	480			Bennett (1938)
Clear L. (Oneida Co.)	92	142	185	240	297	354	394	427	453	473	487			Marinac (1976)
Red Cedar R. (Dunn Co.)	100	190	274	329	383	407	424	444						Paragamian and Coble (1975)
Plover R. (Portage Co.)	91	158	220	297	366	410	440	455	476					Paragamian (1973)
L. Geneva (Walworth Co.)	71	173	277	356	409	452	478							Mraz (1960)

(24%), and aquatic insects (4%); the fish eaten included the common shiner, shorthead redhorse, fantail darter, smallmouth bass, black bullhead, and stonecat. In the laboratory (Paragamian 1976b), the common shiner was most vulnerable to predation by the smallmouth bass, and the hornyhead chub ranked second; the white sucker was the least vulnerable. In angler-caught smallmouths 147–350 mm long from Clear Lake (Oneida County), crayfish made up 65% of the volume of the stomachs, fishes (cyprinids and percids) 22%, and insects 13% (Marinac 1976). In Lake Mendota (Dane County), smallmouth bass averaging 356 mm consumed adult insects (82.5% volume), plant matter (5%), bottom ooze (9.5%), amphipods (2.5%), and insect larvae (0.5%) (Pearse 1921a). In Green Lake (Green Lake County) 114-mm smallmouths consumed cladocerans (37.6% volume), insect larvae (31.9%), fish (13.6%), insect pupae (7.8%), insect adults (5%), amphipods (4.1%), plants (0.2%), and sand (0.2%).

Cahn (1927) reported catching a smallmouth bass which had consumed eight honey bees; this fish had undoubtedly been feeding at the surface. Lachner (1950) reported a 68-mm smallmouth bass which had eaten a 46-mm darter.

W. E. Williams (1959) reported that the smallmouth bass demonstrated a conversion factor of 4.50; i.e., it converted to flesh 1 part of 4.50 parts of food consumed.

In northern Wisconsin lakes during the summer (Hile and Juday 1941) the smallmouth bass inhabited waters at temperatures of 20.3–21.3°C (68.5–70.3°F). According to Emig (1966b), it prefers water temperatures of 21.1–26.7°C (70–80°F), and becomes lethargic at 10°C (50°F). A water temperature of about 10°C (50°F) marks the beginning and ending of the period of nonactivity and of reduced or suspended growth (Hubbs and Bailey 1938). In the laboratory (Larimore and Duever 1968), smallmouth fry acclimated to 30 and 35°C (86 and 95°F) failed to swim in waters which were warmer than their acclimation temperatures. Emig (1966b) noted that, at 21.1°C (70°F), concentrations of dissolved oxygen of 0.96 ppm in Deer River and 0.87 ppm in Beebe Lake (both in New York) were lethal to smallmouth bass.

Smallmouth bass occur most consistently in shallow water, and appear to be almost exclusively inhabitants of the epilimnion. In Nebish Lake (Vilas County), they were captured in water shallower than 7 m, and in Muskellunge Lake they were captured in the epilimnion at about 3 m (Hile and Juday 1941). In Green Lake (Green Lake County), Pearse (1921a) netted smallmouth bass at depths above 20 m, and in Lake Geneva Nelson and Hasler (1942) captured most smallmouths at 6–9 m, although they ranged freely between 3 and 12 m.

During the day adult smallmouths retire to pools, undercut banks, or lairs in fairly deep water. Hubbs and Bailey have described their activity between dusk and dawn (1938:33):

> . . . At dusk they move about more freely, and in lakes are then frequently seen splashing at the surface far from shore. They may remain active on moonlight nights, but ordinarily lie on the bottom in their open-eyed sleep until awakened by the first rays of dawn, hardly perceptible to man. Hunger then seems to impel them to search vigorously for food, which they often find on the very shallow marginal waters into which the forage fish have gone to catch a little rest. They may move so far inshore that their backs are exposed, and splash noisily as they lunge about after fishy morsels.

In winter, smallmouth bass go to deep waters and lie about rocks, ledges, or roots in a semidormant manner; they evidently do not take food at this time.

There appears to be a niche separation between the smallmouth bass and the largemouth bass in waters where these two species occur together. During their first year of life, smallmouths definitely seem to avoid the thick weedbeds of shallow water in which largemouths commonly congregate (Hubbs and Bailey 1938). Smallmouth young seek shelter in the lee of a stone or a brick, or in the cavity under a flat object. In lakes, smallmouths prefer to rest in the proximity of a rock ledge, a submerged log, or a boulder. In flowing water, smallmouths commonly lie in the protective backwater of a large boulder, a stump, or a rock ledge, where a minimum of physical exertion is required to retain their positions. Adult smallmouths are rarely taken near beds of submerged or floating plants, which are the favored retreats of largemouth bass.

In laboratory experiments designed to clarify aspects of the niche separation between the largemouth and the smallmouth bass, both species exhibited crepuscular activity, but the largemouth also showed a midday activity peak. The smallmouth bass avoided bright light, and its peak activity periods occurred at the beginning and at the end of the dark periods. The activity of the largemouth bass was much more depressed during dark periods, and rose sharply at the onset of light periods.

The smallmouth bass apparently has much less inclination to school than the largemouth bass (Mraz 1964d). Schooling is common among smallmouth fry in the nest, but they soon disperse.

Emery (1973) noted two kinds of daytime activity among smallmouth bass. In one of these, loosely aggregated pods of smallmouths moved slowly over an area, describing a path which led them back to a position of rest; often this was done in association with rock bass schools. In the other activity, smallmouths traveled from one area or range to another, moving in shallow water for as much as several kilometers a day.

Larimore (1952) found that smallmouth bass which had been transferred overland and released in other parts of a stream were capable of returning to their home pools from either upstream or downstream. Latta (1963) concluded from a 3-year study that this species was essentially nonmigratory; although 1 out of 3,141 tagged smallmouths had traveled 149 km (92 mi), only 11 individuals moved more than 32 km (20 mi). Smallmouth bass which were tagged and recaptured in Green Bay and in the Lake Michigan side of the Door County peninsula tended to remain in a given area (Wiegert 1966); only a few larger fish moved any great distances—a 33-cm fish tagged in Little Sturgeon Bay was recovered in the Ahnapee River (Kewaunee County) after traveling approximately 73 km (45 mi). In Missouri streams, 63% of the smallmouth bass had moved less than 1.6 km (1 mi) from their place of release, and over 97% were taken within 40 km (Funk 1957).

In the Black River (Clark County), 10 smallmouth bass were associated with the following species: blackside darter (18), northern hog sucker (17), shorthead redhorse (10), rock bass (4), slenderhead darter (1), rainbow darter (17), banded darter (18), golden redhorse (7), hornyhead chub (8), blacknose shiner (74), common shiner (33), largescale stoneroller (10), brook silverside (1), white sucker (1), johnny darter (6), and stonecat (1) (R. Urban, pers. comm.).

IMPORTANCE AND MANAGEMENT

Young smallmouth bass are preyed upon by older generations of bass, sunfish, perch, and large fish predators, as well as by crayfish, birds, frogs, and snakes.

The smallmouth bass is a known host to the glochidial or larval stage of the mucket clam (*Lampsilis siliquoidea*) (Hart and Fuller 1974).

Wisconsin anglers use a wide variety of tackle when fishing for smallmouth bass; sophisticated spinning and flyrods are used alongside the old-time cane pole. All of these, fished with minnows, angleworms, hellgramites, crayfish, and adult mayflies, attract the smallmouth. Dry flies, wet flies, and casting and spinning baits complete the smallmouth arsenal. Harlan and Speaker (1956) concluded that it "is almost impossible to tell the angler what kind of bait to use" when fishing for the smallmouth.

Jordan and Evermann (1923) quoted a Dr. J. A. Henshall, who wrote of the smallmouth bass (p. 356):

> . . . He is plucky, game, brave and unyielding to the last when hooked. He has the arrowy rush of the trout and bold leap of the salmon, while he has a system of fighting tactics peculiarly his own. . . . I consider him, inch for inch and pound for pound, the gamest fish that swims.

The smallmouth bass is distinctly a sport fish, and commercial harvesting is not permitted in Wisconsin. Fishing regulations for this species are liberal; since 1955 they have included an early opening for both the smallmouth and largemouth bass seasons in the 12 southern counties, and no size limit. The open season allows a daily bag limit of 5 to 10 smallmouths, and a size limit is imposed only in some northwestern counties where the minimum length must be 10 in. Liberal regulations in southern Wisconsin have been justified on the grounds that natural mortality and predation eliminate many smallmouth bass before they reach 10 in (254 mm); thus the removal of the minimum size limit provides more fishing without depleting future stocks (C. Brynildson 1957). For details pertaining to specific waters, current state fishing regulations should be consulted.

The best-known smallmouth bass fishing waters are those of Green Bay and Lake Michigan, which surround the tip of Door County. In one study, about 81% of the smallmouth bass caught there were taken after 1 July, and only 19% were taken during June (Wiegert 1966). In Lake Michigan south of Door County, the numbers of smallmouth bass taken drop off quickly. Only seven were reported caught from the Point Beach Nuclear Plant fishing pier (Manitowoc County) during 1972 and 1973 (Spigarelli and Thommes 1976).

According to Nord (1967), there are few bona fide smallmouth bass fishermen on the Mississippi River, and most smallmouths are taken incidentally with other species. In 1957, the smallmouth bass ranked sixteenth in the Mississippi River sport fishery, and the majority of the fish were taken above Pool 8; in 1962–1963, it ranked fifteenth. The projected sport fishery catch of smallmouth bass in Pools 4, 5, 7, and 11 in 1967–1968 was 5,351 fish weighing 2,233 kg (4,918 lb) (Wright 1970).

The flesh of the smallmouth is white, firm, and flaky, with a fine savor and a juicy, succulent quality. It is considered by gourmets to be superior to any fish except the lake whitefish of the Great Lakes. Its flesh is nutritious, and it has a low fat content which permits the successful angler to freeze his catch for later enjoyment (Schneberger 1972d).

Before the establishment of its walleye population, Escanaba Lake (Vilas County) was highly regarded for its smallmouth bass fishing (Kempinger et al. 1975). In the early years, smallmouth bass accounted for 1–11% of the annual total weight harvested by anglers, but in recent years it has amounted to less than 1%. From 1946 to 1969, 4,397 smallmouth bass were caught from Escanaba Lake, weighing a total of 993 kg (2,189 lb). In the Red Cedar River (Dunn County) the estimated harvest of smallmouth bass during 1973 was 5.1 kg/ha (Paragamian 1973). In Clear Lake (Oneida County), during 1974 and 1975, the smallmouth harvest ranged from 2.1 to 3.8 bass/ha (Marinac 1976).

In Livingston Branch (Iowa County), the standing stock of smallmouth bass was 51.6–82.9 kg/ha (C. Brynildson and Truog 1965). In the Red Cedar River (Dunn County) Paragamian (1973) estimated 132 smallmouth bass/ha and a standing crop of 15.1 kg/ha; in the Plover River (Portage County), he estimated 118 smallmouth bass/ha and 17.5 kg/ha. In Clear Lake (Oneida County), Marinac (1976) estimated 8.7 bass/ha and 1.1 kg/ha.

Smallmouth bass management is beset with many unanswered questions. In northern Illinois, when stocked in 12 ponds representing most kinds of warmwater pond habitats, the smallmouth bass reproduced successfully in 6 ponds and failed to reproduce in the other 6. This failure may have resulted from an absence of sexually mature fish, or from the inability of the smallmouths to compete successfully with largemouth bass and green sunfish (Bennett and Childers 1957). These researchers concluded that smallmouth bass are most successful in ponds by themselves, and that if they have to compete with such species as largemouth bass, green sunfish, bluegills, and bullheads, their growth and survival rates are reduced. Larimore (1954) noted that when smallmouth bass were introduced into a stream already containing native smallmouth bass, there was a decline in the number of native smallmouths in several pools which contained a concentration of stocked fish. This decline may have been caused by the movement of native smallmouths to other parts of the stream, or by a lack of native fish to replace those removed by anglers.

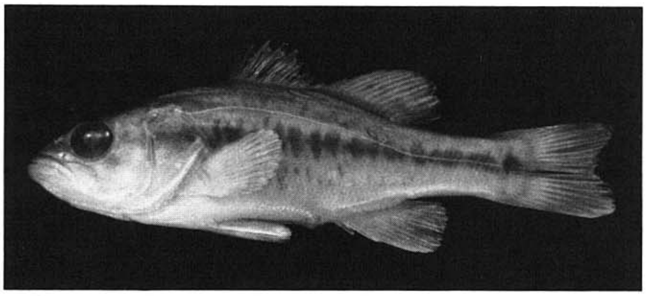
In Canada, the introduction of ciscoes in Lake Opeongo as food for lake trout proved to be detrimental to the smallmouth bass, and resulted in a drastic decline in the smallmouth bass resource (Emery 1975).

A smallmouth bass, unlike a salmonid fish, cannot be safely stripped of its eggs; however, it will perform normal spawning activities in artificial ponds if satisfactory conditions are provided (Hubbs and Bailey 1938). To create such conditions, a large pond may be stocked with forage minnows, crayfishes, and microcrustaceans; and aquatic vegetation allowed to grow up; gravel spawning beds should be prepared. Bass introduced in such ponds spawn and remain throughout the season in the ponds with the young fish. No subsequent food or care is needed, except for the fertilization of the water to increase the growth of natural foods. The costs of labor are slight, and little or no expense is involved in feeding the fish, but production is inefficient for the area utilized because of losses through cannibalism, insufficient food, and predation. Pond management techniques, and techniques for trapping and transporting smallmouth bass are given by Mraz (1964d). The details of feeding and caring for the young are discussed by Hubbs and Bailey (1938), and by Langlois (1936).

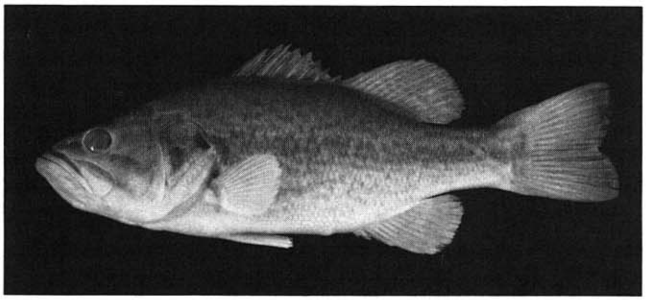
Largemouth Bass

Micropterus salmoides (Lacepède). *Micropterus*—small fin; *salmoides*—troutlike, in gameness and in quality as food, and often called "trout" in the South, where the original was captured.

Other common names: northern largemouth bass, largemouth, bigmouth bass, black bass, largemouth black bass, green bass, line side, green trout, Oswego bass, bayou bass, slough bass, lake bass.



Immature 52 mm, outlet of Williams L. (Marquette Co.), 29 July 1960



Subadult 184 mm, L. Poygan (Winnebago Co.), 23 July 1960

DESCRIPTION

Body slender to robust, slightly compressed laterally, oval in cross section. Length 229–305 mm (9–12 in). TL = 1.24 SL. Depth into TL 3.5–4.2. Head length into TL 3.2–3.5. Mouth large, slightly oblique. Upper jaw reaching at least to posterior edge of eye in adults, and from middle to posterior edge in young-of-year; lower jaw heavy, blunt, decidedly longer than upper jaw; conical, pointed teeth in brushlike pads on upper and lower jaws; lower pharyngeal arches narrow, with numerous fine teeth. Gill rakers on first gill arch stout, long, straight, and pointed. Dorsal fins 2, scarcely joined; first dorsal fin with 10 spines and second with 12–14 soft rays. Anal fin with 3 spines, 11 (10–12) soft rays; pelvic fin thoracic, with 1 spine and 5 rays; pectoral fin short and rounded, when laid forward across cheek not reaching eye; caudal fin moderately forked. Scales ctenoid, in lateral line 60–68; lateral line complete. Chromosomes 2n = 46 (W. LeGrande, pers. comm.).

Back and head dark green to light green; sides lighter; belly and ventral region of head whitish. A prominent lateral stripe from snout through eye to base of tail, interrupted anteriorly as a series of blotches of varying diameters, and becoming a solid, even stripe on caudal peduncle (in young-of-year, stripe appearing as a series of vertical blotches). Streaks on each side of head, radiating backward from snout or eye either faint or absent; dark opercle spot about size of pupil of eye. Eye golden brown. Vertical fins lightly pigmented, paired fins generally clear; caudal fin alike in young and adult, without the bright colors of the smallmouth young. Adults from mud-bottom lakes are dark olive brown to black, with markings hardly discernible.

In breeding male, colors darken.

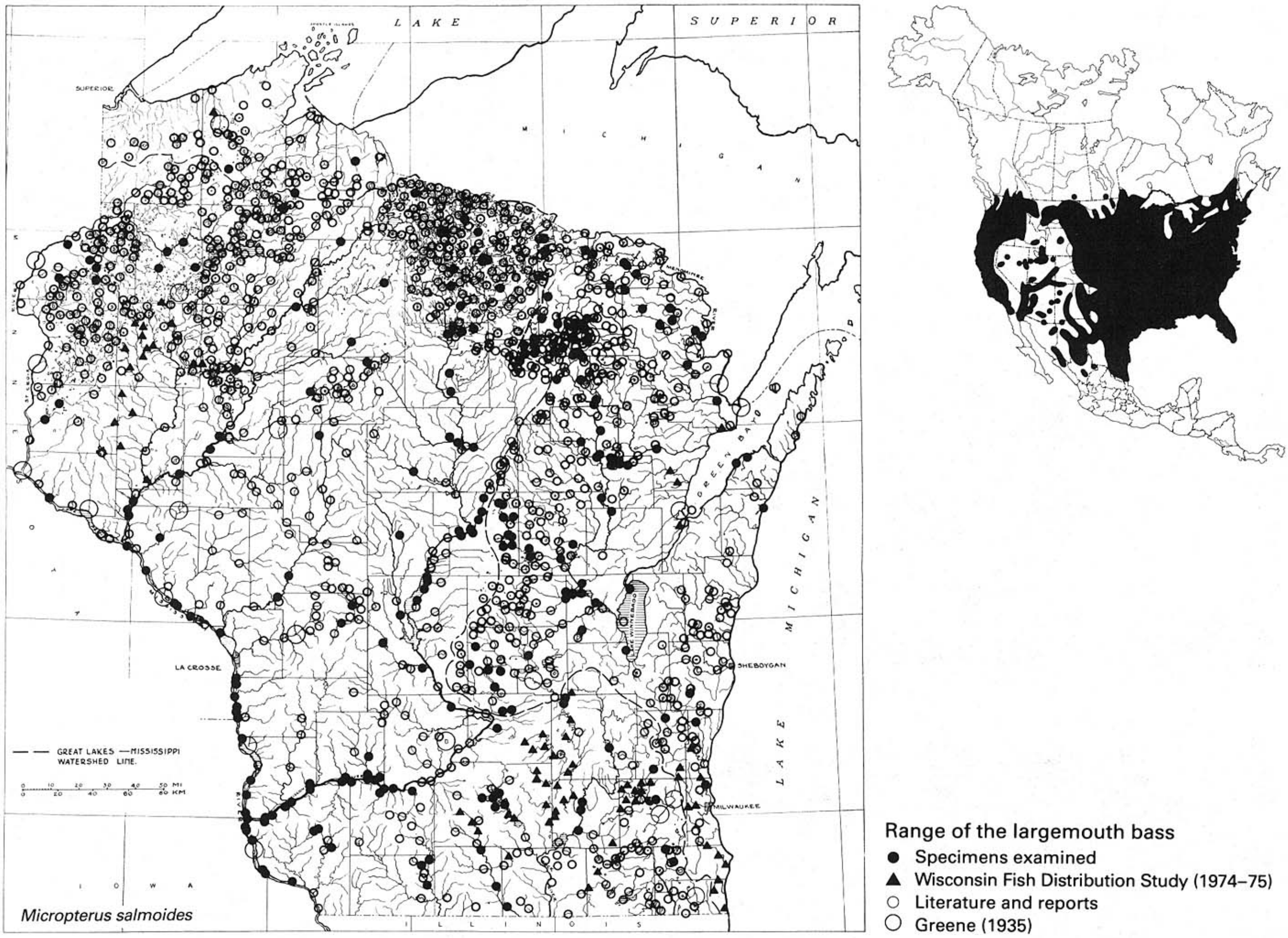
Sexual dimorphism: Males over 350 mm with circular, scaleless area around urogenital opening; females with pear-shaped, scaleless area (W. D. Parker 1971).

Hybrids: Artificial largemouth bass × smallmouth bass (see p. 816), largemouth bass × rock bass, largemouth bass × bluegill, largemouth bass × warmouth, largemouth bass × black crappie (West and Hester 1966, Schwartz 1972, *Sports Afield* June 1977:147–148).

DISTRIBUTION, STATUS, AND HABITAT

In Wisconsin, the largemouth bass occurs in all three drainage basins; it is least widespread in the driftless area of southwestern Wisconsin. Wisconsin is near the northern limit of distribution, and it has been suggested that its presence in the state, especially in the northern counties, resulted from introductions. In the neighboring Upper Peninsula of Michigan, its absence in early reports and records prompted Taylor (1954) to suggest that the largemouth bass may not have been native to the Upper Peninsula, although it is widely distributed there today. Unfortunately, early records of its status in northern Wisconsin are not available. In northwestern Wisconsin it was present in at least 61 of 65 lakes sampled from 1975 to 1977 (H. Snow, pers. comm.). In Waukesha County, it was found in 29 of 40 lakes sampled (Poff and Threinen 1963).

The largemouth bass originally ranged east of the Rocky Mountains from southern Quebec and Ontario through the Great Lakes and the Mississippi Valley to the Gulf of Mexico, and from northeastern Mexico to Florida and the Carolinas (Hubbs and Lagler 1964). Details of its original range and of its present range (a result of extensive introductions) are given by Rob-



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

bins and MacCrimmon (1974). Its present world distribution includes North America, Central America, South America, Africa, Europe, Guam, Hawaii, Japan, Lebanon, New Zealand, and the Philippines.

The largemouth bass is abundant in medium to large rivers, and occasional in the lower extremities of small streams opening into them. It is common in lakes, ponds, sloughs, and backwaters, and in some landlocked pools of the Wisconsin and Mississippi rivers. Priegel (1967a) considered it common in the weedy bays along the western shore of Lake Winnebago. It occurs in a number of Milwaukee County lagoons. It is rare at the barriers of the tributaries to Lake Superior (McLain et al. 1965). Impoundments in streams without native largemouth bass populations are soon stocked with this species; hence it is quickly expanding its range into new areas.

In Wisconsin, the largemouth bass was encountered most frequently in clear to slightly turbid water at depths up to 1.5 m, over substrates of sand (31% frequency), gravel (20%), mud (20%), silt (9%), rubble (7%), boulders (6%), clay (4%), and detritus (3%). It occurred in rivers of the following widths: 1.0–3.0 m (19%), 3.1–6.0 m (13%), 6.1–12.0 m (17%), 12.1–24.0 m (28%), 24.1–50.0 m (19%), and more than 50 m (4%). The largemouth bass occurs mostly in shallow areas with sparse to dense vegetation—the same type of habitat that produces bluegills.

BIOLOGY

An excellent single reference for basses is Stroud and Clepper (1975). The following account is largely derived from Mraz et al. (1961) and Mraz (1964d).

The spawning of the largemouth bass in Wisconsin occurs from late April to early July. Nests were observed in Browns Lake (Racine County) as early as 3 May and as late as 25 May. The average spawning date was 9 May at the former Burlington Hatchery (Racine County), and 15 May at the Delafield Research Station (Waukesha County). Largemouth bass spawn about 2 weeks later in the northern part of the state than in the south. In Vilas County lakes, largemouth bass had finished spawning by the third week of June, according to Parker and Hasler (1959).

The selection of nest sites begins when water temperatures reach 15.6°C (60°F), and eggs are laid when the water temperatures are at 16.7–18.3°C (62–65°F). It is generally assumed that the largemouth bass does not spawn at temperatures much below 17.8°C (64°F) (Breder and Rosen 1966). The species is self-sustaining in Puerto Rican reservoirs where water temperatures average 25.5°C (78°F) throughout the year (Robbins and MacCrimmon 1974). In Minnesota near the Twin Cities, the first spawning of largemouth bass occurred 2–5 days after the daily mean water temperature had reached and remained above 15.6°C (60°F). Such temperatures occur first in shallow bays, which are generally warmer than the main body of water.

In water containing both largemouth and smallmouth basses, the largemouth spawns a little sooner than the smallmouth. The shallower, protected spawning sites among emergent vegetation in quiet bays, which are preferred by the largemouth, warm to the optimum temperatures sooner than do the deeper, rockier sites used by the smallmouth (Scott and Crossman 1973). In a Delafield (Waukesha County) pond with carp present, three largemouth bass nests originally constructed along a gravel shore were deserted before the eggs were laid, and the bass renested within a very heavy bed of coontails and water buttercups (Mraz and Cooper 1957b); inside the dense vegetation, the nests were constructed on a bottom of mud and plant fibers. Successful hatches of bass fry were produced from these nests.

The male largemouth bass usually selects a sand or gravel bottom upon which to build a nest; however, largemouths will also nest on soft bottoms, where they are able to expose such hard objects as roots, twigs, and snail shells on which to deposit the eggs (Hubbs and Bailey 1938). The largemouth bass nest is placed in about 0.2–1.8 m of water; the average depth is about 0.6 m (Breder and Rosen 1966). The male largemouth constructs a nest by using his fins to sweep out a huge basin, which may be 1 m diam and 0.3 m into the bottom. Mraz noted that deep depressions may be dug to get down to sand, or gravel, or even to a firm layer of sticks. Largemouth bass usually nest about 9 m apart from each other, and never nest in colonies as do most sunfishes.

Territorial defense against intruders is practiced by the largemouth bass as it is by other sunfishes. Eddy and Surber (1947) found that the guarding largemouth male strikes almost anything within at least a 7-m radius of the nest; he does not feed on food objects, but chews on them and then ejects them some distance away.

According to Reighard (1906), the spawning of the largemouth bass takes place at dusk (p. 15):

> . . . The male was in the nest or near it and repeatedly the female approached. The male circled to her outer side and bit her flank and she then went away. Three or four other bass, probably males, were seen ten or 15 feet outside the nest. I returned at 7 P.M. and found the same conditions. The female was seen to approach the nest and to turn on her side with her head pointed obliquely downward and to float thus, as though half dead. In this position she entered the nest and the male followed and took up a similar position. What happened in the nest could not be clearly seen. The tails of the two fish lay side by side on the bottom with their tails together and parallel. It could also be seen that sometimes one and sometimes apparently the other fish lay turned partly on its side. At this time no doubt the eggs were emitted. After being in the nest for a short time the fish came out, and the female was seen to be still floating, head downward. They then returned to the nest and continued thus for half an hour, alternately lying on the bottom within the nest and floating on its border. It was then too dark to make further observations.

The male largemouth bass receives more than one female in his nest. The eggs may be deposited in the center of the nest, along the rim, or even outside of the nest. According to Mraz et al. (1961), adult females carry 2,000–20,000 eggs in their ovaries; the number of eggs per female is largely a function of size. Not all the eggs will be emitted at once, and one female may lay eggs in several nests. Each nest usually contains about 5,000 eggs. The eggs are demersal and adhesive, and amber to pale yellow in color; when fertilized they are 1.5–1.7 mm diam (Scott and Crossman 1973, Merriner 1971a).

Hatching time in stable, warmwater temperatures is from 3 to 7 days. At the Burlington Hatchery, the average hatching time was 7 days, according to 20 years of records. A sudden drop in water temperature delays hatching time and may even kill eggs, but eggs carried in the nest for as long as 2 weeks have hatched successfully. It is generally believed that the welfare of the eggs is dependent upon the nest cleaning and water circulation provided by the male when he fans the nest. The eggs in many well-guarded nests have developed fungus infections and have been lost, however. Bass eggs left unattended have sometimes been hatched in porcelain trays. Kelly (1968) showed that temperature is not the main cause of largemouth bass egg mortality in the 12.8–23.9°C (55–75°F) range.

On hatching, young largemouth bass are transparent and 3 mm long. Counts made in Punch Lake (Vilas County) showed as many as 6,000 largemouth bass fry were produced in one nest, with an average of 3,000 fry per nest and a total production, in a good year, of about 37,500/ha (15,000/acre). After hatching, the fry remain in the bottom of the nest until the yolk is absorbed, usually a period of 6 or 7 days. They then rise from the nest, and begin feeding and schooling (Scott and Crossman 1973, Kramer and Smith 1960a). At this time, the fry are 5.9–6.3 mm long. They may remain in a brood as long as 31 days, and are guarded over part or all of this time by the male. At this stage young largemouths are a pale green, rather than black like the smallmouth bass.

Meyer (1970) illustrated the largemouth fry at the 5.4-mm, 10.2-mm (19-day), and 15.5-mm (31-day) stages. Fish (1932) illustrated and described the 75-mm stage.

Largemouth bass begin life as a swarm of fingerlings. The swarm is generally composed of young from a single nest, although the joining of 2–5 schools is common; in such cases, the respective males accompany the group. As feeding begins and the fish start to grow, the swarm spreads out until it covers several square meters. During this period, the male remains with the group and valiantly defends his brood of young against all comers. Nevertheless some young are lost to predation, and others may starve to death if plankton supplies are insufficient when feeding begins after yolk-sac absorption. Some predation is in the form of cannibalism by larger young on newly hatched broods. The bass which feed on fish grow more rapidly than the others during the first year, and retain that advantage in later years.

In early July, young-of-year largemouth bass in northern Wisconsin lakes averaged 32 mm TL; in Lake Poygan (Waushara County) during mid-July, they averaged 42 (28–51) mm TL; and in the Mississippi River (Grant County) on 24 September, they averaged 67 (55–86) mm TL. In Pewaukee Lake (Waukesha County), young largemouths averaged 40 mm in early August, and 68 mm on 10 September.

The growth of largemouth bass in Wisconsin is more moderate than the growth of this species in some southern states. Stroud (1949) noted that it reaches 190-, 343-, and 371-mm (7.5-, 13.5-, and 14.6-in) TL in Douglas Lake, Tennessee, during the first 3 years of life. Northern largemouth bass are longer lived than southern fish, which seldom live beyond 5 years.

Largemouth bass register great increases in length during the first 2 years of life; thereafter, weight gains are greater.

Padfield (1951) determined that females tended to be longer and heavier than males for each age group studied, but the differences between the sexes were slight. Differential mortality occurs, however; females reach a maximum of 9 years of age, and males reach a maximum of only 6 years. Females appear to be better fitted for survival under adverse conditions than males.

The growth of largemouths ceases at temperatures below 10°C (50°F). Stunted populations occur mostly in small, infertile lakes, many of which are found in northern Wisconsin; a lake with a stunted population may contain no fish over 254 mm (10 in) long (Mraz et al. 1961).

Young largemouth bass up to 76 mm (3 in) long are abundant in many waters, and frequently make up a large percentage of the fish taken in research nets; however, only a small number of the young reach maturity. Mature fish are generally 3–4 years old and 254–305 mm (10–12 in) long; they continue to reproduce year after year. There seems to be no mortality associated with the stresses of reproduction. The old-

Age and Growth (TL in mm) of the Largemouth Bass in Wisconsin

Location	1	2	3	4	5	6	7	8	9	10	11	12	13	Source
Northern Wisconsin lakes	71	165	246	297	335	353	386	424	450	470	490	486	490	Bennett (1937)
Birch L.[a] (Washburn Co.)	81	193	257	325	363	391	432							Snow (1969)
Clear L.[a] (Sawyer Co.)	56	165	224	262	333	386	419							Snow (1969)
Flora L. (Vilas Co.)	107	173	231	284	315	345	381	404	437	470				Parker (1956)
Punch L. (Vilas Co.)	56	137	193	236	254									Mraz et al. (1961)
Mississippi R. (Buffalo Co.)	102	244	325											Christenson and Smith (1965)
Cox Hollow L.[a] (Iowa Co.)		155	183	211	318	381	465	513						Dunst (1969)
L. Wingra (Dane Co.)	96	166	208	251	293									Churchill (1976)
L. Mendota (Dane Co.)	114	246	320	366	396	437	460	478	480	503	518			Bennett (1937)
Browns L. (Racine Co.)	91	170	229	272	305	345	411	452	467	478	498	521	511	Mraz and Threinen (1957)

[a] Lengths at capture.

est largemouth bass reported was age XVI, and was 541 mm (21.3 in) TL (Carlander 1977).

Most largemouth bass do not exceed 0.9–1.4 kg (2–3 lb) in weight, but occasionally a 2.7-kg (6-lb) fish is taken. The heaviest largemouth bass known from Wisconsin was 5.07 kg (11 lb 3 oz) taken on 12 October 1940 from Lake Ripley (Jefferson County). A record 819-mm, 10.09-kg (32¼-in, 22-lb 4-oz) fish was caught in Montgomery Lake, Georgia, in 1932. The giants of this species occur in Florida and Georgia.

The foods of fingerling largemouth bass are principally microcrustaceans—copepods, cladocerans, and ostracods. As largemouths reach a size of 51–76 mm, insects, insect larvae, and fish begin to appear in their diets. Larger largemouth bass eat fish, crayfish, frogs, and larger insects (Mraz et al. 1961, Keast 1965).

In Lake Mendota (Dane County), seven largemouths averaging 135 mm (5.3 in) TL contained the following amounts of food: fish 45%, algae 14.2%, amphipods 13.4%, crayfish 12.1%, insect adults 10.7%, and plants 3.6% (Pearse 1921a). In Murphy Flowage (Rusk County), crayfish comprised 54.6%, fish 38.8%, and insects 1.5% of the total weight of all items consumed (Snow 1971). The fish eaten, in decreasing order of importance, were bluegills, tadpole madtoms, brown bullheads, yellow perch, black crappies, minnows, and largemouth bass. Dragonfly nymphs were the predominant insects consumed; other items eaten were frogs, inorganic materials (stones up to 19.5 g), plant materials, mammals, tadpoles, annelids, and pelecypods. Shorttail shrews were found in two largemouth stomachs.

Snow (1971) noted that, after a drawdown of water in a northern Wisconsin flowage, which was accompanied by a known decline in the abundance of aquatic vegetation and an apparent decline in the abundance of crayfish, largemouth bass increased their consumption of bluegills. He suggested that a drawdown might be used to alter the feeding habits of bass to make them prey more selectively on bluegills.

Largemouth bass which had eaten golden shiners were found to have eaten more food than largemouths that had eaten insects. Largemouths also grew more rapidly on a diet of fish than on a diet of insects, regardless of whether they ate the same amount or not (MacKay 1963). In the largemouth, foods are converted to fish flesh in a ratio of 4:1—4 kg of food produces 1 kg of flesh (Mraz et al. 1961). Small largemouth bass fed in colder waters than big largemouths, but no large bass took food voluntarily in water below 10°C (Markus 1932).

Aquarium tests have shown that bass will readily swallow forage fishes whose maximum depth of body is equal to the mouth width of the bass (MacKay 1963). Largemouths are sight feeders that hunt for food; a small school of 5–10 largemouth bass roaming the shallows is a common sight. Apparently they feed at all hours, but feeding is most often observed in early morning or late in the day. The actual prey-capture behavior was discussed by Nyberg (1971), who indicated that the attack velocity was greater for moving prey, such as minnows, than for crayfish and worms. In some cases, the prey was not completely swallowed up initially; it was caught and held in the jaws until the forward motion of the bass stopped—then it was sucked in. McKnight (1968) demonstrated that largemouth fingerlings that were fed minnows grew better and weighed more than bass which were fed a commercially prepared, pellet-type feed. He suggested that the bass prefer live, swimming foods.

Barkalow (1950) reported that a largemouth bass which swam slowly beneath and behind a feeding duck in the shallows may have been feeding as well. He postulated that largemouth bass follow other animals and feed on the prey that are flushed from hiding by these animals.

The largemouth bass is truly a warmwater fish that prefers shallow water; it is seldom found in water more than 6 m deep. It prefers temperatures of 27.2–30°C (81–86°F) and its upper lethal limit is 35.6°C (96°F) (Clark 1969). Immature largemouth bass, however, have been collected from water with temperatures as high as 37°C (98.6°F) (Siler and Clugston 1975), and largemouths were known to survive a 38°C (100.4°F) water temperature in a shallow Michigan pond (Bailey 1955).

In Lake Monona (Dane County), largemouth bass tended to concentrate in the heated outfall of a power plant (Neill and Magnuson 1974). They preferred water temperatures of 29.1°C (84.4°F) in the laboratory and 29.7°C (85.5°F) in the field. Sonic tracking studies (Clugston 1973) have suggested that largemouth bass regularly migrate in and out of thermal plumes. During the winter (Gibbons and Bennett 1971), largemouth bass sought out heated areas in a reservoir receiving heated effluent from a reactor.

Water temperature plays an important role in determining the swimming performance of largemouth bass. Hocutt (1973) found that at 5°C (41°F) the largemouth bass swam sluggishly, but at temperatures of 15–35°C (59–95°F), it swam at speeds above 13.7 m/min.

Water temperature is an important limiting factor in the adaptation of largemouth bass to new waters within and beyond the native range (Robbins and MacCrimmon 1974). High lethal temperatures limit the success of largemouths in tropical lowlands, and the need for warm waters for successful spawning limits the northward dispersal of the species in North America and Europe.

In Minnesota field studies performed by suspending largemouth bass in live boxes at varying depths, Moore (1942) observed largemouth bass mortality within 24 hr at a water temperature of 15°C (59°F) and at an oxygen level of 3.1 ppm. At winter water temperatures, all bass died within 48 hr at an oxygen level of 2.3 ppm. In winterkill lakes of southeastern Michigan, largemouth bass and bluegills had a toleration threshold for dissolved oxygen of about 0.6 ppm (Cooper and Washburn 1949).

Carlander (1977) cited references which classifed largemouth bass as suitable for slightly alkaline waters, and for brackish waters of up to 24.4 ppt salinity.

Given a modestly abundant food supply, largemouth bass seem to be capable of feeding and maintaining themselves even in permanently turbid water (Miller 1975). Miller postulated that turbidity inhibits mating and adversely affects the survival of eggs and the young rather than the survival of juvenile or adult bass.

Numerous authors have noted the strong schooling tendency of largemouth bass fry, and the school-like behavior of small groups of immature and mature bass that range the edges of shallow waters in lakes and ponds. Similar behavior has seldom or never been observed among other bass species, and the cause and function of such movements by the largemouth can only be speculated upon at present (Miller 1975).

During the day, largemouth bass cruise above aquatic plants at depths of 1–3 m, or lie under lily pads or in the shade of overhanging trees, piers, or brush. In the evening, largemouths tend to move into shallow water, apparently to feed. After dark they return to deeper water, where they rest on the bottom under logs or trees (Moyle 1969). They rest with the throat region touching the substrate, with the pelvic and median fins erect, and with the tail slightly elevated (Miller 1975). They are seldom found at depths greater than the deepest water in which rooted vegetation grows.

Largemouth bass generally move into deeper waters in winter (Lewis and Flickinger 1967), but usually remain more active than smallmouth bass during the winter months. In the spring, largemouths migrate into bays that have warmed up sooner than the main body of water.

Largemouth bass that were displaced during the spawning season tended to return to the site where they had originally been captured (Parker and Hasler 1959). They returned in an indirect way—by following the shoreline rather than swimming directly to the site from the center of the lake, where they had been released. Hasler and Wisby (1958) noted that displaced largemouth bass did not return to their capture area with the same precision as did green sunfish. A strong tendency by largemouths to remain in a home area within 91 m of their point of capture was reported by Lewis and Flickinger (1967). However, one largemouth bass which had been fitted with a transmitter, traveled a minimum distance of 3.1 km (2 mi) in 33 min after its release, or 3.6 times its total length per second, at a water temperature of 25°C (77°F) (Larimore and Dufford 1976). MacKay (1963) cited a study of largemouths in which the distance from the point of tagging to the point of recapture averaged 4.3 km (2.7 mi).

In areas of the world where the largemouth bass has become naturalized, there is little evidence that introductions into larger bodies of open water have resulted in appreciable declines in the population levels of native species. In smaller lakes, ponds, and reservoirs, however, introduced largemouths may result in a population explosion of the bass, the decimation of all forage species, and the stunted growth of the bass (Robbins and MacCrimmon 1974).

In Wisconsin, almost all species of fish are associated with the largemouth bass, except for the cold-water fishes. The largemouth lives principally with bluegills, pumpkinseeds, golden shiners, and bullheads. Competing predator species have been thought to cause a decline in largemouth bass populations; the introduction of walleyes into landlocked lakes in northeastern Wisconsin inhabited only by bass and panfish, for example, had this effect (Mraz et al. 1961).

For details on the niche separation between the largemouth bass and the closely related smallmouth bass, consult the smallmouth bass species account.

IMPORTANCE AND MANAGEMENT

Young largemouth bass are eaten by other centrarchids, by esocids, and by the larger percid fishes. Since adult bass are rapid swimmers, it is unlikely that they often become the prey of birds and other fish. Adams and Hankinson (1926) reported on one largemouth bass from Oneida Lake, New York, which had a lamprey scar from a wound that may have been responsible for its death. Perhaps a more important enemy of the largemouth bass is the bass tapeworm, which attacks the reproductive organs and renders the bass sterile.

The largemouth bass is host to the glochidial stage of a large number of important clams, including *Amblema plicata*, *Fusconaia ebena*, *Megalonaias gigantea*, *Quadrula nodulata*, *Andonta grandis*, *Lasmigona complanata*, *Strophitus undulatus*, *Actinonaias carinata*, *Lampsilis ovata*, *Lampsilis siliquoidea*, *Lampsilis teres*, *Ligumia recta*, and *Ligumia subrostrata* (Hart and Fuller 1974).

The largemouth bass is eagerly sought by anglers in Wisconsin. In a survey of vacationers, 28% preferred bass over other species and the bass had a higher popularity rating as a sport fish than all other species.

The largemouth bass bites on almost any type of bait as long as it moves. Live baits such as worms, minnows, frogs, insect larvae, and crayfish have all been successful. Surface plugs or underwater plugs work well, and fly fishermen usually use a large popper. Laboratory experiments have shown that the largemouth bass is able to distinguish colors quite readily. It prefers red, which it is able to distinguish easily from all other colors except violet (Mraz et al. 1961). Colors have been worked into a wide assortment of bass plugs and artificial flies. Evening and early morning hours are usually the best fishing times. Snow (1971) analyzed baits and methods of capture for largemouth bass in Murphy Flowage (Rusk County).

In the Mississippi River, the largemouth bass ranked 12th in the sport fishery in 1957, and 10th in 1962–1963 (Nord 1967). For 1967–1968, the estimated sport fishery catch in Pools 4, 5, 7, and 11 was 30,545 fish weighing 19,960 kg (44,010 lb) (Wright 1970).

In Murphy Flowage (Rusk County) from 1955 through 1969, anglers caught 7,176 largemouth bass weighing 3,370 kg (7,426 lb); the annual harvest averaged 6.8 fish and 3.1 kg/ha (Snow 1978). In Escanaba Lake (Vilas County) from 1946 through 1969, anglers caught 2,271 largemouth bass weighing 1,184 kg (2,611 lb). This species never provided more than 2% of the total annual catch from Escanaba Lake, and never more than 8% of the total annual weight harvested (Kempinger et al. 1975). At Browns Lake (Racine County) in 1953, anglers caught 2,671 largemouths, or about 4.5 kg/ha (4 lb/acre). Early in the history of the impounded Yellowstone Lake (Lafayette County), a partial and incomplete creel census placed the yearly harvest of largemouths at 65–183 fish and 10.1–31.4 kg/ha (9–28 lb/acre) (Mraz et al. 1961).

Largemouth bass young are useful as bioassay animals. They adjust readily to captivity and are not sensitive to handling (Ward and Irwin 1961).

According to Bennett (1951), legal length limits have no value in largemouth bass conservation, and there appears to be no advantage in closed seasons and in bag limits. There has been no correlation established between the number of largemouth bass of spawning size in a population and the number of young bass produced. In Browns Lake (Racine County), Mraz (1964c) found that, with liberal angling regulations (including no size limit and an earlier opening of the season), there were slightly better growth rates among largemouths toward the end of a 6-year study. He concluded that, during the study period, liberalization of bass-fishing regulations afforded an increased opportunity for anglers to pursue their sport without harm to the largemouth population.

Largemouth bass meat is moderately firm and has a mild flavor. It is also nutritious; analyses show that an edible portion contains 76.7% water, 20.6% protein, 1.8% fat, and 1.2% ash. The low fat content allows largemouths to be kept frozen for a long time. In the early part of the fishing season, largemouths from weedy waters with mud bottoms have been known to retain a muddy flavor acquired from the lake bottom during their partial hibernation (Eddy and Underhill 1974).

The management of largemouth bass has challenged fishery researchers for many years. Population estimates on three separate occasions at Browns Lake, a 158-ha bass-bluegill lake in Racine County, placed the largemouth population at between 88 and 138 individuals more than 152 mm long, and the standing crop weight at 30.3–37 kg/ha (27–33 lb/acre) (Mraz et al. 1961); about 34 kg/ha (30 lb/acre) were regarded as normal for this glacial lake.

Like a bluegill population, a largemouth bass population may become overcrowded and stunted. Punch Lake (Vilas County) contained only one species of fish—a slow-growing population of large mouth bass which reached 254 mm (10 in) in the fourth or fifth year (Churchill 1949a). After a removal program was instituted, the size of the fish at the end of the third summer's growth had increased from 178 mm (7 in) in 1939 to 203 mm (8 in) in 1942. The introduction of hybrid muskellunge × northern pike to further control the population resulted in a greater increase in largemouth growth; the average size of the bass in 1948—at the end of the third summer following the introduction—was 241 mm (9.5 in). Following a thinning operation in Flora Lake (Vilas County), in which bluegills, pumpkinseeds, rock bass, yellow perch, white suckers, and golden shiners were removed in large numbers yearly, no change in the linear growth of largemouth bass was observed, but there was an increase in weight (Parker 1956).

Though variable from year to year, the natural reproduction of largemouth bass is generally adequate to sustain satisfactory fishable populations. Formerly bass hatcheries were an important fish management activity in Wisconsin, but in recent years they have been reduced or eliminated. Stocking is confined to winterkill lakes, or to new or rehabilitated waters. The introduction of a few pairs of adult largemouths is sufficient to achieve repopulation; natural nurseries, such as small ponds with large numbers of stunted bass, can be tapped for such seed stock.

An analysis of the production of young largemouths in ponds in southern Wisconsin suggests that high populations of carp may depress the production of largemouth bass (Mraz and Cooper 1957b). This is not true in all cases, however, for two ponds containing carp and largemouth bass yielded 2,540 and 14,125 young bass per hectare. Compared with the stocking rates of fingerling largemouth bass commonly employed in fish management work, this rate of production would appear to be entirely adequate to maintain bass populations, if other conditions were suitable.

Where excessive carp populations have caused turbidity and destroyed vegetation, the usual management approach has been either to eliminate the carp by fish toxicants or to reduce them by seining. A substantial carp reduction results in clearer water, which is necessary for sight feeders like the largemouth bass, and in restored weed beds, with the food resources they harbor (Mraz et al. 1961).

Where the primary interest of a pond owner is sport fishing and large fish are preferred, a combined population of largemouth bass and golden shiners is superior to a bass-bluegill combination, in that bass reach a catchable size in a shorter time. In Wisconsin, largemouth bass can be raised alone, or with golden shiners or fathead minnows as a food source (Klingbiel et al. 1969). In most cases, the minnows disappear in about 4 years, but the bass may do almost as well without them. Golden shiners are generally favored over fathead minnows because the adult shiners become larger and, therefore, are less apt to be eaten. Although largemouth bass and bluegills are a recommended combination in many states, this combination is not recommended in Wisconsin (Klingbiel et al. 1969:14–15):

> . . . Generally bluegills become overpopulated and stunted. These fish are of no value because they are too large for largemouth bass to eat, and too small for angling. Bluegills will also compete for food with the smaller bass and will eventually stop bass reproduction by eating the young. Bass-bluegill management has been successful in very few ponds in Wisconsin.

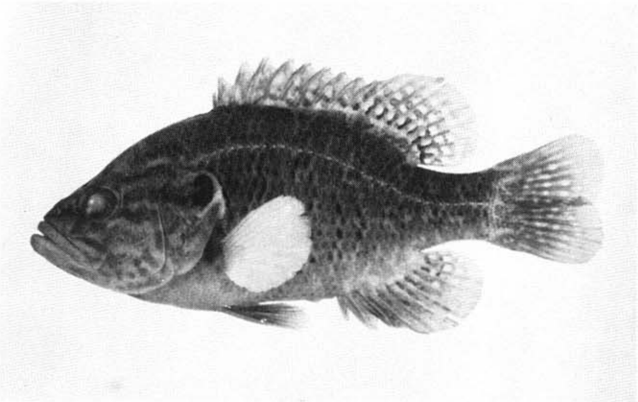
The recommended stocking rate for largemouth bass is 250 25–51-mm fingerlings per hectare; such fingerlings are available in July. Golden shiners or fathead minnows may be stocked with the bass at the rate of 1,000 adults per hectare. Fishing should begin when the bass are 3 years old; harvesting is extremely important because overpopulation occurs easily, particularly in the northern part of Wisconsin, where growing seasons are short and waters are relatively infertile. The angler should keep no fish larger than about 300 mm (12 in), since large bass help to control the numbers of small fish. For example, a 450-mm (18-in) bass can eat a 200-mm (8-in) bass.

Largemouth females and smallmouth males have been artificially crossed to produce the "meanmouth" hybrid, which as a yearling is 203–305 mm (8–12 in) long and weighs up to 454 g (1 lb). This hybrid is fertile, can reproduce at age I, and has the ability to backcross with the parent species. It is very aggressive. There is concern that, if released into the natural environment, the genetic swamping of either the smallmouths or largemouths might result. Consequently, the hybrids have not been considered for use in fisheries management (*Sports Afield*, June 1977: 147–148).

Warmouth

Lepomis gulosus (Cuvier). *Lepomis*—scaled operculum; *gulosus*—gluttonous.

Other common names: warmouth bass, goggle-eye, black sunfish, wide-mouthed sunfish, stumpknocker, mud bass, wood bass, weed bass.



Adult 142 mm, Rinehart L. (Portage Co.), 13 June 1977

DESCRIPTION

Body deep, compressed laterally. Length 89–127 mm (3.5–5.0 in). TL = 1.24 SL. Depth into TL 2.6–3.0. Head length into TL 2.8–3.1. Mouth large, oblique. Upper jaw reaching to middle of eye or beyond, with supramaxillary well developed; lower jaw decidedly longer than upper jaw; conical, pointed teeth in brushlike pads on upper and lower jaws; well-developed teeth on pad in midtongue; lower pharyngeal arches narrow with bluntly conical teeth. Gill rakers on first gill arch long, thin and straight. Opercular flap inflexible. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins about 2.3 times length of anal fin base; first dorsal fin with 10 spines, second with 9–10 soft rays. Anal fin with 3 spines, and 8–10 soft rays; pelvic fin thoracic (almost directly beneath the pectoral fin), with 1 spine and 5 rays; pectoral fin rounded, moderately long, and when laid forward across cheek reaching posterior edge of eye; caudal fin scarcely forked. Scales ctenoid, gill covers and cheeks scaled. Scales in lateral line 36–40; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Body brown, with obscure vertical bars or with lines of dark dots along scale rows; ventral region of head and belly light brown. Sides of head with 3–5 distinct dark lines, radiating outward from eye. Iris red or reddish brown. Vertical fins darkly pigmented and mottled with spots in irregular parallel lines; dorsal fin lacking a distinct basal blotch; paired fins lightly pigmented.

Breeding male bright yellow and eye bright red.

Hybrids: Warmouth × pumpkinseed, warmouth × green sunfish, warmouth × bluegill, warmouth × redbreast sunfish, warmouth × redear sunfish (Childers 1967). Artificial warmouth × largemouth bass (Merriner 1971b).

SYSTEMATIC NOTES

Until recently the warmouth was the sole species within the genus *Chaenobryttus*. Bailey et al. (1970) noted that it is closely related to the typical sunfishes of the genus *Lepomis*, and that it does not differ structurally from the closest of these (*cyanellus*) any more than *cyanellus* does from the more divergent forms. *Gulosus* is now regarded as a species of *Lepomis*, and *Chaenobryttus* is downgraded to subgeneric rank.

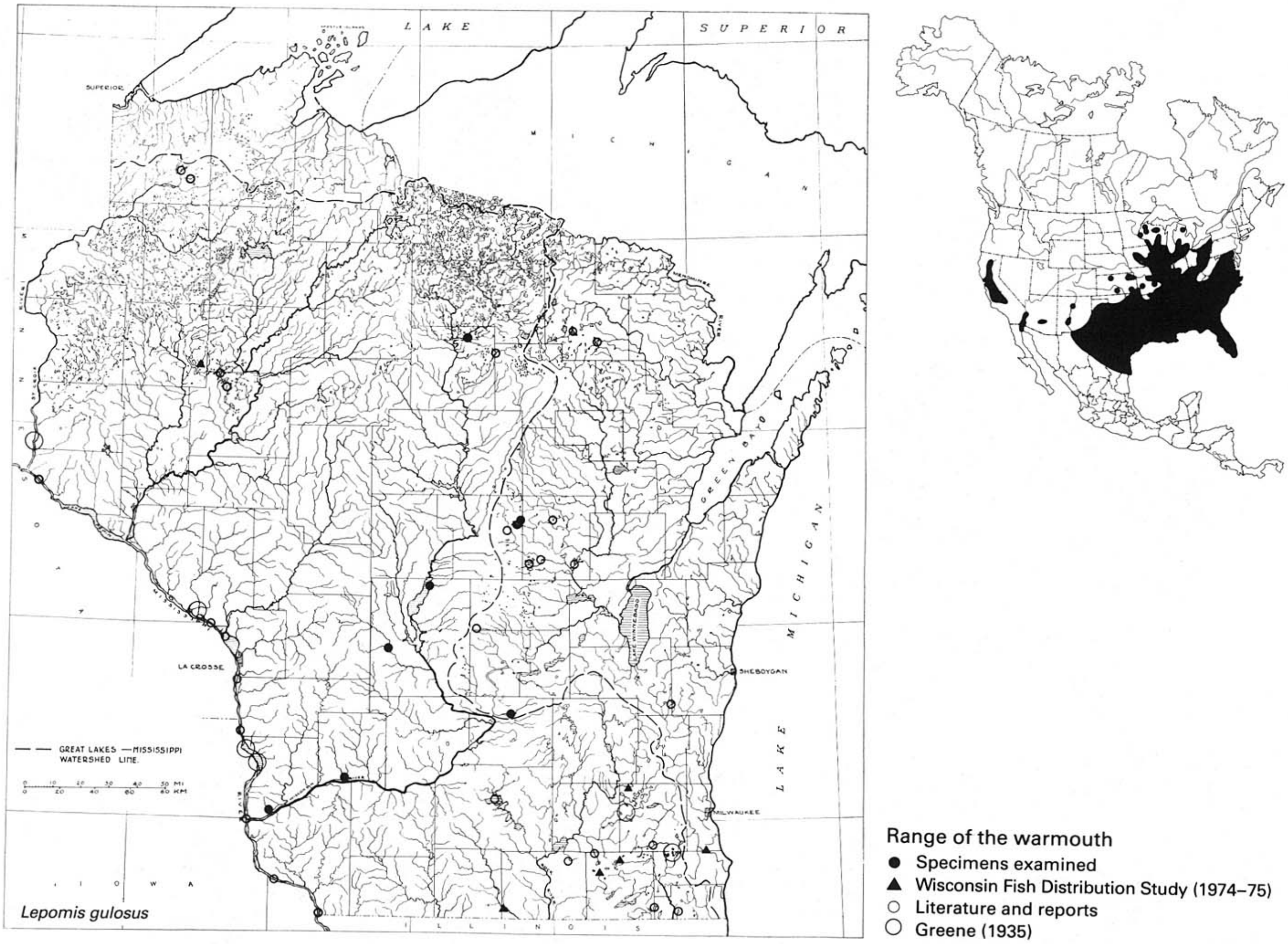
DISTRIBUTION, STATUS, AND HABITAT

In Wisconsin the warmouth occurs in the Mississippi River and Lake Michigan drainage basins. In the Mississippi basin this southern species reaches the northern limit of its distribution. It is not known from the Lake Superior basin.

Greene (1935) had no records of the warmouth from the Lake Michigan basin. Recent records place it in the headwaters of the Wolf and Fox river systems, which suggests a migration into that system via the Fox-Wisconsin canal at Portage. It is also likely that the warmouth was introduced through fish rescue transfers from the Mississippi River into eastern Wisconsin. Extensions of the warmouth's range in northwestern Wisconsin are based on the following reports: Moose Ear Creek (Barron County) (Wis. Fish Distrib. Study 1974–1975); Chain Lake (Chippewa County) (Sather and Threinen 1963); Long Lake and Upper Ox Lake (Douglas County) (Sather and Johannes 1973); and Town Line Lake (Chippewa County) (H. Snow, pers. comm.).

Few specimens of this species have been taken in Wisconsin. Since 1962, collections placed in UWSP are (number of individuals in parentheses): #1505 (1) Gran Grae Creek (Crawford County); #908 (1) and #4183 (1) Mills Creek (Richland County); #3576 (2) Severson Lake (Portage County); #4160 (3) Petenwell Flowage (Adams County); #4164 (1) Fox River (Columbia County); #4614 (3) Pleasant Lake (Walworth County); #5580 (3) Rinehart Lake (Portage County); and #5722 (1) Lake Alice (Lincoln County).

The warmouth has been reported from 9 of 40 Waukesha County lakes sampled (Poff and Threinen 1963), and it has also been reported as present among



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

the fish in smaller lakes (Laura and Skidmore ponds, Genesee) in the same county (Cahn 1927). Mackenthun (1946) reported it from Turtle Lake (Walworth County), Silver and Powers lakes (Kenosha County), Storrs Lake (Rock County), and Forest Lake (Fond du Lac County).

Throughout Wisconsin the warmouth is rare to uncommon. Except for the southeastern corner of the state, populations appear to be widely scattered. Apparently its range in Wisconsin is expanding as a result of the establishment of reservoirs, the increasing siltation of our waters, and inadvertent transport and stocking. The warmouth is probably more commonly distributed in southern and central Wisconsin than the record indicates, since it can easily be overlooked. Even when the warmouth is known to exist in small numbers in a given body of water, its secretive habits in dense vegetation obscure its presence.

In Wisconsin, the warmouth occurs in lakes, ponds, low-gradient streams, and drainage ditches. It is associated with muddy or turbid waters, dense growths of aquatic weeds, and bottoms of soft mud, sand, or gravel. According to Seeburger (1975), in Walworth County the warmouth prefers lakes, ponds, and smaller rivers with mud bottoms. In the Mississippi River it is associated with quiet backwater lakes.

BIOLOGY

The life history of the warmouth has been extensively studied in central Illinois by Larimore (1957). Unless otherwise designated, the following account is derived from his work.

In Illinois, the nesting season of the warmouth begins during the second week of May, reaches its peak early in June, and starts to decline after the first of July; however, it often extends well into August. The length of the nesting season differs among populations in different lakes, and probably varies considerably from year to year. Evidence indicates that a warmouth may spawn several times during a summer. It spawns at water temperatures approaching 21.5°C (70.7°F).

The warmouth's nesting sites are on bottoms of loose silt, sand with loose silt, silt containing sticks and leaves, rubble, or rubble covered with a thin layer of silt. Warmouths show some preference for rubble lightly covered with silt and detritus, and are careful to select a spot near a stump, root, rock, clump of vegetation, or some similar object. Nests are not found in an area that is completely exposed, or in an area of clear sand, such as the bluegill selects. Nests are usually built at depths of 0.6–0.8 m (0.2–1.5 m).

The warmouth is not a colonial nester; the nests are usually widely separated unless the nesting areas are restricted, in which case nests are sometimes found close to one another. Richardson (1913) reported that a dozen nests of this species had been found at Havana, Illinois, in a circle 6 m diam, in water 15–25 cm deep. The nests were 10–15 cm across and of irregular shape; they evidently had been quickly and carelessly made, compared to bluegill and bass nests.

As in other sunfish species, the male warmouth excavates the nest. Violent sweeping motions of his tail clear loose debris away from the selected spot and produce a shallow irregular concavity. As he enters the nest site, he turns abruptly upward, giving three or four violent sweeps with his tail while balancing in an almost vertical position and checking his forward motion with his pectoral fins.

The nesting site is guarded from intruders by the male warmouth. According to Larimore (1957:66):

> . . . He assumes a belligerent attitude by swimming toward the intruder with his mouth open and his opercles spread; at the same time, his eyes become red and his body becomes light yellow in color. As the nesting male nears the intruder, he usually turns abruptly to one side or upward and, with vigorous movements of his tail fin, forces small pulses of water toward the intruder. He may also nip. . . .

When a female warmouth that is not yet ready to spawn is placed in a tank with a nesting male, she is charged, nipped, and driven to the surface. Unable to escape the male in an aquarium, she may eventually be killed by his continued aggression.

In getting a female to his nest, the male warmouth assumes an aggressive attitude. He approaches her with opercles widely spread and his mouth open; his body changes colors in courtship as it does when he fights off an intruder—an adjustment requiring only 5–10 sec. If the female is ready to spawn, she is easily directed toward the nest, and spawning soon follows. Spawning behavior has been described by Larimore (1957:44):

> On entering the nest site, both male and female begin to circle, the female being nearer the center of the nest, slightly on her side and somewhat beneath the male. . . . As they circle inside the nest, the female works her jaws three or four times and suddenly jerks her body violently, giving the male a sharp thump on the side. Each time the female jerks, she extrudes about 20 eggs. The thump she gives the male probably stimulates a discharge of sperm, although no milt was ever seen coming from the genital pore. After circling the nest several times, the female interrupts the activities and leaves the nest site. The male usually follows her a short distance but returns quickly to the nest to assume guardianship. At this point in the spawning activity, males often have been observed to fan the nest with sweeping motions of the tail in a manner similar to that exhibited when nest building.

Male warmouths ripen slightly earlier in the season than females, and they remain sexually active somewhat longer than females. Larimore determined that warmouths over 137 mm (5.4 in) long attained spawning condition sooner and spawned over a longer period of time than did 89- to 137-mm (3.5- to 5.4-in) fish. The male protects and fans the eggs.

Larimore noted that hybrids can be produced in the laboratory between the warmouth and a number of species of *Lepomis*, yet such hybrids seldom occur in large numbers in natural populations. In the laboratory, male warmouths have courted green sunfish and bluegill females, but have not succeeded in spawning with them and have seldom been able to guide them to the nest depressions. Such reproductive isolation may be explained by the characteristic sounds produced by males of some *Lepomis* species (see Gerald 1971), which enable females of different species to recognize males of their own species.

Fecundity is a function of the size of the female warmouth. From April to June in Park Pond, Illinois, females 89–180 mm (3.5–7.1 in) long held 4,500–37,500 eggs. In Venard Lake in May, females 94–137 mm (3.7–5.4 in) long held an estimated 17,200–63,200 eggs. The diameter of fertilized warmouth eggs is 0.95–1.03 mm. At water temperatures of 25–26.4°C (77–79.5°F), the eggs hatch in 34.5 hr.

Immediately upon hatching, the warmouth prolarvae drop down onto the sand and silt between the coarse gravel particles of the nest. After 36–48 hours they begin to make feeble jumps 2 cm or so above the bottom of the nest. The yolk-sac is exhausted by the fourth day. The young begin active swimming at the end of the fifth day, and swim about the nest in rather compact groups. In outdoor tanks, they begin to feed by at least the seventh day after hatching. The schools gradually dissolve as individuals begin independent searches for food. No juvenile warmouths have been observed in large groups.

Larimore (1957) described development to the 15.7-mm juvenile stage, and photographed stages from hatching (3.4 mm) to the 12.0-mm postlarva. The 15.7-mm young is essentially like an adult in body form.

In ponds and lakes, warmouth fry scatter into dense weed masses, making it impossible for the male parent to keep the young together for close care. After the fry leave the nest area, they receive no parental care. In several Illinois lakes, minnows and sunfishes were observed destroying warmouth eggs and larvae in unprotected warmouth nests. Postlarval and juvenile warmouths which had left the nest were eaten in great numbers by larger fish. Largemouth bass 44 mm (1.75 in) long fed voraciously on warmouths 19 mm (0.75 in) long, which in turn had been eating large numbers of postlarval warmouths. In the laboratory, a 19-mm warmouth ate 11 postlarvae (4 days old) in 5 min; another ate 12 in the same length of time. The survival of late warmouth broods is frequently higher than that of early broods because as the season advances the aquatic vegetation becomes more dense and there is less danger of drops in water temperature.

In Severson Lake (Portage County), young-of-year warmouths were 35 mm long on 4 August. In southern Wisconsin streams in the second half of September, young warmouths were 44 mm TL.

For combined Wisconsin collections of warmouths, the calculated length at each annulus was: 1—37 mm; 2—74 mm; 3—90 mm; 4—126 mm; and 5—147 mm. The best growth was demonstrated by warmouths from Pleasant Lake (Walworth County), which had values of 40, 79, 108, 143, and 160 mm at the annuli.

In Iowa, the calculated total lengths at the annuli (estimated weights in parentheses) were: 1—41 mm (1 g); 2—91 mm (15 g); 3—147 mm (68 g); 4—178 mm (129 g); 5—190 mm (175 g); 6—203 mm (214 g); and 7—221 mm (242 g) (Lewis and English 1949). In Illinois (Larimore 1957), these values were: 1—42 mm (2 g); 2—86 mm (12 g); 3—125 mm (40 g); 4—163 mm (91 g); 5—189 mm (153 g); 6—204 mm (196 g); 7—215 mm (232 g); and 8—217 mm (239 g). In Enright Pond, Illinois, fish of the first brood produced in the lake attained a length of 152 mm (6 in) during their first 13 months. The less turbid the water, the greater is the growth of warmouths.

In Illinois, annuli usually form about the first week in May. The condition value (K_{TL}) for warmouths 81–208 mm (3.2–8.2 in) TL ranged from 2.01 to 2.29. Larimore noted that there was a decline in condition for the larger warmouth in the early fall and again in winter. No consistent differences in condition were evident between males and females.

In Venard Lake, Illinois, both sexes matured at age I, when they had reached lengths between 79 and 86 mm (3.1–3.4 in); in Park Pond they did not mature until they had reached age II and a minimum length of 89 mm (3.5 in).

Larimore found that the majority of large warmouths were males. A 244-mm, 454-g (9.6-in, 1-lb) male (age VI) was collected from Park Pond, Illinois. Trautman (1957) reported a specimen 284 mm (11.2 in) long, with a weight of 454 g (1 lb), from Ohio. A warmouth in Georgia in 1974 weighed 907 g (2 lb 0 oz).

In Illinois, young warmouths feed on plankton, insects, and small crustaceans. Those over 127 mm (5 in) long, feed largely on small fishes. In Park Pond, Illinois, warmouths consumed crayfish (29.7% volume), fish (20.5%), damselflies (15.7%), dragonflies (5.2%), diptera larvae (4.6%), mayflies (2.9%), Entomostraca (0.7%), Hemiptera (0.3%), miscellaneous insects (12.2%), and miscellaneous items (8.2%). In Lake Venard in central Illinois, fish constituted only 5.9% of the volume of the warmouth's diet, but dragonflies made up 23.8%. In Park Pond, where many species of minnows were present, small sunfish were more commonly taken by warmouths. Warmouths may feed upon any items that are readily available, including snails.

When a food item is sighted, the warmouth turns toward it, judges its acceptability as food, and then may move in quickly to snap it up. A motionless object is seldom picked up by a warmouth. The large size of its mouth is better suited to a fish-eating diet than that of most sunfishes. During the summer months, the warmouth's feeding activity reaches a peak early in the morning and practically ceases in the afternoon.

The critical oxygen level for warmouths is 3.6 ppm at a water temperature of 20°C (68°F) (Larimore 1957). The warmouth's ability to survive at low oxygen concentrations allows it to range into habitats that would be unfavorable to other fish species. It is among the last species of fish to die when collections of live fish are concentrated in tanks, tubs, or buckets containing water. However, there was a heavy kill of warmouths in a Michigan lake during the winter when the oxygen level dropped to 0.0–0.2 ppm in the upper 0.3–1.2 m of water (Cooper and Washburn 1949). Gould and Irwin (1962) stated that the warmouth had withstood concentrations of 1.0 ppm oxygen without fatality; it also endured test concentrations of pH ranging from 8.5 to 7.4.

Although essentially a freshwater species, warmouths have been reported in waters with 4.1 ppt salinity in Louisiana (Carlander 1977).

The warmouth's association with turbid water, organic silt deposits, and dense vegetation indicates a greater tolerance of these conditions than most other sunfish have. This may be a factor in lessening its competition with other species.

In learning experiments (Witt 1949), isolated warmouth individuals learned about as quickly as bluegills and more quickly than largemouth bass, but in groups the warmouths made more errors than either largemouths or bluegills. Warmouths could learn to distinguish a worm on a hook from a free worm. After being penalized for making an error, the warmouth was not as cautious as the bluegill in approaching a hooked worm.

According to Larimore (1957), an order of dominance in a natural warmouth population has not been observed. However, in a restricted group, such as that in an aquarium, a hierarchy is quickly established. The aggressiveness of a fish in its pursuit of food or space, and the dominance of the fish relative to other members of the group, determine its position in the hierarchy. The smaller the group, the more stable and definite the order of dominance appears. In groups of more than three or four fish, the order may change frequently.

Warmouths of less than 127 mm (5 in) TL remain in protective cover in shallow water the year around; larger individuals spend more time in deep water than in shallow water. There is no school formation even during the winter, when many fishes form groups. The warmouth has a quiet disposition. It moves around relatively little, displays no show activity except during the spawning season, seeks the cover of weeds and other hiding places, and avoids intense light.

Warmouths were collected from Silver Lake (Kenosha County) along with the common carp, bluegill, black crappie, walleye, bullhead (sp.?), largemouth bass, pumpkinseed, rock bass, bowfin, and other species (Mackenthun 1946).

IMPORTANCE AND MANAGEMENT

The warmouth plays a role in the ecology of the mussels *Amblema plicata*, *Alasmidonta marginata*, *Carunculina parva*, and *Lampsilis teres*, since it is host to the glochidial stage of those species (Hart and Fuller 1974).

Known as an excellent small sport fish, the warmouth will take earthworms, minnows, grasshoppers, crickets, grubs, and artificial baits. In Walworth County, warmouths up to 15 cm have been taken with flyrod and popper late in the spring (Seeburger 1975). In five southern Wisconsin lakes, warmouths composed an average of 2.6% (0.7–7.5%) of the catch (Mackenthun 1946). Other fish species commonly taken from the same lakes were bluegills and green sunfish, and, to a lesser extent, rock bass, largemouth bass, and black crappies.

Exploitation rates are usually lower for the warmouth than for other sunfishes inhabiting the same waters primarily because of the difficulty of fishing in the dense cover that warmouths prefer. Most warmouths are taken incidentally while fishing for other sunfishes. In Wisconsin, the regulations for taking panfish, including warmouths, from inland waters are liberal; an aggregate of 50 panfish may be caught in 1 day. In the boundary waters there is no bag limit on panfish, except in Wisconsin-Minnesota waters where there is a limit of 25 per day.

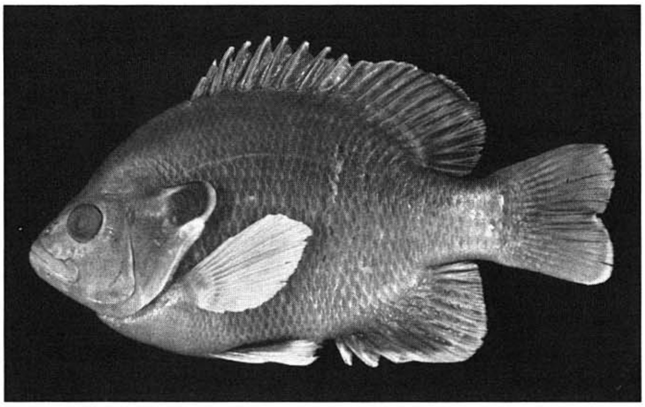
The warmouth is a desirable laboratory fish. Its prolonged spawning season makes suitably sized specimens available for much of the year. It transports well, withstands crowding and low oxygen tensions, and is large enough to be easily handled and yet small enough to be accommodated in most aquariums. It is a good animal for bioassay, but it needs live food and is difficult to collect because it remains in weedy areas (Gould and Irwin 1962).

Unlike other *Lepomis* species, warmouths have no tendency to become dominant at the expense of other species. This has been indicated by the relatively low proportions of warmouths reported in fish populations of Illinois and other states. Larimore (1957) found that, in 17 ponds in central Illinois stocked with 11 different fish combinations (including largemouth bass, smallmouth bass, and several panfish), warmouths tended to establish small broods each year without seriously restricting the reproduction or growth of companion species. However, Larimore also pointed out that small numbers of warmouths which had been introduced into a pond overcrowded with other sunfish seemed unable to establish a population. In ponds in which other populations of fishes had been thinned, an increase in the growth rate of warmouths was noticed.

Green Sunfish

Lepomis cyanellus Rafinesque. *Lepomis*—scaled operculum; *cyanellus*—blue.

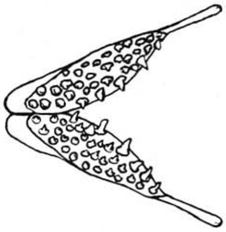
Other common names: green perch, black perch, logfish, blue-spotted sunfish, sunfish, little redeye, blue bass, creek sunfish, rubbertail, sand bass.



Adult 130 mm, Pine R. (Richland Co.), 7 Aug. 1962

DESCRIPTION

Body robust, strongly compressed laterally. Length 102–127 mm (4–5 in). TL = 1.25 SL. Depth into TL 2.4–2.9. Head length into TL 2.8–3.1. Mouth large, terminal, slightly oblique; lips large. Upper jaw extending to about middle of eye; small, blunt teeth in brushlike pads on upper and lower jaws; rarely, a few teeth on tongue; lower pharyngeal arches narrow and strong with conical, blunt teeth. Gill rakers on first gill arch long, straight and thin. Opercular flap inflexible. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins about 2.5 times length of anal fin base; first dorsal fin with 9–11 spines, second with 10–12 soft rays. Anal fin with 3 spines and 9–10 soft rays; pelvic fin thoracic, with 1 spine and 5 rays; pectoral fin rounded, moderately long, and when laid forward across the cheek barely reaching eye; caudal fin scarcely forked. Scales ctenoid, gill covers and cheeks scaled. Scales in lateral line 44–51; lateral line complete. Chromosomes 2n = 46 (Roberts 1967).



Dorsal view of the lower pharyngeal arches of the green sunfish, showing their narrow width and bluntly conical teeth (from *The Fishes of Ohio*, by Milton B. Trautman [Columbus, Ohio: Ohio State University Press, 1957, 499])

Dorsal region brown to olive, with many emerald reflections; sides lighter, with 7–12 faint dark, vertical bars; belly yellow to white. Head with emerald spots, and at times with backward radiating emerald lines; opercular flap with black center and with a broad, light-colored margin. Fins generally pigmented; bases of rear dorsal and anal fins usually with a vague, dark blotch. Young similar to adults, but lacking bands on sides and spots on cheeks and fins.

Breeding male with prominent, yellowish white line along margin of the dorsal, caudal, and anal fins, and with dark, vertical bars along sides (Hunter 1963).

Hybrids: Green sunfish × bluegill, green sunfish × pumpkinseed (Wis. Fish Distrib. Study 1974–1979); green sunfish × longear sunfish, green sunfish × orangespotted sunfish, green sunfish × redbreast sunfish, green sunfish × redear sunfish (Childers 1967).

DISTRIBUTION, STATUS, AND HABITAT

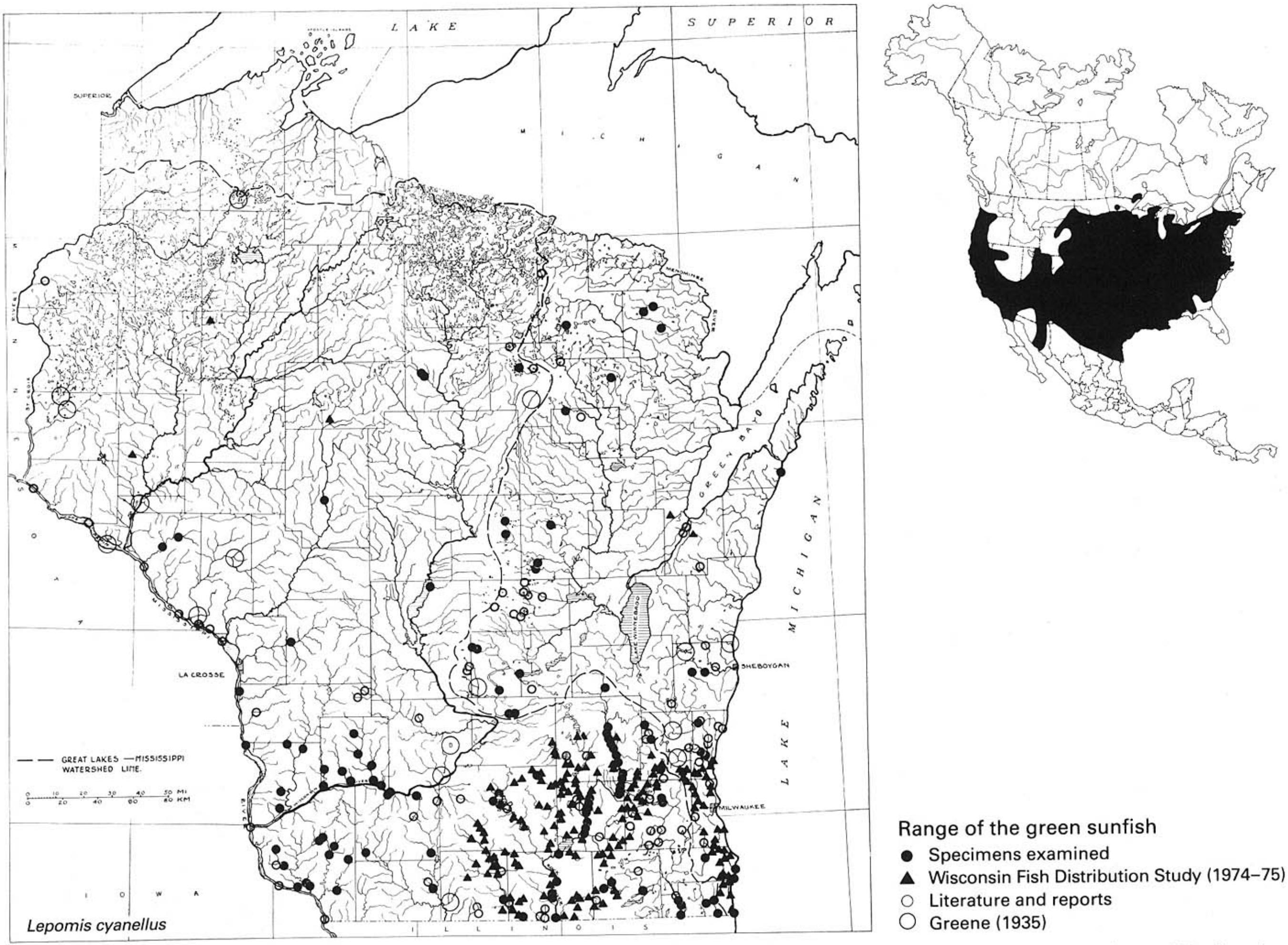
In Wisconsin, the green sunfish occurs in the Mississippi River and Lake Michigan drainage basins. It is well distributed in streams and lakes in the southern one-third of the state, and it is widely dispersed northward. It has not been reported from the Lake Superior basin with the exception of two records from Houghton County, Michigan, where it was probably introduced (Taylor 1954).

The green sunfish was present in over 30% of the Waukesha County lakes sampled (Poff and Threinen 1963); it was rare in Pewaukee Lake (Becker 1964a). It is rare to uncommon in the Wisconsin and Mississippi rivers, and it is generally common in moderate-sized streams and lakes of southern Wisconsin.

The green sunfish usually inhabits quiet pools in warm, shallow waters of ponds, lakes, small brooks, and rivers of low gradient. In Wisconsin, it was encountered in clear to turbid water at depths generally less than 1.5 m over substrates of gravel (23% frequency), sand (17%), silt (17%), rubble (12%), mud (12%), clay (8%), boulders (8%), detritus (1%), and marl (1%). It occurred in low-gradient streams of the following widths: 1.0–3.0 m (18%), 3.1–6.0 m (22%), 6.1–12.0 m (22%), 12.1–24.0 m (28%), 24.1–50.0 m (8%), and more than 50 m (2%).

BIOLOGY

In southern Wisconsin, spawning commences in late May or early June, continues through June and July,



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

and terminates in early August (Hunter 1963). The green sunfish builds and spawns at water temperatures of 15–28°C (59–82.4°F). Breeding activities take place every 8–9 days during the season, and the peak of nest establishment nearly always coincides with a rise in the mean water temperature.

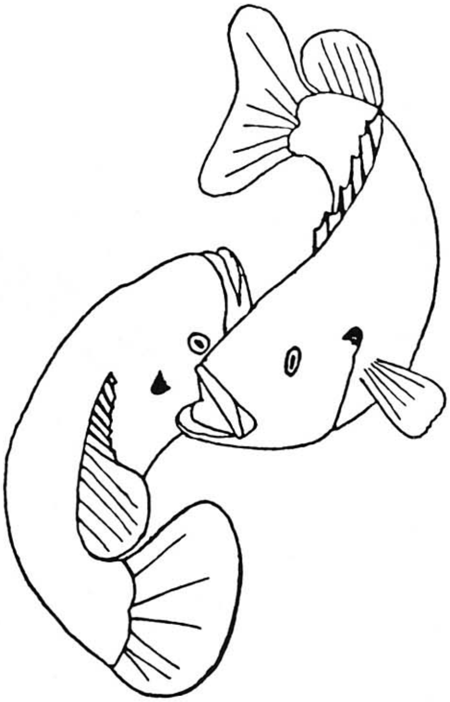
Hunter (1963) discussed in detail the reproductive behavior of the green sunfish in Madison (Wisconsin) ponds. The following account is from this source, unless otherwise indicated.

Green sunfish nests are seldom located in water deeper than 35 cm, and small males may construct nests in water as shallow as 4 cm. The nests are built in the shelter of rocks, logs, and clumps of grass, if these are available; occasionally the abandoned nests of other sunfishes are used.

The nest is constructed by the male, who rises vertically above the nest site and delivers a burst of vigorous outward thrusts with his tail; each thrust displaces some sand and gravel, and gradually a shallow depression is formed. Carlander (1977) indicated that males may remove larger pebbles with their mouths. Each nest is between 15 and 38 cm diam (Carlander 1977), and as many as 25 nests have been observed within a 15 square meter area (Sigler and Miller 1963). Large males occasionally dig several trial nests prior to spawning, generally within a meter of their previous nests. Small landmarks in the vicinity of a nest appear to play a major role in nest recognition.

Hunter observed that aggregations of female and male green sunfish of all sizes gathered around the periphery of the nests of the first males that spawned; he counted 114 fish assembled near the nest of one spawning male. As other nests were constructed and colonization began, the number of fish around individual nests decreased.

Fighting occurs only when the male green sunfish are engaged in constructing nests and spawning. Nesting territories are defended against intruders. The resident male responds aggressively by spreading the opercles wide and by vigorously driving the trespassing fish from the nest. Two male combatants may press their open mouths to their opponent's opercle and rotate in this position. Sigler and Miller



Fighting posture of two male green sunfish (Hunter 1963:15)

(1963) noted that attacking male green sunfish meet their opponents head on, and sometimes even grasp them by the jaw during the engagement.

Witt and Marzolf (1954) reported that male longear sunfish defended larger territories when their nests were isolated than when the nests were a part of a colony. Hunter drew similar conclusions about the green sunfish and observed that where nests of this species were 30 m apart the males defended an area of 1–1.5 m diam, but that where nests were close together the males defended only the area encompassed by the nest.

Gerald (1971) noted that male green sunfish make a grunting sound while courting a female. A nesting male, upon sighting a female, repeatedly rushed toward her and then backed toward his nest, while producing a series of gruntlike sounds. Gerald had the impression that the female produced a single grunt as she first approached the male. The mechanism of sound production is unknown.

The spawning behavior of the green sunfish has been described by Hunter (1963:15):

> . . . Spawning was accomplished in the manner typical of all centrarchids: the male and female circled in the nest side by side, paused momentarily and released sperm and eggs. The consummatory act took place when the female reclined on her side and vibrated while the male remained in an upright position. An isolated pair might circle and spawn in a nest for considerable periods of time but in crowded colonies the male frequently interrupted spawning to chase intruding fish. After spawning, the male expelled the female from the nest with a nip. Both sexes usually spawned with more than one individual. Occasionally a male spawned simultaneously with more than one female. While a pair of sunfish were circling in the nest another female entered the nest, aligned itself with the male, and when the first female rotated on her side the intruding female also slid beneath the male and vibrated.

The presence of a male in a nest appeared to be sufficient stimulus to cause a female to enter the nest. Hunter (1963:15–16) saw females during the latter part of the nesting period move from nest to nest in old sunfish colonies, often being expelled from every nest:

> . . . Females sometimes darted beneath a male, immediately rotated on their sides and vibrated. Sometimes mating was accomplished in this fashion but often the male remained sexually passive, in which case the female was eventually driven from the nest.

During spawning periods, male green sunfish are more active than at any other time during their reproductive cycle. Within a 10-min period, Hunter observed one male execute five spawning acts, make ten trips in and out of the nest, threaten his neighbor once, and gyrate in the nest 39 times.

Gonadal growth is stimulated in both sexes of green sunfish by the simultaneous influence of high water temperature [greater than 15°C (59°F)] and long photoperiods (15 hr or more) (Kaya and Hasler 1972). However, long photoperiods and elevated temperatures [24°C (75.2°F)] will not prevent gonadal regression from occurring during the postspawning period (Kaya and Hasler 1972).

The eggs of the green sunfish are numerous, demersal, and adhesive. Varying egg sizes have been reported: 0.8–1.0 mm diam (Kaya and Hasler 1972), 1.2–1.3 mm (Taubert 1977), and 1.0–1.4 mm (Meyer 1970). In nests over mud and marl, the eggs become attached to the roots of sedges and bulrushes (Hankinson 1908). Eggs held at water temperatures of 24–27°C (75.2–80.6°F) hatch into prolarvae 3.5–3.7 mm long in 35–55 hr (Taubert 1977). Swim-up, following absorption of the yolk-sac, occurs in the 6-mm stage by 145 hours. Taubert illustrated the 3.6-, 5.8-, 8.3-, and 9.3-mm stages, and described the stages up through the 22-day-old metalarva. Meyer (1970) figured the 5.4-mm (9-day), 10.2-mm (30-day), 15.1-mm (37-day), and 23.7-mm (57-day) stages.

Green sunfish were induced to spawn in aquariums at 25°C (77°F) with a daily, 16-hr period of light (W. E. Smith 1975). Within several days a male had established territorial rights, and spawning occurred within 14 days. The eggs hatched 2 days later at 25°C. Larval swim-up and the beginning of feeding took place 5 days after hatching, and the fry fed successfully on newly hatched brine shrimp nauplii. At 30 days after hatching, the mean total length of the fry was 3 cm, and at this time frozen adult brine shrimp were introduced as food. At the age of 16 weeks, green sunfish males were about 10 cm long, and females about 6 cm long. Spawning occurred at 16 weeks and continued at intervals of 6–10 days to the end of the study period, 2 months later. All of these individuals had been brought to maturity together, and there was little aggression exhibited. With the use of the proper cultural techniques, the green sunfish will spawn at less than 6 months of age.

In Wisconsin waters, young-of-year green sunfish were about 29 mm long in mid-July, and 27–37 mm at the end of September. In Madison (Dane County) ponds, young-of-year were 4–9 mm in June, 11–28 mm in July, 19–35 mm in August, and 21–40+ mm in September (Siewert 1973).

The green sunfish is aged by reading scales. Hubbs and Cooper (1935) called attention to a spawning mark on scales, which indicates an abrupt, though temporary, slackening or cessation of growth during the breeding season.

Green sunfish taken from the Pine River (Richland County) on 7 August 1962 had the following calculated growth at the annuli: 1—24 mm; 2—54 mm; 3—91 mm; and 4—117 mm (J. Morzinski, pers. comm.). In Michigan (Hubbs and Cooper 1935), green sunfish exhibited the following growth: 0—8–44 mm; I—24–90 mm; II—54–142 mm; III—68–142 mm; IV—84–168 mm; V—114–188 mm; VI—130–188 mm; and VII—168–196 mm. In Minnesota (Kuehn 1949a), the calculated total length at each annulus was: 1—43 mm; 2—74 mm; 3—99 mm; 4—127 mm; 5—150 mm; 6—168 mm; and 7—183 mm. In the upper Saint Francis River, Missouri (Purkett 1958b), the green sunfish reached a calculated length of 196 mm at the 10th annulus. Males grow faster than females, and tend to live longer.

In Madison ponds, some age-I male green sunfish started to spawn in late July or early August (Hunter 1963). In Michigan (Hubbs and Cooper 1935), few age-I fish were mature, but all age-III fish were mature. The overall size at maturity for both sexes of green sunfish averaged slightly more than 76 mm in southern Michigan, and slightly under that figure in the northern part of the state.

Siewert (1973) demonstrated that a 5°C (9°F) increase in the water temperature above the ambient temperature, with the heat released from the bottom of a body of water, can improve conditions for green sunfish growth in northern latitudes, and that the growth of young green sunfish was better in a heated pond than in the unheated reference pond. Gerking (1952) noted that a 10-g green sunfish used about 33% of the absorbed protein for growth, compared to 20% for a 55-g fish. Carlander (1977) reported that growth among green sunfish was more rapid after poisoning and restocking, and after an almost complete winterkill.

Although the green sunfish is normally small, occasionally a large individual is caught. A 709-g (1-lb 9-oz) green sunfish was taken from Wind Lake (Racine County) on 23 August 1967. A 964-g (2-lb 2-oz) fish came from Stockton Lake, Missouri, on 18 June 1971. Carlander (1977) cited a report of a green sunfish from a Utah reservoir which was 279 mm (11 in) long.

Siewert (1973) observed that young green sunfish consumed zooplankton, and that adults consumed zooplankton, insects, snails, and young-of-year green sunfish. Stomachs examined also contained *Chara* and *Spirogyra*, but Siewert concluded that not much nutritional value was gained from such plant material. In Michigan (Sadzikowski and Wallace 1976), plant materials and odonates were important food sources for the green sunfish and the bluegill, and both of these species consumed more plant materials than the pumpkinseed. The green sunfish has a larger mouth than the bluegill, and its diet contained food items of a larger average size than those in the bluegill's diet, despite the similarities of the food items. Thus, even though these two species eat similar foods, they may actually be exploiting quite different food sources.

Other foods taken by green sunfish include crayfish, terrestrial insects, and fish. In one population, green sunfish ate more largemouth bass eggs and fry than other sunfish, but the number taken was not significant after mid-May (Mullan and Applegate 1968), when the green sunfish turned to gizzard shad and sunfish young for food. Green sunfish 51–99 mm long contained a volume of about 33% fish larvae in late June. Forbes and Richardson (1920) reported that more than one-third of the diet of green sunfish in Illinois was made up of fish, the remainder of insects and crayfishes. In California, green sunfish eliminated mosquitofish and threespine sticklebacks from a pool in a stream as water levels decreased (Greenfield and Deckert 1973).

According to Sigler and Miller (1963), green sunfish prefer to eat animal materials, but are able to shift to plant materials when animals are unavailable. Unusual animal items reported eaten include a short-tailed shrew (Sigler and Miller 1963) and a bat (Carlander 1977).

Green sunfish survive water temperatures as high as 33–34°C (91–93°F) (Sigler and Miller 1963) and even 36°C (97°F) (Proffitt and Benda 1971). In the laboratory, they actively avoided temperatures of more than 30.3°C (86.5°F) and less than 26.5°C (79.7°F), and preferred a median temperature of 28.2°C (82.8°F) (Beitinger et al. 1975). Jones and Irwin (1962) determined a temperature preference of 26.8°C (80.2°F) for this species. The green sunfish was able to withstand sudden changes of temperature as great as 11°C (20°F) without immediate mortality, provided the upper lethal limit was not exceeded; some delayed mortalities were noted, however (Nickum 1967).

Green sunfish tolerated pH changes from 7.2 to 9.6, and from 8.1 to 6.0, at water temperatures of 17–19.5°C (63–67°F), with 4–9 ppm of oxygen (Wiebe 1931). At winter temperatures, they survived at an oxygen level of 3.6 ppm, but died when the oxygen level was at 1.5 ppm over a 48-hour period (Moore 1942). Green sunfish showed an initial decline in feeding and growth when exposed to concentrations of ammonia greater than 2 ppm (Jude 1973). When exposed to 3, 7, and 15 ppm of cadmium, green sunfish exhibited reduced food intake and growth. Cadmium elimination after exposure to high concentrations for short periods was complete within 60 days. Siewert (1973) reported a complete kill of green sunfish in a pond in which hydrogen sulfide had developed during June.

The green sunfish can stand more turbidity and silt than any other sunfish species except the orangespotted sunfish. In several green sunfish studies high levels of silt turbidity did not seem to affect feeding or attack behavior but did affect the social hierarchy and resulted in increased scrubbing movements against the bottom or side of the aquariums (Heimstra et al. 1969). In clear water, one fish in a group typically made almost all attacks, with attacks generally ending in a chase, and it appeared as though a definite social hierarchy was established. Under the turbid conditions, attacks were less frequent, activity was reduced among the fish, and there was not as much indication of a social hierarchy. Horkel and Pearson (1976) found that an increase in the amount of clay suspended in water resulted in increased ventilation rates among the fish, and an overall reduction in their activity. In high turbidity, green sunfish engaged in "coughing,"—a quick, short expulsion of water from the oral cavity, which, according to Lagler, Bardach, and Miller (1962), is a violent sweeping of water over the gill lamellae to free them of accumulated detritus.

The green sunfish seeks the warm, shallow waters of smaller lakes and reservoirs, and spends much of its time in the vicinity of weed beds. Its aggression appears to be directed against members of its own species, rather than against other species. Hunter and Wisby (1961) noted that when swarms of redfin shiners appeared above the nests of spawning green sunfish the male sunfish only rarely responded aggressively toward them. The green sunfish enters small streams when moving upstream in the spring. According to Walden (1964), there is a legend in Missouri that the green sunfish forsakes the streams for the meadows after a heavy fall of dew.

The green sunfish is quite sedentary. In one tagging experiment, 77.8% were recaptured less than 1.6 km (1 mi) from the point of release, and 95.6% were recaptured within 16 km (10 mi) (Funk 1957). This species is most active while illumination levels are changing at dawn and dusk (Beitinger et al. 1975). Green sunfish 7.1–9.7 cm long, stimulated by water draining into a pond from a discharge pipe, jumped to heights 10 times their body lengths and leaped a horizontal distance of 0.6 m (Ellis 1974).

When displaced, green sunfish appeared to return to the home area more than did bluegills, pumpkinseeds (Kudrna 1965), and largemouth bass (Hasler and Wisby 1958). Green sunfish took less time to home than the other centrarchids studied; they started directly toward the site of capture rather than swimming in circles in a searching fashion. Hasler and Wisby noted that individual green sunfish in shallow ponds appeared to return in the spring to the same area occupied the previous summer.

Fifty-nine green sunfish were collected in 1971 from the Rock River (Dodge County) along with the common carp (66), spotfin shiner (79), fathead minnow (4), shorthead redhorse (1), black bullhead (48), stonecat (1), orangespotted sunfish (1), and black crappie (1).

IMPORTANCE AND MANAGEMENT

In a desert impoundment, green sunfish were the major food for the largemouth bass (Biggins 1968). In food preference studies (Lewis et al. 1965), channel catfish selected green sunfish after crayfish and fathead minnows.

The green sunfish acts as a host to the glochidial stages of a number of mussels (Hart and Fuller 1974): *Amblema plicata*, *Fusconaia ebena*, *Quadrula metanevra*, *Anodonta grandis, Anodonta imbecilis, Lasmigona complanata, Strophitus undulatus, Actinonaias carinata, Lampsilis teres, Leptodea subrostrata,* and *Ellipsaria lineolata.*

The green sunfish bites readily on worms, grasshoppers, crickets, and artificial flies, and puts up a fight about equal to that of a rock bass. Because of its small size, the green sunfish is most often caught incidentally by anglers fishing for bluegills. Fishermen regard green sunfish as bait stealers. The occasional large green sunfish which is taken makes an excellent panfish. Wisconsin's fishing regulations for panfish from inland waters, including green sunfish, are liberal; an aggregate of 50 panfish may be caught in one day. In most boundary waters there is no bag limit on panfish, except in Wisconsin-Minnesota waters where there is a limit of 25 panfish.

The green sunfish has been used as an experimental animal, since it is easily handled and makes a good bioassay animal (Ward and Irwin 1961).

Because of its small size and frequent abundance, the green sunfish is often regarded as a nuisance (Eddy and Underhill 1974, McKechnie and Tharratt 1966). Many overcrowded populations show evidence of stunting. The largest populations of green sunfish occur in habitats where there is little competition from other sunfish species, and since the green sunfish is more tolerant to turbidity and siltation than other sunfishes, it tends to be favored in such waters. Trautman (1957) noted an increase in green sunfish numbers in several streams where a decrease in longear sunfish numbers was most marked. Although the green sunfish is stunted in Utah and competes for both food and space with some sport fish, Sigler and Miller (1963) concluded that it is probably not detrimental enough to warrant expensive steps to curtail it.

The natural hybridization of green sunfish with other sunfish species is quite common, and is thought to result from the rarity of one of the parental species and the abundance of the other in a body of water. A scarcity of nesting sites may also lead to hybridization (Cross 1967). Hybrids exhibit hybrid vigor in that they are larger than the parents and are more aggressive in taking anglers' lures. According to Cross, such hybrids can be produced in a pond by stocking the pond with a few male bluegills and a few female green sunfish. The young hybrids can then be seined and transferred to other ponds in limited numbers to ensure their growth to a large size.

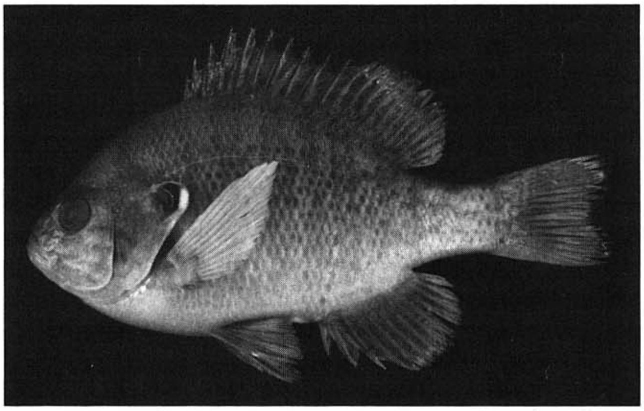
Hubbs (1955) described green sunfish × pumpkinseed hybrids in a Michigan stream, in which the hybrids constituted about 95% of the sunfish population. The hybrids had migrated upstream about 8 km (5 mi) from a pond which held the parent species.

A golden color mutation in the green sunfish has been found and developed in Texas (White 1971). Called the "Texas golden green," it is highly prolific and reaches sexual maturity in less than 6 months. Its golden color makes it extremely vulnerable to predation. Studies are being conducted on its use as a forage fish.

Pumpkinseed

Lepomis gibbosus (Linnaeus). *Lepomis*—scaled operculum; *gibbosus*—formed like the nearly full moon, referring to the body shape.

Other common names: pumpkinseed sunfish, yellow sunfish, common sunfish, sunfish, round sunfish, punky, sunny, sun bass, pond perch, bream.



Adult 135 mm, Hilbert L. (Marinette Co.), 21 June 1966

DESCRIPTION

Body very deep, strongly compressed laterally. Length 127–190 mm (5.0–7.5 in). TL = 1.26 SL. Depth into TL 2.4–3.1. Head length into TL 3.3–4.0. Mouth short, terminal, slightly oblique. Upper jaw scarcely reaching front of eye, or not reaching eye; lower jaw slightly longer than upper jaw; small blunt teeth in brushlike pads on upper and lower jaws, no teeth on tongue; lower pharyngeal arches with pads almost as broad as long, and with a few large, low, molarlike teeth. Gill rakers on first gill arch short and knobby, scarcely longer than wide. Opercular flap flexible only at tip. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins about 2.3 times length of anal fin base; first dorsal fin with 10–11 spines, second with 10–12 soft rays. Anal fin with 3 spines, and 10–11 soft rays; pelvic fin thoracic with 1 spine and 5 rays; pectoral fin pointed, long, and when laid forward across cheek reaching front of eye; caudal fin scarcely forked. Scales ctenoid, gill covers and cheeks scaled. Scales in lateral line 38–43; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Dorsal view of the pumpkinseed's broad and heavy lower pharyngeal arches with large, molarlike teeth (from *The Fishes of Ohio*, by Milton B. Trautman [Columbus, Ohio: Ohio State University Press, 1957, 519])

Back brown to olive; sides lighter; breast and belly orange to red-orange. Back and sides speckled with orange, yellow, blue, and emerald spots. Sides of body with 7–10 faint vertical bands (especially prominent in female). Several narrow, wavy, emerald or blue lines alternating with orange-brown lines radiate backward from snout and eye. Opercular flap with black center and with a thin, light-colored margin which enlarges posteriorly into a halfmoon crimson spot (fading to white in preserved specimens). Membranes of soft dorsal, caudal, and anal fins with brown pigmented spots (diffuse brown chromatophores in young-of-year) but no pronounced large, black blotch; small faint orange to olive spots on soft dorsal and caudal fins; pectoral and pelvic fins with slight dark pigmentation. Young similar to adult female, but lacking the bright colors.

Breeding male more brilliantly colored than female; breeding female exhibiting more prominent dark, vertical bands.

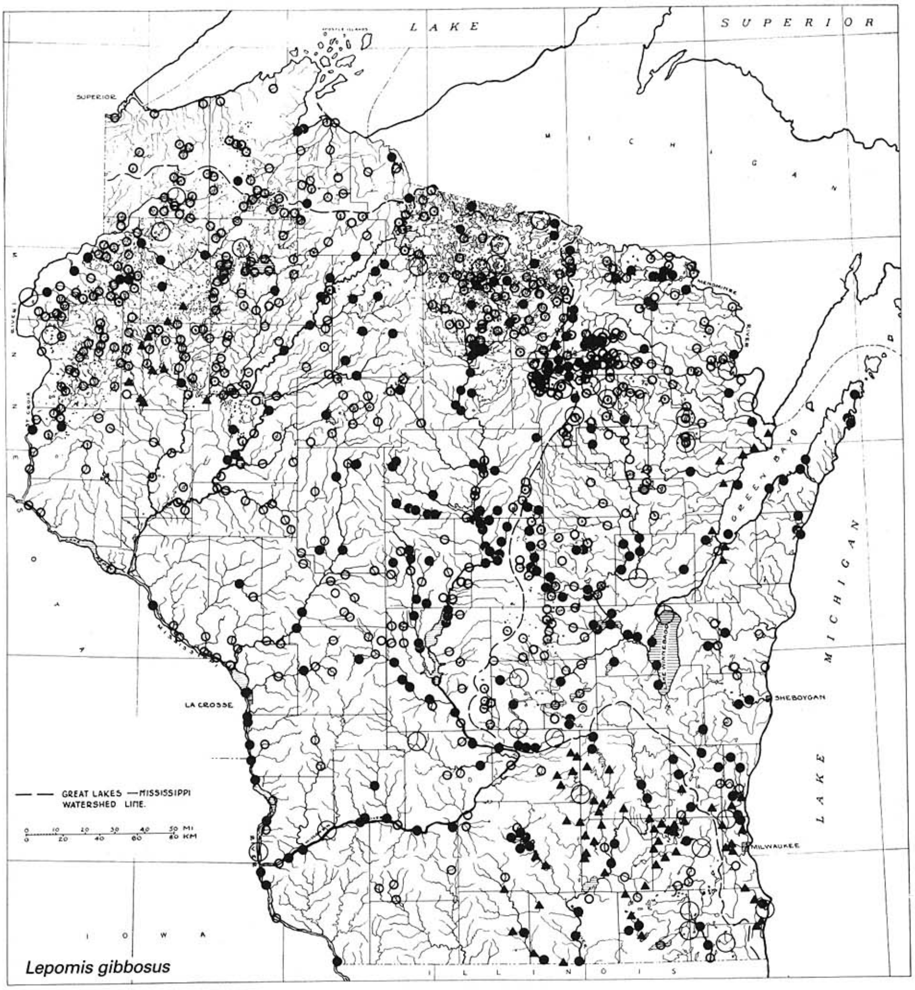
Hybrids: Pumpkinseed × warmouth, pumpkinseed × green sunfish, pumpkinseed × bluegill, pumpkinseed × orangespotted sunfish, pumpkinseed × redbreast sunfish, pumpkinseed × longear sunfish (Childers 1967). Pumpkinseed × green sunfish, and pumpkinseed × bluegill. (Wis. Fish Distrib. Study 1974–1979).

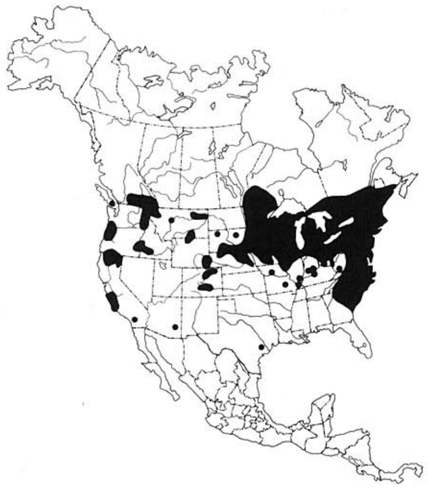
DISTRIBUTION, STATUS, AND HABITAT

The pumpkinseed occurs in all three drainage basins in Wisconsin and in the shallow, protected bays of Lakes Michigan and Superior. It is widely distributed throughout the state except in the unglaciated region, where its populations are disjunct.

The pumpkinseed is taken occasionally in protected bays in Lakes Superior and Michigan, and in Green Bay. It has been reported generally in small numbers from the mouths of tributary streams to Lake Superior (Moore and Braem 1965, McLain et al. 1965). The pumpkinseed was reported from 23 of 40 Waukesha County lakes sampled (Poff and Threinen 1963). It is a common inhabitant of many ponds, lakes, and streams. The establishment of impoundments on many creeks and rivers has created favorable habitats for this species. It is easily established in new waters.

In Wisconsin, the pumpkinseed was encountered most frequently in cool to moderately warm waters





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

which are clear to slightly turbid; it was found at depths of less than 1.5 m, over substrates of sand (28% frequency), gravel (19%), mud (18%), silt (13%), boulders (8%), rubble (7%), detritus (4%), clay (2%), hardpan (1%), and bedrock (1%). It occurred in weedy ponds, lakes and reservoirs, and in low-gradient streams of the following widths: 1.0–3.0 m (13% frequency); 3.1–6.0 m (12%); 6.1–12.0 m (9%); 12.1–24.0 m (36%); 24.1–50.0 m (20%); and more than 50.0 m (11%).

BIOLOGY

Pumpkinseeds spawn sometime between early May and August. C. E. Johnson (1971) noted that in Wisconsin pumpkinseeds prefer to spawn from late May to July at water temperatures of 19.4°C (67°F), on sand or gravel in shallow, warm bays. Nest building starts when water temperatures reach 13–17°C (55–63°F). Nests are usually found in 0.3–0.8 m of water, and are about 31–38 cm diam (Wis. Conserv. Com. 1958). As many as 10–15 nests may be seen together in a small area, although Clark and Keenleyside (1967) found that pumpkinseed nests in two ponds were an average of 60 and 54 cm apart, and were more scattered than the nests of bluegills, which were 50 and 32 cm apart. In Michigan, Carbine (1939) noted that pumpkinseed nests occurred singly or in groups of two or three and that occasionally pumpkinseed nests were found within a bluegill colony.

The nest is constructed by the male pumpkinseed. It is a more or less circular depression in the bottom, made by a fanning movement of the tail. Objects too large or heavy to be removed by this method are pulled away with the mouth (Adams and Hankinson 1926). Males defend territories around their nests with typical sunfish aggressive behavior—spreading of the opercula, charging, biting, chasing, and, rarely, mouth-fighting. Pumpkinseeds maintain larger territories than bluegills; approaching fish of either species were often attacked by nesting pumpkinseeds when they were about 1 m from the nest (Clark and Keenleyside 1967). R. J. F. Smith (1970) noted that prespawning aggression among male pumpkinseeds failed to occur when water temperatures had dropped to 11–13°C (52–55°F).

While nest building is going on, female pumpkinseeds spend most of their time in the deeper water. Breder (1936) noted that if a female cruised out in the vicinity of the nests she was pursued by one or more males; and that such attention usually drove the female back to the inactive group of females which remained somewhat removed from the nests. Eventually, after considerable play of this kind, the female settled closer to the bottom and withstood the male's attack; in this case, the male usually began to court her—i.e., to drive her into his nest. Breder has described this behavior (1936:30):

> . . . The direction of 'driving' appears to be determined entirely by the direction the pursued elects to follow. This view would give the role of spawning determination to the female. That is to say, the males having established themselves on a nest pursue practically anything, giving up the chase only when it leads far away from the nest. This view fuses the 'fighting' and 'courting' behavior into one, with the behavior of the female as the determining element.

When a gravid female enters a nest, the male and female swim side by side in a circle, making approximately 11 circuits per minute, while touching bellies. During a rotation, the female inclines to one side at about 45°, and emits some eggs, and the male simultaneously releases sperm. According to Breder, spawning may last an hour. In an aquarium in which three females and one male were present, a spawning pair was joined by a second female, and the three fish attempted perhaps with success to spawn together. The male was upright between the two females, which inclined on either side of him; all were facing in the same direction.

Breder and Rosen (1966) reported that a male pumpkinseed sometimes actually operated over two nests intermittently. Males may spawn at least twice in a season in the same nest, with the same or with other females.

The male pumpkinseed guards the eggs against other fishes, and he will go so far as to bite hands and fingers held near the nest. The spreading of his gill covers and the display of his colors appear to be instrumental in driving away intruders, as well as in attracting the female.

It has been generally assumed that the pumpkinseed and other sunfish relatives guard only the eggs and not the young. In this connection, Breder and Rosen (1966) cited a report of a male pumpkinseed which was found tending the young in the bottom of a nest. The young were rather active, and now and then one of them left the nest and swam up to the surface. When the parent fish snapped up the stray, he appeared at first to be devouring his young; it was soon discovered that each time the parent took a young fish in his mouth he immediately returned to the bottom of the nest, head downward, and spat the young into the nest near the ground. Breder (1936) noted that a few students have seen sunfishes transporting their young by oral or other means, but that he has never seen such behavior himself.

The production of Lake Wingra (Dane County) pumpkinseeds, which were 112–141 mm TL on 31 May 1972, was 5,800 (4,100–7,000) eggs; the production of 119–135-mm fish on 29 June was 4,500 (2,400–6,700) eggs (Churchill 1976). Two females from northern Wisconsin, 122 and 126 mm TL, held 5,460 and 5,850 eggs in late June (G. Lutterbie, pers. comm.). In Deep Lake, Michigan, Carbine (1939) collected 1,509 fry from one nest and 14,639 from another.

Pumpkinseed eggs, which are about 1 mm diam, are demersal and adhere to bottom objects such as soil particles, small stones, roots, and sticks. Hatching occurred in 47 hr at temperatures of 19.0–24.7°C (66–76.5°F) (Balon 1959); and in about 3 days at 27.8°C (82°F) (Breder 1936). Balon provided extensive details and illustrations of the embryonic development of the pumpkinseed from fertilization to the 5.2-mm prolarva at 157 hr. Fish (1932) described and illustrated the 18.5-mm stage.

Young pumpkinseeds live on or near the shallow water breeding areas. According to Cahn (1927), they leave the nest almost at once, after which no further parental care is displayed. Young-of-year in central

Age and Growth (TL in mm) of the Pumpkinseed in Wisconsin

Location	1	2	3	4	5	6	7	Source
Bucks L. (Rusk Co.)	46	81	137	170	188	190		Snow (1969)
Murphy Flowage (Rusk Co.)	43	69	94	119	137	155		Snow (1969)
Lowland L. (Chippewa Co.)		51	64	79	94	97		Snow (1969)
Flora L. (Vilas Co.)	54	79	106	128	151	171		Parker (1958)
Flora L. (Vilas Co.)[a]	53	76	99	122	144	154	173	Parker (1958)
L. Wingra (Dane Co.)	48	87	120	134	137			Churchill (1976)

[a] Pumpkinseed × bluegill hybrids.

Wisconsin lakes were 38 (28–46) mm TL in August, and 46 (39–57) mm in September.

Snow (1969) suggested that there may be a higher growth rate among pumpkinseeds found in drainage lakes, where alkalinity is high, than among those found in seepage lakes, where alkalinity is low.

In nature pumpkinseeds reportedly reach age X, although most do not exceed ages VI–VIII. They have lived up to 12 years in captivity (Carlander 1977). Fast-growing males may mature at age I; others mature at ages II and III.

A 454-g (1-lb) pumpkinseed was caught 15 January 1976 from Bishop Lake (Forest County). Mackenthun (1948) reported one pumpkinseed from southern Wisconsin in the 241–251-mm (9.5–9.9-in) group.

The stomachs of 24 Wisconsin pumpkinseeds, 50–169 mm long, contained crustaceans, rotifers, snails, clams, flatworms, aquatic insect larvae, and terrestrial insects (D. Bendlin, pers. comm.). In Green Lake (Green Lake County) during late summer, pumpkinseeds which were 146 mm long had eaten insect larvae (59.5% volume), clams (6.1%), snails (26.5%), and leeches (7.5%). In Lake Mendota (Dane County), pumpkinseeds which were 118 mm long, had consumed insect larvae (29.3% volume), insect pupae (0.5%), insect adults (4.2%), amphipods (3%), ostracods (29.5%), snails (11%), leeches (5.9%), plant material (5.5%), and sand (11.1%).

In Illinois (Forbes 1880), the food of nine adult pumpkinseeds consisted of mollusks (46%), (including *Planorbis*, *Amnicola*, and *Valvata*), insects (20%), crustaceans (22%), and vegetation (12%); the plants were *Chara*, *Myriophyllum* and algae. In southern Canada (Keast 1965), fish fry and mollusks were important in the pumpkinseed's midsummer diet. Scott and Crossman (1973) reported that larval salamanders have been eaten by pumpkinseeds. Except for specimens less than 70 mm long, pumpkinseeds of all sizes consume more gastropods than the other sunfish species (Sadzikowski and Wallace 1976). This is made possible by the pumpkinseed's wide pharyngeal arches and round, molarlike teeth, and probably helps to minimize competition for food with other cohabiting sunfish.

Evidence in one study showed that the pumpkinseed fed daily from 0500 to 0730 hr, that steady feeding began about 0930 hours, and was followed by a marked acceleration in feeding between 1500 and 1730 hours (Keast and Welsh 1968). A brief period of feeding occurred after midnight. Keast noted that the pumpkinseed is a diverse feeder—8–10 different food items were present in significant volumes in its diet. In laboratory experiments, at a water temperature of 22.7°C (73°F), the pumpkinseed digested all digestible organic matter it had eaten within 22 hr (Kitchell and Windell 1968).

The water temperature preference of small pumpkinseeds tested in the laboratory, was 31.5°C (88.7°F) (Coutant 1975). Reynolds and Casterlin (1977) noted that published preferred temperatures for this species ranged from 24.2°C (75.6°F) to 32°C (89.5°F). Young pumpkinseeds that were found in the thermal outfall of a power plant on Lake Monona (Dane County) in August had body temperatures higher than 29°C (84°F) (Neill and Magnuson 1974). In a shallow Michigan pond, a 38°C (100.4°F) water temperature resulted in a large fish mortality among umbrid, catostomid, cyprinid, ictalurid, and percid species; among the more resistant species was the pumpkinseed. In southern Canada (Hallam 1959), the pumpkinseed associated with rock bass and smallmouth bass at an average summer water temperature of 21°C (70°F).

O'Hara (1968) determined that the bluegill is better adapted to higher temperatures than the pumpkinseed. In general, the pumpkinseed lives in cooler waters than other members of the genus. However, O'Hara (1968) also determined that small pumpkinseeds are better adapted to warmer temperatures than larger fish, because temperature has less effect on the respiratory metabolism of small fish.

Power and Todd (1976) studied the effects of increasing temperatures on the social behavior of pumpkinseeds in territorial groups. When subjected to a 1°C temperature increase every other day until they succumbed, their social behavior remained remarkably unchanged by thermal stress until the temperature reached nearly lethal levels. As the temperature rose, ritualized behavior increased in frequency and then fell off; behavioral and physiological signs of stress appeared at temperatures of 31–38°C (88–100.4°F).

The pumpkinseed has been used as a test animal to predict the ecological impact of cold shock during the winter when thermal discharges from power stations were terminated. Becker et al. (1977), determining the pumpkinseed's resistance to abrupt and to gradual cold shock, found that the lower 50% mortality temperature limit was 12.3°C (54.1°F) among fish acclimated to a 30°C (86°F) temperature, 9.6°C (49.3°F) among fish acclimated to 25°C, and 4.5°C (40.1°F) among fish acclimated to 20°C (68°F). Prior to death, the fish suffered from a loss of equilibrium at temperatures slightly higher than the lower mortality limit. Such fish are in a helpless state and will eventually succumb.

At a summer temperature of 26°C (79°F), the lowest observed oxygen tension at which pumpkinseeds survived for 24 hours was 4.3 ppm; at a temperature of 15°C (59°F), 3.1 ppm (Moore 1942). In southeastern Michigan lakes (Cooper and Washburn 1949), the pumpkinseed showed a relatively high tolerance of oxygen deficiency; it survived in waters in which the oxygen level dropped to 0.2–0.3 ppm during winter stagnation.

In one study, reproductive isolation appeared to be complete between pumpkinseeds and longear sunfish (Steele and Keenleyside 1971). Female pumpkinseeds showed a preference for pumpkinseed males even in the absence of visual cues, but pumpkinseed males did not discriminate between females of the two species in either the presence or absence of visual cues. The female's choice of a spawning partner of the same species may be an important ethological isolating mechanism between these two species. It is probable that auditory recognition, as described by Gerald (1971), plays some role in species isolation. When equal numbers (1:1 sex ratio) of pumpkinseeds and bluegills were stocked in ponds in southern Ontario (Clark and Keenleyside 1967), no spawning between the two species was attempted, nor were any hybrids found in the large numbers of yearling and 2-year-old offspring. The biologists determined that behavioral isolation through the visual recognition of mates of the same species was probably the major barrier to hybridization.

Observations by scuba divers have disclosed that juvenile pumpkinseeds travel in abundant and loose schools in shallow water (0.5–0.1 m) in areas of emergent water plants (Emery 1973). The young swim near the surface. Adults, however, are found in deeper water over rocky or plant-covered substrates, and only rarely school. Adults are often observed in pairs or in small aggregations of three or four individuals.

Pumpkinseeds are active by day. At dusk they move toward the bottom, where they rest. Resting areas are usually in interstices of rocky cliff areas or near fallen logs. Emery noted that pumpkinseeds become pale and barred at night.

There is evidence that the pumpkinseed is a homing fish. In an Iowa study, 64% of the displaced pumpkinseeds had homed (Kudrna 1965). A greater percentage of large fish homed than small fish. According to Kudrna, pumpkinseeds, when displaced in a new territory, initially spent time moving in circles as if searching for familiar landmarks. Reed (1971) noted that many displaced pumpkinseeds returned to their original home range within 24 hr, and that most fish tagged and released in the general area of capture showed little, if any, tendency to stray.

Forty-five pumpkinseeds were collected from a pond on the south branch of the Popple River (Florence County) along with white sucker (1), pearl dace (2), finescale dace (25), northern redbelly dace (58), golden shiner (319), fathead minnow (3), common shiner (4), blacknose shiner (695), brassy minnow (2), black bullhead (2), yellow perch (6), and Iowa darter (3).

IMPORTANCE AND MANAGEMENT

Small pumpkinseeds form part of the food of almost all predatory fishes such as basses, walleyes, yellow perch, northern pike, and muskellunge. Even larger pumpkinseeds and other sunfish may eat the young. Because the pumpkinseed spends much time in shallow water, it is exposed to many enemies. It is known to have been eaten by cormorants, mergansers, and herons (Adams and Hankinson 1926).

The pumpkinseed is host to the glochidial stage of the mollusks *Amblema plicata* and *Anodonta implicata* (Hart and Fuller 1974).

Adams and Hankinson have suggested, with "abundant confirmation," that the pumpkinseed destroys mosquito larvae.

Although the pumpkinseed has been termed the "small boy's fish," it is sought by adult anglers as well. It can be caught by still-fishing methods with worms, grasshoppers, and other small, live baits, but it also responds to small dry flies, to poppers, or to standard wet fly trout patterns. It is caught during the day, and especially in late afternoon. Its flesh is white, flaky, sweet, and delicious.

In Escanaba Lake (Vilas County), the total sport fishery harvest of pumpkinseeds from 1946–1969 was 138,338 fish weighing 11,140 kg (24,559 lb) (Kempinger et al. 1975). Pumpkinseeds ranked second in the number of fish caught; they constituted 36.3% of the total numerical catch, and a third (17.8%) of the total weight. The pumpkinseed population in Escanaba Lake, based on fish 114 mm long and larger, was estimated at 52,000 in 1959; too few were taken, however, to provide estimates from 1966 through 1969. Pumpkinseeds comprised 1.5%, 8.0%, and 3.4% of the total catches from Black, Oak, and Laura lakes (Vilas County) from June through August 1970 (Serns and McKnight 1974). In Murphy Flowage (Rusk County), the total harvest of pumpkinseeds from 1955 to 1970 constituted 1.9% of the total fish catch by number and 1.4% by weight (Snow 1978).

In Wisconsin, the regulations for taking panfish, including the pumpkinseed, from inland waters are liberal. An aggregate of 50 panfish may be caught in one day. In most boundary waters there is no bag limit on panfish, except in Wisconsin-Minnesota waters, which have a limit of 25.

The pumpkinseed is undoubtedly among the most strikingly colorful and beautiful of Wisconsin fishes. Jordan and Evermann (1923) called it "a very beautiful and compact fish, perfect in all its parts, looking like a brilliant coin fresh from the mint." It makes an interesting and attractive aquarium fish.

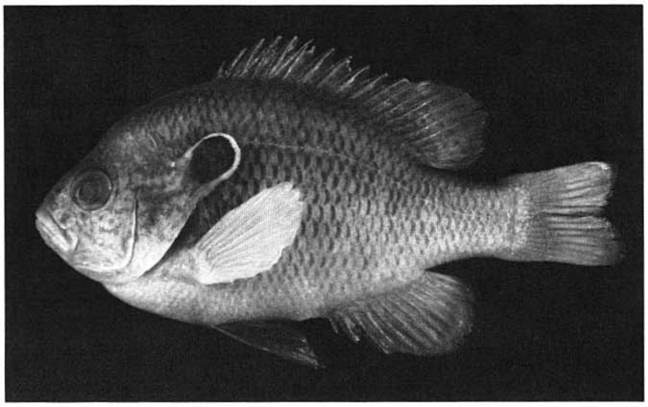
In Lake Wingra (Dane County), the estimated biomass (kg/ha) of pumpkinseeds during 1972–1974 ranged from 3 to 4 for juveniles and from 4 to 11 for adults (Churchill 1976). The total biomass of Lake Wingra in 1973 was 668 kg/ha; it consisted of pumpkinseeds (14 kg/ha), bluegills (503 kg/ha), white crappies (56 kg/ha), black crappies (20 kg/ha), and yellow bass (75 kg/ha).

In waters which are overpopulated with pumpkinseeds, stunting is a problem. The thinning of such populations either by mechanical means or by partial poisoning may help, although biological controls in the form of fish predators may provide a more satisfactory solution. When the numbers of bluegills, pumpkinseeds, and their hybrids were reduced in Flora Lake (Vilas County) by netting operations, all responded favorably with an increase in the linear rate of growth, and the pumpkinseeds showed an increase in weight at all lengths (Parker 1958).

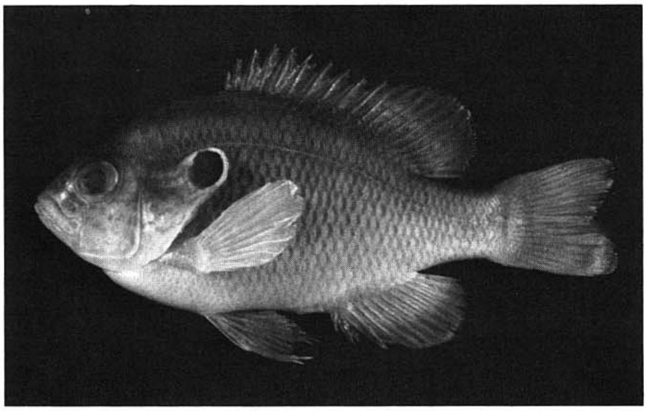
Longear Sunfish

Lepomis megalotis (Rafinesque). *Lepomis*—scaled operculum; *megalotis*—great ear, in reference to the prominent opercular flap.

Other common names: northern longear, Great Lakes longear, longear, blue and orange sunfish, pumpkinseed.



Adult male 94 mm, Milwaukee R. (Ozaukee Co.), 2 Aug. 1963



Adult female 80 mm, Milwaukee R. (Ozaukee Co.), 2 Aug. 1963

DESCRIPTION

Body deep, strongly compressed laterally. Length 71–94 mm (2.8–3.7 in). TL = 1.26 SL. Depth into TL 2.4–3.0. Head length into TL 2.7–3.4. Mouth moderately large, oblique, with jaws of equal length. Upper jaw reaching pupil of eye; conical, pointed teeth in brushlike pads on upper and lower jaws, no teeth on tongue; lower pharyngeal arches narrow, with pointed teeth. Gill rakers on first gill arch short, thick, knoblike (about as long as wide), and crooked. Opercular "ear flap" flexible and often much elongated in adults. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins about twice the length of anal fin base; first dorsal fin with 10 spines, second with 10–11 soft rays. Anal fin with 3 spines, and 9–11 soft rays; pelvic fin thoracic with 1 spine and 5 rays; pectoral fin short, bluntly pointed to rounded, and when laid forward across cheek barely reaching posterior edge of eye; caudal fin slightly forked. Scales ctenoid, in lateral line 34–38; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Back olive to rusty brown; sides lighter; breast and belly yellow to orange-red. Back and sides with specks of yellow, orange, emerald, and blue; 8–10 vertical bars conspicuous to absent. Cheeks orange with wavy blue streaks radiating back from mouth and eye. Ear flap black, narrowly edged with pale red to yellow (white in immature and all preserved specimens). Dorsal and anal fins olive, often with rusty orange wash; in preserved specimens, soft dorsal fin with parallel rows of light dots. Pectoral fins clear to lightly pigmented.

Breeding male iridescent green above and bright orange below; the vertical fins a deep rusty orange, and the pelvic fins blue-black. Scale pockets with dark-pigmented crescents pointing anteriorly. Breeding females less brilliantly colored.

Hybrids: Longear sunfish × orangespotted sunfish, longear sunfish × green sunfish, longear sunfish × bluegill, and longear sunfish × pumpkinseed (Childers 1967).

SYSTEMATIC NOTES

The Wisconsin form is *Lepomis megalotis peltastes* (Cope), the northern longear sunfish. *L. m. megalotis* (Rafinesque), the central longear sunfish, is distributed south of the Lake Erie—Ohio River divide to Louisiana (Trautman 1957). The northern longear sunfish differs from the central longear sunfish by having an ear flap which usually extends upward at a 45° angle, rather than almost horizontal to the body axis; by having a single large, reddish spot in the white border of the ear flap, rather than several small reddish spots; and by reaching a length of about 100 mm, compared to 230 mm.

DISTRIBUTION, STATUS, AND HABITAT

The longear sunfish occurs in three widely separated distribution centers in southeastern, eastcentral, and northwestern Wisconsin within the Mississippi River and Lake Michigan drainage basins. It has not been reported from the Lake Superior basin. In Wisconsin, the longear sunfish is near the northern limit of its distribution.

Specimens examined (numbers of individuals in parentheses): UWSP 862 (32) Milwaukee River at Saukville and Waubeka (Ozaukee County), 1963;

Range of the longear sunfish
- ● Specimens examined
- ▲ Wisconsin Fish Distribution Study (1974–78)
- ○ Literature and reports
- ◯ Greene (1935)

UWSP 4607 (2) East Branch Rock River (Washington County), 1971; UWSP 5009 (1) Fox River (Brown County), 1973; UWSP 5561 (1) Little Lac Court Oreilles (Sawyer County), 1976; and UWMZ 4373 Pensaukee River (Oconto County), 1957.

The Wisconsin Fish Distribution Study (1974–1978) reported: (4) Lac Court Oreilles (Sawyer County), 1968; (6) Pensaukee River (Oconto County) 1975; and (7) West Branch Milwaukee River (Fond du Lac County) 1978. Greene's (1935) mapped records are all indicated by large open circles on my map. Seeburger (1975) reported the longear sunfish from Mukwonago River below Phantom Lake (Waukesha County) 1972. Other reports: M. Johnson and J. Weckmiller (pers. comm.), Mukwonago River below the dam in Mukwonago (Waukesha County), 1968; C. Norden (pers. comm.) (6) Milwaukee River at Saukville (Ozaukee County), 1966; R. Heizer (pers. comm.) (12) Little Suamico River (Oconto County), 1974; Mraz (1960) (6) Lake Geneva (Walworth County), 1958.

Greene (1935) suggested that the presence of the longear sunfish in the Milwaukee and lower Root rivers may have resulted from crossovers from the Des Plaines and Illinois-Fox rivers at high water, or by means of stream capture, probably the former. Its presence in the headwaters of the upper Fox, in the Wolf River system, and in the Suamico River near its mouth indicates its probable dispersal into these waters by means of the glacial Fox connectives. Its occurrence in the mouth of the Ahnapee River (upper Kewaunee County) indicates its possible derivation from glacial Lake Oshkosh during a later stage, when that lake drained into Lake Chicago.

According to Gerking (1953), the longear sunfish is a very abundant, if not the most abundant, centrarchid fish in smaller midwestern streams. However, its numbers have decreased in large Ohio streams as a result of its intolerance of turbid conditions (Trautman 1957). In recent years it has been eliminated from the Root River (Racine County), the lower Milwaukee River (Ozaukee and Milwaukee counties), the East Branch of the Rock River (Washington County), and at least some sectors of the Illinois-Fox and Des Plaines rivers (Walworth, Racine, and Kenosha counties). The population from the East Branch of the Rock River (Washington County) was lost through the use of antimycin in a massive carp control project; unfortunately, no attempts were made to salvage this longear sunfish population. The population losses in other locales were undoubtedly caused by the effects of serious soil erosion and turbidity.

Wisconsin accords the longear sunfish threatened status (Wis. Dep. Nat. Resour. Endangered Species Com. 1975, Les 1979). Many sports fishermen confuse this species with the common pumpkinseed, and there appears to be little protection afforded to the longear by the fishing regulations. Perhaps the best way to ensure its protection is to establish a suitable refuge in a sector of a stream already containing sizeable populations (e.g., the Saukville to Waubeka sector of the Milwaukee River). Since the longear sunfish is a sedentary species that seldom moves beyond a home range of 30–60 m, a refuge of a few kilometers of stream would appear to be adequate.

The longear sunfish usually inhabits streams of clear, shallow, nearly still, and moderately warm water, in or near areas of aquatic vegetation. In its habitat in the Milwaukee River 1 km above Saukville, the stream is 18–24 m wide, has an average depth of 0.3 m (greatest depth 0.5 m), and a bottom composed of rubble, gravel, and some sand. The water is clear, and moderate amounts of aquatic vegetation are present. At Waubeka, where the river forms a pondlike widespread, the rocks, boulders, and rubble are overlaid with a thin layer of silt. Occasionally the longear sunfish occurs in lakes.

BIOLOGY

In Wisconsin, the longear sunfish probably begins to spawn in June and is known to spawn in early August. At the same latitude in Michigan, spawning occurs from late June to August when water temperatures are 23.3–25°C (74–77°F) (Hubbs and Cooper 1935). Spawning has been reported in late July in Kansas, when temperatures were as high as 30.5°C (87°F) (Cross 1967).

The male longear sunfish builds the nest in gravel, if it is available; otherwise the nest is built in sand or hard mud. Males construct their nests by a sweeping action of the tail similar to that of nest-building bluegills (H. C. Miller 1963).

Nests may be built in water 0.2–3.4 m deep, although they are most frequently reported at 0.25–0.36 m (Boyer and Vogele 1971, Adams and Hankinson 1926, Witt and Marzolf 1954). The longear generally appears to nest in small colonies of 5–13 nests which are from a few cm to about 0.3 m apart (Hankinson 1920, H. C. Miller 1963), although colonies of several hundred nests are known (Keenleyside 1972). Often the nests within the colony are so close together that their rims nearly touch. Nests are approximately 0.5 m diam, and more or less circular, but some nests are irregular in shape and difficult to discern except for the attending fish (Hankinson 1920).

The male longear is highly territorial, and although a guarding male aften chases intruders through the territories of other males, the territory itself appears to include only the immediate nest area and the space above the nest to approximately 1 m (Boyer and Vogele 1971). A territorial male defends a nest from individuals of his own and of other nonpredatory species of fish, but does not defend it from such surface-feeding fishes as the blackstripe topminnow. When a largemouth bass 46 cm long approached one longear nest for an instant, the sunfish turned toward the intruder as if to challenge him, but then abruptly turned and fled, seeking the meager cover offered by a small, dead branch (Witt and Marzolf 1954). Within seconds after the bass had left the vicinity, the longear was back in its own nest.

Boyer and Vogele have called attention to lateral threat displays which occur between male longear sunfish near spawning colonies and between males guarding adjacent nests. A weak lateral display was seen when a spawning female quickly spread and folded the dorsal spines upon reentry of a male who had chased excess females from the nest. According to Boyer and Vogele, the frontal threat, in its various forms, is the most frequent type of aggressive behavior among longears, and particularly common and vigorous during reproductive activities (p. 22):

> . . . The longest displays were by males on adjacent nests. Each male spread his fins except the spiny dorsal fin and made alternate short thrusts forward followed by backing into a lateral position. While the male was in the lateral position, the rayed portion of his dorsal fin often was quivered repeatedly; this appeared to be an intention movement for the thrust which soon followed.

Aggressive encounters with contact, especially in the early nest building phase, probably account for superficial injuries observed on guarding males. In one Boyer and Vogele study, the rayed portion of the dorsal fin of nearly every guarding male had been split, and many other males had portions of their fleshy opercle lobes torn away. Among even-aged longear sunfish raised in the laboratory, there was less extreme aggression, and no injuries to either males or females (W. E. Smith 1975). On the other hand, Miller (1963) reported that longear females were killed by continued male attacks, especially when the fish were confined in small aquariums.

When single male longear sunfish in aquariums were presented simultaneously with two female sunfish (one a longear female, and either a pumpkinseed or a bluegill female) the nesting male longears courted females of their own species more vigorously than they did those of the other species (Keenleyside 1972). The longear males were generally more aggressive toward longear females than toward bluegill females but were equally aggressive toward their own and pumpkinseed females. Gerald (1971), in preliminary experiments on the courtship sounds produced by nesting males, noted that both male and female longear sunfish responded by swimming toward such calls, at least during spawning. Male longear sunfish were induced to court and call to dead females that were manipulated on a string.

When female longear sunfish were seen entering a nesting colony, the males began leading. Leading involved spreading the fins (except the spined portion of the dorsal fin, which was only sometimes spread briefly), swimming straight toward a female, and then returning directly to the nest (Boyer and Vogele 1971). If a female followed a male into his nest area, the male swam in a descending spiral toward the bottom, with one side tilted inward toward the side of the female.

A spawning or prespawning female sometimes made peculiar movements upon entering a nest, before she began to circle with a male: she bit the substrate, then turned on one side and darted away. When turned on her side, the female's back was directed either toward or away from the pursuing male. At other times, a female entered a nest, bit the substrate, and immediately began to circle with the male (Boyer and Vogele 1971).

Spawning in a longear sunfish colony typically increases in frequency during the day, and peak activity occurs in the afternoon when water temperatures are at their peak. Spawning details have been given by Witt and Marzolf (1954:189):

> . . . The male circled within the 8-inch center of the nest, always keeping the female between him and the center of the nest. They circled within the nest both clockwise and counter-clockwise, the direction dependent upon how the male reentered the nest after chasing an intruder. The male always remained in an upright position, while every 10 to 15 seconds the female would roll on her side, to within 20 degrees of the horizon, and bring her vent in close proximity to his. This posture lasted only 2 seconds, during which time both fish shuddered, the female more violently than the male.

Interruptions known as intrusions sometimes occur at the height of spawning. Keenleyside (1972) determined that the main function of nest intrusion by females is to eat eggs; males apparently intrude to fertilize the eggs in another male's nest.

Spawning sessions reported by Boyer and Vogele (1971) usually ended immediately following a spawning movement, with the female darting from the nest and the male chasing her. A female leaving one nest after only a few spawning movements often went immediately to another nest to spawn. Two or more females were often present in one nest at the same time, and two females were frequently observed circling on the inside of a single male. The male usually forced out one of the females (usually the female farthest on the inside), and thus limited the occupancy of the nest to only one female at a time. From 7 to 20 eggs are emitted in one spawning movement.

Immediately after the female leaves, the male begins to fan the nest. At first he maintains a normal attitude over the center of the nest while he moves his paired fins and his caudal peduncle rapidly. He then assumes a vertical posture over the nest, standing on his tail; in this position he fans the nest vigorously enough to dislodge small pebbles. Witt and Marzolf (1954) assumed that the first method of fanning insures a complete mixing of sperm and eggs, and possibly cleans the eggs of excess sperm, and that the second method of fanning drives the eggs deep into the interstices between the large pebbles, where they are probably more protected from predators.

Hankinson (1920) observed a longear nest from which the sunfish had been driven away and which had been entered by bluntnose minnows, redfin shiners, and stoneroller minnows. The stonerollers were seen consuming sunfish eggs. Longear sunfish eggs are also eaten by hog suckers, white suckers, and redhorse suckers (Keenleyside 1972). Boyer and Vogele (1971) observed defending male longear sunfish feeding in or adjacent to their nests, and even consuming eggs from their own nests.

Longear sunfish eggs are demersal and adhesive, and may become attached to the roots of plants after the plants have been cleaned of bottom mud (Breder 1936). In the Milwaukee River on 1 August 1963, an age-II, gravid female (75 mm, 9.5 g) with ovaries 12% of body weight, held an estimated 745 eggs, 1.3 mm diam. An age-III female (93 mm, 18.99 g) had ovaries 13.4% of body weight, and held an estimated 1,620 ripe eggs; a few immature, white eggs were present in various sizes up to 0.7 mm diam.

The number of longear sunfish eggs found in 12 nests varied from 137 to 2,836; the number of larvae varied from 52 to 1,132 (Boyer and Vogele 1971). Taber (1969) illustrated developmental stages from 6.0 to 19.0 mm. Hatching occurs in 3–5 days, although in the laboratory, at 25°C (77°F), embryos hatched in 2 days, and swim-up and feeding began 7 days later (W. E. Smith 1975). In nature, larvae left the nest as each clutch developed, rather than all at one time. Boyer and Vogele (1971) noted that the lengths of 70 advanced larvae collected from one nest were 5.8–7.5 mm; the average length was 6.9 mm. Males often continued to guard the nest even after the last larvae had emerged (Huck and Gunning 1967). In October, the young are 20–56 mm TL (Trautman 1957).

Longear sunfish from the Milwaukee River (Ozaukee County), collected 1 August 1963, showed the following growth:

Age Class	No. of Fish	TL (mm)		Calculated TL at Annulus (mm)			
		Avg	Range	1	2	3	4
I	14	65.5	52–73	30.1			
II	7	76.9	71–83	26.4	55.7		
III	9	90.3	84–94	27.2	60.9	76.0	
IV	2	99.0	96–102	32.0	55.0	75.0	92.0
Avg (weighted)				28.6	58.2	75.8	92.0

In southern Michigan (Hubbs and Cooper 1935), the calculated lengths at the annuli (sexes combined) were: 1—44 mm; 2—57 mm; 3—73 mm; 4—78 mm; 5—111 mm; and 6—105 mm. Growth in males was slightly greater than in females. Hubbs and Cooper have discussed the validity of the spawning mark in this species. Aging of the longear is by scale analysis. Relatively few longear sunfish live to be older than 4 years; but in Michigan one fish was found to be approximately 9 years old.

At Wisconsin's latitude, maturity begins at age II. According to Hubbs and Cooper, however, occasional large yearling longears in scattered localities may mature soon enough to spawn in their second summer.

Of 1,129 longear sunfish collected in Michigan, the majority were from 53 to 89 mm long; the largest was about 140 mm (5.5 in). A 115-mm fish (UWSP 4607), collected from the East Branch of the Rock River (Washington County), is the largest Wisconsin specimen known. Trautman (1957) reported a maximum size of 236 mm (9.3 in) and 284 g (10 oz).

In northern Arkansas (Mullan and Applegate 1968), longear sunfish up to 48 mm long consumed aquatic insects (49.5% volume, mostly midgeflies), microcrustaceans (41.2%), fish eggs (9.1%), and terrestrial foods (0.1%). Longears 51–99 mm long consumed aquatic insects (64.7% volume and mostly midgeflies), fish eggs (15.4%), terrestrial foods (7.7%), detritus (4.9%), microcrustacea (4.2%), mollusks (0.8%), bryozoans (0.7%), filamentous algae (0.7%), fish (0.7%), and mites (0.2%). Fish 102–201 mm long ate aquatic insects (42.1% volume, and mostly midgeflies), terrestrial foods (18.6%), fish (12.0%), detritus (12.0%), fish eggs (10.8%), malacostracans (3.1%), microcrustacea (1.0%), bryozoans (0.3%), and mollusks (0.1%). Large longear sunfish also ingested moderate to heavy quantities of young bass in May, and newly hatched sunfish in June. In a Kentucky study (Lotrich 1973), fish were the principal food of longear sunfish.

Longear sunfish apparently feed more extensively at the surface of the water than some other sunfishes. Mature insects constitute a large percentage of their food. On two occasions longears were observed following hog suckers and feeding on organisms that the suckers stirred up (Huck and Gunning 1967). Gerking (1952) determined that young longear sunfish used about 33% of the protein that they consumed for growth, but that the oldest longear sunfish (105 g) used only 5% of the available protein for growth.

A number of behavioral characteristics of the longear sunfish have been observed by researchers. H. C. Miller (1963) referred to the longear sunfish species as "quite timid" though not as timid as the orangespotted sunfish. The comfort movement most frequently observed among longear sunfish was chafing, during which the fish brushed their sides or bellies along the substrate or a protruding stick (Boyer and Vogele 1971). Convulsive coughing occurred occasionally in individuals that were rapidly eating eggs from a nest; such coughing resulted in the ejection of gravel from the mouth. Observers have reported that longear sunfish become inactive at night, although surface feeding has been observed under bright moonlight in late summer. In intense darkness the fish rested on the bottom with their pelvic fins and the forward parts of their bodies, (from the midventral line to the chin) touching the substrate; the pectoral fins were spread at right angles to their bodies.

The typical home range of the longear has been estimated to be from 30 m to no more than 60 m of stream (Gunning 1965, Gerking 1953). In one study, the majority of longear sunfish that were displaced to a new location migrated back to their original home. Gunning (1959) presented evidence to show that blinded longears are able to return to their home range as quickly and accurately as fish not visually impaired; he concluded that blind fish apparently recognize the home area by a characteristic odor or a combination of odors. Olfaction is probably more important than vision in the homing ability of the longear sunfish.

During the winter in Louisiana, at least some longear sunfish desert their home ranges. Only about one-third of the fish marked in the summer range were taken in the same section during the winter (Berra and Gunning 1972). In Arkansas during March, longear sunfish were seen hiding singly or in small groups under rocks or stumps on the bottom, but as the water warmed they became more active; aggregations of fish dispersed when the water temperature reached 17.8°C (64°F) (Boyer and Vogele 1971). The longear has been found at water temperatures up to 37.8°C (100°F) (Proffitt and Benda 1971).

In a Missouri movement study, 70% of the recaptured longear sunfish had made no movement, 20% had moved downstream, and 10% had moved upstream (Funk 1957).

Hallam (1959) found that longear sunfish in southern Ontario commonly associated with rock bass and smallmouth bass at an average water temperature of 21°C (70°F). The longear avoids association with coldwater mottled sculpins and brook trout, having been taken only once with the latter.

In Illinois, the longear sunfish is a frequent companion of the green sunfish (Forbes and Richardson 1920). In the Milwaukee River at Saukville (Ozaukee County), 29 longear sunfish were taken with these species: golden redhorse (3), largescale stoneroller (16), hornyhead chub (5), creek chub (2), bluntnose minnow (3), common shiner (151+), striped shiner (77), rosyface shiner (25), spotfin shiner (5), sand shiner (32), redfin shiner (5), black bullhead (1), blackside darter (1), logperch (1), johnny darter (1), smallmouth bass (1), pumpkinseed (3+), and rock bass (5).

IMPORTANCE AND MANAGEMENT

In Wisconsin, the longear sunfish is too small to be considered a food fish for man, and its populations are too sparse to be of much importance as food for other fishes and animals; nor is it abundant enough anywhere in the state to be a serious competitor of other fishes. Worms, grasshoppers, and small minnows are good natural baits.

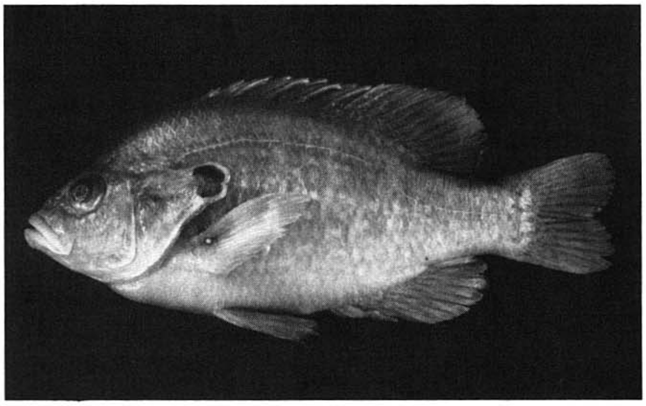
The longear sunfish adjusts well to captivity. It is not susceptible to injury from handling, is not unduly aggressive, and appears to be a promising species for use as a laboratory test fish (Ward and Irwin 1961, W. E. Smith 1975). In the laboratory, W. E. Smith was able to get this species to spawn, to raise the young to maturity in 22 weeks (males 10–12 cm, females 7–9 cm), and to produce successive generations under conditions of long photoperiod and a water temperature of 25°C (77°F). The adults continued to spawn with regularity every 6–10 days for 14 months.

In Bull Shoals, Arkansas, where the longer sunfish has become the predominant sunfish, it is a highly successful competitor, and production in 1968 was at 45.8 kg/ha (41 lb/acre) (Boyer and Vogele 1971). In Jordan Creek, Illinois, 2,015 longear sunfish weighed 38.6 kg, compared to 32.8 kg for 369 smallmouth bass and 108.2 kg for 32,361 minnows collected from the study areas (Durham 1955a).

Orangespotted Sunfish

Lepomis humilis (Girard). *Lepomis*—scaled operculum; *humilis*—humble, insignificant.

Other common names: orangespot, redspotted sunfish, dwarf sunfish, pigmy sunfish, pumpkinseed.



Adult 107 mm, Pecatonica R., above Mifflin (Iowa Co.), 15 Aug. 1962

DESCRIPTION

Body moderately deep, compressed laterally. Average length 51–76 mm (2–3 in). TL = 1.25 SL. Depth into TL 2.8–3.5. Head length into TL 2.8–3.3. Mouth small, oblique. Upper jaw reaching to front of eye; lower jaw slightly longer than upper jaw; conical, pointed teeth in brushlike pads on upper and lower jaws, no teeth on tongue; lower pharyngeal arches narrow, with short, pointed teeth. Sensory head pores greatly enlarged, especially those above the upper lip groove—more so than in any other species of *Lepomis*. Sensory pits (2 depressions in skull between eyes) larger than in any other sunfish, the width of each pit about equal to distance between the pits. Gill rakers on first gill arch blunt and straight, the longest 3–4 times longer than wide. Opercular ear flap prominent, often elongate, flexible. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins about 2 times length of anal fin base; first dorsal fin with 10–11 spines, second with 10 soft rays. Anal fin with 3 spines, and 8–9 soft rays; pelvic fin thoracic with 1 spine and 5 rays; pectoral fin rounded to bluntly pointed, and when laid forward across cheek reaching to about anterior edge of eye; caudal fin scarcely forked. Scales ctenoid, gill covers and cheeks scaled. Scales in lateral line 36–41; lateral line complete. Chromosomes 2n = 44–46 (W. LeGrande, pers. comm.).

Male: back olive, sides lighter, and ventral region of head and belly yellow to white. Back and sides with up to 7 broad, dark bands; orange spots on sides of head and body; black spot on ear flap, margined with white. Vertical fins usually not mottled, but broadly margined with red-orange in life. Female: head and body brown, no orange. Soft dorsal fin and caudal fin base mottled with brown spots; paired fins largely unpigmented. This species provides an excellent example of sexual dichromatism in central North American fish; the males are more brilliantly colored than the females.

Breeding male brilliantly colored, with conspicuous orange-red spots, orange fins; and orange-red eye; anterior pelvic fin and entire anal fin margined with black.

Hybrids: Orangespotted sunfish × green sunfish, orangespotted sunfish × bluegill, orangespotted sunfish × longear sunfish, and orangespotted sunfish × pumpkinseed (Childers 1967).

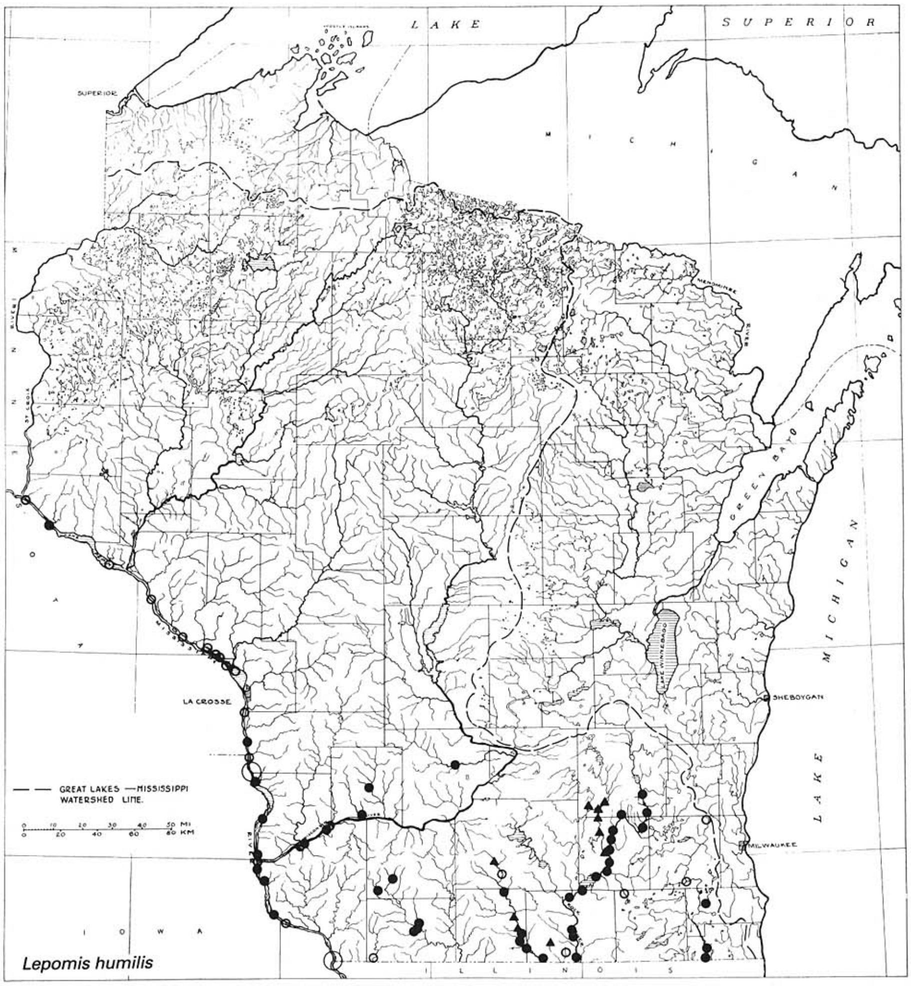
DISTRIBUTION, STATUS, AND HABITAT

In Wisconsin, the orangespotted sunfish is known only from the Mississippi River drainage basin. Greene (1935), who collected in the late 1920s, recorded it at several locales from the Mississippi River upstream to the Victory-Genoa sector (Vernon County); his only other collection came from the Galena River (Lafayette County), almost on the Illinois line. The literature report from the headwaters of the Fox River at Lannon (northeastern Waukesha County) was supplied by Cahn (1927). Since the late 1920s, the orangespotted sunfish has infiltrated the lower Wisconsin River basin, the Sugar and Rock river basins, and the Mississippi River upstream to its junction with the St. Croix River.

The orangespotted sunfish, probably more than most species, has extended its range in recent years, and, considering its habitat needs, will probably continue to extend its range northward. The orangespotted sunfish is found in soft-bottomed pools, and it is tolerant of silt and some pollution. The extension of its range is promoted by the tilling and clearing of land.

The orangespotted sunfish is uncommon to common in Wisconsin. Its status appears to be secure, although in Illinois, where the habitat seems to be increasing, there has been evidence of a decline in its numbers in some areas (P. W. Smith 1968).

In Wisconsin, the orangespotted sunfish was encountered most frequently in turbid water, over substrates of mud (31% frequency), gravel (22%), clay (16%), sand (13%), silt (6%), rubble (6%), and boulders (6%). It was found in sloughs, in backwater



Lepomis humilis

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

lakes, and in sluggish streams down to 5 m in width, in waters supporting a scanty to moderate amount of vegetation.

BIOLOGY

Spawning at Wisconsin's latitude occurs from late May to August. It begins when water temperatures reach about 18.3°C (65°F), and continues at temperatures of 23.9–31.7°C (75–89°F) in water depths of 10–61 cm. The nest of the orangespotted sunfish is similar to the nests of other sunfishes, but somewhat smaller—15–18 cm diam, and 3–4 cm deep. According to Barney and Anson (1923), the nest is constructed by the male, which, by powerful pushes with his head, and "by flirts of the tail, combined with active trembling of the fins, removes the smaller pebbles and lighter sand from a bowl-shaped pocket." The nest is circular, or nearly so. The following account of nesting and spawning behavior is derived from Barney and Anson (1923) unless indicated otherwise.

The nests of the orangespotted sunfish are often built in colonies. In a freshly drained Iowa pond, some 960 nests were counted along a bank that was 111 m long; the nests had been excavated through an 8–10 cm deposit of mud until a solid bottom of gravel had been exposed. In Kansas, Cross (1967) reported that males of this species defended individual territories of 30–60 cm diam. When frightened from their nests, several males may move together into deep water before returning, seconds later, to their respective breeding territories.

Breeding behavior has been described by Barney and Anson: "The two fish after much maneuvering and occasional splashing come to a position with the bellies touching each other, whereupon the eggs and sperm are delivered." The females leave the nest after spawning, while the male remains on the nest until the eggs have hatched.

In central Missouri (Pflieger 1975), the red shiner and redfin shiner have been observed spawning over nests of the orangespotted sunfish.

The number of eggs produced by orangespotted sunfish is a function of the size of the female. A 105-

mm female held 4,700 eggs (Barney and Anson 1923). In southern Wisconsin (G. Lutterbie, pers. comm.), on 27 June, a 57-mm female held about 795 eggs; and in mid-July, fish 64- and 69-mm long held an estimated 718 and 1,159 eggs respectively. The transparent, amber eggs are about 0.5 mm diam. They are slightly adhesive, and cling to stones, pebbles, and sand grains on the floor of the nest, where they are continually fanned by the quivering fins of the male. Occasionally the male leaves the nest to fight off intruding males intent on feeding on the eggs; at such times the eggs are vulnerable to predation by minnows (e.g., red shiners), which will instantly swarm into an unguarded nest (Cross 1967). Barney and Anson also observed darters and spottail shiners raiding nests when the orangespotted sunfish males were engaged in fighting off their own kind.

Orangespotted sunfish eggs hatch in 5 days at water temperatures of 18.3–21.1°C (65–70°F). In Wisconsin, the growth of young-of-year has been reported as follows (G. Lutterbie, pers. comm.):

Date	No. of Fish	TL (mm) Avg	TL (mm) Range	Location
11 Sept 1971	67	30	19–41	Rock R. (Jefferson Co.)
19 Sept. 1971	16	34	26–40	Rock R. (Jefferson Co.)
27 Sept. 1970	20	37	31–45	Rock R. (Rock Co.)

On the Mississippi River near Fountain City (Buffalo County), the average calculated lengths at the annuli were: 1—28 mm, and 2—66 mm (Christenson and Smith 1965).

In Iowa ponds, Barney and Anson (1923) determined the lengths for each year class of orangespotted sunfish: 0—10–24 mm (July to September); I—25–45 mm; II—40–55 mm; III—49–74 mm; and IV—56–93 mm. In Oklahoma (Jenkins et al. 1955), orangespotted sunfish had the following calculated growth at the annuli: 1—53 mm; 2—81 mm; and 3—99 mm; in Illinois (Lopinot 1958), these values were: 1—71 mm, 2—89 mm, 3—94 mm, and 4—137 mm.

Orangespotted sunfish that hatch early attain sexual maturity by August of the following year (i.e., at age I). The great majority, however, lay their first eggs in May of the third year of life (i.e., at age II). Barney and Anson noted that there is a normal retardation of growth as the sunfish reaches sexual maturity.

The largest Wisconsin orangespotted sunfish seen was 112 mm (4.4 in) long. In a Louisiana collection (Carver 1967), the maximum total length of this species was 147 mm (5.8 in).

In the stomachs of 11 Wisconsin orangespotted sunfish, D. Gaudet (pers. comm.) reported insect larvae (Trichoptera, Ephemeroptera, Plecoptera, Odonata, unidentifiable parts), crustaceans (*Daphnia*, copepods, *Gammarus*), mites, and ctenoid fish scales. In Illinois (Stegman 1969), 28 orangespotted sunfish had eaten crustaceans, aquatic insects, and dipterous larvae as primary foods. In 41 stomachs from Iowa fish, Kutkuhn (1955) found that insects (Trichoptera, Ephemeroptera, Diptera, Homoptera, Hemiptera) constituted 87% of the volume of food, crustaceans (Eucopepoda, Cladocera) 8% and Hydracarina 4%; he also found traces of algae and debris. In another Iowa study (Harrison 1950), stomach contents were almost 100% aquatic insect remains, but part of a butterfly and a terrestrial beetle were also observed. Barney and Anson agreed that the orangespotted sunfish feeds primarily on crustaceans and insect larvae, but they reported that it occasionally eats small fish; a 75-mm orangespotted sunfish had eaten two small individuals of its own species.

The orangespotted sunfish is able to tolerate low levels of dissolved oxygen. Gould and Irwin (1962) reported that this species had the ability to withstand oxygen concentrates of 1.7 ppm without sustaining casualties. The majority of the orangespotted sunfish tested in another study tolerated rapid changes of pH, from 7.9 to 9.2, and from 8.1 to 6.0, when the dissolved oxygen was 8 ppm (Wiebe 1931). Wiebe observed this species spawning in water at pH 9.3. Carver (1967) noted that this species was not collected in salinities exceeding 0.74 ppt.

According to Gerald (1971), male orangespotted sunfish produce courtship sounds which are species specific. Males were induced to court and to call to dead females that were manipulated on a string. Also, 11 orangespotted sunfish responded to playback of orangespotted male courtship sounds, and 3 orangespotted sunfish responded to the courtship calls of the longear sunfish.

In the Illinois-Fox river system (Waukesha County), Cahn (1927) reported that the associates of the orangespotted sunfish were the grass pickerel and the central mudminnow. In the Sugar River (Rock County), I found this species associated with: the quillback, river carpsucker, northern hog sucker, white sucker, creek chub, golden shiner, bluntnose minnow, fathead minnow, common shiner, emerald shiner, spotfin shiner, weed shiner, sand shiner, bigmouth shiner, channel catfish, black bullhead, blackstripe topminnow, johnny darter, smallmouth bass, green sunfish, pumpkinseed, and black crappie.

IMPORTANCE AND MANAGEMENT

In an Iowa pond which was stocked with adult largemouth bass and adult yearling orangespotted sunfish, the latter were apparently used extensively as forage fish by the bass. Although the bass reproduced successfully, there were no signs of orangespotted sunfish reproduction; Barney and Anson (1923) suggested that the small adult and young orangespotted sunfish served as food for the bass. Cross (1967) noted that, where it is abundant, the orangespotted is a significant forage item for larger centrarchids. On the other hand, the orangespotted sunfish may also compete for food with young bass, bluegills, and crappies (Cross 1967, Clark 1960).

Barney and Anson also noted that it may play a role in the natural history of freshwater mussels. It may be the host of glochidial stages of *Anodonta corpulenta* (Coker et al. 1921), and perhaps of other noncommercial mollusks. A natural infection of the orangespotted sunfish with the glochidia of the valuable yellow sand shell mussel (*Lampsilis anodontoides*) has been reported, but this is of doubtful significance, as the yellow sand shell has never been carried through its transformation into adult form experimentally other than on the gars.

The orangespotted sunfish has little or no value as a sport or a food fish, although it takes the hook readily when it reaches 75–100 mm (3–4 in).

It is used occasionally as an aquarium fish because of its brilliant colors, and it appears to live well in captivity as long as it has sufficient *Daphnia* and other live foods (Harlan and Speaker 1956).

This species makes a good bioassay animal because it transports and holds well, and it is not particularly excitable (Gould and Irwin 1962).

Barney and Anson (1923) suggested that in some locales, the orangespotted sunfish may be a valuable fish for mosquito control.

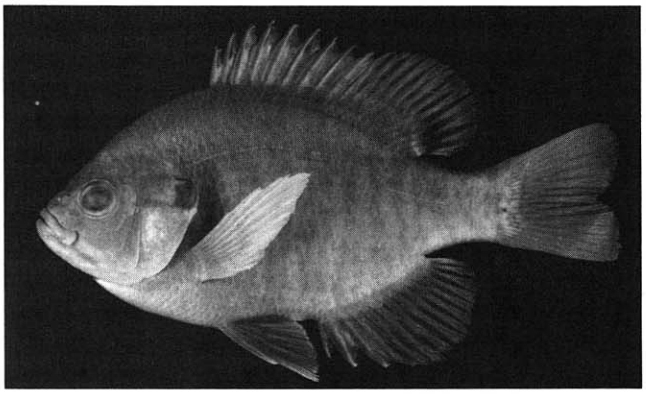
The standing crop of orangespotted sunfish in an Oklahoma pond was 2.9 kg/ha, with a net annual production of 1.6 kg/ha (Whiteside and Carter 1973).

Trautman (1957) noted that, as the orangespotted sunfish moved eastward in Ohio, the first specimens collected on the eastern frontier were hybrids between the orangespotted sunfish and some other sunfish species. When he collected in the same locality a few years later, after the eastern frontier had moved beyond this locality, pure orangespotted sunfishes were taken, usually in far greater numbers than the hybrids.

Bluegill

Lepomis macrochirus Rafinesque. *Lepomis*—scaled operculum; *macrochirus*—large hand, possibly in reference to the size of the pectoral fin.

Other common names: bluegill sunfish, northern bluegill sunfish, common bluegill, blue sunfish, bluemouth sunfish, sunfish, pale sunfish, chain-sided sunfish, bream, blue bream, bluegill bream, coppernosed bream, blackear bream, roach, dollardee, sun perch, strawberry bass.



Adult 143 mm, Waupaca R. (Waupaca Co.), 13 June 1960

DESCRIPTION

Body deep, strongly compressed laterally. Length 127–178 mm (5–7 in). TL = 1.25 SL. Depth into TL 2.2–2.6. Head length into TL 3.5–3.9. Mouth small, strongly oblique. Upper jaw almost reaching to anterior edge of eye; lower jaw decidedly longer than upper jaw; conical, pointed teeth in brushlike pads on upper and lower jaws, no teeth on tongue; lower pharyngeal arches moderately wide, with thin, pointed teeth. Gill rakers on first gill arch long, straight, and pointed. Opercular "ear flap" flexible. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins less than twice length of anal fin base; first dorsal fin with 10 spines, second with 10–12 soft rays. Anal fin with 3 spines, and 10–12 soft rays; pelvic fin thoracic with 1 spine and 5 rays; pectoral fin long, pointed, and when laid forward across cheek reaching to and generally beyond anterior edge of eye; caudal fin slightly forked. Scales ctenoid, gill covers and cheeks scaled. Scales in lateral line 39–45; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Back olive brown; sides vary from brown to green, with 5–9 vertical, double chainlike bars (more prominent in young); side at times with blue or purple reflections; throat and belly white, yellow or orange-red. Ear flap black to edge. Pale blue lines extending backward from mouth and chin. Fins brown pigmented; a prominent dark blotch toward rear of soft dorsal fin, occasionally present toward rear of anal fin (in young-of-year, dorsal spot appears as a series of microscopic round, distinct chromatophores in the last few interradial membranes). Colors vary according to habitat: fish from dark waters are dark olive or almost black dorsally, and somewhat lighter ventrally; fish from clear waters are light blue-green dorsally, and almost white ventrally.

Breeding male with bright orange to rusty breast and a bluish sheen over body; pelvic and anal fins dusky.

Sexual dimorphism: In mature bluegills, the urogenital opening in the male usually terminates in a small, funnel-shaped pore; in the female, the opening resembles a small, swollen, doughnutlike ring—probably the result of a slight eversion of the urogenital tract (McComish 1968).

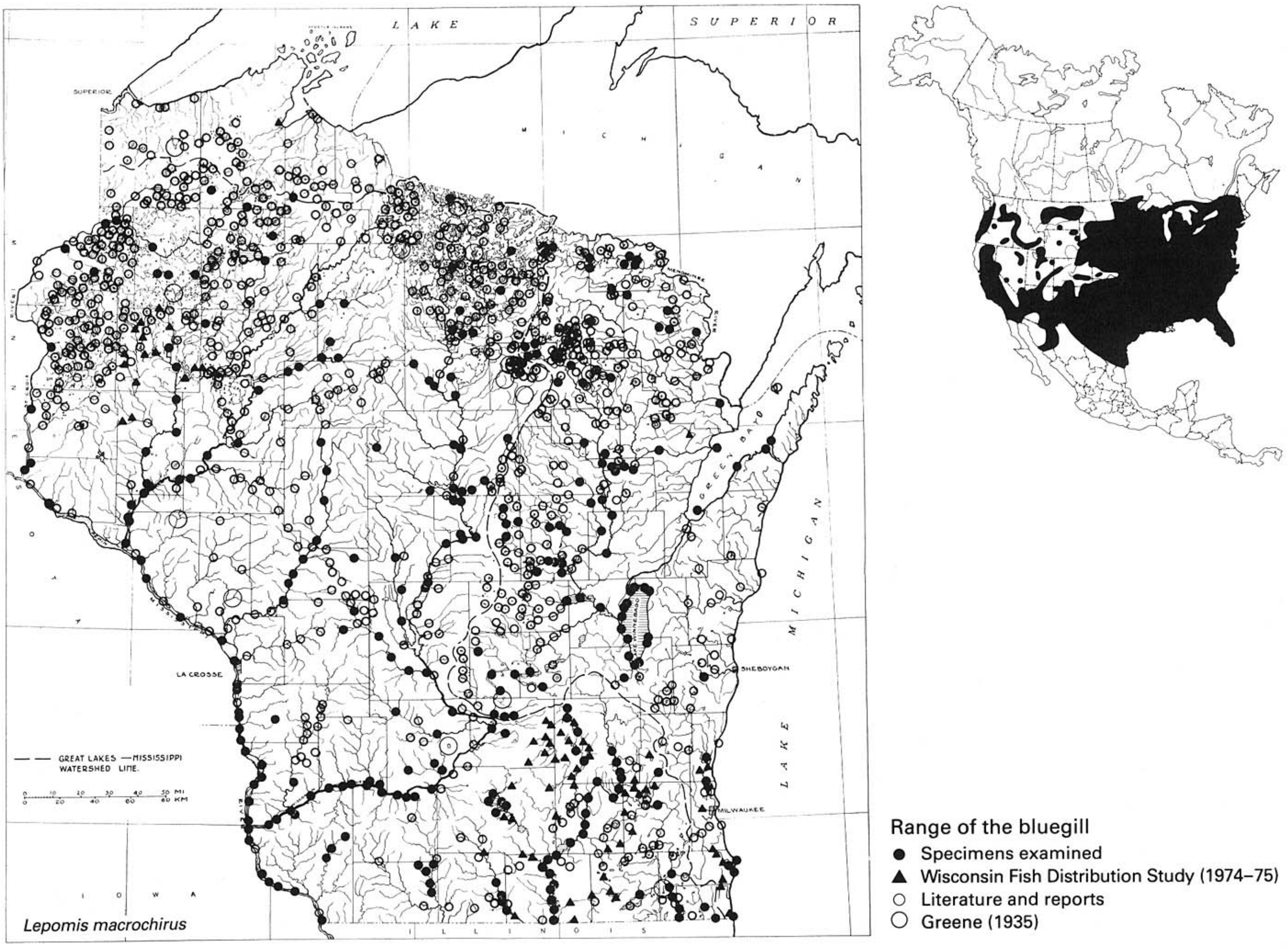
Hybrids: Bluegill × pumpkinseed, bluegill × green sunfish (UWSP specimens, Wis. Fish Distrib. Study 1974–1975). Other natural hybrids: bluegill × warmouth, bluegill × orangespotted sunfish, bluegill × redear sunfish, bluegill × redbreast sunfish, bluegill × longear sunfish, bluegill × spotted sunfish (Childers 1967). Artificial hybrids: bluegill × white crappie, bluegill × black crappie (Carlander 1977).

SYSTEMATIC NOTES

Synonyms are *Lepomis pallidus* (Mitchill), *Helioperca incisor* (Cuvier and Valenciennes), and *Helioperca macrochira* (Rafinesque). The Wisconsin subspecies is the northern bluegill, *Lepomis m. macrochirus* Rafinesque. The form *Lepomis machrochirus purpurascens* (Cope), which is distributed in Atlantic Coast streams from the Carolinas to Florida, may be a distinct species, according to Hubbs and Lagler (1964).

DISTRIBUTION, STATUS, AND HABITAT

The bluegill occurs in all three drainage basins in Wisconsin. Originally it was not found in the Lake Superior basin (Greene 1935), but as a result of widespread stocking it is now present and reproducing in many lakes and rivers. It is considered rare at the barriers of tributary streams to Lake Superior (McLain et al. 1965). In Waukesha County, bluegills occurred in 32 of 40 lakes sampled, and, along with the black crappie, it had the highest frequency occurrence of any species (Poff and Threinen 1963). It is present in most medium-sized streams to large rivers, and in nearly all lakes throughout the state. The bluegill is



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

the most abundant sunfish and centrarchid in Wisconsin.

In Wisconsin, the bluegill was encountered most frequently in clear water (occasionally in slightly turbid and turbid water) at varying depths, over substrates of sand (29% frequency), gravel (20%), mud (17%), silt (11%), rubble (8%), boulders (7%), clay (4%), detritus (2%), hardpan (1%), marl (1%) and bedrock (trace). It is an inhabitant of lakes, ponds, reservoirs, and backwater sloughs, and it was found in quiet to moderately swift waters in streams of the following widths: 1.0–3.0 m (12%); 3.1–6.0 m (7%); 6.1–12.0 m (20%); 12.1–24.0 m (32%); 24.1–50.0 m (22%); and more than 50.0 m (6%). It prefers warm-water habitats with a moderate amount of rooted vegetation.

BIOLOGY

In Wisconsin, bluegill spawning occurs at water temperatures of 19.4–26.7°C (67–80°F) from late May to early August; spawning peaks in June. Clugston (1973) noted that water temperatures which exceed 20°C (68°F) for long periods may extend bluegill spawning, and that ripe female bluegills were collected all year from a primary cooling pond.

Winter aggregations of bluegills break up when the water temperature reaches 10°C (50°F) (Scott and Crossman 1973). The males appear first in the shallow water of spawning areas; they generally select a sand or gravel bar which can be hollowed out for a nest. A shallow depression, 5–15 cm deep and about 30 cm diam, is swept out by the male in water 0.8 (0.3–1.5) m deep. H. C. Miller (1963:111) has described this process:

> Nest sweeping begins with side to side undulations of the caudal peduncle while the male is horizontal and stationary. The undulations become strong, and the body bends at the base of the caudal peduncle first to one side then to the other. . . . Pectoral fins are held at right angles to the body, spread, and flat. They move alternately pushing forward and up to counter the tendency for forward or upward locomotion. Dorsal, anal, and pelvic fins are depressed. These movements bring . . . males to a nearly vertical position, slightly ahead of their starting point.

The effect of this vigorous sweeping is to stir the loose substrate material with the caudal fin, much as a broom would. Repeated sweepings create a depression, with the loosest and finest bottom materials forming a rim around the edge. The nest resembles a miniature volcanic crater that has been weathered away close to the ground (Harlan and Speaker 1956).

Occasionally a bluegill builds an isolated nest, but usually bluegills construct colonies of 40–50 nests within a radius of 18–21 m (Harlan and Speaker 1956); in some colonies, the nests almost touch one another (Snow et al. 1962). Occasionally bluegills use the nests of the pumpkinseed and the rock bass; bluegills may also use their own nests several times during the season (Carbine 1939).

The male bluegill defends the nest, before and after spawning, against all species, but most vigorously against other male sunfishes. Lateral displays, with maximum fin erection and caudal fin elevation, occur commonly among nesting male bluegills (H. C. Miller 1963). The most aggressive and frequent behavior observed in most species of *Lepomis* is the frontal threat display. In this behavior, the dorsal, anal, and pelvic fins are displayed, and the fish moves forward toward the opponent; the caudal fin has a locomotive function and is not involved in the display posture. The attack consists of a butt or a bite, usually directed at the side of the other fish, but more frequently the display ends short of attack and is better described as a thrust, rush, chase, or swipe. Miller reported bluegill attacks in which highly aggressive males rushed each other and hit mouth to mouth.

H. C. Miller (1963:122) called attention to behavior exhibited by males which she called rim circling:

> . . . Males over their nests repeatedly circle the rim of the nest with fins in Lateral Display position. As they circle, their fins and the vertical bars on the sides become darker. Color fades when the circling stops. . . . The sight of spawning fish was a stimulus which made males without partners circle their rims faster and more persistently.

The approach of females or other fish caused males to rim circle more frequently and rapidly. Since this behavior makes the performing male conspicuous, it may serve to attract females to the nest.

The factors involved in the male bluegill's recognition of the female bluegill when females of other species of sunfish are present are not clearly understood. When male bluegills were presented simultaneously with a female bluegill and a female pumpkinseed, they responded more strongly to the former (Keenleyside 1967). Male bluegills produce courtship calls which may be characterized as a series of grunts (Gerald 1971). In preliminary experiments, the response of bluegills to play back of their recorded calls indicated that bluegills may be attracted by their conspecific calls, at least during spawning.

After a female bluegill enters the nest, the male and female swim about the nest in a circular path; they eventually come to rest with the male upright and the female at an angle, with their bellies touching. A few eggs and some milt are released, and the spawning behavior is repeated. A female does not necessarily deposit all of her eggs in one nest, nor is one nest necessarily used by only one female.

The egg production of Lake Wingra (Dane County) bluegills (122–144 mm) on 25 May was estimated at 4,800 (2,900–8,000); on 29 June it was estimated at 2,900 (1,900–4,600). Churchill (1976) suggested that the earlier figure may provide a better estimate of the total production, but even that figure is probably low, since most of the fish were completely ripe at capture and may have already deposited some of their eggs. In Minnesota, Vessel and Eddy (1941) estimated fecundity for age-IV to age-VIII fish at 25–46 thousand eggs; they noted a tendency for egg production to increase with increases in the weight, age, and length of the fish.

The bluegill's eggs are small, demersal, and adhesive. Egg diameter varies from 1.09 mm after water hardening (Merriner 1971a) to 1.2–1.4 mm (Meyer 1970). Hatching occurs in 71 hr at a water temperature of 22.6°C (72.7°F), in 34 hr at 26.9°C (80.4°F), and in 32.5 hr at 27.3°C (81.1°F) (Carlander 1977). During incubation the male aerates the eggs and keeps them clean of debris with gentle fanning, and drives all intruders from the nest.

Newly hatched bluegill fry are 2–3 mm long. According to Meyer (1970), larvae are free-swimming at 5.0–5.5 mm, 3 days after hatching. At 8.9–9.4 mm all fin rays are formed. Meyer illustrated the 5.5-mm and 10.3-mm stages, and Taber (1969) illustrated the stages from 5.2–21.5 mm.

In Michigan, 4,670–61,815 bluegill fry were reported per nest—the average for 17 nests was 17,914 fry (Carbine 1939). In northern Wisconsin, Churchill (1949b) reported 22 thousand fry per nest. Shortly after hatching, the male abandons the young, which in northern Wisconsin appear in the limnetic zones from late June through July (Faber 1967).

The growth of bluegills is rapid. In Murphy Flowage (Rusk County), bluegills average about 19 mm long in August, and about 38 mm long in September (Snow et al. 1962).

Bluegills are typically aged by analysis of their

Age and Growth (TL in mm) of the Bluegill in Wisconsin

Location	1	2	3	4	5	6	7	8	9	10	11	Source
Murphy Flowage (Rusk Co).	38	74	104	135	155	170	180	203	229			Snow (1969)[a]
Clear L. (Sawyer Co.)	36	56	66	81	97	104	127	137	147			Snow (1969)[a]
Muskellunge L. (Vilas Co.) (1935–1938)												
Males	44	75	96	120	140	154	165	174	169	180	184	Schloemer (1939)
Females	44	74	98	119	135	144	158	163	166			
Flora L. (Vilas Co.)	53	72	88	110	124	138	149	163	165	176		Parker (1965)
L. Wazeecha (Wood Co.)	44	76	109	138	175	195	219					Wolff (1974)
L. Sherwood (Adams Co.)	62	91	119	133								Wolff (1974)
Upper Mississippi R., Pools 3–6	56	104	147	160	185	198						Kittel (1955)
Mississippi R. (Buffalo Co.)	51	112	163	213								Christenson and Smith (1965)
L. Mendota (Dane Co.)	43	95	135	163	181							El-Shamy (1976)
L. Wingra (Dane Co.)	50	88	122	139	152							Churchill (1976)

[a] Average empirical length for year.

scales. The annuli are generally clearly depicted, although care must be taken to identify false annuli. Coble (1970) determined that false annuli may form as a result of handling the fish, or of interrupted feeding during the growing season. Southern Wisconsin bluegills average better growth than bluegills from northern Wisconsin, although they are not as long lived. More than 500 southern Wisconsin bluegills had condition values (K_{TL}) averaging 1.83 (1.63–2.18, with the largest bluegills exhibiting the best condition).

Male bluegills grew more rapidly than females in some populations that were studied, but the differences were usually small; in a few populations, females grew larger than males (Carlander 1977). In other studies, no differences in the growth of the sexes were detected. Swingle (1956) reported a repressive factor, probably a hormone in the water, which increases with population density and retards reproduction, but does not retard it sufficiently to prevent crowding and slow growth. The growth and condition of bluegills is better in waters with strong predator populations than in waters with few predators.

In the South, a few bluegills may reproduce during their first summer of life. At Wisconsin's latitude, some individuals mature at age I, and most mature at age II or III.

In most Wisconsin lakes, an age-IV bluegill is about 15 cm long and weighs 71 g. A 227-g (8-oz) bluegill is about 7 years old. A 305-mm, 1,588-g (12-in, 3.5-lb) bluegill was taken in a fyke net from Sand Lake (Washburn County) in 1945 by Wisconsin Department of Natural Resources personnel (Fischthal 1948), and a 1,701-g (3-lb 12-oz) fish was caught in Little Clam Lake (Ashland County) in 1953 (Snow et al. 1962). A 381-mm , 2.16-kg (15-in, 4-lb 12-oz) bluegill was taken from Ketona Lake, Alabama, in 1950 (*World Almanac* 1976).

When bluegills 5.0–5.9 mm long first start to feed, their food consists of rotifers and copepod nauplii (Siefert 1972). At 7 mm other rotifers and *Cyclops* spp. appear in the digestive tracts. In 8-mm fish, cladocerans become dominant in the diet; they include *Bosmina, Ceriodaphnia, Chydorus, Daphnia,* and *Polyphemus.*

Adult bluegills feed mainly on aquatic insects, small crayfish, and small fish (Carlander 1977). In six fish (avg 147 mm) examined from Lake Geneva (Walworth County), aquatic vegetation (*Chara*) occurred in five stomachs, insects (midge larvae, mayfly and stonefly naiads, insect fragments) in three, and snails in one (Nelson and Hasler 1942). In Lake Mendota (Pearse 1921a), four bluegills had eaten insect larvae (0.5% volume), insect adults (11.2%), snails (0.8%), oligochaetes (0.8%), plants (75.6%), and algae (10%). In Green Lake (Green Lake County), 165 bluegill digestive tracts held insect larvae (33% volume), insect pupae (1.7%), insect adults (12.9%), mites +, crayfish (9.2%), amphipods (14.8%), cladocerans +, snails (0.5%), sponges (0.5%), plants (21.3%), algae (1.7%), bottom ooze (2.2%), and sand (2.2%).

In three northern Wisconsin lakes, 65% of the diet of bluegills consisted of insects, including Diptera larvae, mayfly nymphs, caddisfly larvae, dragonfly nymphs, ants, and miscellaneous insects (Couey 1935). Plants constituted 10% of the total food consumed, but made up 30% of the food from one lake; in the other two lakes no plant food had been eaten. The plants consisted mostly of fragments of leaves and terminal buds of large aquatic plants, and a small amount of filamentous algae. The mollusks present were snails from the genera *Physa, Planorbis,* and *Amnicola.*

Kitchell and Windell (1970) noted that plant material makes up about 20% of the volume of the annual diet of natural bluegill populations. In controlled feeding experiments in the laboratory, those bluegills that were fed algae (*Chara*) in addition to a maintenance level of animal food showed a slightly greater percentage increase in weight than comparable fish fed on a maintenance diet of animal food alone. It was also evident that bluegills do gain some nutritional value from algae; however, bluegills neither will nor can consume enough *Chara* to meet metabolic requirements.

Leeches and fish eggs are also eaten by bluegills. When food is scarce, bluegills commonly eat their own eggs; male bluegills, especially, eat early spawns (Swingle and Smith 1943).

The optimum temperature for feeding by bluegills has been given as 27°C (81°F), and the maximum temperature at which bluegills feed has been given as 31°C (88°F) (Kitchell et al. 1974, Stuntz 1976). Feeding decreases at temperatures below 10–12.8°C (50–55°F). Baumann and Kitchell (1974) found that bluegills tended to be limnetic during the daytime, feeding largely on plankton, but that they moved to littoral areas about sundown to feed on benthic organisms and organisms attached to or living on aquatic plants. The bluegill is a grazing fish, taking this and that, and often hunting individual dipteran midge larvae or plankters. It is also a sight feeder that readily takes insects which fall on the surface of the water; these are eaten with a sucking, popping sound. Bluegills feed almost continuously during the growing season, although feeding peaks occur at 1500 hours in the afternoon and again in the evening after 2030 hours (Keast and Welch 1968). Intermittent feeding occurs at night; in one population that was examined, only 20% of the fish had empty stomachs by 0730 hours.

The kind of food eaten by bluegills may be dictated in part by the kinds of associate fishes that are present. Werner and Hall (1976) demonstrated that, when the bluegill is stocked alone, prey from the vegetation made up 61% of its diet; when bluegills were stocked with pumpkinseeds and green sunfish, however, the bluegills concentrated on prey from the open water column, such as *Bosmina* and *Cyclops*. The bluegill's long, fine gill rakers retain small prey, making such a niche shift possible. Similarities in the food eaten by bluegills and green sunfish may not be what they seem (Sadzikowski and Wallace 1976). The green sunfish has a larger mouth, and ingests food items of a larger average size; thus, even though these two species consume similar kinds of food, they may actually exploit quite different food sources.

In winter, the bluegill feeds sparingly, usually on planktonic cladocerans and copepods (Moyle 1969). In summer, at a mean water temperature of 20°C, bluegills may consume average weekly rations of up to 35% of the body weight (about 5% per day); during the winter, when the water averages between 2 and 3°C, bluegills may consume less than 1% of body weight per week (about 0.14% per day) (Lagler et al. 1977).

The temperature preferred by young bluegills in the laboratory was 31.2°C (88.2°F) (Beitinger 1974). When suddenly exposed to water at 36.1°C (97°F), 35% of the fish died, and, among those fish that survived, thermoregulatory performance was slightly impaired. Nickum (1967) found that bluegills were able to withstand sudden changes in temperature as great as 11.1°C (20°F), if the upper lethal temperature limit was not exceeded; delayed mortalities sometimes occurred, however. Young bluegills in a Lake Monona (Dane County) thermal outfall area had estimated acclimation temperatures between 29.4 and 31.3°C (84.9 and 88.3°F) (Neill and Magnuson 1974); the highest body temperatures among 31 bluegill specimens was 31.8°C (89.2°F). Clugston (1973) found bluegills at 35–41°C (95–105.8°F) in heated effluent waters from a power plant.

When juvenile bluegills in aquariums were given a choice between an environment at their preferred temperature (31.0°C) with a large, socially dominant bluegill present, or an environment at a higher or a lower temperature without the presence of the dominant fish, they selected the latter (Beitinger and Magnuson 1975).

In winterkill lakes, the toleration threshold of bluegills for dissolved oxygen was about 0.6 ppm (Cooper and Washburn 1949). Moore (1942) determined an oxygen threshold of 0.8 ppm for the bluegill. Bluegills will not tolerate low oxygen nearly as well as northern pike, perch, and bullheads (Snow et al. 1962). Bluegills and largemouth bass are among the first fish to die off in winterkill lakes.

Woodbury (1941) presented evidence of a sudden mortality of adult bluegills when oxygen in Lake Waubesa (Dane County) reached a super-saturation level during late April. In death all of the fish looked normal, except for small gas bubbles under the skin and in the fin rays. The gills were damaged extensively, and most filaments contained gas emboli large enough to block the capillaries and to obstruct blood flow. Analysis of the water showed very high amounts of dissolved oxygen caused by algal bloom.

Trama (1954) found that bluegills tolerated a pH ranging from 4.00 ± 0.15 to 10.35 ± 0.15. Although there was 100% survival at these ranges, adverse physiological reactions occurred. Bluegills have been taken in water with 4.5 ppt salinity (Bailey et al. 1954).

Bluegills travel in loose schools, and 10–20 fish can often be seen swimming together. Activity and feeding are greatest at dawn and dusk, although feeding occurs at low levels during other times of the daily cycle. Bluegills on the Mississippi River were most active from 0800 to 1000 hr and from 1600 to 2200 hr (Ranthum 1969). During the day, large bluegills remain in or near cover (Stuntz 1976), while at night they disperse into all areas of a shallow lake. In early spring, when vegetation has not yet emerged to provide cover, bluegills select habitats in areas of shade, or in areas where cover is permanent, such as in the shelter of a beaver lodge or a fallen tree. According to Stuntz, the substrate is important in habitat selection only during the spawning season; temperature does not appear to influence habitat selection in the field. In a deep, northern Wisconsin lake (Hile and Juday 1941), bluegills, rock bass, and smallmouth and largemouth basses inhabit the warmwater of the epilimnion, most commonly at depths of 3 m. The young occupy the shallows continuously.

In Lake Wingra (Dane County) during September, bluegills moved onshore after sunset and offshore after sunrise. All size classes sampled appeared to participate in these movements (Baumann and Kitchell 1974). In winter, bluegills remain near the bottom of a shallow lake, or they may collect below the discharges of power plant condensers (Snow et al. 1962). In the spring, they migrate up sluggish streams or into channels which have warmed up before the main body of water.

The bluegill has a home range particularly during the spawning period. In an Iowa study (Kudrna 1965), 60% of the larger bluegills that were displaced had homed. When bluegills were released in a displaced area, however, they swam about as if searching before they began to home.

In the Platte River (Grant County), fish associated with 6 bluegills were: the white sucker (47), central stoneroller (17), longnose dace (8), hornyhead chub (140), creek chub (1), bluntnose minnow (61), suckermouth minnow (3), common shiner (88), rosyface shiner (25), sand shiner (1), Ozark minnow (20), stonecat (3), johnny darter (7), fantail darter (21), smallmouth bass (11), and green sunfish (2).

IMPORTANCE AND MANAGEMENT

Bluegill fingerlings are preyed upon by largemouth bass, northern pike, yellow perch, black crappies, pumpkinseeds, bullheads, and by bluegills themselves. Herons and otters take smaller bluegills. Two- to three-year-old bluegills are eaten by adult largemouth bass and by northern pike; however, the bodies of larger bluegills are too deep to be swallowed by predators.

The bluegill is a host to the glochidial stage of the following mussels: *Amblema plicata, Fusconaia flava, Megalonaias gigantea, Anodonta grandis, Quadrula metanevra, Quadrula nodulata, Pleurobema cordatum, Actinonaias carinata, Carunculina parva, Lampsilis ovata, Lampsilis radiata luteola, Ligumia recta,* and *Ligumia subrostrata* (Hart and Fuller 1974).

The bluegill in Wisconsin is perhaps the best known and the most sought-after sunfish. It is easily caught. Small terrestrial or aquatic baits, including worms, grasshoppers, crickets, and grubs, are all acceptable to the bluegill. Artificial popping bugs and flies are particularly effective when bluegills are concentrated in the shallows during nesting. Wintertime jigging in weed beds, with a fly grub for bait, also produces excellent results. The bluegill is a game fighter, carries the lure in tight circles, and uses the flat of its side against the pull of the line.

In Pools 4 to 6 on the Mississippi River (Kittel 1955), the bluegill, carp, black crappie, and white bass yielded the greatest numbers taken per trap net lift. High yields persisted between the years 1957 and 1977 (Ebbers and Hawkinson 1978). The estimated sport fishery catch of bluegills in Pools 4, 5, 7, and 11 for 1967–1968 was 311,008 fish weighing 48,140 kg, or about 154 g (⅓ lb) per fish (Wright 1970). In 1970, the bluegill provided catch rates of 0.31 and 0.34 fish per man hour—the highest for any species in two Vilas County lakes (Serns and McKnight 1974). From 1955 through 1970, a total of 373,520 fish of various species were caught by 53,637 anglers from Murphy Flowage (Rusk County); of these, 312,342 (84%) were bluegills (Snow 1978).

In Wisconsin, bluegills are not permitted in the commercial catch, but liberal sport fishing regulations exist. In inland waters, an aggregate of 50 panfish, including bluegills, may be caught in 1 day. In most boundary waters there is no bag limit, except in Wisconsin-Minnesota waters, where there is a limit of 25 per day (Wis. Dep. Nat. Resour. 1979).

As a food fish, the bluegill is highly respected, and it is often referred to as the "bread and butter fish." Its flesh is firm, white and flaky. Since the flesh has little fat, bluegills may be kept frozen in storage for long periods.

The bluegill is an easily cared-for aquarium fish, and, because it is readily available, it is perhaps our most common native fish kept in home aquariums.

Dense populations of bluegills are possible because they are largely primary consumers, producing fish flesh directly from the most basic foods. In many of Wisconsin's lakes, the bluegill is the most common sport fish present. Lake Wingra (Dane County), for instance, is a very productive lake, with an average standing crop of about 494 kg/ha of fish over 75 mm long (Churchill 1976). Most of the crop consists of panfishes, and about 75% of the biomass consists of bluegills. During one period of study, the biomass of bluegills over 75 mm long varied from 140 to 500 kg/ha, while the number of bluegills over 2 years old varied from 7,000 to 25,000 per hectare. In October 1972, Churchill estimated a population of 3.4 million bluegills in Lake Wingra that were age I or older.

From Stewart Lake (Dane County), C. Brynildson (1955) recovered 440 kg/ha of fish, which were mostly bluegills, and he felt that the recovery was incomplete. On the other hand, in Escanaba Lake (Vilas County) from 1956 through 1969, bluegills made up 3% or less of the available standing crop of sport fishes (Kempinger et al. 1975). In some lakes managed for walleyes, coho salmon, and other sport species, bluegill numbers may be low, with correspondingly low returns to the angler (Serns and McKnight 1974).

The stunting of bluegills and yellow perch occurs in many waters throughout Wisconsin, and has often been called the number one fish management problem in the state. Wisconsin and other states have attempted to correct the problem by reducing or eliminating these populations through seining, trapping, angling, and the use of poisons (e.g., rotenone and antimycin). Predators have been introduced in some waters to curb bluegill numbers. Where it has been possible to do so, levels have been lowered in lakes or impoundments to concentrate fish for removal, or to facilitate predation.

In Flora Lake (Vilas County), bluegills, pumpkinseeds, and hybrids of these two species responded favorably in linear rate of growth after their numbers had been reduced by trapping, but only the pumpkinseeds were heavier at the overall mean length (Parker 1958). In Cox Hollow Lake (Iowa County), a new impoundment, stocked bluegills, largemouth bass, and northern pike showed an initial rapid population expansion and superior growth, followed by a tremendous decline in both population size and growth (Dunst 1969). The majority of Cox Hollow Lake anglers during the 1970s caught many small, thin bluegills that were less than 15 cm (6 in) long.

When stunted bluegills are transferred to a lake that has no existing sport and panfish populations, phenomenal growth may occur. Bluegills 97–152 mm long and weighing 11–71 g were placed in Sand Lake (Washburn County), where previous populations had been winterkilled; within 1 year the bluegills were 188–226 mm long and weighed 153–338 g. In that year they had increased their average lengths approximately 1.7–1.9 times, and their average weights 9–17 times (Fischthal 1948). Two years after the fish population of Stewart Lake (Dane County) had been removed and the lake restocked with 722 largemouth bass fingerlings and 2 pairs of adult bluegill breeders, the lake was opened to fishing. An estimated 300 bass (330–406 mm long) and 2,000 bluegills (127–203 mm long) were creeled during the opening day of fishing (McCutchin 1949).

Attempts have been made to control extremely slow-growing bluegill populations by introducing predators. In Clear Lake (Sawyer County), where the bluegills appeared to be suffering from intense intraspecific competition, muskellunge were stocked at several times the normal level, and walleyes were heavily stocked (Snow 1968). There was no appreciable change in the growth of the bluegills, and no drastic change in their abundance—they continued to make up 85–95% of the total population. The walleyes showed poor survival, which raised the issue of their importance as a predatory species. Snow suggested that, when the density of a bluegill population is above a certain unknown level, predator stocking can exert little, if any, control on the bluegill population. The stocking of northern pike in Murphy Flowage (Rusk County) also failed to reduce the numbers of bluegills; in fact, the numbers of bluegills, particularly small ones, continued to increase, while their growth continued to decline. The impact of the stocked pike on the native pike population and on angler harvest was unfavorable (Snow 1974a).

The failure of predators to control stunted bluegill populations is mentioned in the literature (Beyerle 1971, Carlander 1977). An evaluation of the effects of thinning on panfish populations was provided by Buchanan et al. (1974). Carlander suggested that bluegill growth stops when the carrying capacity of a given body of water is reached, i.e., when any factor becomes limiting. For example, growth slowed after thermal stratification occurred and oxygen depletion concentrated bluegills near the surface.

In addition to the limiting factors that affect their growth bluegills over age III to IV sustain an annual mortality rate of 57–99% (Carlander 1977). In Murphy Flowage (Rusk County), Snow (1978) determined that bluegills sustained a total average mortality rate of 61% annually, and an estimated annual natural mortality rate of 53% in the absence of fishing.

Even where management techniques succeed in reducing bluegill populations, success is usually temporary, and overcrowding and stunting recur within a few years. It is difficult to achieve a balance in the ecosystem which keeps populations at an optimum level.

The bluegill is commonly stocked in new farm impoundments and in newly dug farm ponds. At Delafield (Waukesha County), Mraz and Cooper (1957b) demonstrated that bluegill reproduction in ponds was more consistent than that of carp, largemouth bass, and black crappies. Bluegills spawned successfully in all ponds; they averaged nearly 10,000 fish per hectare in six trials, and ranged from 1,235 to 33,900 young fish per hectare. Such a reproductive capacity soon leads to overcrowding unless a relatively large population of predator fish has been established before the bluegills are introduced.

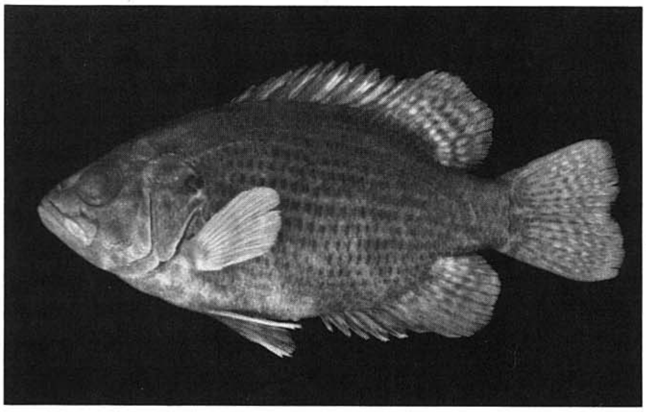
Although largemouth bass and bluegills are a recommended combination of species for farm ponds in many states, this combination is not recommended in Wisconsin. Klingbiel et al. have summarized the problem in Wisconsin (1969:14–15):

> . . . Generally bluegills become overpopulated and stunted. These fish are of no value because they are too large for largemouth bass to eat, and too small for angling. Bluegills will also compete for food with the smaller bass and will eventually stop bass reproduction by eating the young. Bass-bluegill management has been successful in very few ponds in Wisconsin.

Rock Bass

Ambloplites rupestris (Rafinesque). *Ambloplites*—blunt armature; *rupestris*—living among rocks.

Other common names: northern rock bass, redeye, redeye bass, goggle eye, rock sunfish.



Adult 129 mm, Blake Cr. (Waupaca Co.), 7 June 1960

DESCRIPTION

Body robust, compressed laterally. Length 152–203 mm (6–8 in). TL = 1.25 SL. Depth into TL 2.7–3.3. Head length into TL 2.9–3.4. Mouth large, slightly oblique. Upper jaw extending to beyond middle of eye, and lower jaw projecting beyond upper jaw; small, blunt teeth in broad bands on upper and lower jaws; pharyngeal pads with teeth at back of throat. Dorsal fins 2, but broadly joined and appear as 1; base of dorsal fins twice as long as anal fin base; first dorsal fin with 10–12 spines, second with 10–12 rays. Anal fin with 5–7 spines and 9–11 soft rays; pelvic fin thoracic with 1 spine and 5 rays; pectoral fin rounded, short, and when laid forward across the cheek does not reach eye; caudal fin scarcely forked. Scales ctenoid, gill covers, cheeks, and back of head scaled. Scales 39–43 in lateral line; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Dorsal region of head, back, and upper sides brown to olive; ventral region lighter. Eyes bright red to orange. All fins pigmented; vertical fins with distinct white spots posteriorly. Each scale pocket below lateral line with a prominent black spot, forming 8–10 horizontal rows of spots. In young up to 51 mm, sides variably marbled in black and white. Breeding males blackish, with eye color intensified.

Sexual dimorphism: In male, a single urogenital opening behind the anus; in female, 2 openings (genital and urinary) behind the anus (Moen 1959).

Hybrids: Artificial rock bass × black crappie, rock bass × bluegill, rock bass × banded sunfish, rock bass × warmouth, and rock bass × largemouth bass (Hester 1970, Tyus 1973).

DISTRIBUTION, STATUS, AND HABITAT

In Wisconsin, the rock bass occurs in the Mississippi River, Lake Michigan, and Lake Superior drainage basins. It is present in the shallow waters of the Great Lakes, and in many of the softwater lakes in northern Wisconsin, but it is less common in lakes southward.

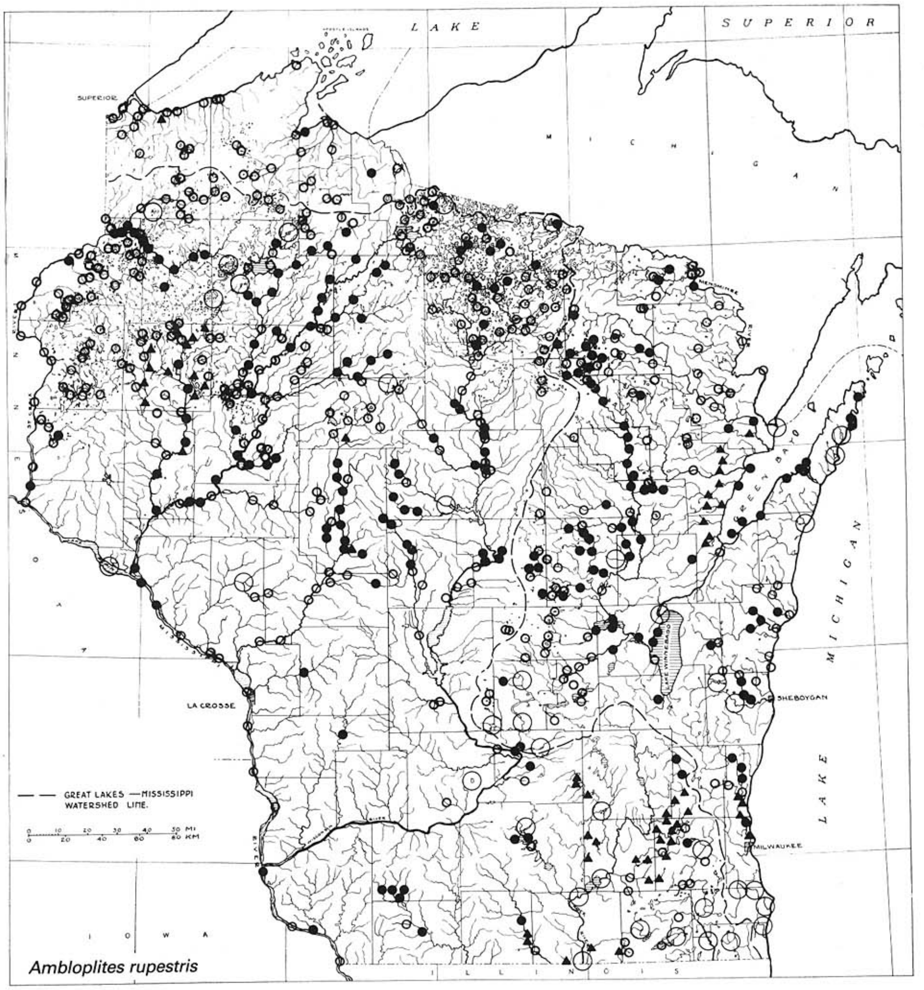
The rock bass is common in medium to large streams and in lakes throughout Wisconsin, except in the southwestern quarter, where it is rare. According to McLain et al. (1965), it is common in the mouths of tributaries to Lake Superior. In some lakes where the waters are becoming enriched, the rock bass population has declined. This species was common in the Rock River between Hustisford and Watertown up to 1920, but has since become rare in that area (H. Neuenschwander, pers. comm.).

Although the rock bass is found in many kinds of water, it shows a distinct preference for clear, cool to warming waters over a gravel or rocky bottom, with some vegetation present. It was encountered in clear water (60% frequency), slightly turbid water (27%), and turbid water (13%) of varying depths, over substrates of sand (26% frequency), gravel (20%), mud (13%), rubble (12%), boulders (12%), silt (9%), bedrock (4%), clay (2%), detritus (1%), hardpan (1%), and marl (1%). It was found in lakes and reservoirs, and in streams of the following widths: 1.0–3.0 m (6% frequency), 3.1–6.0 m (15%), 6.1–12.0 m (9%), 12.1–24.0 m (31%), 24.1–50.0 m (24%), more than 50 m (16%).

BIOLOGY

In Wisconsin, the rock bass moves into areas of very shallow water during late May and early June when water temperatures reach 15.6–21.1°C (60–70°F). Spawning is initiated when water warms to 20.5–21°C (69–70°F) and may continue to 26°C (79°F) (Carlander 1977). Spawning takes place in water from a few centimeters deep to more than 1.0 m deep, in circular, dish-shaped nests. The male builds the nest by fanning out sand and debris over a bottom of coarse sand or gravel to create a depression of 20–25 cm (8–10 in) diam.

Details of the spawning behavior of rock bass are provided by Trautman (1957), Breder (1936), and Breder and Rosen (1966). Immediately preceding and during the spawning season, adult females congregate in pools. A female approaches a nest only when



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

she is ready to deposit her eggs. She is driven into the nest by the male, who guards her carefully until the eggs have been deposited. During spawning and fertilization, the female reclines on her side and the male remains upright. The two fish engage in a peculiar rocking motion in a head-to-tail position. Only a few eggs at a time are extruded, and at each deposition milt is extruded by the male. This behavior may continue for an hour or more, after which the female leaves the nest and does not return. The eggs are carefully looked after by the male, who takes up a position above the nest, and every now and then fans the eggs with his fins. A few days after the eggs have hatched, the fry gradually rise out of the nest; the male soon leaves them to shift for themselves.

Observations of rock bass in aquariums disclosed a female with a distinctly blunt and red ovipositor who attempted to mate with a male that was fanning a batch of eggs. She quivered considerably, and the two fish performed the peculiar rocking motion in a head-to-tail position. This male continued with little interruption to fan the eggs he was guarding. During the fanning period, males in the aquarium drove off large crayfish (*Cambarus*), which were kept as scavengers, whenever the crayfish got within a few centimeters of the eggs. Such struggles continued for an hour until the crayfish eventually withdrew.

A 173-mm, 136-g female rock bass captured 7 June from Blake Creek (Waupaca County), had ovaries 14.2% of her body weight. She held an estimated 6,300 mature (orange) eggs, 1.7–1.9 mm diam, and a small number of immature (white-yellow) eggs, 0.7–1.3 mm diam. In Minnesota (Vessel and Eddy 1941) the fecundity of rock bass varied from 2,000 to 11,000 eggs, depending on the size of the fish. Females 18–20 cm long and weighing 227–340 g produced 2,000–7,000 eggs. The average female lays about 5,000 eggs.

Rock bass eggs are adhesive, and hatch in 3–4 days at water temperatures of 20.5–21.0°C (69–69.8°F) (Eddy and Surber 1947). In Michigan (Carbine 1939), the number of rock bass fry per nest varied from 344 to 1,756; there was an average of 796 fry for each of the nine nests counted.

Fish (1932) illustrated and described the 10.5-mm stage. The young rock bass remain for several months in shallows near or within vegetation.

In Wisconsin, the growth of young rock bass varies with the latitude and with the characteristics of the water:

Date	No. of Fish	TL (mm) Avg	TL (mm) Range	Location
11 June	2	20	19–21	Wolf R. (Langlade Co.)
9 Aug.	3	27	25–29	L. Poygan, south shore (Winnebago Co.)
8 Aug.	2	39	39–40	L. Poygan, north shore (Winnebago Co.)
10 Aug.	11	35	29–39	L. Mendota (Dane Co.)
19 Aug.	13	28	19–37	L. Winnebago (Winnebago Co.)
18 Sept.	48	36	29–55	Namekagon R. (Washburn Co.)
20 Sept.	33	39	25–50	Butternut L. (Price Co.)
1 Oct.	15	43	37–61	Flambeau R., south fork (Price Co.)

The paper on Wisconsin rock bass by Hile (1941) is a classic in the treatment of growth data and in the comparison of growth increments from different years.

The calculated weights for the Muskellunge Lake rock bass, years 1 through 11, were: 1, 4, 10, 20, 36, 56, 82, 108, 141, 165, and 187g (Hile 1942).

The general growth curves for the Lake Nebish population show that male rock bass grow more rapidly than females, and that the differential growth of the sexes is not distinctly apparent before the fourth year. Hile noted that most of the season's growth had been completed by the time of capture in late July and early August. Good growth was correlated positively with high temperatures, especially in June and September. Good growth and heavy precipitation in June also were correlated positively. Hile suggested that the correlation between rainfall, fluctuations in growth, and the strength of year classes may depend on the enrichment of Lake Nebish by materials washed in during periods of heavy downpour. Temperatures may have a direct effect on the physiological processes of the fish, and may also affect the abundance of fish food in the lake.

In Nebish Lake, most rock bass reach maturity at ages II and III. The slower-growing fish do not reach maturity until age IV (Hile 1941). Most rock bass survive for 6–8 years, although individuals of this species have lived at least 18 years in captivity (Breder 1936).

Normally rock bass do not exceed 227 g (.5 lb) in weight, but a 794-g (1-lb 12-oz) individual was caught from Green Lake (Green Lake County) on 14 February 1971. A 1.5-kg (3-lb 5-oz) rock bass was taken in Lake Cadillac, Michigan, in 1946. Scott and Crossman (1973) reported an individual 340 mm long which weighed 1.64 kg (3 lb 10 oz). Adams and Hankinson (1926) reported rock bass weighing up to 1.70 kg (3.75 lb).

In Illinois, young-of-year rock bass fed on cladocerans, *Cyclops*, corixid, chironomid and neuropteran larvae, and some land insects (Forbes 1880). In northern Wisconsin lakes, insects (including dipteran, ephemerid, and caddisfly larvae, dragonfly nymphs, and ants) were the most important foods consumed by rock bass, followed by crayfish and fish (Couey 1935). In Green Lake (Green Lake County), rock bass had ingested crayfish (64% volume), cladocerans (12%), insect larvae (11.8%), mites (4.2%), amphipods (2.9%), insect pupae (0.6%), ostracods (0.2%), and sand (4.2%) (Pearse 1921a). In Lake Mendota (Dane County) rock bass, Pearse found crayfish (50%), cladocerans (14%), plant materials (10%), amphipods (5.8%), insect adults (5%), algae (3%), insect larvae (2%), and sand (11.2%). Of 24

Age and Growth (TL in mm) of the Rock Bass in Wisconsin

Location	No. of Fish	1	2	3	4	5	6	7	8	9	10	11	12	13	Source
Birch L. (Washburn Co.)	117	46	71	112	150	175	208								Snow (1969)[a]
Bucks L. (Rusk Co.)	27	56	130	183	229	249	292								Snow (1969)[a]
Clear L. (Sawyer Co.)	33	46	58	99	124	157	178								Snow (1969)[a]
Nebish L. (Vilas Co.)															
Males	395	43	77	112	145	170	187	199	209	216	224	233			Hile (1941)
Females	586	41	76	110	138	159	173	183	190	198	205	212	218	227	
Allequash L. (Vilas Co.)		44	67	88	111	139	163	179	190						Hile (1942)
Muskellunge L. (Vilas Co.)		40	62	83	106	128	149	168	185	203	214	222			Hile (1942)
Trout L. (Vilas Co.)		39	62	87	113	148	181	198	216	227					Hile (1942)
Wolf R. (Oneida Co.)	26	27	66	113											B. Mauch (pers. comm.)
Pecatonica R. (Iowa Co.)	5	41	73	148											B. Mauch (pers. comm.)

[a] Empirical means, not measured to annulus.

stomachs examined from Lake Geneva (Walworth County), 4 held *Micropterus* sp., 8 held mimic shiners, and 14 held crayfish (Nelson and Hasler 1942).

Keast (1965) noted that the rock bass was a fairly diverse feeder, and that the larger fish avoided small food items because of the high energy outlay necessary to obtain a sufficient quantity of them. He found that there were two periods of feeding: in the evening from 1700 to 2100 hr, and in the morning from 0730 to 1200 hr.

During the summer in lakes of northern Wisconsin, the rock bass was found at 14.7–21.3°C (58.5–70.3°F) (Hile and Juday 1941); in streams of southern Ontario (Hallam 1959) it occurred at 20.7°C (69.3°F). The preferred temperatures of rock bass from Lake Monona (Dane County) were 27.3°C (81.1°F) in the laboratory and 27.5°C (81.5°F) in the field (Neill and Magnuson 1974). In a shallow Michigan pond (Bailey 1955), a water temperature of 38°C (100.4°F) resulted in the deaths of large numbers of fish, including rock bass.

In winter, rock bass inhabit deeper water, where they remain in a condition of semihibernation. After spawning they are usually found in 2–5 m of water in the region of submerged vegetation (Schneberger 1973). In lakes of the northeastern highlands during July and August, rock bass were taken down to the following depths (depths at which the greatest number were taken given in parentheses): Nebish Lake 10.9 m (6 m); Muskellunge Lake 12.9 m (4 m); and Trout Lake 6.9 m (5 m). Fish of all sizes showed a preference for the warmer epilimnion, except in Nebish Lake, where larger rock bass were found in the upper thermocline, 2–4 m below the smaller fish. Penetrations by rock bass into deeper regions of the water are rare. In Lake Geneva (Walworth County), Nelson and Hasler (1942) captured most rock bass at 9 m, although small numbers occurred down to 12 m.

Moore (1942) determined that rock bass were unable to tolerate oxygen tensions of 2.3 ppm at winter temperatures. In the laboratory at 22.8°C (73°F), Bouck (1972) noted that rock bass hyperventilated and stopped feeding during the low-oxygen periods, and showed impaired growth when the oxygen level of the water was lowered from near saturation to 3 ppm for an 8 hr period per day over 9 consecutive days.

Mercury-contaminated yellow perch and rock bass from Lake St. Clair, which were stocked in two earthen ponds and held for a 26-month period, increased 88% and 183% respectively in mean weight during that period (Laarman et al. 1976). Although the concentrations of total mercury in the fillets had declined 53% in the yellow perch and 59% in the rock bass, all of the reduction in mercury concentrations was attributable to dilution by growth. The data suggested an initial redistribution of residues from other tissues to the muscle and a continued incorporation of background amounts of mercury during growth.

A trapping study (Spoor and Schloemer 1939) revealed that rock bass were captured in far greater numbers at night than during the day. The highest rate of capture was between 1900 and 2100 hr, and a slight increase occurred between 0300 and 0400 hr. The study offered little evidence of daily inshore and offshore movements.

In an extensive tagging effort in Missouri streams, Funk (1957) classified the rock bass as sedentary; 64% of the rock bass were captured within 1.6 km (1 mi) of the point of release and 98% within 40 km (25 mi). In Indiana (Scott 1949), rock bass showed a strong tendency to remain in a very limited area, ranging within a 1.6 km section of stream during the 2-year study; however, a few fish wandered widely—as much as 30 km (19 mi) upstream and 13 km (8 mi) downstream from the point of tagging. MacLean and Teleki (1977) determined that rock bass along the north shore of Long Point Bay in Lake Erie inhabit a restricted home range during the nonreproductive season, but undertake a 36–40 km (22–25 mi) spawning migration to the Inner Bay in the spring.

In northern waters, the rock bass is often associated with the smallmouth bass, perch, bluntnose minnow, hornyhead chub, rosyface shiner, northern hog sucker, johnny darter, rainbow darter, and fantail darter.

The rock bass can change color with great rapidity—from silver to almost solid black, or to silver with black splotches (Eddy and Surber 1947). Pflieger (1975) called it "the chameleon of the sunfish family."

IMPORTANCE AND MANAGEMENT

It is not known to what extent rock bass are preyed upon by other species. The rock bass does serve as a host to the glochidial stage of a number of important mussels, including *Amblema plicata*, *Amblema marginata*, *Arcidens confragosa*, *Actinonaias carinata* and *Lampsilis radiata luteola* (Hart and Fuller 1974).

The rock bass is not considered an important sport fish in Wisconsin, and is usually caught only incidentally while fishing for other species. It will take worms, white grubs, minnows, spoons, spinners, bucktails, cut-bait, crayfish, and grasshoppers, and occasionally it will rise to a fly. It usually hits the angler's lure with much vigor and begins a strenuous fight, but it tires easily.

In the Mississippi River, the estimated sport fishery catch of rock bass in Pools 4, 5, 7, and 11 during 1967–1968 was 2,888 fish weighing 340 kg (747 lb) (Wright 1970). The numbers of rock bass in the catch diminish rapidly as one moves downstream. In three Vilas County lakes during 1970 (Serns and McKnight 1974), the estimated catch of rock bass was 1,015 from Stormy Lake, 1,001 from Black Oak Lake, and 605 from Laura Lake. The fish averaged 15–18 cm long.

In Escanaba Lake (Vilas County), from 1946 to 1969, 13,171 rock bass weighing 1,657 kg (3,652 lb) were caught by anglers (Kempinger et al. 1975). The estimated population, based on rock bass 10 cm and larger, varied annually from 1,000 to 5,600 from 1956 through 1963. In Murphy Flowage (Rusk County), from 1955 to 1969, 8,084 rock bass weighing, 1,059 kg (2,335 lb) were caught by angling (Snow 1978).

At one time, Wisconsin imposed a size limit on this species. Currently all minimum size limits, bag limits, and closed seasons have been eliminated (Wis. Dep. Nat. Resour. 1979). The rock bass is classified as a sport fish in Wisconsin.

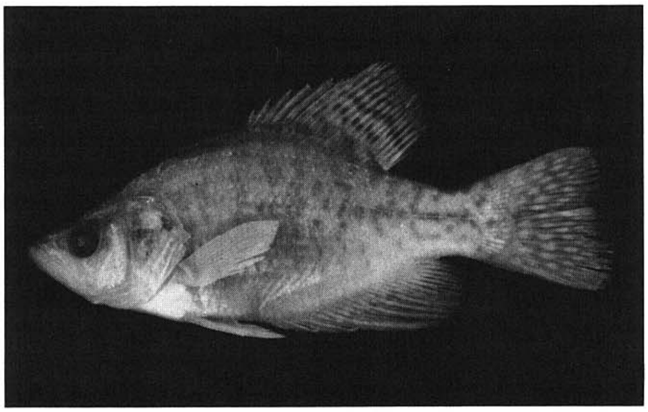
There are conflicting reports concerning the palatability of the rock bass, but most reports indicate that the flesh of fish from clear, cool water is firm and white and has an excellent flavor.

The propagation and stocking of rock bass are not commonly practiced in Wisconsin or in neighboring states. It is a prolific fish in nature. When the fish population was thinned by trapping in Flora Lake (Vilas County), rock bass exhibited a marked increase in their linear growth rate, even though the total number of rock bass present also increased (Parker 1958). In a Michigan lake, partial poisoning with rotenone resulted in an increased growth rate in rock bass of all ages (Beckman 1941).

White Crappie

Pomoxis annularis Rafinesque. *Pomoxis*—sharp opercle; *annularis*—having rings, the vague vertical bars of the sides.

Other common names: silver crappie, pale crappie, ringed crappie, crappie, crawpie, silver bass, white bass, newlight, bachelor, campbellite, white perch, strawberry bass, calico bass, tinmouth, papermouth, bridge perch, goggle-eye, speckled perch, shad, John Demon.



Adult 166 mm, L. Winnebago (Calumet Co.), 17 Aug. 1960

DESCRIPTION

Body deep, strongly compressed laterally (slab-sided). Length 165–229 mm (6.5–9.0 in). TL = 1.29 SL. Depth into TL 2.7–3.9. Head length into TL 3.2–4.0. Mouth large, moderately oblique. Upper jaw reaching at least to middle of eye; lower jaw heavy, tip jutting beyond tip of upper jaw; minute conical, pointed teeth in brushlike pads on upper and lower jaws; lower pharyngeal arches long and narrow, with numerous fine teeth. Gill rakers on first arch close-set, long, slender, and straight; about 28. Dorsal fins 2, but completely joined and appear as 1; 6 (4–7) spines, 12–16 rays, base length of dorsal much shorter than distance from dorsal origin to eye; base length of dorsal fin equal to or slightly shorter than base length of anal fin. Anal fin with 6 spines and 17–18 rays; pelvic fin thoracic, with 1 spine and 5 rays; pectoral fin elongate, and when laid forward across cheek reaching eye; caudal fin slightly forked. Scales ctenoid, in lateral line 39–46; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Back and upper head dark green with many blue, green, and silvery reflections; sides lighter, with 5–10 vague, vertical bands composed of dark blotches which become indistinct on lower sides of body; ventral region of head and belly whitish. Eyes yellow to green. Irregular dark opercle spot scarcely larger than diam of pupil of eye. Dorsal, caudal, and anal fins heavily vermiculated, contrasting with round to oblong light-colored spots (which are less evident in the anal fin); paired fins unpigmented to lightly pigmented. Spots almost absent in large adults (especially the females) from turbid waters.

Breeding male usually darker and more distinctly marked than female; males may be as heavily spotted as male black crappie (Trautman 1957).

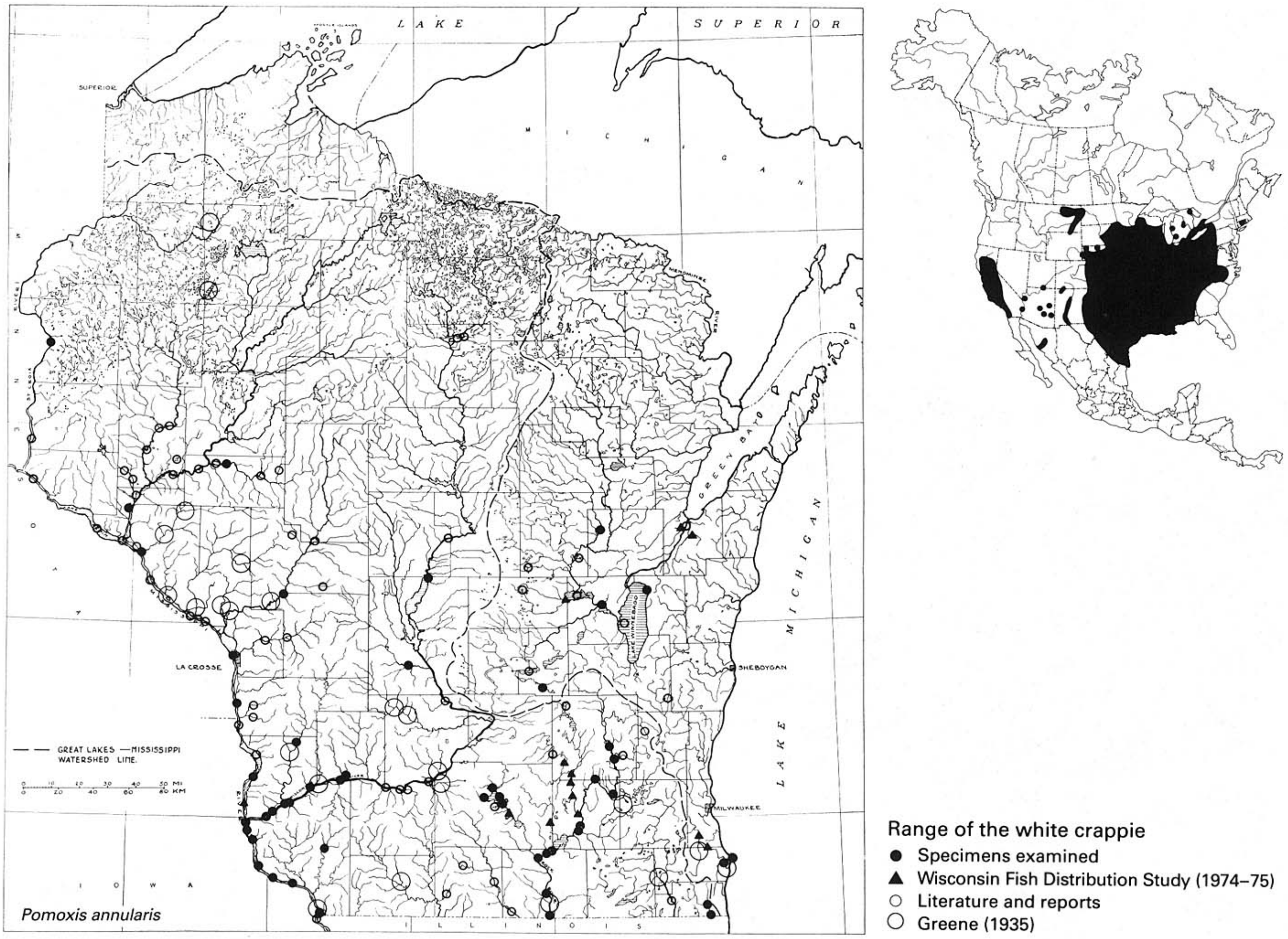
Hybrids: White crappie × black crappie (Hubbs 1955, Trautman 1957), white crappie × flier (Burr 1974). Hybrids are predominantly males (Schneberger 1972b).

DISTRIBUTION, STATUS, AND HABITAT

In Wisconsin, the white crappie occurs in the Mississippi River and Lake Michigan drainage basins, where it is near the northern limit of its distribution. It has not been taken from the Lake Superior watershed. In the past 50 years this species has extended its distribution to the lower Chippewa–Red Cedar basin, the midreaches of the Wisconsin River, the Madison lakes region, the Beaver Dam and Crawfish rivers, and the Fox-Wolf river system of the Lake Michigan basin. Earlier records from the Lake Michigan drainage were only from the Root River in extreme southeastern Wisconsin (Greene 1935).

Although some range extension was undoubtedly a result of this species' natural expansion into suitable habitats, some also resulted from the intended or the inadvertent stocking of white crappies with other species. Stocking has been suggested as the source of the Smith Lake record of the upper St. Croix drainage (Sawyer County) (Greene 1935, Schneberger 1972b). The white crappie's continued presence in the St. Croix River above the St. Croix Falls Dam (Polk County) has been verified by two specimens (UWSP 4819) taken in June 1974. In the Madison Lakes, white crappies were first reported in the 1944 carp seining of Lake Wingra, where, according to Noland (1951), the crappies appeared in large numbers and were the most abundant panfish in the lake. Noland concluded that the white crappie had probably been introduced as a result of fish rescue and transfer operations.

The establishment of the white crappie in the Fox-Wolf river system of the Lake Michigan drainage is of recent occurrence, although it could have been overlooked by Greene in his survey during the 1920s. Its means of entry is uncertain, but three possibilities exist: (1) via the Fox-Wisconsin canal at Portage, (2)



Range of the white crappie
- ● Specimens examined
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- ○ Literature and reports
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via fish rescue and transfer operations from the Mississippi River, and (3) via southern Lake Michigan into Green Bay. The first two means of entry seem most likely, because if the species had entered from Lake Michigan it would have left some seed stock in tributary streams along western Lake Michigan, and this is not the case. Earlier Greene (1935) suggested that the white crappie's means of entry into the Root River watershed (Milwaukee and Racine counties) may have been through the drainage ditch connecting the Illinois-Fox river and the Root River watersheds during high water.

Although Cahn (1927) reported that the white crappie was found in nearly all of the larger lakes and in some of the smaller lakes in Waukesha County, it was more recently reported (Poff and Threinen 1963) in only 2 of 40 lakes sampled in Waukesha County. Priegel (1967a) considered the white crappie rare in Lake Winnebago, and V. Hacker (pers. comm.) reported it as common in Kingston Pond of the Grand River (Green Lake County). The white crappie is common to uncommon in the Rock, the lower Wisconsin, and the Mississippi rivers. In addition to extending its range in Wisconsin, the white crappie appears to be increasing in numbers.

In Wisconsin, the white crappie occurs in sloughs, backwaters, landlocked pools and lakes, and in the pools and moderate currents of moderate-sized to large streams. It inhabits areas of sparse vegetation. It prefers slightly turbid to turbid water, and occurs at varying depths within the warm, shallow-water upper layer, over substrates of sand, mud, gravel, rubble, clay, and silt.

BIOLOGY

Rutledge (1971) has prepared a bibliography of literature containing specific life history references to white and black crappies. The spawning of the white crappie has been dealt with at length by Hansen (1951, 1965), Morgan (1954), and Siefert (1968, 1969a); unless otherwise indicated, the following account is based on these sources.

Spawning occurs in May and June at water temperatures of 14–23°C (57–73°F) with most spawning occurring at 16–20°C (61–68°F). Contrary to what has been observed in other centrarchid species, the white crappie does not desert the nest when the water temperature drops. The white crappie may nest at depths of 5 cm to 1.5 m, generally within 10 m of the shore, on hard clay or gravel, or on the roots of aquatic or terrestrial plants. Hansen reported white crappie nests in water 10–20 cm deep along an undercut sod bank of red clay. In one nest, the eggs were attached to blades of lawn grass and to grass roots which were dangling in the water only 5 cm below the surface; the fish guarded this nest from a position below the eggs.

The white crappie nests in colonies, and as many as 35 nests have been reported in one colony; solitary nests are rare. Nests in circular colonies were spaced 0.5–0.6 m apart; those in linear colonies were found to be 0.6–1.2 m apart. White crappies nest in or near plant growth if it is available. Well-defined nest depressions are generally absent, and a nest may consist of a circular area 12–15 cm across, from which a thin layer of silt has been swept. In some habitats, the nest may be 30 cm across. Siefert has described nest construction (1968:254):

> Nest preparation consisted of short vigorous periods (3 to 5 sec) of body movement as the abdomen touched, or nearly touched, the substrate. During this time the fish remained in an upright position. Sediment was swept out of the nest with fin and body movements, but only the loose silt layer was removed and a well-defined nest depression was not constructed. Occasionally the female exhibited the same nest sweeping movements as the male immediately before and during the spawning run.

Territorial behavior was observed among white crappies places in breeding pens. The territorial crappies were aggressive, and vigorously chased all intruders from the defended area, usually by snapping or butting at intruders, and by flaring their opercles. Territories averaged 1 m^2, and generally were established near a submerged tree branch or a corner of the pen; they did not always correspond to a later nesting site.

Spawning acts by white crappies in breeding pens were observed between 0850 and 1600 hr, and most spawning began before 1200 hours. Siefert described spawning behavior (1968:255):

> . . . The female, after being repulsed from the territory a number of times, would finally stop retreating from the territory when chased, and would be accepted by the male. After circling the nest several times the female would position herself beside the male and face the same direction as the male. They would remain motionless for a few seconds, and then the sides of their bodies would touch. Both fish then would slowly move forward and upward with their bodies quivering. The female would slide under the male in the process, pushing him up and to the side, causing the pair to move in a curve as the sex products presumably were emitted. The male exerted a steady pressure on the female's abdomen. Each spawning act lasted from 2 to 5 sec with most lasting 4. Intervals between acts ranged from one half to 20 min. Maximum number of acts in one spawning run was 50, and the longest duration of any run observed was 145 min.

In two instances, Siefert watched an intruding male quickly position himself on the unoccupied side of the female and participate in the spawning act; however, immediately following spawning, he was chased from the area by the defending male. On another occasion, a female mated with a second male guarding a nest site which was about 1 m away from the territory of her first mate. The male of the primary spawning vigorously chased the female away from the second male's nest; the second male, in turn, chased the invading first male back to his own territory.

Following egg laying, the male white crappie guards the eggs (Breder and Rosen 1966:424):

> . . . The male fish jealously guarded the eggs and kept the water about them in constant motion with his pectoral fins. Other fish were kept away and objects that came near the eggs were savagely bitten. If a person placed his hand within six inches of the surface of the water, the male fish would leap clear of the water and strike the hand viciously.

The white crappie's eggs average 0.89 mm diam, and are demersal and adhesive. They are usually scattered over an area larger than the actual nest (Siefert 1968). Nests surrounded by *Chara* contain more eggs on the periphery than in the middle. The eggs sampled from two white crappie nests showed evidence of multiple spawning over a period of less than 2 days; the eggs were in two distinct stages of development.

Lake Wingra (Dane County) females, 159–187 mm TL, held an average of 12,000 (6,200–24,000) eggs on 25 May. On 29 June, females 163–176 mm TL averaged 3,300 (300–5,100) eggs (Churchill 1976). These egg counts appear to be low, and probably represent females which had already partly spawned. In Ohio (Morgan 1954), the total number of eggs produced by white crappies varied from 1,908 in a 149-mm fish to 325,677 in a 330-mm fish.

The hatching time of white crappie eggs kept at water temperatures of 21.1–23.3°C (70–74°F) varied between 24 and 27.5 hr (Morgan 1954). The embryos hardly encircled the yolk at hatching, and the movements of the larvae were quite feeble. The larvae were 1.215–1.98 mm long, and so poorly developed that Morgan did not expect them to live. Siefert (1969b) found that the minimum total length of white crappie upon hatching was 2.56 mm, and that the yolk material was absorbed before the fish reached 5 mm.

Morgan (1954) illustrated and described the white crappie's embryonic development from fertilization through the 6-mm stage (14.5 days after hatching). There has been no evidence of scale formation on fish less than 16 mm TL, and the first fully scaled fish observed was 27 mm long (Siefert 1965). Larval white and black crappies (5–16 mm long) in Missouri River reservoirs can be separated by the number of postanal myomeres and the number of total myomeres: for the white crappie, these are 19 or less and 30–31 respectively; for the black crappie, they are 21 or more and 32 respectively (Siefert 1969b). In larvae greater than 16 mm, there are 5–6 dorsal spiny rays in the white crappie, and 7 in the black crappie.

In western reservoirs, the white crappie larvae are initially collected in nursery areas near coves and boat basins, but during the summer they move out of protected areas into the open reservoir (Siefert 1969a). In Lewis and Clark Lake, South Dakota, the young are in the pelagic zone during July and August, but in September larger numbers of fish are taken with bottom trawls in water less than 6 m deep (Gasaway 1970).

The average yearly growth of male and female white crappies is about the same; however, late in life females grow faster than males (Morgan 1954).

Determining the age of white crappies by counting the number of annuli present is difficult, because the annulus may be formed over a period of several months, or not at all during some years (Morgan 1954, Hansen 1951).

In Iowa, the condition (K_{TL}) of white crappies 102–260 mm long averaged 1.29 (1.11–1.42) (Neal 1961). In Illinois, the highest coefficient of condition (K_{SL}) for a 279-mm fish was 3.38 (Hansen 1951).

Maturity occurs at age II in some individuals, but most white crappies are mature at ages III and IV (Nelson 1974, Siefert 1969a, Morgan 1954).

As a rule, the white crappie is short-lived; few survive more than 5 years. In an Illinois study (Starrett and Fritz 1957), a natural death rate of over 50% occurred in large broods during their third year of life. An exceptionally old fish—age XIII, with a weight of 1.62 kg (3 lb 9 oz)—was reported by Harlan and Speaker (1956) from Corydon Reservoir, Iowa.

The largest white crappie reported by Christenson and Smith (1965) from the Mississippi River (Buffalo County) was 325 mm (12.8 in) long. A 1.59-kg (3-lb 8-oz) fish was taken by Cahn (1927) from the Neosho Mill Pond (Dodge County). A record white crappie, 533 mm long and weighing 2.35 kg (21 in and 5 lb 3 oz), came from Enid Dam, Mississippi, in 1957 (*World Almanac* 1976).

The first foods eaten by white crappies are rotifers and copepod nauplii, followed, as the fish increase in size, by *Daphnia*, *Diaptomus*, and *Leptodora*. Zooplankton are almost the only food eaten during the first year, but a few amphipods and chironomids are taken in late fall and spring (Carlander 1977).

Entomostraca continue to be a significant food throughout the life of white crappies in most waters, but insects and forage fish are usually the major foods of large crappies. In Pool 19 of the Mississippi River, the food of 83 white crappies included *Hexagenia* naiads (42%) and *Potamyia flava* larvae (11%); the remainder of the food was composed chiefly of immature Diptera, Odonata, Zygoptera, Hemiptera, and fish (Hoopes 1960). In a later study (Ranthum 1969), fish were the most important food item in the white crappie diet, followed closely by chironomids, and *Hexagenia* mayfly naiads and adults; other insects contributed little to the food volume. Five of the crappies in this study contained two or three gizzard shad each; another contained a bluegill or a crappie; in another specimen four minnows were found. Schneberger (1972b) has suggested that the white crappie eats its own young.

In an Iowa study (Neal 1961), plant materials and insect adults never accounted for more than 5% of the stomach contents of white crappies. Food items found in the stomachs included ostracods, fish eggs, plant seeds, algae, Hydracarina, nematodes, unidentified Crustacea, and insect eggs.

In a Pennsylvania reservoir, during most months young white crappies fed exclusively on zooplankton, mostly in the morning and early afternoon; an

Age and Growth (TL in mm) of the White Crappie in Wisconsin and Other Northern Waters

Location	1	2	3	4	5	6	7	8	9	Source
L. Wingra (Dane Co.) 1972–1973	92	140	165	175	179					Churchill (1976)
Mississippi R. backwater (Buffalo Co.)	66	152	231	277	297					Christenson and Smith (1965)
Clear L. (Iowa)	72	144	184	208	231	272	272			Neal (1961)
Avg for northern waters	66	138	193	238	268	286	313	318	363	Carlander (1977)

estimated 14–17 hr period elapsed for the food to pass through the stomach (Mathur and Robbins 1971). These researchers suggested that plankton feeding by adult white crappies of all sizes is related to their long gill rakers.

Gammon (1973) determined that the optimum water temperature range for the white crappie, based on its selection and avoidance of thermal zones, was 27.0–28.5°C (80.6–83.3°F). Triplett (1976) noted that the initiation of power plant operations resulted in a nearly continuous congregation of fish in the outfall area. The maximum temperature at which the white crappie has been captured was 31.1°C (88°F) (Proffitt and Benda 1971). The white crappie is active at summer water temperatures as high as 30.6°C (Morgan 1954). During the winter months when warm-acclimated fish in a warmwater outfall (28–30°C) were forced into a cold lake water (0–2°C), they manifested apparent oxygen hunger, and continued exposure to the cold water was fatal (Agersborg 1930). From June to August, no white crappies were found in water with less than 3.3 ppm oxygen (Grinstead 1969). This species tolerates pH ranging from 6.2 to 9.6 (Schneberger 1972b).

The white crappie is a schooling species. White crappies in the Mississippi River are more nocturnal than diurnal; their activity peaks between 2000 and 2200 hr and between 0400 and 0600 hours. There is a rapid decline in movement between the evening and morning peaks and a more gradual decline between the morning and evening peaks. In Ohio, test net catches have shown that white crappies are most active between 1700 hours and 0500 hours (Morgan 1954). Sport fishermen are most successful in the late afternoon or early evening, at which time the crappies come into the shallow waters near shore to feed on minnows and small fishes, or on insects that appear on the water (Harlan and Speaker 1956).

In a Missouri study, Funk (1957) determined that 30% of the tagged white crappies moved less than 1.6 km (1 mi) from the point of release; 40% moved less than 16 km (10 mi); and 70% moved less than 40 km (25 mi). The movements of white crappies appear to be random or haphazard. In Illinois, four white crappies were recaptured 5.6, 12.9, 25.8, and 29.1 km upstream, from tagging points; others were retaken 1.8 and 3.2 km downstream (Thompson 1933). White crappies have a strong, positive reaction to water currents, and this may be a factor in their migration (Schneberger 1972b). Siefert (1969a) determined that a substantial portion of tagged white crappies emigrated from Lewis and Clark Lake (South Dakota) into the tailwaters below Gavins Point Dam; these fish passed unharmed through the turbines, since no other water releases occurred, and contributed to the tailwater white crappie fishery.

In the Mississippi River at Wyalusing (Grant County), 14 white crappies were associated with the following species: longnose gar (10), bowfin (1), gizzard shad (89), quillback (187), smallmouth buffalo (1), shorthead redhorse (3), golden redhorse (7), common carp (2), central stoneroller (1), silver chub (1), golden shiner (110), bullhead minnow (145), pugnose minnow (8), emerald shiner (340), spotfin shiner (245), spottail shiner (589), river shiner (428), sand shiner (6), bigmouth shiner (1), tadpole madtom (1), northern pike (1), white bass (119), yellow bass (4), yellow perch (5), walleye (2), western sand darter (5), river darter (1), logperch (11), johnny darter (28), smallmouth bass (1), largemouth bass (31), pumpkinseed (1), bluegill (173), orangespotted sunfish (8), rock bass (1), black crappie (178), brook silverside (118), and freshwater drum (17).

IMPORTANCE AND MANAGEMENT

The white crappie is preyed upon by large game fishes, including largemouth bass, smallmouth bass, northern pike, and muskellunge (Schneberger 1972b).

The white crappie is host to the glochidial stages of the following mollusks: *Amblema plicata, Fusconaia ebena, Fusconaia flava, Megalonaias gigantea, Quadrula pustulosa, Elliptio dilatata, Anodonta grandis, Lasmigona complanata, Actinonaias carinata, Carunculina parva, Lampsilis ovata, Lampsilis radiata luteola, Lampsilis teres, Ligumia recta*, and *Proptera laevissima* (Hart and Fuller 1974).

The white crappie is taken with small minnows and a variety of artificial baits. Hansen (1951) noted that in the morning more black crappies were caught than white, and that in the evening the reverse was true. Extreme care must be taken in landing this fish, since its mouth is very tender, and the hook is easily pulled out. The white crappie is considered an excellent panfish.

Compared to the black crappie, which is much more abundant in Wisconsin and has a statewide distribution, the white crappie is of limited angling and economic importance. Commercial fishing for either crappie species is not allowed in Wisconsin. However, liberal angling regulations for inland waters permit a daily bag limit of 50 panfish, including crappies and there is no bag limit in boundary waters, except in Wisconsin-Minnesota waters, where the daily bag limit is 25 panfish (Wis. Dep. Nat. Resour. 1979). Up-to-date fishing regulations should be consulted for current regulations, since these are subject to change.

In suitable waters, the production of white crappies may be considerable. In Lake Wingra (Dane County), the estimated population and biomass (kg/ha) during May 1972 were 31,000 and 12 kg/ha respectively; during May 1973, they were 120,000 and 56 kg/ha; and during May 1974, they were 43,000 and 13 kg/ha (Churchill 1976). In Alabama (Swingle and Smith 1939), 10 white crappies weighing 1.87 kg (4 lb 2 oz) were stocked in February in a 0.72-ha, unfertilized pond; on draining the pond the following November, 3,780 white crappies weighing 16.38 kg (36 lb 2 oz) were recovered.

The white crappie is an easy fish to propagate. It thrives in fairly warm water in shallow ponds, lakes, and reservoirs where the bottom may be muddy. Vegetation is not essential to its existence. When fish of this species are needed for stocking in newly created or rehabilitated waters, sufficient numbers can be obtained by netting in waters where an abundant population exists. Consideration should be given, however, to the desirability of introducing this species in areas where limited growth may occur.

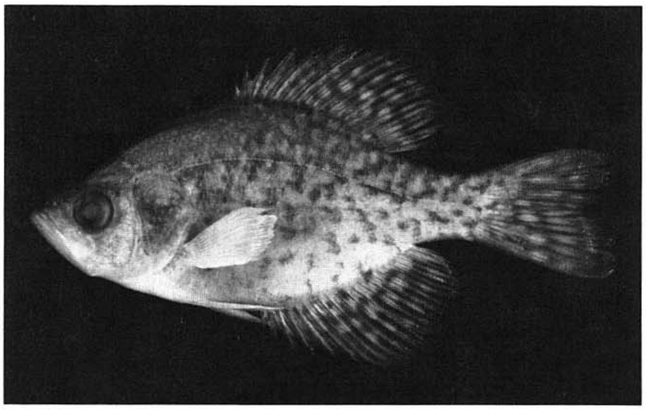
Fluctuations in the numbers of white and black crappies have been reported from a number of waters (Ball and Kilambi 1973, Starrett and Fritz 1957). In Beaver Reservoir, Arkansas, Ball and Kilambi noted that black crappies were dominant in the early impoundment period, whereas white crappies became dominant during the late impoundment period. They ascribed this pattern of dominance to the feeding habits of the two species: white crappie adults consumed fishes all year round, whereas black crappie adults consumed benthic insects in the spring and fishes in other seasons; the apparent reduction in the number of insects and earthworms during the late impoundment gave the advantage to the white crappie.

As is the case in other species of the centrarchids, stunting occurs among white crappies where the fish population level is too high for the available food. It has been shown that the growth of white crappies improved after population was thinned (Carlander 1977), but there was no clear-cut improvement in growth following the removal of carp from fish populations (Scidmore and Woods 1960). After an extensive review of the factors affecting crappie growth and dominant year classes, Rutledge and Barron (1972) suggested a number of methods to correct stunting. These included increasing the food supply; stocking predators like largemouth bass and northern pike (there has been little evidence of success with the longnose gar); the introduction of sterilized fish to control year class abundance; encouraging crappie harvest; and thinning populations by the use of toxicants, by trapping and seining, and by fluctuating the water level.

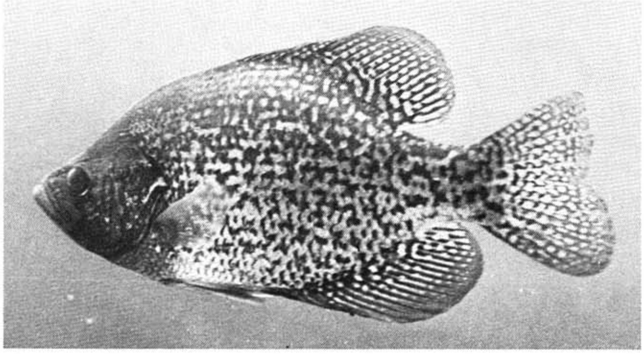
Black Crappie

Pomoxis nigromaculatus (Lesueur). *Pomoxis*—sharp opercle; *nigromaculatus*—black spotted.

Other common names: crappie, crawpie, calico bass, strawberry bass, speckled crappie, specked perch, speckled bass, speck, grass bass, Oswego bass, shiner, moonfish, barfish, silver bass, lake crappie, butter bass, bitterhead, banklick bass, lamplighter.



Subadult 116 mm, L. Winnebago (Fond du Lac Co.), 19 Aug. 1960



Adult (living) (Wisconsin DNR photo).

DESCRIPTION

Body deep, strongly compressed laterally (slab-sided). Average length 178–254 mm (7–10 in). TL = 1.30 SL. Depth into TL 2.9–3.5. Head length into TL 3.3–3.8. Mouth large, moderately oblique. Upper jaw reaching at least to middle of eye; lower jaw heavy, tip jutting beyond tip of upper jaw; minute conical, pointed teeth in brushlike pads on upper and lower jaws; lower pharyngeal arches long and narrow, with numerous fine teeth. Gill rakers on first arch close-set, long, slender and straight; about 29. Dorsal fins 2, but completely joined and appear as 1; 7–8(6–9) spines, 14–16 rays; base length of dorsal equals distance from dorsal origin to eye; base length of dorsal fin equal to or slightly shorter than base length of anal fin. Anal fin with 6–7 spines and 17–18 rays; pelvic fin thoracic, with 1 spine and 5 rays; pectoral fin elongate, and when laid forward across cheek reaching eye; caudal fin slightly forked. Scales ctenoid, in lateral line 34–44; lateral line complete. Chromosomes 2n = 48 (W. LeGrande, pers. comm.).

Back and upper head dark green with blue, green, and silvery reflections; sides lighter, with irregular pattern of distinct dark blotches, and no vertical bands (although in some individuals partial bands on upper back and caudal peduncle); ventral region of head and belly whitish. Eyes yellow-brown. Irregular, dark (often diffuse) opercle spot scarcely larger than diam of pupil of eye. Dorsal, caudal, and anal fins heavily vermiculated alternating with round to oblong yellow to pale green spots; paired fins unpigmented to lightly pigmented. Individuals from clear water show sharply contrasting patterns; fish from turbid waters look pale.

Breeding male head and breast dark, usually darker and more iridescent than in female.

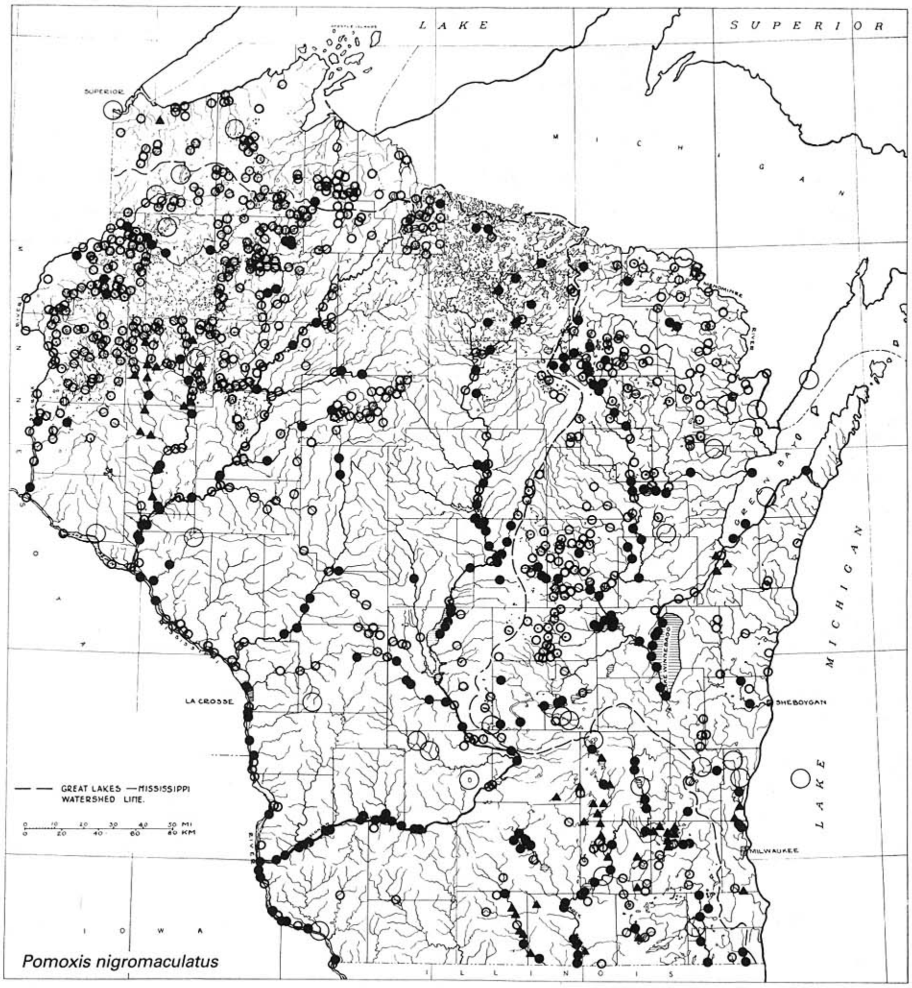
Hybrids: Black crappie × white crappie (Hubbs 1955, Trautman 1957). Artificial black crappie × bluegill, black crappie × warmouth, black crappie × largemouth bass, black crappie × rock bass (Hester 1970).

DISTRIBUTION, STATUS, AND HABITAT

The black crappie occurs in all three drainage basins in Wisconsin. This glacial species is well distributed throughout the state, except in the streams of the driftless area of southwestern Wisconsin.

The black crappie originally did not range through the central and northcentral portions of Wisconsin, in the area bounded by Waushara, Forest, Bayfield, and Dunn counties (Greene 1935). Within this area, which represents over 25% of the surface area of Wisconsin, only a few collection sites were known up to the late 1920s. Greene did not encounter this species in the counties along Lake Michigan north of Ozaukee County, except for those draining into the western edge of Green Bay. Since the 1920s, however, the black crappie has been extensively introduced into many lakes and ponds throughout the state, including those areas from which it was not originally known. Between 1920 and 1925, the Wisconsin Department of Natural Resources made available large numbers of fish for stocking, mostly black crappies rescued from Mississippi River backwaters.

The black crappie is common in lakes and larger rivers throughout the state. It is abundant in the



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

sloughs and backwaters of the Wisconsin and Mississippi rivers, and it is occasionally captured in the lower extremities of the larger tributaries of the Wisconsin River. It is abundant in Pewaukee Lake and Lake Poygan (Becker 1964a, 1964b), and in Lake Winnebago it is the most abundant species of the sunfish family (Priegel 1967a). In Waukesha County, the black crappie and the bluegill appeared in 32 of 40 lakes sampled (Poff and Threinen 1963)—the highest frequency of occurrence of all fishes in those lakes. In the upper Mississippi River, the black crappie is more common than the white crappie (Barnickol and Starrett 1951, Kittel 1955, P. W. Smith et al. 1971). At the barriers of tributary streams to Lake Superior, the black crappie occurs sporadically, and is "occasionally taken from 4 Wisconsin streams" (McLain et al. 1965). This species is the native crappie of Lake Wingra (Dane County), and was ranked as a dominant fish species in the lake during the first two decades of this century (Noland 1951). However, in the 1944 carp seining in Lake Wingra, the black crappie was outnumbered 3.5 to 1 by the white crappie, and in 1972–1974, by a ratio of 3 to 1 (Churchill 1976).

The black crappie is usually found in the clear, quiet, warm water of ponds, small lakes and bays, and in the shallow waters of large lakes, sloughs, backwaters, and landlocked pools. It is almost always associated with abundant growths of aquatic vegetation. In Wisconsin, it was encountered in clear to slightly turbid water, over substrates of sand (32% frequency), mud (20%), gravel (18%), silt (9%), rubble (9%), boulders (9%), clay (2%), hardpan (1%), and detritus (1%). It occurred in streams of the following widths: 1.0–3.0 m (2%), 3.1–6.0 m (9%), 6.1–12.0 m (10%), 12.1–24.0 m (38%), 24.1–50.0 m (31%), and more than 50 m (10%). It prefers clearer, deeper, and cooler waters than does the white crappie (Schneberger 1972a).

BIOLOGY

In Wisconsin, the black crappie usually spawns in May and June; however, during a colder season, spawning may be delayed until July. Favorable spawning temperatures range from 17.8 to 20°C (64 to 68°F), although activity may begin at 14.4°C (58°F) (Sigler and Miller 1963). The male sweeps out a nest of 20–23 cm diam, near *Chara* or other vegetation, in sand or fine gravel; nests also have been observed on muddy bottoms. Nests are built in shallows of 25 cm–0.6 m, as well as at depths up to 2 m or more. The nests are generally spaced 1.5–1.8 m apart.

Pearse (1919) observed about a dozen male black crappies on nests in a lagoon of Lake Wingra (Dane County) on 20 May. The nests were bare places on a clay bottom, adjacent to submerged aquatic plants along the edge of an undercut clay bank, in 0.6 m of water. In Illinois, a black crappie nest was hollowed out under the leaves of a water parsnip, and was surrounded by smartweed and *Juncus* (Richardson 1913). Some of the eggs had adhered to fine roots in the bottom of the nest, but most were on the leaves of the water parsnip, 5–10 cm above the bottom of the nest. This nest was guarded by a 15-cm-long male, who was so gentle that he moved away when a hand reached toward him. Normally, the male black crappie guarding a nest is quite belligerent and will attack intruders or objects within his territory. He guards the nest and protects the young until they start to feed.

The female black crappie may spawn with several males and may produce eggs several times during the spawning period. Water-hardened eggs average 0.93 mm diam (Merriner 1971a). The number of eggs produced by fish 3–8 years old was 3,000–188,000, or approximately 132,000/kg (60,000/lb) of fish (Vessel and Eddy 1941). In Indiana, 3- and 4-year-old black crappies averaged 33,700 and 41,900 eggs respectively (Ulrey et al. 1938). The fecundity of Lake Wingra females that were 163–180 mm TL on 25 May was 11,400 (7,900–19,100) eggs (Churchill 1976). The median hatching time in the laboratory was 57.5 hr at 18.3°C (65°F) (Merriner 1971b).

In Vilas County lakes, black crappie larvae first appeared during the first half of June and continued to appear in small numbers through most of July (Faber 1967).

Characteristics useful in separating larval black crappies from larval white crappies, are given in the white crappie species account (p. 860).

In southern Wisconsin, young-of-year black crappies were 25 mm long at the end of June, 45 mm long in July, 51 mm long in August, and 64 mm long at the end of September (R. Lorenz, pers. comm.). The growth of black crappies in the Fountain City backwater areas (Buffalo County) was generally faster than in any other Wisconsin waters reported.

More than 50% of male and female black crappies are mature at age II; 83% of the males and 79% of the females mature at age III (Nelson 1974).

In the Mississippi River (Pools 4–6) during 1955, Kittel (1955) noted the following frequency of occurrence in survey samples of each age class from I through VII: 106, 120, 67, 5, 10, 11, and 1. From this limited sample, it appears that after age III the mortality of black crappies is high and that few large crappies remain in the fishery. Kelley (1953) noted a decline in trap-net catches of 4- and 5-year-old fish from May to September, and concluded that the principal cause was natural mortality. In Murphy Flowage (Rusk County) from 1955 to 1969, the natural mortality of black crappies was 42%, and the estimated mortality through angling was 11% (Snow 1978). In Illinois, a natural death rate of more than 50% occurred in large broods of white and black crappies during their third year of life; anglers took about 7% of the harvest of catch-sized crappies, and the remainder was largely lost through natural mortality (Starrett and Fritz 1957).

In 1947, a 457-mm, 1.70-kg (18-in, 3-lb 12-oz) black crappie was caught from Mirror Lake (Sauk County). A 457-mm, 1.79-kg (18-in, 3-lb 15-oz) fish was taken from Blue Spring Lake (Jefferson County) in 1961 [Wis. Conserv. *Bull.* 1961 26(6):22]. A 502-mm, 2.04-kg (19.75-in, 4-lb 8-oz) crappie was hooked from the Gile Flowage (Iron County) on 12 August 1967 (Wis. Dep. Nat. Resour. 1977); although listed as a white crappie, it was more than likely a black crappie since white crappies are not known from the Lake Superior drainage. A 489-mm, 2.27-kg (19¼-in, 5-lb) black crappie was taken from the Santee-Cooper Reservoir in South Carolina in 1957 (*World Almanac* 1976).

The black crappie is carnivorous in its feeding habits. The food of very young black crappies is primarily *Cyclops* and Cladocera; small insect larvae are less important (Pearse 1919). The food of 140 black crappies 165–200 mm long, taken between February

Age and Growth (TL in mm) of the Black Crappie in Wisconsin

Location	1	2	3	4	5	6	7	Source
Drainage lakes, northwestern Wis.[a]	61	124	173	203	229	249	246	Snow (1969)
Seepage lakes, northwestern Wis.[a]			163	168	196	229	239	Snow (1969)
Mississippi R., Pools 4–6	84	137	187	234	269	282	302	Kittel (1955)
Mississippi R. (Buffalo Co.)	69	145	216	262	290			Christenson and Smith (1965)
L. Wingra (Dane Co.)	73	133	170	202	269	296	352	Churchill (1976)
Spauldings Pond[a] (Rock Co.)	114	152	165					Threinen and Helm (1952)

[a] Actual lengths at time of capture, not calculated to annulus.

and October in Lake Wingra (Dane County), was composed of Cladocera (33% volume), chironomid larvae and pupae (24%), amphipods (11%), fish (9%), ephemeropteran nymphs (6%), copepods (5%), adult (flying) chironomids (4%), and Odonata nymphs (2%); other food items, each forming less than 1% of the digestive tract materials included hemipteran nymphs and adults, caddisfly larvae, grasshoppers, beetles, ostracods, mites, snails, leeches, algae, miscellaneous plants, silt, and debris. In Lake Mendota (Pearse 1921a), the black crappie had consumed the following foods: fish (16.6% volume), insect larvae (13.3%), insect pupae (10.8%), insect adults (19.2%), cladocerans (16%), copepods (4.2%), ostracods (6.6%), and plants (13.3%).

In the diet of black crappies from northwestern Wisconsin lakes, Van Engel (1941) found that fish outranked invertebrates in importance when measured by the volume of food in stomachs, although the latter were found in a greater number of the stomachs; e.g., in Silver Lake, fly nymphs were present in 44% of the stomachs and fish in 38.7% of the stomachs, but the fish accounted for 88.2% of the total volume of food and the nymphs for only 2.7%. In January and February collections at Big Round Lake, *Leptodora* and fish were absent from the diet, and *Chaoborus* larvae were found in 94–97% of the stomachs and accounted for 30–50% of the volume of food. In July, fish appeared in the diet of only those crappies over 14 cm SL; the fish consumed were bluntnose minnows, perch, bluegills, and largemouth bass. In a Mississippi River study (Ranthum 1969), 21 of 36 black crappies contained fish, including gizzard shad and one small bullhead. Fish were an important summer food, particularly in July and August. In November and December, cladocerans made up most of the food volume.

A study of feeding periodicity in Illinois (Childers and Shoemaker 1953) indicated that the black crappie feeds most actively at dusk, from 1600 to 1800 hr, and that a second less active feeding period occurs at dawn, from 0600 to 0800 hr. Light feeding continues at night from 1800 to 0600 hr; there is practically no feeding during the day.

The black crappie is a midwater feeder. It feeds among aquatic vegetation in the open water, and to some extent at the surface. The black crappie's numerous gill rakers permit it to consume planktonic crustaceans at least until it reaches a large size, if not throughout life. The success of the black crappie in many waters may be attributed to its ability to consume foods of all types and sizes. The black crappie is one of the few members of the centrachid family that continues to feed during the winter and that does not go into semihibernation.

Although Reynolds and Casterlin (1977) determined that the black crappie had the lowest temperature preference [24°C (75.2°F)] of the fish tested, Neill and Magnuson (1974) noted that the preferred temperature of crappies from Lake Monona (Dane County) was 28.3°C (83°F) in both the field and the laboratory. Black crappies in the heated area of a South Carolina reservoir had higher length-weight relationships and higher mean coefficients of condition than those from unheated portions (Bennett 1972).

Moore (1942) determined an oxygen threshold for the black crappie at 1.4 ppm at near-freezing temperatures. In Lake Traverse, Minnesota, crappies were distressed but alive at 1.1 ppm oxygen (Moyle and Clothier 1959). The thresholds found by Cooper and Washburn (1949) in Michigan winterkill lakes were notably lower: In one lake, with an approximate minimum concentration of dissolved oxygen of 0.8–0.5 ppm in the upper 0.3–1.2 m of water there was good survival of black crappies; in a lake with a concentration of 0.3–0.1 ppm, there was still some survival of that species, although black crappies and other species also sustained heavy mortalities.

The black crappie, more than any other species, suffered sudden mortality in waters of Lake Waubesa and the Yahara River (Dane County) which were supersaturated with dissolved oxygen as a result of algal bloom (Woodbury 1941). All of the fish looked normal in death except for small gas bubbles under the skin and in the fin rays. The gills contained gas emboli large enough to obstruct the blood flow, and death was due to respiratory failure.

The black crappie is a gregarious fish that travels in schools. Moyle (1969) observed schools of 20–25 fish; during the day each school was located around a submerged tree, usually at a depth of 1–3 m, but during the evening the schools moved out over deep water, where they remained within 1–3 m of the surface. Keast (1965) has noted some nocturnal movement into the shallows by the black crappie and the rock bass. Young black crappies may often be found swarming in shallow, quiet, or protected waters. Adult fish may rest suspended and motionless, except for occasional flicks of the pectoral fins.

The movements of the black crappie include migrations. Black crappies living in large bodies of water may migrate several kilometers (Schneberger 1972a). Evidence of winter movement under the ice by black crappies in a backwater channel of the Mississippi River was determined by Greenbank (1956); the greatest movement occurred in early February when the ice had its greatest snow cover.

In Glass Lake (Grant County) of the Mississippi River, 509 black crappies were found with these species: longnose gar (1), gizzard shad (32), bigmouth buffalo (2), spotted sucker (4), white sucker (1), golden shiner (76), pugnose minnow (4), spotfin shiner (2), spottail shiner (32), weed shiner (1), tadpole madtom (4), grass pickerel (4), northern pike (5), white bass (3), yellow bass (3), yellow perch (36), walleye (8), logperch (6), johnny darter (1), mud darter (1), largemouth bass (112), bluegill (2), white crappie (6), and brook silverside (28).

IMPORTANCE AND MANAGEMENT

While black crappies are carnivorous in their feeding habits, they are also eaten by a number of other animals. Fish that prey on black crappie fry and fingerlings include perch, walleyes, bass, northern pike, and muskellunge. Yearling and adult crappies are suitable prey for the larger muskellunge and northern pike (Schneberger 1972a). Fish-eating birds that feed on black crappies include the great blue heron, American merganser, kingfisher, and bitterns. Otter and mink are probably the only predatory mammals that feed on the black crappie. Schneberger suggested that snapping turtles and water snakes may occasionally feed on this species.

The black crappie is host to the glochidia of the following mollusks: *Amblema plicata*, *Fusconaia ebena*, *Fusconaia flava*, *Megalonaias gigantea*, *Quadrula nodulata*, *Elliptio dilatata*, *Anodonta grandis*, *Actinonaias carinata*, *Lampsilis radiata luteola*, and *Lampsilis teres* (Hart and Fuller 1974).

Schneberger (1972a) has suggested that the activities of the carp may benefit the feeding and breeding activities of the black crappie by converting the habitat from a weedy to a more open-water environment. Crappies have been known to be relatively abundant in areas populated by carp.

In Iowa, Neal (1961) noted that there was a shift in the dominant population in Clear Lake from black crappies to white crappies. He suggested turbidity as a reason for this change. The spread northward into Wisconsin of the white crappie, its greater incidence in Wisconsin waters in recent years, and the increased turbidity of our waters imply that a similar population shift may be occurring in Wisconsin. The shift in crappie species incidence in Lake Wingra, noted above, supports this view.

The black crappie ranks high as a sport fish and a panfish. It is caught on small minnows, worms, and a wide variety of artificial lures, and occasionally it will rise to a dry fly. The black crappie has a tender mouth, from which hooks are easily torn. Because it is active and feeds throughout the winter, this species is a popular quarry for ice fishing enthusiasts in some parts of Wisconsin.

The rank of the combined crappie species in the Mississippi River sport catch was fourth in 1957 and second in 1962–1963 (Nord 1967). The estimated catch of all crappies for Pools 4, 5, 7, and 11 in 1967–1968 was 277,369 fish weighing 68,090 kg (150,100 lb), or a weight of 245 g (0.54 lb) for each fish caught (Wright 1970). Considering the relative abundance of the species, the figures undoubtedly represent more black crappies than white crappies for all pools, with almost a total dominance of black crappies in the upriver pools. In Pools 4–6 during 1955, the average number of black crappies taken per trap net lift was 17.5 out of a total of 32.4 fish of all species (Kittel 1955). By comparison, yellow and white bass averaged 3.6 fish per lift, carp 2.0, and white crappies 0.2.

In Escanaba Lake (Vilas County), the black crappie never exceeded 6% of the spring standing crop of sport fishes available to the angler from 1956 through 1969 (Kempinger et al. 1975). During the same period in which the other centrarchid populations declined, the black crappie population also decreased and remained low. From 1955 through 1969, 7,482 black crappies weighing 2,422 kg (5,339 lb) were caught by anglers from Escanaba Lake: this represents 2% of the total number of fish of all species caught, and 3.9% of the total weight harvested. In Murphy Flowage (Rusk County) from 1955 to 1970, the black crappies harvest represented 4.4% of all the fish caught and 5.8% of their weight (Snow 1978). The estimated total number of black crappies caught from June to August 1970 in Black Oak Lake (Vilas County) was 445 fish (190–290 mm); these constituted 5.3% of the total catch (Serns and McKnight 1974). The estimated catch from Laura Lake (Vilas County) was 121 black crappies (229–328 mm), or 1.7% of the total catch.

When large sport fish prove uncooperative, when human appetites have been whetted for a ready fish dinner, it is the crappie which often fills the bill.

The flesh of the black crappie is white, flaky, and tasty; however, fish from some waters may have a slightly muddy taste. An overnight soaking in cold saltwater, followed by a thorough rinsing before cooking, is said to improve the taste. Schneberger (1972a:13) has described methods for cooking black crappies:

> . . . They are usually fried in a heavy skillet after having been dipped in flour, in a flour and cornmeal mixture or in

a commercially prepared breading. Any number of cooking oils, shortenings or combinations with butter may be used depending on individual preferences. A well-known fishing guide prepares the cooking fat by first frying bacon in butter. Bacon sandwiches are then eaten along with the fried fish.

In 1976, crappies were bringing $1.89 per pound ($4.16/kg) in a Milwaukee food store.

In Wisconsin, commercial fishing for the black crappie is not allowed, but liberal sport fishing regulations are in force. The season in inland waters is year-round; there is no size limit, but there is a daily bag limit of 50 panfish, including the black crappie. In boundary waters there is no bag limit, except in Wisconsin-Minnesota waters, where the daily limit is 25 panfish. Up-to-date regulations should be consulted, since regulations are subject to change.

Many problems have been associated with the management of black crappies, some of them evolving from the widespread stocking of this species in waters formerly famed for their larger sport fish species. In the 1947–1948 Biennial Report of the Wisconsin Conservation Commission (1949) the black crappie was called the "carp of the north" because it became so abundant in many northern Wisconsin lakes, prevented the growth of other fishes, and often became stunted itself as a result of competition. By preying on the young of other species, especially predator fish species, black crappies may greatly alter other fish populations.

Undoubtedly the crappie has been blamed for imbalances among fish species which should be attributed to other factors. In the late 1800s, Long Lake had a reputation for being one of the best smallmouth bass lakes in Bayfield County (O'Donnell 1943). In 1891 carp were planted in the lake in order to "make fishing better." The bass fishing began to decline rapidly, and by 1920 had become so poor that angling had almost been abandoned. Around 1930, yellow perch were introduced, and in 1937 Long Lake received 700 adult black crappies, the first record of this species in that lake. Fishing remained poor. In 1941 the lake was netted and poisoned; the only species which seemed to have been holding its own was the dominant black crappie: all size groups from 51–305 mm were taken. O'Donnell viewed the black crappie as "ecologically dominant," although carp made up 55.1% of the total weight.

The removal of larger fishes through selective fishing causes crowded populations of stunted crappies. Even with liberal angling regulations, overpopulations are often a problem. Studies by the Wisconsin Department of Natural Resources at Murphy Flowage and at the Northern Highlands Forest Research Station show that angling is not able to control populations to prevent overcrowding. The stocking of large predator species to control overpopulation has not been successful because of the rapid removal of the predators by anglers (Schneberger 1972a).

The history of Spauldings Pond (Rock County) (Threinen and Helm 1952) also illustrates runaway black crappie populations. In 1945, bluegills made up 47% of the total fyke net catch from the pond; by 1946 this figure had declined to 8.3%; and by 1951 it had dropped to 4.6%. The incidence of crappies in the catch increased from 47% in 1945 to 87.5% in 1946, and to 91% in 1951. At the same time, stunting occurred among the crappies: the largest crappie in 1945 measured 284 mm (11.2 in), whereas the largest fish in 1951 measured a mere 178 mm (7 in).

Black crappies, carp, largemouth bass, and bluegills were stocked in a number of experimental ponds at the Delafield Hatchery (Waukesha County) (Mraz and Cooper 1957b). The adult fish were stocked during April and May, and the ponds were drained during December. For this 5-month period, the average survival rates for the four species were: carp 95.5%, largemouth bass 49.5%, bluegills 35.8%, and black crappies 44.0%. Reproduction of black crappies in these small ponds was uniformly low, never exceeding 1,258 per hectare, and failing entirely in two trials out of six.