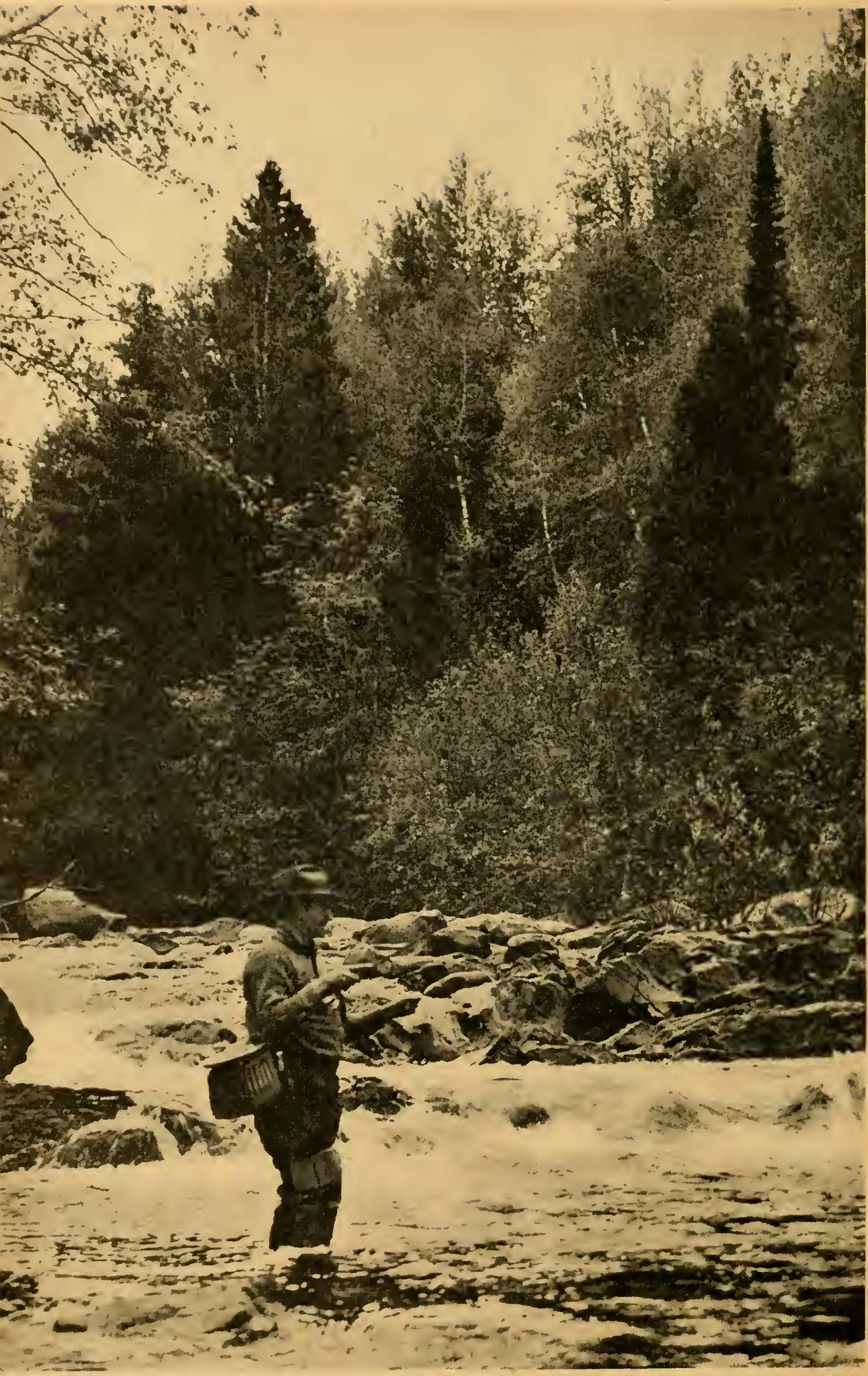


Northern FISHES

With Special Reference to the Upper Mississippi Valley

Samuel Eddy
UNIVERSITY OF MINNESOTA

and

Thaddeus Surber
MINNESOTA DEPARTMENT OF CONSERVATION

Revised Edition
THE UNIVERSITY OF MINNESOTA PRESS, *Minneapolis*

SECOND EDITION

PRINTED AT THE COLWELL PRESS, MINNEAPOLIS

3 2

Foreword

Of the many forms of outdoor sports and recreation indulged in by the people of the northern states, fishing easily takes the lead. The states of Minnesota, Wisconsin, and Michigan have within their boundaries some of the most wonderful fresh-water fishing grounds in America. Of these states Minnesota has the most extensive inland waters. In 1940 in Minnesota alone 651,295 residents took out licenses to fish. This figure does not include the boys and girls under the age of sixteen, who are not required to purchase licenses and who no doubt equal in number the adults who do purchase them, thus making an estimated number of 1,302,590 resident anglers. Thus in a state with a total population of 2,792,300 (1940) nearly half the residents were fishermen, or at least potential ones. In addition 94,458 nonresidents bought licenses in Minnesota. Not only have fishes sporting value, but also they form one of the most valuable food resources of the Lake States.

For years fishermen and others have been asking the authors for all sorts of information about fishes and fishing. This book has been prepared to answer, in part at least, some of these hundreds of questions. At the same time it presents the results of a comprehensive, systematic study, the need for which has long been recognized by those engaged in the propagation and maintenance of native fishes and by many sportsmen as well as scientific workers.

The writers have studied fishes mostly within Minnesota, and consequently this book is based primarily on fishes of this state. Minnesota extends 5° 54′ of latitude, or 400 miles, and is 354 miles from east to west across its widest part. Lying in the center of the continent, it contains within its boundaries the headwaters of three great drainage systems. These systems flow, respectively, northward to Hudson Bay, eastward to the Atlantic Ocean, and southward to the Gulf of Mexico. Minnesota has therefore what are commonly recognized as the Hudson Bay drainage system, the Great Lakes basin, and the Upper Mississippi River basin. Each one of these systems contains certain species of fishes not found in one or both of the other systems. All together these species make up a large fish fauna.

The largest rivers, which are mostly navigable, include the Mississippi, Minnesota, St. Croix, Rainy, and St. Louis rivers, the Red River of the North, and Red Lake River. All but the St. Croix have their sources within the state and are fed by thousands of lakes, creeks, and brooks. Minnesota has an area of 84,287 square miles, of which 5637 square miles are water. Within the state are well over 10,000 lakes. The largest is Red Lake in the north central part of the state, which has an area of approximately 440 square miles. Other large lakes are Cass, Leech, Winnibigoshish, and Mille Lacs, all tributary to the Mississippi River. The numerous deep, clear, rocky lakes in Cook, Lake, and St. Louis counties are mostly within the Hudson Bay drainage system. The remainder of the lakes in these counties are within the Great Lakes basin and drain through numerous streams into Lake Superior.

The conditions of Minnesota waters are changing rapidly, however. Power dams are being built, creating lakes in rivers. Once-drained lakes and swamps are being restored by dams and diversion ditches, thus adding more waters for fish life. Over a period of years forests have been threatened not merely through the activities of the lumberman but more seriously by fires, which have likewise affected the lakes within these areas. Happily there is a vast area of untillable land in the northern and northeastern counties, large blocks of which are still heavily forested and are dotted with innumerable lakes and streams in which relatively undisturbed fish life can be perpetuated indefinitely. In the central lake region, forest fires have been few and have exerted little influence on lake conditions. In the prairie region both streams and lakes have been affected, not only by drainage and intensive cultivation of surrounding lands but by periodic drought as well. It is in the prairie region that the fisheries have suffered the greatest depletion. Obviously conservation measures must be taken. This book seeks to provide information that will be helpful not only to the sportsman but also to all who are interested in conserving our fish resources.

The extensive investigations on which this book is based were financed largely by the Minnesota Department of Conservation and the University of Minnesota. The authors wish to acknowledge also the many helpful suggestions and criticisms given them by Dr. Carl L. Hubbs of the University of Michigan. They are deeply indebted to Dr. Hubbs, to Dr. Karl F. Lagler, and to the Cranbrook Institute of Science for permission to modify and adapt their keys to the minnows and darters of Minnesota. They are under obligation also to Dr. John B. Moyle and Kenneth Carlander for their splendid assistance in the identification of the minnows and darters, and to John Dobie of the Minnesota Department of Conservation, who has spent much time in making the photographs of actual specimens with which the volume is illustrated. The colored plates have been prepared by Ruth Delano of the University of Minnesota. Much of the statistical work on lake surveys, age determinations, and population studies was done with the assistance of several WPA projects. Most of the egg counts referred to were made by Dr. M. F. Vessel at the University of Minnesota. The authors are gratefully indebted to Doctors W. A. Riley and D. E. Minnich of the University of Minnesota, who read and criticized the manuscript. They acknowledge their obligations also to the many graduate students, game wardens, and others who contributed in various ways.

S. E. and T. S.

Foreword to the Revised Edition

This revision is an attempt to bring the book up to date and to correct the various errors which somehow insist on creeping into a first edition. New records of fishes have been incorporated. Dr. C. L. Hubbs has generously aided by pointing out mistakes and obscure passages in the first edition. He also rechecked the identifications of the fishes collected from Lake of the Woods by Evermann and Latimer over thirty years ago and now in the U.S. National Museum. The numerous errors which he discovered have altered the distribution of many species.

Several illustrations which have been added were provided by Mr. Lytton Taylor, outdoors writer for the *St. Paul Dispatch*. Much of the material in the first fifty pages has been rearranged and expanded. Some of this material appeared originally in short articles by the senior author at various times in *The Minnesota Volunteer,* a publication of the Minnesota Department of Conservation.

S. E.

Table of Contents

DIAGRAMS

FIGURES

A Fisherman's Luck

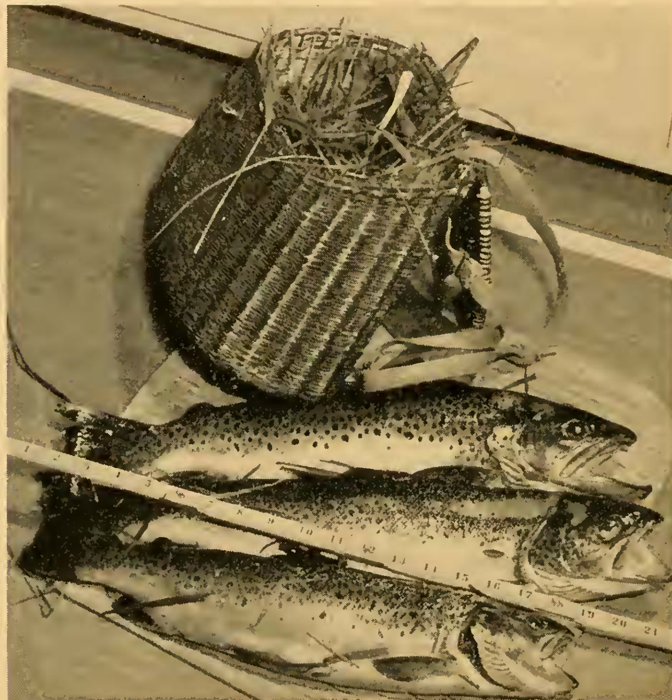
On what does success in fishing depend? Fishes have furnished one of the oldest and most popular of sports throughout the world and for all peoples. Ever since primitive man invented the fishhook his descendants have been searching for a sure method to make fishes take it. Since the days of Izaak Walton much has been written on the subject, but most fishermen are still blundering along. Success in fishing depends partly on perseverance, partly on skill, and partly on luck, any one of which may predominate. Perseverance is a personal quality and can be cultivated. Skill can be acquired too. On the other hand, luck is an unknown factor.

It is indisputable that on some days fishes do not bite as well as on others. Censuses secured from many anglers on the number of fishes caught per fishing hour prove this fact. Some people believe the weather determines whether the fish will bite or not. Some believe that falling atmospheric pressure will cause many fishes to bite. Others believe that fishes bite according to the phases of the moon. None of these explanations has yet been proved. As far as we know, fishes bite only because they are hungry or because they are pugnacious and so strike angrily at the intruding bait. Then, too, fishes must be capricious, for almost every fisherman can remember times when his wife at one end of the boat hauled in one fish after another while he at the other end could not get even a nibble or a strike. Such experiences as these leave little doubt that luck plays a part in fishing.

To become a successful angler one must have some knowledge of the habits and requirements of the various species of pan and game fishes. It is part of the purpose of this book to supply some of the knowledge, not by giving explicit directions for catching any particular fish, but by providing such information about fishes as will enable the intelligent fisherman to direct his fishing efforts more wisely. No one can learn to be a successful fisherman merely by reading a book. There are no fixed rules as to methods or baits, although certain general methods and classes of baits may apply more to one species of fish than to another. However, some species will sometimes show a distinct preference for certain baits and then without advance notice will change their preference. One summer the crappies in a certain lake were biting readily on grasshoppers and apparently were not interested in anything else. The next summer they were satisfied with nothing less than live minnows.

Certain techniques of fishing are more successful than others for catching certain species. Still-fishing with the time-honored bait of worms is largely relied on for catching sunfishes, perch, and bullheads. However, an occasional bass, crappie, walleye, or northern pike can also be caught by this method. Bass fishing, on the other hand, requires a much more specialized technique, which differs from that necessary to catch walleyes, northern pike, or trout.

Fishing for different species is generally done in different waters. Bass are usually found in the weeds and three or four types of bait must be tried until a successful one is found. The largest sunfishes and crappies often congregate out beyond the weeds where the bottoms



Fisherman's luck, a nice catch of brown trout.

drop off to deep water, but after sunset they may rise to the surface over shallow weed beds. Walleyes are usually in the deeper waters and respond best to live and artificial minnows and to still-fishing, trolling, or casting. Sometimes, however, the bass may be in the deeper waters, and the walleyes, particularly in the evenings, in the shallow, all of which demonstrates that a single rule is of little value. The fisherman must use his judgment and when one method fails must try others, always keeping within the general class of baits and lures suitable for the particular fish he is trying to catch. Often every method will fail and nothing will induce the fish to bite.

Since fishing depends on the way fishes bite, every fisherman should know something about their feeding habits. These habits vary greatly. It is well known that walleyes seem to feed more after sunset, the time of day when northern pike sometimes stop feeding. This observation is corroborated by the results of experimental nets, which usually show the walleyes coming into shallow water after sunset and the northern pike moving out into deeper waters.

Such fishes as bass, sunfishes, crappies, and bullheads eat about one-twentieth of their body weight per day during the summer. There seems to be a limit to their capacity, which can generally be measured as the total amount of food they will consume on an empty stomach. When a fish has been fed until it will eat no more, it takes very little during the following 24 hours. The time varies with different species. Even if this quantity of food is divided into a series of feedings, the fish will eat very little after it has reached its capacity. This may explain why fishes sometimes do not bite, especially in seasons of abundant food production.

Though fishes usually bite because they are hungry, some species strike because they are pugnacious. The male bass strikes at any moving object near its nest. Though it eats very little during the breeding season, it is highly pugnacious at this time.

Seasonal changes, particularly in temperature, cause considerable difference in the feeding habits of fishes. The length of daylight may also be a factor. All fishes consume less food in winter than in summer. Some fishes, such as northern pike and walleyes, feed more or less throughout the winter. Other fishes, like black basses and sunfishes, seem to become semidormant in winter. In the aquaria at the University of Minnesota such fishes as largemouth bass, sunfishes, and dogfishes almost cease feeding during the winter, though the water never freezes. One winter when the water was kept at summer temperatures these fishes continued feeding and in a month's time had exhausted their normal winter minnow supply.

Crappies alone of the sunfish family are heavy winter feeders in northern waters. Although they will bite readily throughout most of the winter, often during the late winter months or early spring there comes a time when they almost stop feeding. We find that crappies frequently change their diet entirely during the late winter months and feed almost exclusively on planktonic crustacea, which at other times do not form any considerable part of their diet.

Bluegills do not bite readily in northern lakes in winter and so it has been assumed that they do not feed extensively during the colder months. However, in Michigan it was discovered that they would bite readily on certain live aquatic insect larvae, which are now used successfully as bait for winter angling. Minnesota bluegills when kept in aquaria feed very little in winter.

Northern fishermen have long complained about the poor fishing in August and the last part of July. Creel censuses of northern lakes show that fishes do not bite as well most days during the late summer as they do during the early summer. Several factors may be responsible for this. This season is the period of greatest food production in northern waters and consequently fishes may be well fed and not hungry. Also the water reaches its highest temperature during the last of July and the first part of August, and many fishes may seek the cooler and deeper waters. There is a further possibility that some fishes may not feed much when the water temperature is above their optimum, just as many fishes feed little or not at all when temperatures are extremely low.

How fishes detect their food — whether by sight, taste, or smell — is a controversial question. In some species the sense of taste must be poor, for otherwise they would not eat such unpalatable objects as pieces of wood and bits of corncob. Undoubtedly many game fishes are attracted to their food by sight, but since they are rather nearsighted they apparently detect their food by the movement of the object rather than by recognizing its detailed appearance. Bass and northern pike, even those kept in captivity, do not feed readily on nonliving food.

The best results in feeding dead animals to bass are generally obtained by moving the food over the surface of the water. The bass usually take it readily under these conditions. One smallmouth bass kept for some years was first fed on live mice from the janitor's traps. Dead mice held no attraction until it was discovered that if the mice were pulled by the tail over the surface of the water the bass would take them readily. It was also discovered that the bass would strike at a finger moved through the water.

Different fishes attack their food differently. Bass, walleyes, and dogfish spot their prey, turn and eye it momentarily, and then seize it. Sometimes they will mouth it for a second before swallowing it. Northern pike and muskellunge will poise aimed at a minnow. As long as the minnow is stationary they do not strike, but when the minnow moves they strike it almost faster than the eye can follow. Gars slide smoothly alongside of their prey, dead or alive, and with an easy and graceful sideswipe seize it in their long jaws, completely severing a large fish into halves. Most game fishes swallow their food head first. Their prey may be seized by the tail but it is usually shifted into proper position before being swallowed.

Because of this propensity of many game fishes to strike moving objects, the fisherman can fool them with artificial minnows, plugs, and spinners. Frequently fishes follow an artificial bait of this nature but seem unable to make a decision to strike. Sometimes a little inducement through the sense of taste or smell may help. An angleworm or a minnow on the hook of the spinner will usually give just enough inducement to cause the fish to strike when otherwise he might not.

Some fishes, particularly those that feed at night, find their food by the sense of smell or taste rather than by sight. The sense of taste in fishes may be on the lips, the skin, or the barbels. Bullheads become very much excited when food is thrown to them; they swim and gyrate about the food, trying to locate it. They must come close or touch it before they can seize it, and there is no evidence that they see it even then.

Carp kept in aquaria at the University of Minnesota are fed corn. They mouth over the bottom until they locate the corn and then suck it up with some sand and mud. They forcibly eject the entire mouthful and swimming ahead suck the corn back in before it settles to the bottom. Thus they separate the corn from the sand and mud and at the same time make the water muddy.

Paddlefish feed almost automatically, apparently without need of sight, taste, or smell, although it is claimed that they locate water rich in microscopic food by means of taste or smell. They swim slowly with a spiral motion. Their mouths are always wide open, the water passing in and out through the gill-clefts. The microscopic organisms are strained out continuously and swallowed as they accumulate. In the same way some species of the whitefish family, such as the cisco, feed extensively on planktonic crustacea, which they strain from the water by means of fine gill-rakers. This diet must be rather monotonous, at least as far as effort is concerned. As a group, however, no animals have a greater range of food than fishes.

All fishes have a general fishy taste, but most fishes have some individual flavor. The general fishy taste is not limited to these animals but is a property of aquatic life in general. Some water plants taste fishy. The individual flavor of fishes is partly influenced by the food they eat. Any fish, no matter how high it ranks as a game species, may become highly unpalatable if it feeds on certain substances. Bullheads, carp, suckers, crappies, sunfishes, and buffalofish when feeding on muddy bottoms, particularly where decayed vegetation is abundant, have a decidedly muddy or weedy flavor. However, when these same fishes are transferred to waters with clean bottoms, the taste of the flesh becomes much more palatable in a few weeks. The same is true of the flavor of game fishes, but to a lesser degree, because such fishes usually restrict their diet to living prey. Fishes from waters polluted by sewage usually have a flavor reminiscent of sewage gas. The fisherman should always remember that the cleaner the water from which he catches his fish, the better will be their flavor.

Fishing Technique

The art of fishing has become a highly complicated one, with a variety of techniques. It is outside the scope of this book to give detailed instructions about fishing techniques — there are excellent field manuals available. But the amateur angler may find useful a general discussion of fishing methods.

If fishes could read and learn the rules, fishing would be a much simpler and more certain art. Then it would be safe to lay down a definite technique for catching each species.

Each of the accepted methods of fishing has its own class of devotees who worship their particular art to the utter disregard of every other. The scorn and disdain of the fly fisherman for the cane-pole fisherman is scarcely equaled. In the Lake States a vast number of the anglers belong to the cane-pole class. Members of this class sit on a bank or in a boat hour after hour, holding a long cane pole with a line and hook baited with anything from angleworms to bits of liver or perch. Patiently they watch the bobbing float and wait for some fish to swallow their bait, seldom pulling in their line until they are certain the nibbling fish has securely swallowed their hook. They usually are not particular about the species they catch, but are glad to get any one of a wide variety.

A modification of this type of fisherman is the tight-line fisherman, who fishes without a float and often without a pole, using only a hand line with which he expertly hooks any fish that nibbles at his bait. These fishermen constitute the great majority of the anglers of the northern lakes. They are usually more interested in catching enough fish to cover the frying pan than in refined methods of fishing or the technical aspects of fish habits.

A more advanced group of fishermen are the bait casters, who constitute a sort of middle class. They have graduated from the cane pole and place their trust in short casting rods. Using various artificial minnows, plugs, spoons, and spinners, they troll and cast into all possible habitats, hoping to entice certain more exclusive game fishes to strike at their moving lures. Frequently they embellish their lures with more substantial bait like minnows or frogs.

The aristocrats among anglers are the fly fishermen, who may be divided into dry- and wet-fly devotees. Using the lightest of tackle, they limit their catches to the game fishes that will rise to artificial flies. Most trout fishermen belong to this class. Of all fishermen, fly fishermen may truly be said to fish more for sport than for fish. Although the fly fishermen are relatively few in number, they are very

Spear houses on a Minnesota lake.

enthusiastic and constitute the most active of our various classes of anglers.

Fishing is usually a warm weather sport, but in many northern states winter fishing through the ice has long been a popular sport. Certain fishes can be taken readily through the ice by spearing and by angling. Spearing involves the use of a tiny dark house placed over a hole in the ice in which is usually suspended a live minnow or other lure to attract the fish. The fisherman sits in the dark house watching the dimly lighted water below, his spear ready to impale any fish which approaches his lure. This type of fishing is highly selective because the fisherman can see and choose his fish before spearing it. Consequently larger northern pike and other fishes are taken by this method than by ordinary angling. In many states spearing is now eliminated or restricted by law.

Angling through the ice is the most popular form of winter fishing because it involves only the use of simple tackle. All the equipment required is a hook, a line, a float or bobber, a short rod or stick, and some implement to cut a hole in the ice. Usually a live minnow is used for bait and the fisherman patiently shivers and waits for a bite. Less rugged fishermen drive their automobiles alongside the holes and turn on the heater and the radio. Great numbers of crappies, perch, and an occasional walleye and northern pike are caught by winter angling.

The catching of a fish involves many details which confuse amateurs and bother even experienced fishermen. The correct method of baiting a hook is not as simple as the common practice of spearing the bait with the hook — many minnows and frogs are lost because they are improperly placed on the hook. Hooking a minnow through the tail, jaws, gills, or belly usually results in a waste of bait. For casting the minnow should be threaded on the hook by passing the hook in through the mouth and out through the side as far back of the dorsal fin as possible. Some safety-pin hooks are on the market which thread the minnow on the pin alongside the hook. For still-fishing, when it is desirable that the minnow display some motion, the hook should be passed through the back muscles just under the dorsal fin.

Most fishermen hook frogs through one or both jaws, leaving most of the body and legs dangling below the hook. After a few casts the frogs tend to loosen and soon fly off. Furthermore, the fish generally has to grab and swallow the entire frog before getting to the hook. There are available several varieties of special frog hooks, some with a harness for the frog, which place the frog far enough up on the hook so that any fish is likely to be hooked when it first grabs the frog.

Worms can simply be threaded on the hook, leaving any surplus to dangle from the end. A more attractive arrangement can be made by looping the worm and passing the hook through each loop. Several worms can thus be crowded onto a single hook, providing a tempting bait that may attract a bass even when all else fails. One trouble with such a bait in many northern lakes is that small perch and sunfishes delight in nibbling off the loops without touching the hook. Grasshoppers and various other insects should be threaded on the hook.

Fishing rods and a large variety of tackle are necessary for the more refined methods of fishing with flies or by bait casting. The equipment necessary for fly fishing and bait casting includes rods, reels, lines, leaders, and lures. These items differ greatly for the several methods of fishing, as well as for the types of fishes sought.

Many fishes other than trout can be caught with a fly rod. Great sport can be had using a fly rod for both largemouth and smallmouth bass, striped bass, rock bass, crappies, sunfishes, walleyes, northern pike, and perch.

The fly rod is light and slender and should have a whiplike action. Some are made of steel and others of split bamboo. Steel rods are often stiff and subject to vibration, but they are sturdier and better built for rough use than the bamboo rods. Split-bamboo rods are the favorite with most experienced fishermen. Expensive rods usually last longer, but a cheap rod may have as good action as a more expensive one. Rods are often gauged by their weight, but the value of a fly rod is its casting ability rather than its weight. Rods of the same weight and length may differ greatly in their casting ability.

A number of reels for fly fishing are on the market, most of which are single action. They may or may not have an automatic action for reeling in excess line. Most fly fishermen believe that a reel should balance the weight of the rod. Fly reels serve mostly as a storage place for the line, which is stripped off the reel by the hand as it is cast out. Some anglers use the reel to pull in the fish when it is caught, while others merely strip the line in.

An oiled or dressed line should be used for fly fishing. Untapered lines can be used for wet-fly fishing and for casting heavy surface lures. Tapered, hard-finished lines should be used for dry-fly fishing and many prefer them for all fly-rod fishing. The lines are likely to crack if allowed to stay on the reels for any length of time. They should be dressed with one of the several preparations on the market, taken off the reels, and hung in hanks when not in use.

The line should be fastened to the lure by a gut or nylon leader, the length of which may vary from three to twelve feet. The leader gives a semitransparent connection between the lure and the line in order that the fish may not detect any connection. Gut leaders should be soaked before using. It is not necessary to soak nylon leaders, but they seem to be more pliable and to work better if soaked first.

There are two methods of fishing with a fly rod. One method is with dry flies, which float on the surface; the other is with wet flies, which sink below the surface. In either kind of fishing, a large assortment of flies and other fly-rod lures is necessary since the bait used successfully one day may fail the next. Most artificial flies are made to imitate various insects which may form a part of the fishes' diet. A vast number of patterns have been designed for trout, salmon, and other fishes. A true fly fisherman studies the type of insect which he thinks the fish are feeding on and then tries to offer them his best imitation. Dry flies must float, so they usually have a large body and should be doped with paraffin oil. The line should also be kept well oiled. The aim in dry-fly fishing is to drop the fly on the water so that it resembles an insect alighting on the surface. Consequently, dry flies should resemble adult insects.

Wet flies are unoiled and are constructed to sink readily. They resemble immature (nymphs) and larval insects, which normally live under water, as well as adult insects. Wet flies should be allowed to sink slowly in the water, and then slowly reeled in. Other fly-rod lures, some of which can be used either dry or wet, are often very effective. These consist of spinner combinations, tiny wooden and cork plugs, spoons, and feather combinations, which by proper handling of the rod can be made to act like a darting minnow. There are other popular lures such as cork and feather combinations, and small rubber frogs and hellgrammites, which often prove attractive on the surface.

The purpose of fly fishing is to drop the lure into any desired spot in such a way as to make the fish think it is natural food and unconnected with a line. For dry-fly fishing always cast upstream so that the fly can float downstream in a natural manner. Try to drop the fly on the water so that it will fall lightly. The art of fly casting is not as complicated as it seems, but depends largely on practice. Holding the rod in front, strip off ten or twelve feet of line with your left hand, and then quickly raising the rod cast the line behind you. As the rod reaches a vertical position, hesitate long enough for the line to straighten out behind you. Then cast forward, stripping out more line

They start young and begin with the cane pole.

with the left hand. If you do not have the desired amount of line out as the lure reaches the water, cast it back again and repeat until you have sufficient line to allow your lure to drop in the water where you want it. The important rule is not to allow the rod to go back any great distance past a vertical position, and to allow sufficient time for the line to straighten out behind but not enough for it to drop into a bush or the water. If the line is not allowed to straighten out, the lure is liable to be whipped off. Many fishermen advocate using the motion of the right forearm and wrist, holding the elbow close to the body, but others achieve successful casting with the open arm movement.

Bait casting involves the use of a short and relatively heavy rod and the casting of heavy plugs and other lures which are then reeled in slowly to imitate a live fish or other natural bait. The art of bait casting demands some practice, but almost anyone can soon manage to get the lure out to some distance and drop it where a fish should be. Backlashes will occur, but after some practice and by using the thumb for a brake many can be eliminated. Reel the lure in slowly, allowing it to hesitate every few feet in case some doubting fish needs time to make up his mind.

In trolling, too, it is important to give the fish plenty of opportunity for striking at the bait. Fishes may strike if you troll too fast, but they often miss the hook. Sometimes they overshoot and are hooked in the tail instead of in the proper place. When trolling let out from seventy-five to a hundred or more feet of line. It is well to keep twenty-five to fifty feet of line in reserve on the reel.

The array of lures displayed by the average sporting store may be bewildering. Most of the many kinds displayed are only modifications of several basic types. The main purpose of all lures is to present an imitation of some natural food animal or to make such a bewildering flash that no respectable game fish can resist it. Any lure that has plenty of action when drawn through the water has possibilities, because game fish are largely attracted by motion. One type of lure utilizes spinner combinations. Spinners may be combined with various artificial flies, bucktails, or hooks baited with live minnows or pork strips. The spoon types are very popular for northern pike and many other fishes. Spoons come in a large assortment of colors and in various sizes. Some people are very particular about color, but the writers doubt that most fishes are so particular. The authors have often used brightly colored spoons until the paint was worn off and yet the spoons continued to be as attractive as when new.

Wooden baits or plugs are made in a wide variety of forms. Some imitate a minnow and become submerged when in action. Others skim over the surface and a fish striking at them must break water with a spectacular splash. Any wooden lures with sufficient action have possibilities. One kind that has become very popular dives deep into the water and darts swiftly from side to side. Some of these lures are made in small sizes suitable for a fly rod. The hooks on various lures tend to become dull after long usage and a hard-striking fish may not become hooked. The hooks should be frequently inspected and sharpened with a small whetstone or file, which should be part of every fisherman's equipment.

All artificial bait-casting lures should be fastened to the line by a strong wire leader combined with a swivel. The line may be selected to suit the fisherman's taste. Braided and nylon lines are popular. Better casting can be done with a lighter line, those of twelve to eighteen pounds' test proving most satisfactory, although some use even lighter lines. Heavier lines are better suited for trolling. After fishing dry your line by stringing it between two trees or posts. Wet lines deteriorate very rapidly.

Some fish grab the lure hard and are hooked at the first strike; others grab the lure in their mouths without being hooked. On finding it unpalatable they will quickly spit it out unless the fisherman sets the hook. There is no positive rule for setting the hook, but the usual method is to pull back strongly on your rod after feeling the first strong tug as the fish strikes, and then start to reel in. If you have hooked your fish, he will give several tugs as he tries to throw the hook from his mouth. He may even start to pull away and may break water. Whether you are bait casting or fly fishing, try to keep a tight line on your fish at all times. It is easy for a poorly hooked fish to throw off the hook if the line is slack. Start reeling him in but always be prepared to let him have line when he wants it. Usually he will make several short rushes away and then continue to come your way as you reel in again.

When the fish nears the boat or the fisherman, he usually starts fighting in earnest. Give him line and then reel in the moment he weakens. Keep this up until your fish is tired and can be brought up for landing. Many a fish escapes because he is not sufficiently subdued; when brought close up for landing, he will give a wild dash, breaking the line unless the fisherman is alert and releases the reel to give the fish line for this final rush. The surest way of landing your fish is with a dip net, although some expert fishermen can successfully divert the final rush of a large fish so that he will flip over into the boat. Many fishes, both large and small, are lost if they are lifted out of the water by the line, because when clear of the water their weight, which was largely displaced in the water, tears the hook from their mouths.

Fishes caught in warm weather may spoil quickly. Sometimes a fish placed on a stringer early in the morning dies in a short time and shows signs of decomposition by afternoon. If possible fishes should be kept alive until they can be dressed and placed on ice. Fishes are often fatally injured by the hook, especially if the hook penetrates the gills or the nearby circulatory structures, and may die soon after being caught. Fatal injuries may occur through careless handling; avoid touching the gills because slight injuries to these delicate structures can kill the fish.

If a fish is not seriously injured, it can be kept alive all day by using the safety-pin type of stringer and stringing each fish separately by passing the pin through the lower jaw. The practice of pinning the upper and lower jaws together may prevent the fish from opening its mouth for respiration. Never pass a stringer through the gills since this injures the gills and kills the fish. If live-boxes or tanks with suitable running water are available, fishes can be kept alive for several days. Fungus growths are liable to occur if the water is warm. In stream fishing, all fishes placed in a creel will spoil quickly unless they are killed by a blow on the head and packed in moss or grass. They will keep even better if they are eviscerated.

State laws should be consulted when it is necessary to transport fishes for some distance. In some states the law requires the head to be retained on fishes in transit. Gills and entrails spoil very quickly and may taint the rest of the fish unless they are removed. Portable ice-boxes are very useful for transporting fishes by automobile.

Sphagnum moss, plentiful in the bogs in the far north, makes an excellent insulator for icing fish. Fishes packed with a few pieces of ice in a box lined with sphagnum moss will keep fresh for several days. If ice is not immediately available, the gills and viscera should be removed and the body cavity filled with sphagnum or grass. Fishes should be protected from flies at all times.

The further preparation of a fish depends on the size, the kind, and individual preferences. Most people merely scrape off the scales, cut out the fins, and remove the head and viscera. The fishes are then either sliced or split into pieces convenient for cooking, or they may be left whole for baking. Many fishes are improved by skinning rather than scaling. This tends to eliminate much of the strong fishy taste and is recommended particularly for those fishes which are excessively slimy. For skinning, start by making an incision with a sharp knife around the body back of the gills and lengthwise along the middle of the back and belly, taking care to cut around both sides of all fins unless they have already been removed. The skin can then be removed from each side by chipping it away with a sharp knife. A smoother job can be done by loosening the skin with the fingers aided by the knife along the incisions and then working and pulling the skin off backward.

Fishes such as walleyes can be easily skinned by splitting the fish and laying each half skin downward on a board. A sharp knife is then passed between the flesh and the skin back of the shoulder. The half is held firmly on the board, and the knife with the edge turned slightly downward is passed backward to the tail, severing the skin and scales from the meat. Walleyes, tullibee, whitefish, and some others can be easily filleted by splitting and lifting out the backbone and ribs with a knife. Many fishes can be filleted by taking the whole fish and merely cutting the flesh on both sides away from the backbone and ribs.

Fishing is an art, and to be truly successful one must study and know the fishes. It has also become necessary to discover how to conserve and maintain an abundant supply of fishes in order to practice this art. The chapters immediately following are devoted to the dynamics of lakes, the maintenance of conditions that enable fishes to live, and the management of waters for greater production of fishes.

Lake Dynamics

Lakes are usually more or less closed bodies of water, each forming in a broad sense a small world of its own. Within their limits many activities proceed automatically, making it possible for life to continue indefinitely. Fishes represent the end of a long cycle in which the chemical elements producing food pass from raw substances in the water and on the lake bottoms into food for the higher forms of fish life.

Studies of northern lakes show that these lakes vary considerably in the production of both food and fishes. Some lakes are poor in productivity, others are rich, and their differences are due to chemical fertility limited by physical and biotic conditions. Owing to the variation in chemical, physical, and biotic conditions from lake to lake, no two lakes are identical in productivity.

The most beautiful clear blue lakes are not necessarily the most productive of fish life. In fact, the rock-bound lakes, with the clearest of water, are among the least productive as far as pounds of fish per acre are concerned. Although the fishes of these lakes may run larger on the average than in other lakes, there are not as many of them. The sizes and kinds of fishes are no measure of fish production in these lakes of low fertility.

The actual test of the productivity of a lake is the total number of pounds of fish that can be produced, and not the size of individual fishes. Fish size is a matter of individual competition, depending on population density.

In matters of production a lake may be considered in the same way as any piece of land. Land raises products of various sorts — pasture, forest, and grain — from which a crop of livestock or upland game can be produced. Fishes may be considered a water crop, one that takes from two to three years to mature. Consequently, a lake must not only raise abundant fish food in the summer, but also provide suitable winter conditions for several years in succession in order to mature a fish crop. In this way fish production differs from that of upland game, a crop of which can be produced at the end of each summer.

Primarily fish production is based on the richness of a body of water, just as the production or yield of a farmer's field is based on the fertility of the soil. The factors causing fertility in a lake are the same as those that make the soil productive. But just as a farmer's crops depend not only on fertility but also on proper drainage and cultivation, so food and fish production in a lake depend on proper temperature, proper spawning conditions, suitable shelter, predator relations, and a number of other conditions.

The most important factors that determine the productivity of a lake are the elements of fertility, various forms of nitrogen, phosphorus, calcium, and many other elements. These are conditioned by other factors necessary for life such as depth, temperature, bottom types, and dissolved gases.

Food production is usually considered first in the dynamics of a lake. Plant life is the basis for most fish foods and so green plants are the first stage in the cycle from chemical elements of fertility to fish production. These plants include not only the large water weeds along the margins, but also the myriads of tiny and often invisible algae that swarm throughout the water. Although only a few species of fishes eat large quantities of plants directly, plants form the food of many of the lower animals eaten by the forage fishes, which are in turn eaten by the game fishes.

Plants obtain food from the bottom and from chemical substances dissolved in the water. The fertility of a lake therefore starts with the chemical condition of the bottom and the chemical substances dissolved in the water. Since the water dissolves from the bottom almost everything that is soluble, it is possible to estimate the chemical fertility of the bottom by an analysis of the water.

In a body of water the elements of fertility necessary for the maximum production of food and fishes are various forms of nitrogen, phosphorus, calcium, and some other substances — the same in general as the elements of fertility in the soil (Surber and Olson, 1937). Pure water, that is, water with few chemicals dissolved in it, is usually almost sterile for both food and fish production. On the other hand it is possible to have too much of these substances in the water, which is then called mineral water. Several lakes in western Minnesota, particularly since they were reduced in volume in past drought years, have assumed the character of mineral lakes.

Carbonates, usually found in some form of calcium carbonate, or lime, are among the important chemical substances present in lake water. When a considerable amount of lime is present, the water is usually called hard, and if the amount is small it is called soft. Lake Superior, the border lakes, and the lakes in the northeastern portion of Minnesota, where limestone is scarce or absent, usually contain soft water. The waters of lakes of this type produce only a small amount of vegetation and fish food.

Lime and other carbonates in the water are necessary for proper plant growth, because from certain forms of lime (bicarbonates) plants can obtain the carbon dioxide necessary for the manufacture of plant food and the liberation of the valuable oxygen. Carbonates are less

A thousand-pound catch of paddlefish made by the Minnesota Natural History Survey in Lake Pepin, July 10, 1900.

soluble than the bicarbonates, but in the presence of carbon dioxide or carbonic acid they readily change into the more soluble bicarbonates. Plants can utilize some of the carbon dioxide from bicarbonates. In doing so they change the bicarbonates back to the less soluble carbonates, which sometimes precipitate, thus forming the extensive marl deposits common in northern lakes. Carbonates are so important that the fertility of a lake can often be estimated from the amount present in the water.

The many important food elements all pass from one stage to another, eventually ending in the body of some aquatic plant or animal, which dies and decomposes, liberating these elements back into the water to be used over again. This cycle is a repetition of the one that takes place in the farmer's field when crops are plowed under in order to maintain the fertility of the soil.

It is interesting to find that the production of food in a lake in actual pounds per acre is far greater in areas where the surrounding soil consists of fertile farm lands. Some of the lakes in central Minnesota carry as high as 80 pounds (dry weight) of animal food per acre in the shallow waters. The lowest number of pounds of food per acre is found in the lakes that are in areas of rocky and thin infertile soils. Some of the rocky lakes along the Gunflint Trail carry only two-tenths of a pound (dry weight) of food per acre. This correlation is partly due to the fact that the lake obtains its original supply of fertile elements from the drainage waters of the surrounding areas and relies on this source to replenish the elements it loses through ground seepage or outlets. A lake can produce only as many pounds of fish per acre as there are available agents of fertility and in general is no more fertile than the surrounding soils.

Equal in importance to the dissolved contents of the water are the types of bottoms present in a lake. Plants and food organisms have distinct preferences as to types of bottoms. It is impossible for most species of plants to grow in any abundance on solid rock bottoms, and similarly few forms of animal life can find subsistence on bare rocks. Shifting sands likewise are too unstable for the existence of plants or food organisms. On the other hand soft muds, though they foster luxuriant plant growth, may smother many animals. The best type of bottom for food production is a relatively firm but fertile bottom, such as one of mud and sand.

The contour, or shape, of the bottom of a lake may have an important effect on the total amount of food produced. The conditions of warm, fertile lakes usually make only the bottoms above the 20- or 30-foot level suitable for food production. In these lakes the maximum production of food is above the 15-foot level, which is the usual limit of sufficient light penetration for most plant growth. Deep, fertile lakes with steep bottoms are relatively low in production, while shallow, or only moderately deep, fertile lakes with gently sloping bottoms are relatively high in production. The shape of the shore line also influences the total production in a lake. Since the most food is produced in the shallow waters near the shores, a lake with an irregular shore line and many bays has much more productive area than a lake with a smooth shore line and few bays.

The fertility of a lake is not inexhaustible. It is conceivable that a lake may become reduced in fertility just as soil may become drained from overfarming. Though we have no evidence that such a reduction in fertility has taken place to any serious extent in our lakes, it is only good conservation practice to watch for and avoid any undue drain on the fertility of our lakes.

No matter how fertile a lake may be, the oxygen conditions sometimes prove a limiting factor in the production of fishes. Fishes, like all living things, must have a constant supply of oxygen in order to live. Oxygen depletion during a severe winter or as the result of excessive vegetation may make it impossible for fish to survive in an otherwise suitable lake.

The oxygen fishes use for breathing is dissolved in the water, just as salt or sugar may be dissolved. Water can hold only a small amount of oxygen, and this dissolved oxygen is the only source available for the respiration of fishes and most other water animals. The dissolved oxygen in water comes from two main sources — aquatic plants and the atmosphere. All green plants release oxygen as a by-product of photosynthesis, the process in which they take in carbon dioxide or carbonic acid gas and manufacture starch for plant food. This process is the natural way of disposing of the carbonic acid gas produced by decomposition and the respiration of animals and plants. Photosynthesis takes place only in the presence of sunlight.

Water plants, from the big weeds to the microscopic algae which constitute the green scum, liberate oxygen on days when the sun shines. On a bright day one can observe many streams of tiny bubbles ascending through the water from the leaves of a healthy water plant. These bubbles are pure oxygen. They become smaller as they ascend, and many disappear before reaching the surface because they dissolve completely in the water as they ascend. The water over a weed bed on a bright day is usually supersaturated with oxygen, while on a cloudy day or at night this same water may become very deficient in oxygen because the plants cannot liberate this important gas in the absence of sunshine. Even in summer a lake may occasionally suffer oxygen depletion when there are long periods of cloudy weather without any wind action.

The only other source of oxygen in a lake is from the air above the water. When dissolved, oxygen diffuses or spreads very slowly in the water. The surface of the water, in actual contact with the air above, absorbs large amounts of oxygen, but owing to the slow diffusion the oxygen seldom travels beyond a thin film next to the surface, unless the water is agitated by strong waves or currents. In rivers the current alone, through its changing contact with the air, will keep the water well aerated, but in lakes currents are usually weak or entirely absent. Thus the principal source of oxygen in lake water is from the aquatic plants.

The oxygen in a lake is consumed in three principal ways: by fishes and other aquatic animals; by plants that use oxygen as well as liberate it; and last, and perhaps most important, by bacteria and decomposing organic matter. The decomposing organic matter consists partly of dead animals, but mostly of dead plants and the partially rotted ooze that covers the deeper bottoms of our lakes and slowly decays through bacterial activity, creating a heavy demand on the oxygen supply. Consequently, lakes that have abundant vegetation and bottoms covered with rich muds draw heavily on their oxygen supply. An excess amount of vegetation becomes a serious oxygen consumer during the winter. The production of oxygen ceases when the ice is covered with snow, and the supply on hand must last throughout the winter. In deep lakes, which have a considerable volume of water, the supply is usually sufficient, but in shallow lakes, 6 to 10 feet deep, the volume of oxygen that can be stored is seldom sufficient to meet all these demands.

The situation is further aggravated by the fact that these shallow lakes produce the greatest amount of vegetation and consequently have a large amount of dead plant life to decay during the winter. In shallow waters the ice may be so thick that the volume of the water is reduced to a point where it cannot hold sufficient oxygen to last all winter. This critical condition results in a fish-kill. In northern Minnesota many rocky infertile lakes with depths as shallow as 8 feet do not lose their oxygen, while in southern and central Minnesota mud-bottom, fertile lakes of twice that depth may lose their oxygen.

During the winter many of the fishes are semidormant and require much less oxygen than when fully active, but even so fish-kills as a result of oxygen depletion often occur. The fishes are sealed in the lake throughout the winter by the ice, which is thicker in Minnesota than in most other states. The survival of these fishes depends on the presence of a sufficient amount of oxygen stored under the ice at the time of the freeze-up or the penetration of sufficient sunlight to enable the plants to release enough oxygen to meet the demands of the lake and of the fishes until spring.

This fact was clearly demonstrated several years ago in Minnesota, when one of the shallow lakes in Anoka County was studied throughout the winter. This lake was approximately 6 feet deep, with a rich mud bottom, and contained thousands of bullheads. Late in November it froze over solidly and the water was completely sealed from the air by at least 12 inches of ice. Oxygen tests were made frequently through holes cut in the ice, and the supply was found to be normal. Although the ice became 20 inches thick, this condition continued through December and on into the second week in January. The plants were receiving enough sunlight through the ice to enable them to liberate sufficient oxygen to maintain the oxygen content of the water at a level equal to that of the summer. In the second week of January the ice was covered with 6 inches of snow, and the sunlight could no longer penetrate. Two days later oxygen was absent throughout the waters of the lake. In the spring thousands of dead bullheads lined the shore as the ice melted. Not one living fish could be found.

In addition to oxygen depletion as the cause of winter-kills, other conditions may arise and become important factors in killing fish. Fish-kills have been noted under conditions of relatively low oxygen in one lake, whereas in another lake of equally low oxygen content the fishes survived, indicating that other factors, probably associated with decomposition, such as hydrogen sulphide or changes in carbon dioxide tension, may play an important part in killing fishes. Furthermore, there is no doubt that the physiological condition of the fishes may determine their tolerance to these various factors. Of all these factors oxygen depletion is undoubtedly the most important, and the chief cause of most of our fish-kills.

Temperature plays an important part in determining which areas of a lake will be productive. Most animals and plants grow better and more abundantly at high temperatures, although there are a few fishes, such as members of the whitefish family and various species of trout, which must have low temperatures. The temperature of the water depends primarily on the depth. All the heat a lake receives in the summer comes through the surface area exposed to the sunlight. Two lakes of equal surface area, one deep and the other shallow, receive the same amount of heat, and so the deep lake never warms up as much as the shallow one. Consequently we have cold-water lakes and warm-water lakes, depending largely on the depth and surface area. The deepest lake in the region covered by this book is Lake Superior, which because of its great depth of over 1000 feet does not receive enough heat units during the summer to raise its summer temperature more than a few degrees over that of winter. Because most food animals and plants grow faster at high temperatures than at low ones, in the same length of time much more food will grow in the warm water than in the cold.

The major effect of temperature on most of our lakes is the establishment of stratification, resulting in a thermocline and in making only certain parts of lake bottoms available to animals. As the water warms during the summer, the warm water, being lighter than the cold, rises to the surface. By the time summer is well established, a layer of warm water, the epilimnion, usually from 30 to 45 feet thick, lies over the deeper and heavier cold water, the hypolimnion. The intervening area is called the thermocline. In very deep lakes the cold water may have a summer temperature as low as 39° to 40° F. (4° C.).

The cold water is so heavy that it remains at the bottom, and all the heat from the sun is absorbed by the warm upper layer before any of it can reach the cold layers beneath. This stratification becomes so pronounced that after awhile these two layers do not mix. Even at times when the wind, blowing heavily in one direction, piles the warm layer on one side and tilts the bottom layer, the currents in the upper layer may slide over the lower layer without mixing. During the spring and fall, when the lake is either warming or cooling, there comes a time when the temperature of the upper layer is the same as that of the lower layer, and then the thermocline disappears. At this period there is complete circulation or mixing from top to bottom in the deepest parts.

The temperature stratification just described is found only in lakes of 25 or more feet in depth and not more than several miles in diameter. In larger lakes, like Mille Lacs and Red Lake, the action of the wind and waves creates powerful undertows and keeps the water well mixed at all times, preventing stratification. The size of the body of water with the consequent action of wind and waves probably also accounts for the fact that no definite stratification occurs in Lake Superior (Eddy, 1944).

The effect of stratification in fertile lakes is stagnation in the lower layers. The oxygen is soon depleted by any life present and by the decomposition of the bottom muds and organic materials continually settling down from above. Experiments have been made by lowering different species of fishes in wire baskets to different depths in various lakes. In summer the fishes died in a few minutes when lowered to depths below 30 feet, while those closer to the surface always lived. In the fall and spring, when there was no stratification, the fishes lived in baskets at all depths, thus indicating that it was the lack of oxygen and not the pressure that killed these fishes.

The deep bottoms may be rich in fertility, but because of the lack of oxygen, only a few worms and other low forms can live there. How these forms live without oxygen is one of the interesting biological problems. Because of the lack of sunlight at this depth, plants cannot grow and form oxygen. Lower LaSalle Lake in Hubbard County is an example. It is one of the deepest lakes in Minnesota, being 218 feet deep, and is rich in nutritive elements, but the bottom oxygen may be nearly exhausted during the summer months.

In some of the very deep lakes that are low in natural fertility, such as Clearwater, Tuscarora, and Saganaga lakes in Cook County, Minnesota, the volume of water in the lower layer may be enormous. When the lake stratifies in the spring, the lower layer may contain more oxygen than will be used up during the summer by the decomposition of organic wastes. In addition, since these lakes are so infertile that relatively few plants and animals are produced in the upper layer and in the shore waters, there is only a small amount of organic material to decay and use up the oxygen. Furthermore the water is very clear, so that sunlight penetrates farther than in the more turbid, fertile lakes, thus enabling oxygen-producing plants to grow at much greater depths. Consequently the deep, cold bottoms in these lakes have sufficient oxygen to support trout and other cold-water fishes.

Fish Populations

The fertility of a body of water and certain other conditions described in the preceding chapter largely control the poundage and to a certain extent limit the species of fishes produced. However, the size and the rate of growth of the fishes are determined by other factors.

One of the outstanding problems of the fish populations in many lakes is the unsatisfactory size of the dominating species. The enormous number of stunted fishes filling so many lakes is a result of the density of the population in proportion to the carrying capacity of the lake.

Swingle and Smith (1940) showed that a given fish pond would yield a definite number of pounds of fish; that if the population density was low the growth rate was rapid. Kawajiri (1928) showed similar results with rainbow trout. The total available food is evidently the limiting factor.

Under natural conditions the effect of population density upon the growth rates of fishes is difficult to determine. A number of attempts have been made to determine the population densities in various Minnesota lakes, but they have met with little success. The effect of population densities upon growth rates must be largely determined from scattered examples.

In 1938 studies were made of the fish populations of a series of Minnesota lakes in Ramsey County. The population densities were determined by seining large areas and calculating the number of fishes per acre. Data were secured on the bluegill populations in six lakes. These lakes were all of the same general type, comparatively fertile hard-water lakes in glacial drift basins ranging in total dissolved solids from 140 to 270 parts per million. Three lakes showed low populations, 25.34 to 48.63 fishes per acre, and rapid growth, the fish taking 2.82 to 3.48 years to reach a length of 7 inches; three showed high population densities, 80 to 450 fish per acre, and slow growth, the fish taking 4.29 to 4.76 years to reach the same length. The separation into two groups was definite, clearly indicating the correlation between population density and growth.

These studies explain why fishermen may catch large numbers of small fishes in one lake and small numbers of large fishes in nearby lakes. In Long, or Lost, Lake in Clearwater County the bass population is so dense that a fisherman may get his legal limit of largemouth bass within an hour, but they are small, ranging from 7 to 9 inches in length. In this lake the growth is so slow that the bass are calculated not to reach 12 inches in length until they are 5 1/2 years old. In nearby

Lake Itasca, on the contrary, only a few bass are caught each year, but they are 12 inches long when 3 1/2 years old. A similar situation is found among the bluegills in these two lakes. The bluegills in Itasca grow one and a half times as fast as those in Long Lake.

In 1939 in North Lindstrom Lake, Chisago County, the crappies were so abundant that an angler could easily catch his limit in a short time, but these crappies were not over 6 inches long and weighed only about 73 per cent as much as crappies of the same length in other lakes. The growth rate for crappies in this lake was slower than that of most other lakes in the state. The bluegills were also small, weighing only 67 per cent as much as bluegills of the same length in other lakes and showing very slow growth. Apparently the population density in this lake had become so great that growth was extremely slow. Crappies, sunfishes, perch, bass, northern pike, and other species often show large populations of stunted fishes and all the ones examined have shown very slow growth rates.

There is another piece of evidence that population density is an important element in controlling the rate of growth. It has often been noted that when a species is successfully introduced into a new habitat its growth is unusually good, largely because of the small number of individuals present and the lack of competition within the species (Eddy and Carlander, 1939). Walleyes grow more rapidly in the northeastern part of Minnesota, where they have been recently introduced, than they do elsewhere in the state, undoubtedly because of the lack of competition within the species in these lakes.

Creel censuses on many Minnesota lakes have thrown further light on this subject. With the aid of the Civilian Conservation Corps, creel censuses were conducted throughout the summer of 1940 on six lakes in northern Minnesota. Every fish caught was measured, and scales were taken to determine the growth rate. The species studied were largely walleyes, northern pike, largemouth bass, and crappies.

In many of the lakes the catch was small, numbering from 500 to 3000 fishes for the season and averaging from 1 to 5 pounds per acre. However, in one lake studied the catch was very heavy, numbering over 12,000 fishes for the summer and averaging nearly 20 pounds per acre. The rate of catch per man-hour was about the same in all lakes. The growth rate of the fishes was equal to or slightly above the average for that region in all the lakes except one that was heavily fished. In this lake the growth rate was decidedly lower than the average for the region.

From these studies it seems that population density is a factor of great importance in modifying the growth rates of fishes. The productivity of a lake seems to determine the total number of pounds of fish, but the population density seems to control the growth rate of these fishes.

Studies show that the fishes of easily accessible lakes usually have a lower growth rate than the fishes of those lakes that are not reached so easily. Accessible lakes are usually in fertile, agricultural districts and are relatively fertile, whereas inaccessible lakes are usually in infertile, nonagricultural districts and are relatively infertile. When the lake is subject to interference by man, the amount of selective fishing rather than the fertility of the lake appears to determine the size of the fishes.

Although the evidence is not yet conclusive, it seems that these large populations of undersized fishes are associated with heavy fishing. The fisherman is selective and tends to remove the larger fishes. Under normal conditions most fishes produce many more fry than the lake can support. These larger game fishes are the natural checks upon the small fishes, even of their own kind. When the large fishes are removed, the small fishes have no check and so survive in large numbers, becoming crowded and stunted.

The selectivity of the angler is largely responsible for many of the fish population troubles, including the important perch problem. Perch are not as popular with anglers in Minnesota as they are in some other states. In many of the larger lakes, such as Ottertail and Mille Lacs, the fishermen's catch consists predominantly of walleyes and contains very few other fishes. In these lakes the fish population consists of almost equal parts of walleyes and perch, with a very small proportion of other fishes, even the northern pike. These proportions do not constitute a highly desirable balance and can be attributed only to the heavy, one-sided fishing for a single favorite. Such methods are bound to create undesirable population balances and must be corrected.

Experimental work carried on in other states shows that the number of pounds of the particular kinds of fishes supported by a given body of water is limited by its fertility and that more pounds of rough than of game fishes can be supported per acre. Under a given set of conditions the poundage remains the same, no matter what the number of fishes. Accordingly, if the fishes are numerous they are stunted, or undersized; if there are few individuals, the poundage remaining the same, then the fishes are large.

David H. Thompson (1940) has found that he can increase the annual production of fishes in small Illinois lakes or ponds by intensive fishing, removing large numbers of fishes of all sizes and thus releasing the population pressure so that the remaining younger fishes can grow more rapidly. Apparently this principle operates effectively where the fish population is not highly mixed in regard to species. The indiscriminate removal of all age groups by fishing is equivalent to the natural control exercised by large predators.

Fishes have enormous reproductive potentials. Ordinarily they produce more eggs and fry than the lake could possibly support if all the fry grew to adults. Usually the worst enemies any game fish has are the larger individuals of its own kind. Cannibalism is natural among game fishes. The abundant lower age groups must be thinned out to allow normal growth, and the natural agents are the large predacious fishes.

Each year game fishes produce countless millions of eggs in Minnesota lakes. Thousands of these eggs hatch into fry. The question is what happens to these fry. Preliminary studies on sunfishes and crappies have shown that only a very small number of fry, ranging up to 3 per cent, survive to become fingerlings, or one-year-old fishes. From 10 to 75 per cent of the fingerlings survive to become two year olds, and from 10 to 40 per cent of the two year olds survive at the end of the third year, at which time most of these fishes reach what might be called adult size. The results of these studies clearly indicate that a large number of fry must be produced annually, since only a very small fraction will survive to become adults. In an analysis of perch populations one sample of 15,000 perch taken from Ottertail Lake in 1939 contained only a few fish over one year of age. Assuming that the present ratio of age classes indicated the survival of past years, only 2.8 per cent survived to the second summer, 2.0 per cent survived to the third summer, and 1 per cent reached the fourth summer.

In Lake Winnibigoshish thousands of adult walleyes have been tagged annually since 1937. Although not entirely of the same age these tagged samples may be assumed to be a cross section of the adult population. The percentage of survival may be determined by the returns from fishermen's catches in subsequent years. In 1937, 3000 walleyes were tagged. In that season approximately 13 per cent were caught by fishermen; 5 per cent were caught in 1938; 3.5 per cent were caught in 1939; and 1 per cent were caught in 1940. These diminishing returns are indicative of the rate at which the 1937 adult population decreased. These catches account for a total of only 23 per cent of the original population. What has happened to the other 77 per cent? There has been no serious epidemic of dead fishes, so it is reasonable to assume that natural mortality has gradually accounted for these losses. Population samples tagged in subsequent years show a similar decline.

In experimental work where all factors were favorable for growth, walleyes and both largemouth and smallmouth bass have been reared to a weight of 1 pound in one year, whereas it takes about three years for them to reach this weight in an average lake. It is possible for fish to grow at this rate in lakes, but not under the natural conditions existing in the average Minnesota lake, where the population is highly mixed in both sizes and kinds, offering an extremely complex system of competition.

This elastic growth rate of fishes would have great possibilities if it could be utilized under natural conditions. No doubt it is responsible for the rapid growth frequently noted in fishes newly introduced into suitable lakes where they have little competition, particularly from their own kind. Well-balanced and abundant fish populations are what we are seeking in order to provide the best fishing. But until methods can be developed to utilize this growth-rate potential in our lakes, we shall no doubt continue to suffer here and there from unsatisfactory growth and size ratios.

For maximum production fish crops must be watched carefully. A good farmer would not think of having his grain too thick or allowing weeds to take the place of the grain; the same is true of fish crops. The quality of fishes is determined by the conditions of the fish population. The total amount of fishes is limited by the productivity of the body of water. It is possible to increase this productivity by improving the environment; that is, by lake and stream management.

Management of Waters for Fish Production

The lakes of the North Central States have long been famous for their game fishing. However, with the recent increase in population and the increased use of automobiles and even airplanes, the fishing pressure, or amount of fishing, has steadily increased, and in consequence good fishing is disappearing from many popular lakes. In recent years preliminary studies have been made to determine ways to maintain good fishing, and our knowledge of the requirements of fishes and the management of lakes and streams is increasing.

Lake management is the control of a body of water and its contents in such a way as to produce a sustained yield of the fishes best suited to the conditions of the lake. By indicating the amount of fish that can be removed without disturbing the conditions necessary for maximum production, lake management seeks to prevent the damage done by intensive fishing. It involves the improvement of the environment for fish life and the maintenance of a balance of size ratio in the population. The management of all waters should be based on information obtained by surveys of all conditions necessary to life. Lake and stream surveys are not cures for any troubles, but they are the chief means of diagnosing fishing problems.

The surveys determine the productivity and carrying capacity* in terms of the elements of fertility and the resulting food and fishes. Such surveys have been initiated and developed within the last fifteen years, largely within the northern states of New York, Michigan, Ohio, Indiana, Illinois, Wisconsin, and Minnesota.

A complete survey includes basic mapping of the lakes and a census of bottom fauna, plankton, and fishes. The chemical nature of the water, especially the carbonate and in some cases the phosphate, nitrate, and sulphate content, is determined. The temperatures at different depths are determined. The spawning beds and the weed areas are measured. The results constitute an inventory of all the conditions for fish life.

The chief result of lake surveys is the determination and classification of the types of lakes suitable for various game fishes. Each lake should be managed to produce the kind of fishes for which it is naturally adapted. It is not practical, for example, to attempt to manage a walleye lake for lake trout, or a bass lake for walleyes. Minnesota lakes can be divided into soft-water and hard-water lakes, and also into cold-water and warm-water lakes. The proper combination of hardness and temperature determines whether a lake can support cold- or warm-

*The carrying capacity of a body of water is the amount of any or all forms of life supported at a given time. The term is usually used in fish management instead of "annual or total yield," which is virtually impossible to measure.

water fishes. Minnesota lakes suitable for fish can be divided into at least five types according to the species of game fishes for which they are best adapted. Surveys of lakes in neighboring states have yielded similar types.

The first type is the lake trout lake. It is more or less infertile, with much rocky bottom. The shore drops steeply, is almost entirely bedrock, and is unproductive. These lakes are deep, with a maximum depth of over 100 feet. The water in such a lake is low in both mineral and organic content. Owing to the depth of the lake and its low organic content there is plenty of oxygen at the bottom. Although the surface waters may warm up, the bottom waters are always cold enough for the lake trout. Northern pike, suckers, tullibee, and sometimes walleyes are also found in these lakes. These lakes are confined mostly to the border region, from Lake of the Woods through the Superior National Forest, and are located in areas of surface igneous rock, where the soils are low in fertility and the drainage waters are very soft.

In the same area there are some small lakes that have proved to be suitable for stream species of trout. The waters are cold and may not be over 40 feet deep. These lakes are usually fed by springs or cold bog drainage. Brook, brown, and rainbow trout have been introduced in these waters and have done very well.

The second type of lake is one of two kinds in which walleyes thrive. It is difficult to determine the factors necessary for a walleye lake, but walleyes apparently do best in lakes where they have plenty of range. The only small lakes in which they thrive are those that have open channels into other lakes, forming a chain. The first kind of walleye lake is similar to the lake trout type. It has rather rocky shores and is relatively infertile. In fact it has all the characteristics of a large lake trout type except that it is too shallow for lake trout. Many of these lakes are only 75 or 80 feet deep. The cold water below the thermocline has insufficient volume to carry enough oxygen through the summer and consequently is not ideal for lake trout. Some contain a few lake trout, many northern pike, and usually some suckers and perch, but most of them did not originally contain walleyes. The walleyes have been introduced and are thriving better in this type of lake than in any other waters in Minnesota. Lakes of this type are located on rather rocky soils in Lake and Cook counties.

The other type of walleye lake is entirely different, being warmer and quite fertile. This type is large, with sand and mud bottoms, supporting abundant, submerged vegetation in the shoal waters. The lake may range in depth down to 200 feet. Lakes of this type may be divided more or less according to size and depth. In fact, some of the deeper lakes in Minnesota are of this type, but they are not suitable for lake trout because they are fertile and their bottoms are very rich in organic matter. The waters are rather hard, for they contain relatively large amounts of carbonates in solution. The cold underwaters become stagnant and deficient in oxygen for at least part of the year, and the fish are therefore confined in summer to the warm surface waters.

A number of large lakes in central and northern Minnesota, such as Upper Red Lake and Lower Red Lake, Leech Lake, Mille Lacs, and Cass Lake, are of this same type, though relatively shallow. They are from 35 to 40 feet deep and from 8 to 15 miles across, and consequently they are exposed to much wind and wave action. The wave action prevents bottom stagnation and makes the bottom available to fishes everywhere throughout the year. Walleyes are the dominating fishes of these large lakes. Perch, northern pike, suckers, and many other species are common. Sunfishes, bass, and crappies are not common except in bays. The majority of the larger lakes of central Minnesota are of this type, with its several variations. They are located in areas where the soils are fertile and therefore are sometimes surrounded by agricultural land.

The fourth type is the bass, crappie, and sunfish lake. This type of lake is small, but may have numerous bays and inlets. It is rich in organic matter and has large amounts of vegetation. The waters contain relatively large amounts of carbonates. The shores and bottoms are generally mud and sand. This type is usually over 20 feet deep, and a few exceed 100 feet in maximum depth. When the lakes are deep enough, bottom stagnation with loss of bottom oxygen occurs. Since large areas of bottom are inaccessible, the deep lakes of this type are not as productive as some of the shallow ones. Bass, crappie, and sunfish lakes are found in most of Minnesota and Wisconsin, but rarely in the northeastern corner of Minnesota. Northern pike, suckers, perch, and other species are present in most of them, in addition to bass, crappies, and sunfishes.

Many Minnesota and Wisconsin lakes are a combination of the last two types — the second kind of walleye lake and the bass, crappie, and sunfish lake — and are suitable for all these species. They are large and have many bays and inlets, thus virtually combining the conditions of both small and large lakes.

In Michigan, parts of Wisconsin, and to a very limited extent in Minnesota, there is another type of lake suitable for smallmouth bass. This type is a small, shallow, or only moderately deep, lake with rocky shores. Little is known about this type of lake in Minnesota.

The last type consists of the prairie lakes in the southwestern and central parts of Minnesota and also in the Dakotas. These are hardwater, fertile lakes, with rich mud bottoms and shores supporting abundant aquatic vegetation. Most of them are shallow, ranging from 6 to 20 feet in depth. This type of lake is largely inhabited by bullheads, buffalofish, carp, and sometimes walleyes and other game fishes.

Local sportsmen often want to have the rough fishes and bullheads removed and replaced by game fishes. However, these lakes are not very suitable for any of the game fishes, and only by continuous effort can such fishes be maintained. Owing to the shallow depths and the high oxygen consumption, winter-kills occur frequently.

Because of the enormous number of lakes in Minnesota it is impossible to survey every one. These types have been established for the purpose of classifying the other lakes. Most Minnesota lakes, and to some extent Wisconsin lakes, may be classified on the basis of a few factors, such as the chemical condition of the water, the depth and area, and the type of shore vegetation. A few lakes will not fit into the categories just described, but these lakes are generally of intergradient types. In other states local conditions may alter these categories, which must be worked out for each region.

Lake surveys determine the type of lake and the kind of fishes suitable for it and also give some idea of the basic fertility of the lake. But most of the lake surveys commonly used for Minnesota lakes do not determine the number of fishes in the lake or the number that can be supported. Determination of these figures is one of the great problems in fish management and is essential before an intelligent management plan can be made.

Of all aquatic animals fishes are the most difficult to study quantitatively. Fishes move about so readily that no collection obtained over a definite area can be considered an absolute quantitative sample. The only absolute measurement of fishes is by removal of every fish, for which the only practical method would be poisoning. Obviously such a measure would mean the end of the existing fish population and also of further study. Sampling with seines and nets may give some idea of the fish population, but the results cannot be considered more than crude measurements. Most of the work done on the Minnesota fish populations has of necessity been confined to sampling with seines and various types of nets, giving at best only rough estimates.

In a state that has as many lakes as Minnesota, surveys in which the fishes in all the lakes are quantitatively measured are practically impossible. Furthermore, fish populations change from year to year, and so such a census would have to be repeated annually. However, an ordinary lake survey, such as has been developed and used in Minnesota, determines the general fertility of the lake and thus gives some sort of an index to the potential production of the kinds of fishes for which the lake is suited.

The total weight of fishes that can be removed from a lake without disturbing the general production has never been worked out. Fish managers believe, however, that there is a yield limit, just as there is a limit to the amount of game that can be taken from land areas without depleting the necessary breeding stock. In some Minnesota lakes anglers take as much as twenty pounds per acre annually, while in others, including many of the northern lakes, the annual catch is less than three pounds per acre. Obviously, it is important that this yield limit be determined, and it will probably be necessary to limit the amount of fish taken from a lake to conform with it.

Several factors within the fish population may prevent a lake from producing the maximum of the species to which it is best suited. Sur-

Minnesota Conservation Department crew making a fish census of a trout stream by the shocking method. The fishes are temporarily stunned by electricity passing from the electrodes held by each of the outside men.

veys should include a study of the existing conditions of the fish population, not only to determine the species present but also to determine the predominating age groups and the growth rate of the important species. The ratio of the forage fishes to the predacious fishes must be worked out, since forage fishes are a basic food supply for predacious fishes. The ratio between the two-year, three-year, four-year, and other age groups of the predominating fishes must be determined.

Some lakes are overpopulated with small fishes and have too few big fishes. In many fertile lakes that support a heavy fish population, heavy selective fishing keeps the larger individuals of the game-fish population reduced to a low level. However, population balances are difficult to regulate, because such regulation involves restricted fishing.

If fishermen could be induced to remove small game fishes in proportion to the larger game fishes they catch, the competition within the younger age groups would be relieved and a satisfactory growth rate would probably result. The average fisherman, however, can hardly be expected to follow such a radical procedure. Nor does this method take into consideration the populations of non-game fishes which are little affected by fishermen but should likewise be controlled.

Another outstanding defect is the presence of carp and other undesirable species. Finally, one of the most serious problems is the lowering of lake levels through drought and drainage developments. The lowering of lake levels creates oxygen deficiencies in winter and reduces game-fish lakes to bullhead types or even makes them entirely unsuitable for any fish. The extent of these problems is indicated by lake surveys, which thus provide a basis for the management of lakes for fish production.

Improvement of Lakes and Streams

Most of the problems in fish conservation are concerned with the factors that cause poor fishing. Because of the ever-increasing pressure by fishermen, maintenance of good fishing conditions becomes imperative, and the improvement of waters for better fishing is one of the fundamental phases of fish management. Lake improvement consists of such activities as improving the spawning conditions, the carrying capacity, and the conditions for meeting the specific needs of the fishes for which the lake is managed.

As we have seen, food production is one of the most important factors in determining the amount of fish a lake will produce, and attempts have been made to increase the natural fertility. It is possible to increase the fertility of many lakes by adding commercial fertilizer or even ordinary barnyard manure. The proper use of these substances increases the productivity of the lake in food and consequently in pounds of fish. In Europe the fertilizing of fish ponds has been practiced for centuries. Wiebe (1931) and others have shown that certain commercial fertilizers will increase the yield in rearing ponds. This is now a standard practice in pond operations. A few Minnesota lakes have been fertilized, but no check has been made to determine the results.

Many northern lakes are too far from the source of fertilizers to justify the expense of fertilizing. Moreover, in Minnesota the extent of some lakes that could otherwise be profitably fertilized is so great that the expense is prohibitive. However, there is some consolation in the fact that increased fertility would increase the winter consumption of oxygen, and in a region of severe winters too much plant life in a shallow lake would be undesirable.

In some waters the food supply may be increased by introducing forage fishes that do not compete with those already there and so do not disturb the balance. Such a procedure has been followed in some of the northern trout lakes where tullibee were absent. Lake Superior ciscoes, which feed on material that was not being greatly utilized by the trout, have been introduced to provide additional food for the trout. Although the ciscoes were introduced only a few years ago, they have multiplied to such an extent in some lakes that complaints have been made that the trout are so well fed that they will not bite. This step is only the first one, but it seems to indicate the successful results of this procedure. The next step will be to increase the trout population, and eventually trout fishing should be greatly improved.

A good many remedies have been suggested to prevent the serious problem of winter-kills, which occur when the water in a lake does not contain enough oxygen to maintain the fish all winter. Cutting holes in the ice to allow surface aeration has been tried, but the cutting of many small holes does not allow sufficient oxygen to enter the water and diffuse to all parts, largely because the diffusion or spread of oxygen in the water is so slow that the effects of aeration are not found more than a few feet away. The fact that surface aeration is of little value may be seen in summer when, although the entire lake is exposed to the air, fish-kills occur because the plants have temporarily ceased to liberate oxygen. In addition, cutting holes causes the fish to crowd into the holes and actually to smother from overcrowding. Furthermore, in a winter climate like that of Minnesota the holes quickly freeze over again. The remedies for oxygen depletion as well as the factors involved have recently been discussed in detail by Greenbank (1945).

A remedy practical for small bodies of water is clearing the snow from large areas of clean ice. Removing the snow allows the sunlight to penetrate to the plants below and enables them to keep up the liberation of oxygen. In several small lakes where this procedure has been tried it has been successful.

Possible prevention of oxygen depletion may be accomplished through the removal of excessive vegetation along the margin of the lake before the freeze-up. Vegetation, although it usually functions to keep up the oxygen, becomes one of the heaviest consumers when it can no longer liberate oxygen; this is especially true of water weeds, which die and decay during the winter. There are usually enough microscopic plants in the open water to liberate sufficient oxygen so that the lake will not suffer if the larger plants are taken out. The method of removing excess vegetation has been followed in other states, particularly Ohio, to relieve summer-kills as well as winter-kills. It is expensive, for it requires considerable labor and special machinery. If Minnesota had only a few lakes in danger of oxygen depletion, vegetation removal would be possible. However, in a state with many hundreds of lakes in this condition, some of which are of enormous extent, this method is far too expensive for general use.

Of recent years a number of aerators have been placed on the market. These aerators operate on the general principle of pumping air through the water and then circulating by means of propellors or other devices the water thus aerated. This method of aeration is effective over a limited area, determined by the amount of circulation, but it seldom improves the oxygen condition more than 50 feet away. Moreover, some of these pumps are expensive to operate, and many of them require considerable attention lest they freeze. Pumps may be beneficial on a small lake or pond, but as each can aerate only a limited area a hundred or more would be necessary to maintain the oxygen in a lake of considerable size.

In some cases raising the water level a few feet seems to be the best remedy. A rise of only a few feet in the water level of many of our lakes now suffering from low-oxygen conditions would provide a sufficient volume of water to hold the necessary oxygen supply through the winter. This procedure is particularly effective with the lakes, such as Big Kandiyohi Lake in Minnesota, which fell many feet during the drought years of 1932–35 and have never regained anything like their former levels. If the levels of these lakes can ever be restored and maintained, oxygen may once more be retained in sufficient quantities to hold the fishes over the winter.

Remedying oxygen depletion is very difficult. There is no definite amount of oxygen that can be said to be absolutely necessary to sustain fish life. Moreover, fishes differ greatly in their requirements. Unfortunately most game fishes require more oxygen than many rough fishes and hence often die while the rough fishes survive. When the oxygen is about one-third of the normal amount present in the summer, the fishes are in danger. At times fishes may survive on much less, whereas at other times they may die when this point is reached. These differences are probably due largely to the condition of the fishes and to the temperature and other conditions of the water. Often in emergency cases where the oxygen is rapidly disappearing there is no immediate or practical remedy. A careful study of the oxygen supply in various lakes during the late winter will determine when the supply is approaching the critical point. If no means are available for application of some method of aeration, the only procedure left is to rescue or salvage as many fish as possible before it is too late.

In many lakes the spawning conditions can be improved. Conditions for natural propagation should be maintained at the highest possible levels in order to maintain the natural production of fishes. Keeping up the natural production is much cheaper than artificial propagation and stocking. For gravel-nesting species gravel beds should be constructed in lakes with muddy shores. In lakes with very soft mud bottoms boxes of sand may be placed for bass nests. The production of bluntnose minnows, one of our most valuable forage fishes, may be greatly increased by placing spawning boards in shallow water, because these fishes deposit their eggs on the underside of submerged objects. The protection of spawning beds for sunfishes, bass, and crappies from disturbance during the season when the adult fishes are on the nests is important. Several bays containing good spawning beds will produce as many fry as the best rearing pond.

The control of rough fishes is one of the important steps in lake improvement. Rough fishes such as carp and dogfishes may compete with the game fishes or may destroy conditions necessary for such fishes. In some states carp are used as forage fishes because they multiply rapidly and produce a large amount of food for game fishes. However, Minnesota and some other northern states cannot follow this plan because of the destructiveness of carp in northern lakes, long proved by their devastation of vegetation, feeding grounds, and the spawning beds of other fishes. In this way the carp have already eliminated most other fishes from some southern Minnesota lakes. The only sure way of exterminating the carp would be to kill every fish in a body of water with dynamite or with some powerful poisonous chemical. This procedure is expensive and does not insure against the reintroduction of carp, which may occur through the use of young carp as bait in a fisherman's pail. The present method in general use is to control them by seining, by trapping on their favorite spawning beds, and by screening inlets where they may be gaining access from other waters. They are exceedingly prolific, which adds to the difficulty of controlling them.

Proper vegetation in a lake is important for successful maintenance of fishes. Vegetation not only shelters smaller fishes but is the basis for the food of all fishes. It is an important agent in oxygen production. Many lakes have their shore waters cleaned of all types of vegetation, particularly in front of cottages and around bathing beaches. These clean sand bottoms may be ideal for bathing but they are deserts as far as fish food and fry production are concerned.

Some lakes may have too much vegetation. The vegetation may become so thick that it chokes the open waters and prevents free movement of the fishes. It may result also in an accumulation of decaying plant waste during the winter, which uses up the oxygen and causes winter-kills. In some lakes conditions may be improved by restoring and increasing areas of vegetation; in others, by removing vegetation and restricting its growth.

Low and fluctuating water levels are one of the most serious obstacles to fish production in many of the northern lakes. Some lakes have had their levels reduced by drainage; others have had their summer water supply reduced by the removal of surrounding forests, which had acted as reservoirs; and many are subject to great fluctuations in their levels because of power dams.

In many cases lowered water levels mean that the volume of water has been so reduced that moderately shallow lakes are in danger of winter oxygen depletion. Some lakes lose their fertile marginal bottoms, which are replaced by less productive muds of the deeper bottom deposits. Lakes subject to frequent fluctuations caused by power dams are always in danger of having important spawning beds left high and dry at a critical time. They are also subject to frequent destruction of their most important food production areas. Under such conditions no lake can produce its maximum yield of fish. In order to maintain the maximum fish production every effort should be made to keep lake levels normal and to prevent detrimental fluctuations.

Streams differ from lakes mainly in the conditions caused by the current, the absence of great depths, and the absence of complications caused by the stratification present in the deeper lakes. Lakes depend primarily on vegetation for their oxygen supply, but streams secure much of their oxygen from the atmosphere, through the action of their currents. Streams also differ from lakes in that they are not more or less closed bodies of water but have a continual supply of nutritive salts and other elements washing in from land sources.

Many streams in the northern states have deteriorated in recent years through manufacturing, agricultural, and lumbering operations and they are no longer supporting the fish populations they once carried. In many cases it is possible to rehabilitate fishable streams. Because of the numerous lakes available, streams have been neglected in the northern states, and only in the last few years have attempts been made to restore good fishing in the streams in order to relieve the fishing pressure on the lakes.

Scientific surveys of streams are essential before any major improvement can be attempted. Data on the source, volume, and chemical conditions of the water and on the temperature, shade, food organisms, depth, bottom types, pools and rapids, and the fishes present should be secured first in order to determine the conditions requiring correction.

Streams may be divided into a number of types. Small streams are usually swift; large streams are usually slower and have more deep, pondlike areas. Small streams may have cold water or warm water, depending on the source and the local conditions of shade, depth, and current. Cold streams are usually suitable for various species of trout. Warm streams are not suitable for trout, but if large enough are better for largemouth and smallmouth bass, sunfishes, channel catfish, bullheads, and various species of suckers. In the largest streams many additional species may be found, particularly those that prefer quiet waters and muddy bottoms, such as the big catfishes, the buffalofishes, gars, carp, sheepshead, and the paddlefish.

Pollution, loss of cover, erosion, and extreme alternations of high and low water levels caused by extensive drainage and by the cutting of moisture-retaining forests have all contributed to rendering streams unsuitable for the support of large fish populations. In many streams unrestricted seining of minnows destroys the food, the spawning and feeding grounds, and even the game fishes themselves. All these conditions must be remedied in order to restore many streams to their former productivity.

Trout streams have been surveyed and improved more than any other type of streams. Because of their smaller size most of them are easier to improve than are the larger rivers. Detailed instructions for surveying and improving have been described by many investigators: Hubbs, Greeley, and Tarzwell in 1932, Davis in 1938, and Needham in 1938.

Improvement consists in remedying the conditions found to be most unsatisfactory, as far as the results will justify the expense. Most important is the maintenance of a flow of pure water uncontaminated by sewage or by refuse from industrial operations. Silt from eroded watersheds must be reduced, because it smothers the food organisms, destroys spawning beds, fills up pools, and sometimes even smothers the fishes themselves. The silt in streams can be controlled by stopping soil erosion in the cultivated fields of the drainage basin.

The construction of deflectors and various types of dams may direct and concentrate currents so that they will sweep silt downstream and also will wash out holes, providing more of the deeper waters for the larger fishes. Many small streams are so shallow that they may freeze to the bottom in winter. Judicial regulation of current and depth may eliminate deep freezing.

In many trout streams the maintenance of low temperatures is one of the greatest problems. Trout do best in water with summer temperatures ranging from 50° to 65° F. The destruction of shade along the banks may allow the sun to warm the water until it becomes too warm for trout. In such places shade should be restored by planting trees or bushes. The stream may be narrowed and the current forced into the shady part. A cover of bushes and brush may be pulled over the stream. The water can be further cooled by cleaning and enlarging any lateral feeder springs. The few streams that are too cold may be warmed by widening them with dams to spread out the water and expose it to the sun.

Spawning conditions may be improved in almost every stream. All trout require coarse gravel beds for spawning. In streams with bottoms of soft mud and sand, spawning beds of coarse gravel may be constructed at intervals. Spawning conditions can be greatly improved by opening small lateral feeder streams and building spawning beds.

Good trout waters have alternate pools and rapids. Most of the aquatic insects that form an important part of the diet of trout are produced on beds of coarse gravel and small boulders. Sand and solid rock are low in food production. Weed beds on silt bottoms produce large quantities of small crustacea and insects and are important assets for increased productivity. For best results a trout stream should have ample feeding beds with sheltered water easily accessible.

Long straight stretches of swift water may produce abundant food but are usually barren of trout, which need pools for shelter. Pools can be made in streams by damming with logs and rocks. If the pools are too deep, suckers and other fishes may enter and compete. Too many pools mean a shortage of swift water, in which many of the food organisms develop. Pools should be sheltered with overhanging banks or logs. Small trout need weed beds for feeding and cover, and such beds are best developed in the feeder streams. Frequently streams have so much vegetation that they are partly choked by it. This situation should be remedied by removal of part of the cover.

Streams in which the water reaches a temperature of over 70° F. for a considerable period during midsummer cannot be considered good trout streams. If they are of fishable size they may be capable of supporting smallmouth and largemouth bass, sunfishes, and even walleyes and northern pike, and many can be improved to furnish better fishing. As such streams are usually rather large, the cost of mechanical devices for pool shelters and feeding beds may render improvement impracticable. Pollution is a serious factor in rendering many of these streams sterile and can be remedied only by complete elimination. Silt from farmers' fields is just as serious a problem in these warm streams as in the trout streams and can be remedied only by reducing soil erosion.

The seining of minnows for commercial purposes has greatly increased in recent years. Such seining should be stopped, for it not only destroys a valuable food source but also disturbs and damages the spawning and feeding beds. Small warm streams, though not of sufficient size to support adult game fishes, are of great value as reservoirs for forage minnows. They serve as feeders to the larger streams and also as rearing and spawning areas for game fishes. They should be improved and protected wherever possible.

In some streams rough or undesirable fishes furnish an even greater problem than in lakes. Many large streams have become so silted and muddy that game fishes have become scarce and rough fishes very numerous. Rough fishes are much harder to control in rivers than in lakes. The open condition of running waters enables the rough fishes to re-enter an area from either downstream or upstream. Where impassable dams are present, control of rough fishes becomes easier. Continual removal is the only practical control and may be supplemented by encouraging the predatory game fishes.

Warm-water streams of fishable size should be improved as far as conditions warrant, with due consideration of the cost. Clean water is always necessary. Undisturbed feeding and spawning areas should be provided. Wherever possible, pools and sheltered areas should be created and protected. With these conditions improved as much as possible, the streams should be stocked with the desirable species of game and pan fishes. If these fishes can become established, they may aid in reducing any surplus of rough or forage fishes.

Although fish population balances may constitute a problem in streams, they are not usually as serious as in some lakes. Streams, like lakes, have a limited productivity and can support only a certain amount of fish, but if this amount is exceeded and competition becomes too great it is usually possible for stream fishes to escape to other areas of less competition. Owing to the tendency of many species to move upstream or downstream, even to great distances, continued stocking is necessary in some heavily fished waters. There is much less danger of overstocking in streams than in lakes.

The improvement of lakes and streams for the purpose of better fishing is one of the fundamental phases of fish management and consists of improving spawning conditions, carrying capacity, and the conditions for meeting the specific needs of the fishes for which the waters are managed. The existing conditions in the waters for fish life must first be measured in order to determine those needing improvement. In all cases the cost of improvement must be considered in order to determine whether the results will justify the expenditures. In many northern waters the expense would be so great that it would be impracticable to attempt to remedy certain unfavorable conditions known to exist.

Laws and Propagation

For many years the only methods employed for conservation and maintenance of fish were artificial propagation and legal restrictions on size, creel limits, and season. Only recently have the values of these time-honored methods been doubted.

Legal restrictions on size have been enforced for years by many states to prevent fishermen from catching too many fishes and from catching them until they reached adult size and had a chance to spawn. Under this restriction fishermen had to carry a ruler and throw back any fish which did not come up to exactly the legal length, regardless of age. The fact that the undersized fish were liable to be injured and would die after returning to the water caused Minnesota to abolish size limits for hook-and-line fishing many years ago. No bad results can be traced to the removal of this restriction. Under this old restriction the stunted fishes were given preference and were protected. Many of our northern lakes are overstocked with undersized fish and such a restriction would only aggravate this condition.

Modern investigators in some states are now advocating the abolishment of creel limits. They estimate that only a small fraction of the adult fishes are ever caught and that the greater part are left to die a natural death. In order to utilize the fishes which ordinarily die a natural death, some investigators are recommending unlimited catches. It is claimed that a greater removal of fishes will eliminate competition with the younger fishes and will allow them to grow faster and thus maintain the poundage determined by the carrying capacity. The results of this procedure remain to be seen. As we have seen, many Minnesota lakes are not overfished, but are so selectively fished that not enough large fish remain to reduce the younger fish population to fit the carrying capacity of the lake. Accordingly the removal of creel limits on the larger game fishes such as northern pike and walleyes in northern waters is open to question. Even though many of these larger fish die and go to waste, during the few extra years of life gained by protection they perform a necessary function in reducing the younger age classes which the fisherman will not touch. It is undoubtedly true that unlimited catches of pan fishes and other smaller fishes might produce beneficial results in many northern lakes. Since conditions vary in different lakes and differ from year to year and with different species, it is difficult to provide blanket regulations which would provide for all.

The original object in limiting seasons was to protect fishes during their spawning season when many species are particularly easy to catch. Secondarily, this restriction served to limit the number caught by reducing the days open for fishing. At present there seems to be no good reason for removal of closed seasons in the northern states during the spawning seasons. In most years many more fry are produced than the waters could ever support, but the older fishes adjust this by eating up the surplus. This is the aquatic operation of the natural reproductive principle that animals produce overabundance of offspring from which nature must take a toll. The real problem is to maintain a sufficient number of large adult fish to keep the offspring reduced and thus prevent the survival of too many young, which would result in a crowded, stunted population. Any proposed abolishment of restrictions on creel limits and seasons should first be carefully tested on a series of experimental lakes.

In addition to protective laws, it has long been customary to utilize artificial propagation as a supplementary measure in the conservation of fishes. During the past seventy-five years hatcheries for the production of certain game fishes have sprung up all over the United States for the purpose of aiding and improving nature's methods. It seemed obvious to early fishery experts that often only a small number of eggs hatched under natural conditions. It was estimated that if these eggs were hatched under controlled and protected conditions, a much greater number of fishes could be produced and returned to the lake. Consequently, fishermen have felt that if their favorite lake was stocked annually with fry, the problem of fish maintenance would be taken care of. Stocking has become the sedative for fishery headaches.

The eggs of only certain species can be readily propagated under hatchery conditions. Members of the salmon-trout and whitefish families yield readily to hatchery manipulation. Northern pike, walleyes, perch, and suckers can also be easily propagated in hatcheries. Many other fishes, particularly those which build nests, do not readily accommodate themselves to hatchery methods.

The eggs for hatchery operations are obtained by stripping the adult fishes. In some cases, as with trout, these may be brood stock kept in ponds or tanks. Eggs from most other species are usually obtained from wild stock. When the adults become sexually mature they migrate to the spawning beds where traps or nets can be placed to catch them. Often this is on some tributary stream. At this time their bodies are gorged with eggs and sperm which will ripen in a few days. The fishes are eventually relieved of their eggs and milt or sperm by gently manipulating their distended sides. The eggs and the milt are placed in a container and gently stirred. In a matter of minutes the eggs are fertilized. Such eggs harden and change color, and are called eyed eggs. They are then placed in running water for further development. The eggs may be placed on trays in troughs of running water, or in the case of some species, such as walleyes, the eggs may be placed in large jars into which run constant streams of water, keeping the eggs agitated.

After fertilization trout and whitefish eggs can be maintained on ice for weeks before hatching. The eggs of these species must be kept and hatched in the dark because light seems to be fatal. Cold water is also necessary. Their period of development is slow and they usually take several months to hatch. Warm-water fishes usually hatch in one to two weeks. The newly hatched fry are commonly inactive for several days and feed by absorbing food from the yolk sac which is still attached to them. After several days they start searching for food. Their first food is the minute aquatic animals, mostly water fleas *(Daphnia)*, which are common in the shallow water of lakes. Since this type of food is not always easy to supply in the hatchery, the fry may start feeding on each other. Consequently, it has been common practice to plant the fry in natural waters as soon as possible after hatching.

Since most fishes produce enormous numbers of eggs, it is possible to secure many millions of eggs from a relatively few fish. The success of the artificial hatch depends on many factors and the percentage of eggs hatched may vary from 10 to 90 per cent. Nevertheless, with such enormous numbers of eggs, the number hatched frequently runs into many millions. When the newly hatched fry are transported from the hatchery to the lake, thousands can be placed in a ten-gallon can, so that the cost of transportation is much less than for larger fish.

When planted in lakes the rather helpless fry are subject to many hazards. Sudden temperature changes are fatal. Many enemies await them and thousands, if not all, are killed by predators ranging from tiny water bugs to small perch.

In order to avoid these potential losses at planting time, a plan has been developed for rearing them to fingerling size. The fry are placed in small rearing ponds which should be free from any predators, and the ponds are treated with fertilizer to provide an abundance of natural food. Sucker fry and later minnows are provided to furnish food after the first two weeks.

In the fall the ponds are drained and the fingerlings are removed and planted in lakes. Because of their size, natural losses, and the expense of rearing and transportation, only thousands instead of millions can be produced by this method. But stocking with fingerlings is popular in many places because these fish are too large to be consumed by perch and other small predators prevalent around the margins of lakes.

Nest-building fishes, such as bass, crappies, and sunfishes, have refused to accommodate themselves to methods of stripping and insist on retaining their natural methods of reproduction, which involve a sort of courtship and paternal care. However, the desire of conservationists to improve on nature has resulted in the establishment of many rearing ponds for these fishes. A number of adult fish are placed in ponds where they are allowed to build their nests and produce their young. In the fall the young are removed as fingerlings and planted in lakes.

In spite of the fact that these operations have been carried on for many years at a cost of millions of dollars, only recently have any attempts been made to determine the success of fish planting. The investigations of the past ten years have indicated that there is little justification for many of these operations, yet the public has such faith in them that to eliminate them would immediately raise a storm of controversy with the various sportsmen's clubs and other organizations. From the many studies of fish populations and lake surveys, few if any results can be seen from planting fry in waters where the species is well established. In the Great Lakes, where the records of commercial catches over many years are available, no increases can be noted in the age classes spawned in the years when planting was exceptionally heavy (Van Oosten, 1937, 1941, and Hile, 1937). This has also been noted by Dr. Kenneth Carlander of the Minnesota Department of Conservation in Lake of the Woods. Some perch-infested Minnesota lakes in which walleyes are absent have received huge annual plantings for many years, but no adults have ever been reported.

Recent studies already mentioned on the reproduction of these fish show that the number of fry ordinarily produced in a lake is enormous and much more than the lake could possibly support if all survived. In the larger Minnesota lakes which are popular for walleye fishing, such as Mille Lacs, the natural production of fry for one lake is estimated to be about equivalent to the total number produced in all of the state hatcheries. Consequently, man's efforts are puny compared to those of nature.

In view of the fact that many heavily fished northern lakes are already overcrowded with certain species, resulting in large numbers of stunted fishes, the planting of fingerlings may only aggravate this condition. The nest-building fishes reproduce about as well in natural lakes as they do in artificial ponds. They guard their eggs and fry closely and usually prevent excessive losses from predation. Practically the same results achieved in a rearing pond can be obtained in a lake by prohibiting disturbances of favorite spawning beds. This prevents any losses incurred when the parent fishes are frightened from their nests. In most Minnesota lakes there is no evidence that more pan fishes are needed and in many lakes the bass are stocked to the limits of the carrying capacity.

Much of our old scheme of fish conservation by legal restrictions and propagation was based on armchair biology. The use of hatcheries and rearing ponds should be confined to actual needs that are proven and not surmised. Hatcheries and rearing ponds are necessary to supply fishes needed for introduction into waters where they do not already occur. Small cold lakes and ponds can be rendered productive by introducing trout. As already pointed out, there are many lakes suitable for walleyes which have been found to contain no walleyes. Some of these lakes in Cook and Lake counties have been successfully stocked by the introduction of fry and are now excellent fishing lakes. These are cases of introducing a species into suitable waters where there is no competition of its own kind, and do not fall into the category of ordinary stocking. The scarcity of northern pike in some Minnesota lakes is thought to be responsible for the overcrowding of perch and pan fishes; hatcheries can be an important source of northern pike to remedy this condition.

The stocking of streams with trout differs from the stocking of lakes. We shall probably always be dependent on hatcheries and rearing ponds for a supply of fingerlings and larger sizes of brook, rainbow, and brown trout to replenish the many northern trout streams. All the various species of trout found in the northern states have been introduced into suitable waters more or less successfully. In fact, every trout in Minnesota except lake trout can claim more or less recent hatchery ancestors. The combination of heavy fishing, natural losses including migration into unsuitable water, and lack of sufficient spawning and rearing areas make it impossible to maintain satisfactory trout populations in most of the northern streams. Except for these special cases, natural reproduction usually furnishes more fry than the body of water could possibly support.

There is no doubt that many of our old ideas about hatcheries and legal restrictions are no longer valid. We have been meddling with something we knew little about. Modern investigators show that we need different methods for fish conservation than those that have been followed for many years. Instead of relying on artificial propagation and legal restrictions, we must seek to maintain a balance between natural production and our fish catches. Conservation of fishes has been a slow and painful process; it is fortunate that as a group fish are tough and that, with the exception of a few species such as sturgeons and the paddlefish, they have done well under man's blundering attempts to manipulate them by laws and propagation.

Parasites of Fishes

Fishermen are frequently disturbed when they find small yellow or black spots on the fishes they catch. These spots are caused by one or more of a large variety of parasites, with which almost all fresh-water fishes are infected more or less. In fact, it is unusual to find fishes which do not harbor some parasites. With a single exception (the broad fish tapeworm) these parasites are not harmful to human beings, but they can cause extensive damage among fish populations.

Some parasites are external ones which live on the skin or gills; others are internal parasites living in the intestine or in and among the various organs. Many larval forms are found as cysts in the muscles and skin.

Many adult parasitic worms live in the digestive tract and are usually not discovered by the fisherman who discards the viscera without exploring the contents of the intestine. The parasites most often detected are the larval forms of worms encysted in the body or among the viscera. The most common or conspicuous are the several larval flukes — the yellow grubs which live just under the skin and the black grubs which live in the skin. Some tapeworm larvae appear as yellow cysts in the flesh. Most of the flukes and tapeworms of fishes have complicated life histories, the adults living in one species and the larvae living in one or more other species.

A wide variety of parasites attack the surface of the gills and skin of fishes. The largest of these are the eellike lampreys (p. 67), low fishlike vertebrates which measure six to fifteen inches in native Minnesota forms and several feet in the big marine lamprey found in the Great Lakes. Lampreys attach themselves by their funnellike suckers to the skin of a fish and rasp a hole one-half to several inches in diameter. They retain their hold until gorged with blood, leaving the fish in a weakened condition and with a large gaping wound which often becomes infected by fungus and bacteria. These lampreys should not be mistaken for leeches, which are commonly called blood suckers in many regions.

Many, but not all, species of leeches attack fishes. Some of the smaller leeches attach themselves to the gills and the lining of the mouth and opercle. Others may fasten themselves to the outer skin. They suck blood until gorged, and if numerous, may cause considerable damage.

Tiny copepods belonging to the Crustacea may be found crawling over the gills and skin of fishes. Some species burrow into the fins and the gills. These parasites, which are sometimes called fish lice, can do much damage if sufficiently abundant, leaving the fish emaciated and liable to fungus infection.

The larvae or *glochidia* of fresh water mussels are common skin parasites of fishes. Before these larval forms can develop into adult mussels they must pass through a stage as a fish parasite. The *glochidia* of some species of mussels have toothed valves and bury themselves in the skin, particularly that of the fins. *Glochidia* of other species have only small toothless valves and these forms bury themselves in the soft tissue of the gills. *Glochidia* remain on the host several weeks or longer, depending on the temperature. There is some question as to whether they do much actual damage to the fish.

There are several species of microscopic protozoans that sometimes infect the skin and gills of fishes. Some of these are large enough to see with a magnifying glass. They cause small spots and pustules to appear on the skin and eventually cause death. They may spread from fish to fish and cause an epidemic. Minute flukes belonging to the flat-worms may also infect the gills and skin of fishes. Some of these cause serious losses in hatcheries.

A common white fungus (*Saprolegnia*) may attack the skin of fishes wherever the protective mucous coat is broken by careless handling or by wounds. This fungus is present in most warm waters and lives readily on dead animal matter. It grows rapidly in warm water, but does not thrive in cold water; hence it is most prevalent in summer. For some reason fishes in natural open waters are usually not readily infected with this fungus unless in a weakened condition. However, fishes in confinement are highly susceptible to it. The fungus first appears as a white fuzzy patch which spreads rapidly and unless checked usually proves fatal. The most common remedy is a bath for about two minutes or even longer in a 3 per cent salt solution. Fishes which are already in bad shape may die under the treatment, but they would probably die anyway.

Bacteria may cause fin rot, gill disease, furunculosis or boils, and various other diseases. They are usually more prevalent on fishes confined in hatcheries or aquaria than on those in natural waters. Davis (1937) describes many of these parasites in detail and cites the known treatments.

Threadworms or roundworms (*Nematoda*) are very common internal parasites of fishes. They are small slender worms, ranging from microscopic size to several inches or more. Frequently, they infect fishes to such an extent as to kill them or to render them thin and emaciated and susceptible to other infections. These worms can be distinguished from other worms of fish by their shape and their lack of attachment spines. They usually occur in the digestive tract, but may be found in the body cavity and in cysts imbedded in the flesh and viscera. As far as we know, the species of these worms found in fishes are harmless to man. They usually occur in the viscera, so most of them are discarded in dressing the fish.

Spiny-headed worms (*Acanthocephala*) often occur in the intestines of fishes. They resemble roundworms in size, but differ in other ways. They possess an anterior proboscis covered with minute hooks, by means of which they attach themselves to the wall of the intestine. Often large numbers may infect fishes and cause considerable damage.

The larval stages of a number of parasitic worms live in the flesh and skin of fishes. One common species is the yellow grub (*Clinostomum marginatum*), which is a larval form of one of the flukes or flatworms (*Trematoda*). This worm appears as a yellowish swelling in or just under the skin of many fishes, such as rock bass and perch. The adult worm lives in the mouth of various fish-eating birds like the great blue heron. The eggs pass into the water and hatch into free-swimming larvae (*miracidia*), which enter snails. Inside the snails these larvae reproduce and eventually leave the snails as tiny free-swimming forms (*cercaria*), which on finding a fish burrow into the skin and encyst. There they remain until the fish is eaten by a bird. In the bird they complete their development and become adult worms. They are harmless to man and do little damage to fishes. They are practically impossible to eradicate because it would be necessary to destroy completely all fish-eating birds or all snail hosts.

Another very common parasite in most northern fishes is the black grub (*Neascus*), which causes black spots in the skin of perch, northern pike, and many other fishes. This worm is another larval flatworm or fluke. The adults live in the mouths of kingfishers, from which the eggs pass into the water. As in the case of yellow grubs, the first larval stages find their way into snails and eventually pass into a fish, where they form black cysts in the skin, and must be eaten by a kingfisher to complete their development. Frequently a fish may be so heavily parasitized as to be fairly covered with these black cysts. This parasite will not infect man, and the cysts can be removed by skinning the fish. Fishes which spend most of their lives in open water and do not come near the shores where snails live are least infected with this parasite. In Lake Superior, where snails are relatively rare, the parasite is not common.

Some tapeworms have larval stages which form cysts in the muscles of fishes. The most common of these are the several species of *Triaenophorus*, which form the elongate yellow worms found commonly in the back muscles of the tullibee and the white fishes of our inland lakes. The adult tapeworms live in the intestine of the northern pike. The eggs are released into the water and develop into free-swimming larvae which enter copepods (*Cyclops*). When these minute crustaceans are eaten by a tullibee or a whitefish, the parasite is liberated and burrows into the back muscles, forming a large cyst. When the infected tullibee or whitefish is eaten by a northern pike, the parasite is liberated and becomes an adult fastened to the wall of the intestine. This parasite is very abundant in the northern lakes of Minnesota and in Canada, and is responsible for the condemnation of large quantities of tullibee by both state and federal authorities as unfit for human food. There are other larvae of related species, one living in the livers of perch and another in the troutperch (the adult forms are found in the walleye). These parasites are harmless to man. Fortunately the waters of Lake Superior are not highly suited for northern pike, and consequently the very important commercial crop of the ciscoes and whitefishes from these waters is not heavily infected.

Another rather common tapeworm is the bass tapeworm (*Proteocephalus ambloplites*), which is commonly found in both largemouth and smallmouth bass. This worm lives as an adult in the intestine of bass. The eggs pass into the water and hatch into larvae which enter the body cavity of minute copepods, such as a species of *Cyclops*. When the *Cyclops* is eaten by a small bass or certain other fishes, the parasite is liberated in the intestine and undergoes further development, burrowing into the body cavity where it forms a large larva. At this stage they cause great damage because they tend to destroy the reproductive organs and render the fish sterile. When the infected fish is eaten by a large bass, the parasite completes its development into an adult tapeworm in the intestine. They can cause considerable damage among bass, not only rendering them sterile, but also causing them to become thin and liable to other infections.

The only known fish parasite capable of infecting man is the broad fish tapeworm (*Diphyllobothrium*) originally found in northern Europe. It was probably brought to this country by infected immigrants. It is a serious menace to man but fortunately is prevalent only in limited localities in the northern states. It has been found in walleyes, perch, and northern pike. Human infection occurs only from eating raw or improperly cooked fish — the parasite is killed and rendered harmless when the fish is thoroughly cooked. The adult form of this worm lives in the intestine of man and some carnivores. The eggs pass out with the feces and must enter water to survive. The eggs are then eaten by a species of *Cyclops*, inside of which they hatch and develop into larval forms. When the *Cyclops* is eaten by a walleye, northern pike, or perch, the larvae escape and burrow through the intestine into the flesh of the fish, where they encyst and remain until eaten by man or a suitable carnivore. They are then released and mature into adult tapeworms in the intestine.

There is no doubt that the many kinds of parasites which are so common on and in fishes do much damage to their hosts. Their control under natural conditions has never been satisfactorily solved. Many of their life histories have been discovered and usually are found to be very complicated, involving one or more different hosts besides the fish. Eradication of the parasites would mean the complete elimination of one of these hosts. This is impractical if not impossible in most of our natural waters because of the great extent and expense involved. Furthermore, some parasites are carried by birds and would soon be reintroduced from other areas. For the time being, it seems that man will have to make the best of the parasite situation, just as fishes have always done.

The Structure of Fishes

Fishermen are often confused in their endeavors to distinguish certain species of fishes from others. Two closely related species may resemble each other so closely that it is difficult to tell them apart. Some of our common game fishes like the sauger and the walleye are hard to distinguish. The black and the white crappies resemble each other closely. Most people have difficulty distinguishing the several species of sunfishes, the three species of bullheads, and the many species of minnows, which resemble each other closely. A fisherman must know numerous details of fish structure if he wishes to be able to identify many species accurately.

Many species of closely related fishes hybridize readily and the resulting offspring usually offer a combination of the characters of each parent. This has confused even expert ichthyologists, who have mistakenly described such forms as new species.

Color and markings are often variable, unfortunately, and more constant morphological characters should be sought in identifying different species. The coloration of a fish often varies in two nearby lakes, causing local residents to maintain stoutly that they have two different species. Walleyes may be deep brown in one lake and pale silver in another lake. Often the color and even the markings of a species vary in the same lake. Color is often influenced by the color of the water and the bottom. Some fishes like rock bass can change color from almost black to silver in a few minutes, according to the color of their background.

Young fish often differ from adults in markings and color. This frequently causes confusion and is partly responsible for the common but erroneous assumption that the spotted and heavy-bodied adult northern pike is a different species from the slender fingerling, which is streaked with bars.

Structurally modern fishes are sometimes considered to be of a simple vertebrate type, but most of the fresh-water fishes are highly developed modernized forms, truly specialized for efficient aquatic existence. In this modern specialization some fishes have lost or modified many fundamental structures, such as fins, scales, and teeth.

In the description of fishes certain general anatomical terms are used. *Anterior* refers to the front or forward part of the body. *Posterior* refers to the tail or hind part of the body. *Dorsal* refers to the upper side or back, and *ventral* refers to the under or belly side of an animal. (See Diagram 1.)

A fish consists chiefly of two parts, the head and the trunk. There is no neck, but the end of the gill cover, or opercle, marks the posterior boundary of the head. It is usually difficult to determine where the trunk ends and the tail begins. The *tail* is usually defined as the region posterior to the vent. The tail and the tail fin are the important organs of locomotion. The other fins are used by most fishes for balancing, turning, and stopping.

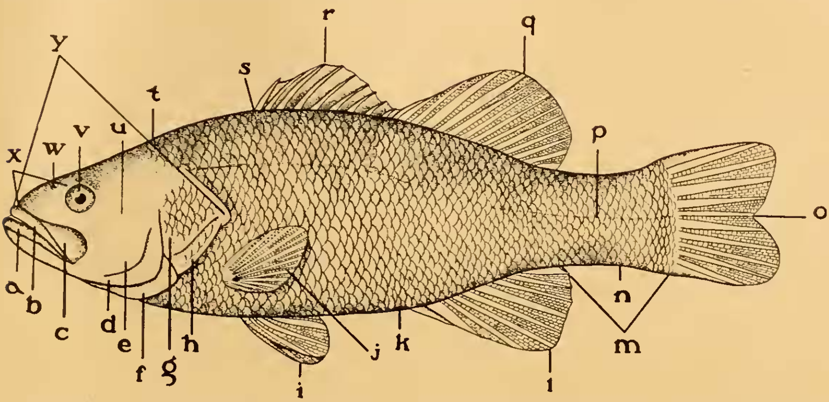


Diagram 1. Hypothetical drawing of a spiny-rayed fish. (a) Lower jaw, or mandible. (b) Premaxillary. (c) Maxillary. (d, e) Preopercle. (f) Interopercle. (g) Opercle. (h) Subopercle. (i) Ventral, or pelvic, fin. (j) Pectoral fin. (k) Anus (vent). (l) Anal fin. (m) Caudal peduncle. (n) Depth of soft caudal peduncle. (o) Caudal fin. (p) Lateral line. (q) Soft-rayed portion of dorsal fin. (r) Spinous portion of dorsal fin. (s) Insertion of dorsal fin. (t) Nape (occiput). (u) Cheek. (v) Eye. (w) Nostril (nares). (x) Snout. (y) Length of head.

The shape of the body varies, but the most characteristic shape is a streamlined modification of an elliptical or ovoid form. Some species, like the sunfishes, are thin and deep-bodied (*compressed*). Others, such as the catfishes, are broad and shallow-bodied (*depressed*). The most extreme body shape found among fresh-water fishes is the long slender form of the eel. The length of a fish is usually considered by fish specialists to be the length from the tip of the nose to the end of the vertebral column at the base of the tail fin. This measurement is known as *standard length* and is usually the length referred to in technical descriptions and keys for identification.

Since the size of the mature fish is indefinite, most of the measurements used are comparative, and even these vary for different age groups. *Head in length* means the number of times that the distance from the tip of the snout to the posterior edge of the opercle including the membrane is contained in the length of the fish. *Depth in length* means the number of times that the greatest distance from the back, or dorsal side, to the belly, or ventral side, is contained in the length of the fish. *Eye in head* means the number of times that the width, or diameter, of the eye is contained in the distance from the tip of the snout to the posterior edge of the opercle. *Eye in snout* refers to the number of times that the diameter of the eye is contained in the distance from the tip of the snout to the anterior margin of the eye.

Externally all fishes are covered by a thin skin containing numerous mucous glands that render the fish more or less slimy. This skin covers the scales and plates. The slime, or mucous covering, is a protective device and prevents the entrance of bacteria and molds. Infections of molds and bacteria frequently result when fishes are handled carelessly and the slime is rubbed off.

Fishes have many sensory structures in the skin. The most conspicuous of these structures is the *lateral line,* which appears as a line running from the opercle to the tail fin about midway on the side of the body. This line really consists of a canal with many nerve endings running under the skin. Although present in most Minnesota fishes it is absent or poorly developed in a few species. Various functions have been assigned to this structure, but the best evidence at present seems to indicate that it is concerned with the perception of vibrations and water currents.

Fishes also have *ears,* which are entirely internal and are buried in the sides of the skull. Structurally the ear is developed more for the sense of balance than for hearing, but the sense of hearing is present.

The sense of smell is developed in fishes, and smell organs with well-developed nerve connections are present in the nostrils. There are many small sensory structures with various sensory functions scattered over the skin, and part of the sense of taste may be located in the skin.

The *eye* of the fish is well developed and consists essentially of the same structures as the human eye. The eyes of most fresh-water fishes are more or less fixed and can be moved only slightly. Nor can the fish readily adjust its vision for distance. Most fishes have their sight fixed for near vision only and hence are nearsighted. Since the water is usually so opaque that it would be impossible to see any great distance, this nearsightedness is probably not much of a handicap. Although it has been claimed that many fishes are at least partly color-blind, most can distinguish certain bright colors like red.

The scales are of at least four types. The most primitive type is the *placoid scale,* found only in the sharks and their near relatives. These scales do not overlap. They have flat bases imbedded in the skin and a conical point or spinelike process protruding through the skin. These processes are similar in structure to a tooth, being composed largely of dentine. There is some controversy as to whether they are tipped with enamel. Scales of this type located on the rim of the jaw have become enlarged and have developed into teeth. The teeth of all vertebrates have been derived from this early tooth-scale.

A second type of scale is found in a few primitive bony fishes, such as the gar. Scales of this type, known as *ganoid* scales, consist of rhomboid plates covered with a hard, enamellike substance known as ganoin. Ganoin differs from enamel in its origin, being derived from the under layer of the skin (*dermis*) rather than from the upper layer (*epidermis*).

A third type of scale is the *cycloid scale*, which is supposed to be the more primitive of the two kinds of scales found on most modern bony fishes. It is the type found on trout, whitefishes, tullibees, and some other fishes. This type is more or less circular in outline, although indentations may occur on the inner margin. These scales are bony without any enamel or ganoin.

A fourth type of scale is the *ctenoid scale*, which is found on the majority of fresh-water fishes. This type is bony and serrated, i.e., has many saw-toothed processes, on the free or outside margin. A few fishes, such as catfishes, have lost all or most of their scales. Others, such as the brook trout and the burbot, have small, almost imperceptible scales.

All cycloid and ctenoid scales are fully formed during the first few weeks of the fish's life. No new scales are added as the fish grows, but as growth proceeds the diameters of the scales increase. The growth of the scale is accomplished by the periodic addition of marginal units known as *circuli*. Growth is not as fast during the winter and through the spawning season as in the summer. Consequently the circuli may be crowded and incomplete during the winter. The resumption of rapid growth in the spring causes new and complete circuli to be laid down outside the incomplete circuli and forms a rather distinct mark known as the *annulus*. The age of the fish can be determined by counting the annuli in much the same manner as the rings on a tree trunk are counted. Any scales lost by accident at any time in the fish's life can be regenerated or replaced by new scales. Regenerated scales cannot be used to determine age because they do not show growth rings previous to regeneration.

Bony plates imbedded in the skin and covered by a thin epidermis are found in many primitive fishes, such as sturgeons, gars, and dogfishes. In the higher bony fishes many of the bony plates of the head have become part of the skull and no longer form part of the skin covering. Some of the bony fishes, such as minnows and suckers, have the head naked; that is, covered by smooth skin only. Others may have the head partly covered by scales.

The size and number of scales in various dimensions of a fish are frequently used in identifying various species. The most important of these counts is the number of scales in the lateral line. Counts of the scales in an oblique line from the lateral line to the middle of the back in front of the dorsal fin and from the lateral line to the middle of the belly anterior to the vent, excluding those of the lateral line, are often used in the identification of various species. In the description of a fish, the perch for example, the number of scales would be written thus: 5–55–17, indicating 5 rows above the lateral line, 55 in it, and 17 below it. These numbers are generally not absolutely the same for all members of a species, and therefore averages and ranges are usually given in descriptions.

The *head* of the fish is considered to be that portion extending from the tip of the snout to the hind margin of the opercular membrane. The *opercles* are the bony flaps covering the gills. In front of the opercle bordering the cheek is the *preopercle*, the lower bone is the *subopercle*, and the bone under the preopercle and in front of the subopercle is the *interopercle*. For purposes of identification the *snout*, or nose, is considered to be the region extending back to the front margin of the eye orbit. The *cheek* is the area lying between the eye and the preopercle. The mouth is said to be *terminal* when it forms the extreme anterior tip of the head. When the mouth is preceded by a snout, it is said to be *subterminal*. The lower jaw is formed largely of the *dentary* bone, but other bones, such as the *splenial, articulare,* and *angulare,* form minor portions. The upper jaw is mainly formed by two bones, the *premaxillary* and the *maxillary*. Sometimes a *supplementary maxillary* may be present. These bones are covered by a thin skin only and can easily be observed externally. The head is said to be *depressed* when flattened from above, or dorsoventrally, as in the catfishes.

The membrane on the under side of the opercle is the *gill,* or *branchiostegal membrane*. This membrane contains a series of supporting bony rays, the *branchiostegals*. The fleshy space under the throat and between the gills is the *isthmus*. Sometimes, as in the perch, the gill-membranes may unite and join the isthmus far forward and are said to be *free from the isthmus*. In other fishes, such as the redhorse, the gill-membranes are joined to the isthmus directly and are said to be *united to the isthmus*. (See Diagram 2.)

Teeth may be present on almost any bony structure in the mouth. In a few fishes teeth are vestigial or absent. The teeth of most fresh-water fishes are conical in shape and vary in size from the numerous tiny spines of the bullhead to the large fangs of the muskellunge. Many fishes have teeth, called *vomerine teeth,* on the vomer bone in the center of the roof of the mouth, and some have teeth on the rudiments of a tongue, although most fishes have little tongue development. Teeth may be located on the *palatine bones* just back of the vomer and on the *pterygoid bones* located back of the palatines. Frequently teeth, known

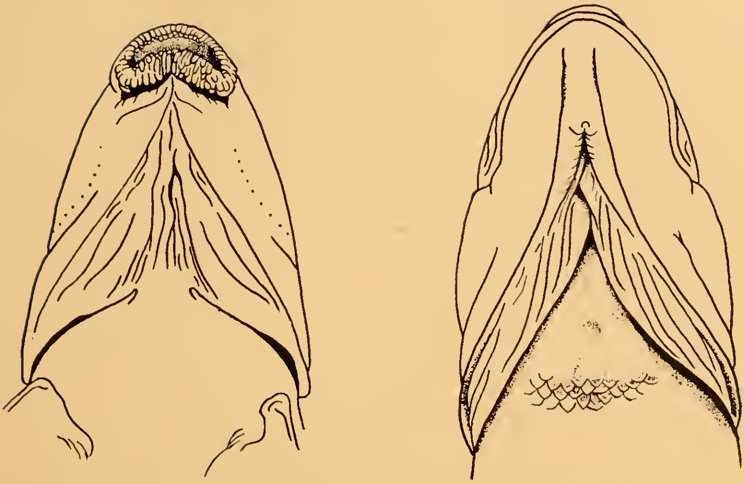


Diagram 2. Left, gill-membranes united to isthmus. *Right*, gill-membranes free from isthmus.

as *pharyngeal teeth*, are found in the throat region on the inner margin of the gill-bars.

Barbels are present on the heads of some fishes. These are soft, thread-like structures above or below the mouth. Barbels form the so-called whiskers of the bullhead.

The *nostrils* are usually double apertures on each side of the snout which open into a pair of blind pits. They do not open into the throat as they do in land animals. The nostrils serve only as organs of smell and have the same nerve connections as those in the higher land animals.

Four pairs of *gills* are present. Each gill is composed of a *gill-bar*, or *gill-arch*, on the outer edge of which are two rows of delicate red filaments. These are the *gill-filaments*, the respiratory structures of the fish. They contain numerous small blood vessels, which lies close to the surface, thus enabling the blood to obtain oxygen from the water which flows through the openings, the *gill-clefts* or *gill-slits*, between the gills. The gill-cleft behind the fourth gill is closed in some species. The gill-clefts are guarded by numerous projections, known as the *gill-rakers*, attached to the inner surface of the gill-bar. In most fishes the gill-rakers are a series of coarse projections along the inside surface of each gill-arch, but in some fishes, the tullibee for example, the rakers consist of long filaments almost as fine as the gill-filaments. The purpose of the gill-rakers is to strain the water and prevent any solid objects or food from passing out through the gill-clefts.

Rudimentary gills are frequently present. These are relics of a time when fishes had more gills than they now possess. Such a gill, known as the *opercular gill,* is found on the lower inner surface of the opercle of some fishes, such as the gar and the sturgeon. This type of gill has the same blood circulation as a normal gill, receiving venous, or nonaerated, blood. The *pseudobranchia* is a rudimentary gill found on the upper inner surface of the opercle of certain fishes. It does not have normal gill circulation but receives only arterial, or aerated, blood. It appears as a small patch of red filaments.

The fifth gill-arch is located next to the shoulder girdle and bears no functional gills. The bones of the upper part of the fourth gill-arch and those of the lower part of the fifth arch are modified and bear teeth, those of the fourth gill-arch being known as the *upper pharyngeals* and those of the fifth as the *lower pharyngeals.* In the perch these pharyngeal teeth are very numerous and fine and are set in several masses, usually two masses in the upper and two in the lower. It is often necessary to know the nature of the lower pharyngeal bones and teeth for identification, especially those of the suckers, minnows, and sunfishes. In the suckers these teeth are arranged in a single row on each side, each row containing numerous teeth, which in some species are all about the same size; in others the lower teeth are very large, graduating to smaller ones as they proceed upward. In the minnows they may be in either one or two rows, but in any case the outer row contains the largest teeth, of which there are seldom more than five. The teeth in this row may have developed grinding surfaces and in some species they may be hooked.

The fins of the fish are of two types, the paired fins and the unpaired, or median, ones. The paired fins consist of the *pectoral fins* and the *ventral,* or *pelvic, fins,* which are respectively homologous to the front and hind legs of land animals. The pectoral, or shoulder, fins are located just behind the gill-arch. The ventral fins may be located just anterior to the anus, or vent, in which position they are termed *abdominal.* Frequently they are located anteriorly in close proximity to, but slightly behind, the pectoral fins, in which case they are called *thoracic.* When they are anterior to the pectoral fins, they are known as *jugular.*

The unpaired fins are always median in position and consist of a *dorsal fin* on the back, a *caudal,* or *tail, fin,* and an *anal fin* located under the tail and just behind the vent. Frequently the dorsal fin is divided into a front, or anterior, part and a hind, or posterior, part. The *length* of the dorsal or the anal fin is the distance along its base, and the *height* is the length of its longest ray. The tail, or caudal, fin may be of either the *heterocercal* or the *homocercal* type (Diagram 3).

The heterocercal type is found only in primitive fishes, such as the sharks, the sturgeons, and the paddlefish. It consists of a fin forked into an upper and lower lobe, the upper lobe being larger. The backbone extends into the upper lobe. In some fishes, such as the gars and the fresh-water dogfishes, a modified heterocercal type is present. In this type the ventral lobe only is developed in adults, leaving a rounded tail. The homocercal type is found in most fresh-water fishes. It is the type of tail fin in which the lobes are equal, although in many species it may not be forked. The backbone does not extend into either lobe.

The fins are supported by bony structures consisting of *soft rays* and *spines*. The soft rays are usually flexible, segmented structures,

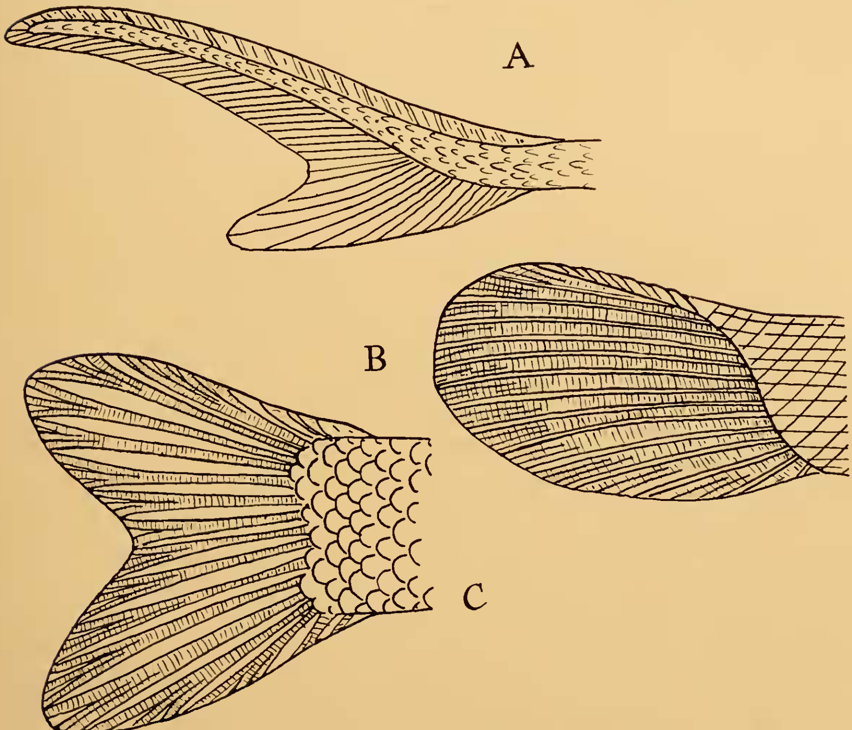


Diagram 3. (A) Heterocercal tail of *Scaphirhynchus platorynchus*. (B) Modified heterocercal tail of *Lepisosteus osseus*. (C) Homocercal tail.

which often branch or diverge at their outer ends. The true spines are often hard, pointed structures which are unsegmented and restricted to median fins. Although true spines are found only in the median fins, the stiffened rays of paired fins are usually referred to as spines. Many fishes have fins containing both spines and rays. In some fishes, such as the trout and the catfishes, a small fleshy lobe is present between the dorsal fin and the caudal fin; this is the *adipose fin* and is entirely without rays or spines. Usually the number of spines is expressed in Roman numerals and the rays in Arabic numerals.

Internally, fishes possess virtually the same systems of organs as the land vertebrates. The *pharyngeal,* or *throat, cavity* opens into the stomach just back of the gills. Owing to the absence of the neck, the *esophagus* is usually not well defined. The *stomach* is so close to the mouth that it is possible to remove food from the stomachs of many fishes by inserting an ordinary pair of pliers down the fish's throat. Most fishes have a simple saclike stomach, but a few, such as the gizzard shad, have highly specialized stomachs.

The stomach empties into the intestine. Near the union of the intestine and the stomach, fingerlike pockets known as *pyloric caeca* are sometimes present. In some species these pyloric caeca are filamentous and very numerous. In sharks and a few primitive bony fishes, such as the paddlefish, the intestine is a short spiral tube, called the *spiral valve.* Most modern fishes have a more or less coiled tubular type of intestine, such as is found in the land vertebrates. The intestine discharges waste through the anus, commonly called the *vent.* Near it are the openings for the *excretory* and *genital ducts.*

Fishes possess a liver, pancreas, and spleen, which in general are similar to those of the land vertebrates. The *kidneys* are straplike organs in the roof of the body cavity, sometimes appearing as dark red streaks below and on each side of the backbone. The *ovaries* or *testes* are also located in this same general region. During or just preceding the spawning season these organs become very large, the ovaries often crowding the entire body cavity with thousands of eggs.

All Minnesota fishes are egg-laying forms. The eggs are laid before they are fertilized, and the male liberates the *sperm,* or *milt,* over or near them. Fertilization is accomplished by the sperm's actually swimming or floating to the egg and uniting with it in the water.

The *swim,* or *air, bladder* is a large, tough-walled sac just below the kidneys and is sometimes divided. In a few fishes, such as the dogfish and the gars, this bladder is connected to the throat region and can be used as a lung. Such fishes as gars, bowfins, and bullheads gulp air into it. In most fishes the swim bladder does not retain its connection with the digestive system but is a closed sac filled with a mixture of oxygen, nitrogen, and carbon dioxide secreted from the blood. Its chief function seems to be as a hydrostatic organ regulating the buoyancy of the fish. Some fishes can use the oxygen in the swim bladder as a reserve supply for respiration and thus descend for several hours into water deficient in oxygen.

The *heart* is located far forward, just under the gills. It is composed of a single *auricle* and *ventricle.* All blood is pumped directly from the heart into the gills, where it is aerated and then distributed to all parts of the body.

The *brain* is small in proportion to the size of the body. A catfish weighing almost as much as a man has a brain not much larger than a man's thumb. Although the fish brain has most of the parts found in the brains of land vertebrates, many parts are not fully developed. Fewer cranial nerves are present. The *forepart,* or *cerebrum,* which forms the thinking region of the human brain, is undeveloped in the fish.

The skeleton is relatively complex. The skull when fully developed contains an enormous number of bones. Many of the bones found in fishes are present in land animals, but in land animals the number is greatly reduced by the fusion of many bones to form single bones. Fishes often have an extra rib, peculiar to them, which enables them to have an inner and outer pair of ribs for each trunk vertebra. Together with the accessory bones between the muscles these ribs make some species exceedingly bony.

Classification and Origin of Fishes

The animal kingdom is divided into major divisions known as phyla. The fishes belong to the great phylum Chordata, which includes all the vertebrates or backboned animals. This phylum is divided into classes, each of which is subdivided into orders. The orders are subdivided into families, which in turn are divided into genera. Each genus contains one or more species. The combination of the generic name and the specific name constitutes the scientific name. To be complete the scientific name should be followed by the name of the author or person who originally described the animal under the species designated. If the genus has since been changed, the name of the original author is given in parentheses. In recent years minor variations of certain species have been noticed in different geographical regions. When these variations occur within definite geographical ranges a third name designating a subspecies is added.

For many years all fishes were included in one class of vertebrates, under the name *Pisces*. In recent years zoologists have realized that the fundamental structures of many fishes vary so widely that this group really contains a number of classes. Consequently investigators have developed various classifications, each dividing the fossil fishes and modern, or living, ones into a number of classes. Considerable controversy has arisen as to which of the several classifications is best, and consequently no one general classification is in universal use.

In general, modern, or living, fishes may be separated into three distinct groups. The first are commonly called the cyclostomes and are represented by the lampreys and the hagfishes. The cyclostomes are jawless forms without paired fins. The cartilaginous fishes (*Chondrichthyes*) form another group. They have well-developed jaws and paired fins, but their skeletons are entirely of cartilage, without any bone at all. This group includes the sharks, skates, rays, and chimaeras, almost all of which are marine fishes. None are found in the fresh waters of North America except in some waters immediately adjacent to the Gulf of Mexico. The bony fishes (*Osteichthyes*) form the last group. They are highly developed fishes with skeletons formed more or less of bone. This group includes a vast number of marine fishes and all the species of the fresh-water fishes of North America, with the exception of the few species of lampreys.

Fishes are said to be the oldest of the backboned, or vertebrate, animals. The oldest well-known vertebrate fossils, remains of animals that lived millions of years ago, are those of fishlike forms known as the Ostracodermi. These earliest forms were without well-developed skeletons, and some were covered with plates. They lacked upper and lower jaws, teeth, and paired fins. The present-day lampreys and hagfishes, though highly specialized, are probably modern relics of these early types.

The sharks appeared soon after these early forms, and although their skeletons were of soft cartilage, they had a definite and characteristic skeleton. They had upper and lower jaws developed from the front gill-arch. The primitive placoid scale appeared, the enlarged scales on the margin of the jaw developed into teeth, and the paired fins appeared. These early sharks were the first true fishes. At one time, ages ago, they comprised all the fishes in the world, and many still remain in the sea today.

The modern Osteichthyes, to which true fresh-water fishes belong, undoubtedly developed from some sharklike ancestor. They first appeared as a series of primitive fishes with cartilaginous skeletons covered by bony plates and scales. A few of this primitive type still remain as sturgeons, paddlefish, gars, and dogfish.

One group of these primitive fishes, now virtually extinct, learned to breathe air by means of the swim bladder. By means of their paired fins they crawled out of the water on to the banks and found a world where there was no competition from other vertebrates. Some of these fishes never returned to the water but became the ancestors of the land vertebrates. Lungs probably developed from swim bladders, and the paired fins became fore and hind legs.

Another group of these primitive bony fishes became the ancestors of the modern bony fishes. They incorporated into the skull the bony plates covering the head, lost at least one of their gill-slits, replaced most of the soft cartilage in their skeletons with hard bone, and formed bony spines and rays to support the fins. Most of the modern fishes have departed as widely from the form and structure of their primitive ancestors as have the land vertebrates descended from the same ancestors.

To aid in the classification of the fishes described in this book, the following taxonomic keys to the families and to the species are included. If the family is unknown, it may be found by using the family key, assuming that the person using the key has studied the pages describing the structure of the fish. To use the key, select the part of each couplet that agrees with the structure of the fish, and continue to the couplet indicated by the number at the right, until the family is reached. Then find the page indicated for the family and follow through the key to the species. In those families represented by only one species no key to the species is necessary.

Artificial Key to Families of Common Fishes

1. Mouth, suckerlike disc without jaws; no paired fins..PETROMYZONIDAE (p. 67)
   Mouth with jaws; one or two pairs of paired fins........................2
2. Tail heterocercal (Diagram 3)..3
   Tail homocercal (Diagram 3)..6
3. Tail typically heterocercal with well-defined ventral lobe; mouth subterminal..4
   Tail heterocercal but with rounded ventral lobe obliterated; mouth terminal..5
4. Long, paddlelike snout nearly one-half length of body; body naked; minute barbels present..............................POLYODONTIDAE (p. 73)
   Short, flat snout; body with bony plates; well-developed barbels present in front of mouth..............................ACIPENSERIDAE (p. 75)
5. Rhombic ganoid scales; short dorsal fin, base less than height; long jaws..LEPISOSTEIDAE (p. 81)
   Cycloid scales; long dorsal fin, base many times height; jaws moderate..AMIIDAE (p. 85)
6. Ventral, or pelvic, fins absent; body eellike.........ANGUILLIDAE (p. 192)
   Ventral, or pelvic, fins present; body not eellike........................7
7. Ventral fins abdominal (see page 58)..............................8
   Ventral fins jugular or thoracic (see page 58)........................20
8. Dorsal fin preceded by free dorsal spines (Figure 55)..GASTEROSTEIDAE (p. 255)
   Dorsal fin not preceded by free dorsal spines..........................9
9. Dorsal fin divided into two parts, or with separate adipose fins behind (Diagram 1; Figure 9)..10
   Dorsal fin single; no adipose fin present............................14
10. Anterior part of dorsal fin very small, of 3–8 slender, flexible spines; the posterior part much larger and consisting of soft rays..ATHERINIDAE (p. 245)
    Anterior dorsal fin large; posterior adipose fin present, fused with caudal fin in a few species..11
11. No scales; barbels on head; single stout spine in dorsal and pectoral fins..AMEIURIDAE (p. 169)
    Scales present; barbels absent; pectoral fins without spines.............12
12. Scales ctenoid; anterior dorsal fin with 2 weak spines. .PERCOPSIDAE (p. 197)
    Scales cycloid; dorsal fin without spines............................13
13. Mouth weak; teeth vestigial or absent; scales large, less than 100 in lateral line..COREGONIDAE (p. 94)
    Mouth strong; teeth well developed; scales small, more than 100 in lateral line..............................SALMONIDAE (p. 105)
14. Head scaly or partially scaly..15
    Head without scales..17

15. Jaws elongated, shaped like a duck's bill; large, irregular teeth; tail deeply forked . . . . ESOCIDAE (p. 185)
Jaws not elongated; weak teeth; tail more or less rounded 16

16. Upper jaw not protractile, formed by maxillary bone. . UMBRIDAE (p. 183)
Upper jaw protractile, formed by premaxillary bone. . . . . CYPRINODONTIDAE (p. 194)

17. Gill-membranes united to isthmus (Diagram 2) 18
Gill-membranes free from isthmus (Diagram 2) 19

18. Dorsal fin with 10 or more rays; pharyngeal teeth numerous, in only one row . . . . CATOSTOMIDAE (p. 117)

Dorsal fin with less than 10 rays (except introduced carp and goldfish); pharyngeal teeth less than 10 on each side, in one or more rows. . . . . CYPRINIDAE (p. 138)

19. Lateral line present; tongue with sharp teeth. . . . . HIODONTIDAE (p. 88)
Lateral line absent. . . . . CLUPEIDAE (p. 90)

20. Body scaleless, but covered with tiny spines or prickles; head large; eyes in top of head; pectoral fins very large. . . . . COTTIDAE (p. 250)
Body with scales. 21

21. Vent anterior to pectoral fins. . . . . APHREDODERIDAE (p. 199)
Vent posterior to pectoral fins. 22

22. Single median barbel on chin. . . . . GADIDAE (p. 258)
No barbel on chin. 23

23. Anal spines, 2 or less. 24
Anal spines, 3 or more, first spine sometimes rudimentary. 25

24. Spinous and soft-rayed portion of dorsal fin completely divided into 2 separate fins. . . . . PERCIDAE (p. 204)
Spinous and soft-rayed portion of dorsal fin confluent. SCIAENIDAE (p. 247)

25. Without longitudinal dark stripes on side of body, or with only one; dorsal fins confluent (but deeply notched in largemouth bass) . . . . CENTRARCHIDAE (p. 226)
With 5 or more usually distinct narrow, dark longitudinal stripes on side of body; dorsal fins either separate or deeply notched. . . . SERRANIDAE (p. 201)

The CYCLOSTOMES

LAMPREYS AND HAGFISHES

The only true vertebrate parasites are found among the cyclostomes. Some zoologists classify the cyclostomes as fishes; others recognize them as a distinct and different group, more primitive than fishes and somewhat degenerate. They are eellike forms found in the sea and in fresh water. They contain two important divisions, the hagfishes and the lampreys. The hagfishes are entirely marine. The lampreys are found both in the sea and in fresh water.

The cyclostomes are all characterized by the absence of several fish characters: paired fins or appendages, true teeth, scales, and upper and lower jaws. They are usually considered very primitive vertebrates in which these structures have not developed. The brain and skull are imperfectly developed. The vertebral column is poorly formed, and most of the supporting structure consists of a stiff, rodlike notochord. The gills open externally through separate gill-clefts.

Most of the members of this group are carnivorous or semiparasitic. The marine hagfishes are very destructive, for they burrow into the bodies of living fishes and devour their flesh until nothing remains but skin and bones. Many of the lampreys are injurious to fishes. The adults attack fishes with their round, suckerlike mouths. They rasp a hole in the side of the fish and suck blood; when gorged with blood they drop off, leaving terrible round sores, which if they do not actually kill the fish weaken it and frequently cause fatal infections. Fish disfigured by fresh lamprey sores lose their market value.

Family PETROMYZONIDAE

THE LAMPREY FAMILY

The lampreys, or lamper eels, are characterized by the circular funnellike "mouth," or buccal cavity, armed with toothlike horny spines. They are without scales or paired fins and possess but a single nostril. The skeleton is wholly of cartilage and consists of an imperfect skull and a poorly developed vertebral column supported by an unconstricted notochord. Seven pairs of external gill-openings are present. The gills are supported by an arrangement of cartilage known as the *branchial basket.*

The buccal cavity, or *buccal funnel,* contains horny, toothlike spines; those immediately surrounding the mouth opening are commonly called the *circumoral teeth.* Bordering the opening of the mouth anteriorly and posteriorly are horny plates bearing spines known as the *supraoral* and *infraoral laminae.* The *transverse lingual lamina* and the *longitudinal lingual laminae* are the teeth of the tongue.

The lampreys of the central United States have nonparasitic larval stages called *ammocoetes.* These larvae are blind, eellike forms living a more or less sedentary life buried in the mud. In this manner they spend a period of years, eventually metamorphosing into active adults. At the end of the larval period the ammocoetes may be larger than the adults. Ammocoetes have been reported by Creaser and Hann (1929) as feeding largely on algae.

The species of lampreys native to Minnesota and its neighboring states are all small. A marine species, the river, or great sea, lamprey, *Petromyzon marinus* Linnaeus, found on the Atlantic Coast, reaches a length of over 2 feet. This species ordinarily ascends rivers to spawn and has become landlocked in certain eastern lakes. It has recently invaded the Great Lakes by way of the Welland Canal, and has caused considerable damage to commercial fishes. It has been reported at the eastern end of Lake Superior and will probably appear off the Minnesota North Shore within a few years.

The classification of the fresh-water lampreys has been revised by Hubbs and Trautman (1937), and four species are assigned as native to the Minnesota region. Three of these species belong to the genus *Ichthyomyzon,* and one species belongs to the genus *Entosphenus,* formerly called *Lampetra.*

Key to Common Species of Family PETROMYZONIDAE

1. Dorsal fin continuous, not divided.................................2
   Dorsal fin distinctly divided; digestive tract rudimentary in adult..........

............American Brook Lamprey, *Entosphenus lamottenii* (LeSueur)

2. Parasitic species; adults retaining a functional digestive tract until a length of more than 7 inches is attained; teeth well developed, regular on posterior field of buccal funnel; length of buccal funnel contained 7.7–16.9 times in total length 3
Nonparasitic species; adults with nonfunctional digestive tract; total length less than 7 inches; teeth more or less degenerate, at least on posterior field of buccal funnel; length of buccal disc contained 15.4–27.7 times in total length ....
....Michigan Brook Lamprey, *Ichthyomyzon fossor* Reighard and Cummins

3. Circumoral teeth, with rare exceptions, all unicuspid (single pointed); myomeres (body segments) between last gill-slit and anus usually 49–52; transverse lingual lamina moderately to strongly bilobed....................
...........Silver Lamprey, *Ichthyomyzon unicuspis* Hubbs and Trautman
Circumoral teeth in part, usually 6–8, bicuspid (double pointed); myomeres between last gill-slit and anus usually 51–58; transverse lingual lamina usually linear or weakly bilobed..............................
.....................Chestnut Lamprey, *Ichthyomyzon castaneus* Girard

GENUS *Ichthyomyzon* Girard

These are medium-sized lampreys. The adults may be distinguished from the genus *Entosphenus* by the presence of a single emarginated dorsal fin which is continuous with the tail, or caudal, fin.

Figure 1. Silver lamprey, *Ichthyomyzon unicuspis*, 8 inches long.

SILVER LAMPREY

Ichthyomyzon unicuspis Hubbs and Trautman

The silver lamprey (Figure 1) is a species recently separated by Hubbs and Trautman (1937) from material previously known as the western lamprey, *Ichthyomyzon concolor* Kirtland. It is a small, slender, eellike animal, 8 to 16 inches long, with a large, funnel-shaped buccal cavity greater in diameter than the body. The circumoral teeth are entirely unicuspid.

Silver lampreys have been reported by Hubbs and Trautman from the Great Lakes including Superior, from Lake of the Woods, and from the Upper Mississippi drainage. Most of the lampreys in the collections of the University of Minnesota from Lake Pepin and Lake of the Woods are of this species. They are very abundant in Lake of the Woods. They are present in the Minnesota and St. Croix rivers and probably in the other large streams and some lakes of Minnesota and neighboring states.

This lamprey is parasitic on fishes and is very destructive, especially in the Lake of the Woods region. When sexually mature the adults ascend small streams to spawn, and die soon afterward. The eggs develop into larval ammocoetes, which drift downstream into quiet pools, where they spend a period of years developing in the sand and mud. Eventually they metamorphose into parasitic adults preying on fishes in large streams and lakes until they become sexually mature.

MICHIGAN BROOK LAMPREY

Ichthyomyzon fossor Reighard and Cummins

The body form of the Michigan brook lamprey is similar to that of the silver lamprey except that the funnellike buccal cavity is much smaller. The adults after metamorphosis have degenerate digestive tracts and do not feed. Hence this species is nonparasitic, and Hubbs and Trautman (1937) consider it a nonparasitic derivative of the silver lamprey, *Ichthyomyzon unicuspis.*

Ichthyomyzon fossor has been reported from the Lake Superior drainage in Michigan, from New York State, and from Wisconsin, by Hubbs and Trautman. It is reported as living in small rivers and creeks. No specimens have been reported from Minnesota waters, and it may not occur in this state. Greene (1935) stated that this species is definitely known from the Mississippi drainage in Wisconsin.

The life history and habits of this species have been studied by Okkelberg (1922). The Michigan brook lamprey passes several years in the ammocoetid stage before metamorphosing. The adults do not feed but usually live for a period of four to eight months before spawning and dying.

CHESTNUT LAMPREY

Ichthyomyzon castaneus Girard

The chestnut lamprey is a small, slender, eellike animal, 8 to 16 inches long, with a large funnel-shaped buccal cavity which, when expanded, is greater in diameter than the body. The circumoral teeth are partly bicuspid. The dorsal and caudal fins are continuous.

This species is distributed through the Upper Mississippi Valley and has been reported in the Great Lakes and in the Hudson Bay drainage. It is not common in Minnesota. Hubbs and Trautman (1937) reported it as rare in Lake Pepin. Several of the lampreys in the University of Minnesota collections from Lake Pepin are of this species.

Its habits are similar to those of the silver lamprey.

GENUS *Entosphenus* Gill

Members of this genus have the dorsal fin broken into two parts and separated from the caudal fin. Only one species of this genus occurs in the Upper Mississippi Valley.

AMERICAN BROOK LAMPREY
Entosphenus lamottenii (LeSueur)

The brook lamprey (Figure 2) is small and very slender, seldom reaching a length of over 8 inches. The funnellike buccal cavity is small, the diameter being only slightly more than that of the body. Most of the teeth are blunt and small; three large bicuspid teeth are located on each side of the mouth. The intestine of the adult is degenerate and nonfunctional. The dorsal fin of the adult consists of an anterior and posterior portion separated by a slight notch, or narrow space.

Figure 2. American brook lamprey, *Entosphenus lamottenii*, 6 inches long.

The brook lamprey ranges northward from Tennessee and Missouri to western Pennsylvania and through the Great Lakes drainage to northern Minnesota. It occurs also in the Atlantic drainage from the Connecticut River to Maryland. It is widely distributed in Minnesota and neighboring states. Surber (1920) reported it from the south branch of the Whitewater River at Elba, Minnesota. An ammocoete provisionally assigned to this species is in the University of Minnesota collections from the Sturgeon River in the Arctic drainage in St. Louis County. The brook lamprey is present in many of the tributaries of the St. Croix River and is very abundant in many of the smaller tributaries of the Minnesota River near Minneapolis. Greene (1935) reported it from a number of small streams in Wisconsin.

The brook lamprey is confined to small, clear streams, where they are often very numerous. However, the ammocoetes are usually hidden in the mud, and so only the adults, during their brief spawning period, are observed. In the Credit River, a small tributary of the

Minnesota River near Savage, Minnesota, the brook lampreys spawn by the hundreds each year from May 5 to May 20. They congregate in the gravel riffles, where they attach themselves to stones by their suckerlike buccal funnels. Shallow nests are hollowed out and the eggs deposited. Frequently several males attend one female.

The larval ammocoetes drift downstream into the pools, where they live buried in the bottom mud. The length of the larval period has been estimated as about five years. Some of the ammocoetes found in the Credit River were larger than the adults. The larval forms are lighter in color than the adults. The dorsal fin of the larval forms is continuous with the caudal fin. The buccal funnel is smaller than that of the adults.

The adults do not feed and hence are nonparasitic. The adult life is short, for the adults die soon after spawning. Detailed life histories are described by Gage (1893 and 1928).

The Osteichthyes or Bony Fishes

Most of our modern fresh-water fishes are characterized by the presence of bone, which distinguishes them from cartilaginous fishes, such as the sharks and their relatives. These latter are characterized by primitive skeletons entirely of cartilage and by uncovered gill-clefts. The cartilaginous fishes are mostly marine; none are found in the fresh waters of North America.

Most fresh-water fishes are highly developed forms. There are a few primitive types, Chondrostei and Holostei, in which very little bone is present, such as the sturgeons, gars, paddlefish, and dogfishes. These forms retain many characteristics of the ancestors of the more highly developed modern forms, the Teleostei, which may be called the bony fishes.

The bony fishes as well as the cartilaginous fishes (Chondrichthyes) are differentiated by the development of upper and lower jaws and two pairs of appendages, or fins. Scales of some type are usually present, although in some fishes they may be lost. Teeth are usually present, but a few species have lost their teeth or have only vestigial ones.

The skeleton of the Teleostei is fully formed and is usually of bone, although some of the more primitive do not have the bones completely ossified, and in a few the bones may remain partly or wholly of cartilage. The gill-clefts are always covered by an opercular flap (see Diagram 1).

Family POLYODONTIDAE

THE PADDLEFISH FAMILY

The paddlefishes belong to an ancient group of fossil fishes which are known by several fossils representing two species. Two modern species are living today. One is the paddlefish found in the Mississippi River system and the other is *Psephurus gladius,* found in the Yangtse River in China. *Psephurus gladius* is said to reach a length of 20 feet. The paddlefishes are smooth-skinned fishes with the snout prolonged into a long, thin, paddle-shaped projection, which is somewhat flexible.

GENUS *Polyodon* Lacépède

There is only one living species in this genus, the characters of which are given below.

PADDLEFISH (Spoonbill Cat)
Polyodon spathula (Walbaum)

The paddlefish (Figure 3) is a primitive fish having a skeleton composed chiefly of cartilage. It has a long, thin, paddlelike snout extending almost one-third the length of the body. The mouth is broad and subterminal. Small teeth are present only in the younger individuals. The skin is smooth and without scales, though traces of rhomboid scales are found on the upper lobe of the caudal fin. The gills are covered by a large, peculiar soft opercle reaching to the base of the ventral fin and ending posteriorly in a point. A spiracle is present. The tail is heterocercal. The color is a uniform leaden gray. Internally the paddlefish has a swim bladder like that found in most higher fishes. It has a peculiar intestine of the spiral-valve type usually found in sharks. The swim bladder is cellular and is connected by a duct with the esophagus.

Its primitive, sharklike form, peculiar anatomy, and large size make the paddlefish one of the most interesting fishes found in the Mississippi Valley. It attains a length of over 6 feet and a maximum weight of 184 pounds (Kuhne, 1939). A specimen 5 feet 10 inches long had a paddle 16 1/2 inches long and 4 inches wide. The eggs are greenish black, therein resembling the eggs of the rock sturgeon, but are very small as compared with rock sturgeon eggs.

The breeding habits were largely unknown until reported recently by Thompson (1933). The young start life without the paddlelike snout, but feed like the adults. In Illinois the adults apparently spawn in April; in Louisiana they spawn in February and March. Nearly ripe females have been procured from Lake Pepin late in May. Alexander (1914) said that in Louisiana the paddlefish are found at the spawning season in schools close to the hard, sandy bottom along the border of lakes.

Figure 3. Paddlefish, *Polyodon spathula.*

Evermann in Kentucky, Forbes in Illinois, and Alexander in Louisiana all agree that during the spawning season the paddlefish move in large schools near the surface. Little has been known about their growth rate; although many people have thought that the rate was slow, it may be quite fast. Dr. R. E. Johnson of the Minnesota Department of Conservation writes that a paddlefish kept in a pond by the Nebraska Game, Forestation and Parks Commission grew at a rate of nearly a foot a year.

Paddlefish live in waters with a muddy bottom. As they swim through the water, the snout weaves back and forth giving the impression of a spirallike movement. They feed largely on minute crustacea, which they secure by swimming with their mouths open. The crustacea are strained from the water by means of long, fine gill-rakers, which form very efficient plankton nets. The stomachs examined by Eddy and Simer (1929) were usually filled with minute water fleas and copepods. Occasionally they may sweep up a few small aquatic insects.

This species originally ranged in the quiet waters of the Mississippi and larger tributaries and bayous from Minneapolis to the Gulf. At present it is much more abundant in the southern part of its range. Only a few specimens of this species are taken annually from Lake St. Croix and from the Mississippi River below Lake Pepin. They were at one time rather abundant in Lake Pepin, and their almost complete disappearance from these waters within the past twenty years is attributed by the commercial fishermen to the Keokuk Dam. Wasteful methods of fishing, mainly for the purpose of procuring the eggs, may partly account for their disappearance. Pollution of the Mississippi, particularly at the head of Lake Pepin, may have been a contributing cause. Paddlefish formerly occurred in the Minnesota River as far up as Mankato and in the St. Croix River to Taylors Falls.

The paddlefish are caught largely in nets and traps, but they have been caught occasionally on setlines. The flesh has an ever-increasing commercial value, for it is almost boneless and closely resembles that of the rock sturgeon in flavor and texture. In some southern localities it commands a high price and is sold as "boneless cat." Part of its value lies in the eggs, which are sometimes mixed with those of the sturgeon to produce caviar of excellent quality.

Family ACIPENSERIDAE

THE STURGEON FAMILY

The sturgeons are the remnants of an ancient and primitive group of fishes in which the primitive cartilaginous skeleton is retained and bony plates have appeared in the skin. Sturgeons are found throughout northern Europe, Asia, and North America. Some species are marine, others ascend rivers periodically to spawn, and others are landlocked. In North America two species are found on the Atlantic Coast. Two other species occur on the Pacific Coast, one of which, *Acipenser transmontanus* Richardson, has been reported as weighing nearly a ton. In the Mississippi Valley there are two species of sturgeons, both present in Minnesota and neighboring states. These species are the rock, or lake, sturgeon and the hackleback, or shovelnose, sturgeon.

Sturgeons are distinguished by their shovellike snout, on the under side of which is a protractile, subterminal mouth with thick papillose lips extensible for sucking up food. Four barbels in a transverse row are present under the snout, anterior to the mouth. No teeth are present except in the very young. The internal skeleton is composed of cartilage and retains a well-developed notochord. The head is covered by bony plates, and rows of shieldlike plates occur on the sides. The gills are four in number. There are no branchiostegal rays; the gill-membranes are joined to the isthmus (p. 57). The dorsal and anal fins are inserted far back. The tail or caudal fin is heterocercal.

Key to Common Species of Family ACIPENSERIDAE

Snout pointed, sub-conic; small spiracle present; lateral bony plates not meeting on tail ....Rock Sturgeon, *Acipenser fulvescens*, Rafinesque

Snout rounded, shovel-shaped, depressed above; spiracle absent; lateral bony plates meeting and covering tail.. ....Hackleback, *Scaphirhynchus platorynchus* (Rafinesque)

GENUS *Acipenser* Linnaeus

The genus *Acipenser* is represented in North America by five species, most of which are marine and anadromous, i.e., ascend rivers to spawn. These fishes are characterized by a small spiracle and by a short, pointed snout. Many of them reach a very large size.

ROCK STURGEON (Lake Sturgeon, Red Sturgeon, Nah-way of the Red Lake Chippewas)
Acipenser fulvescens Rafinesque

The rock, or lake, sturgeon (Figure 4A) is the largest of the native fishes of Minnesota and neighboring states. Individuals weighing over

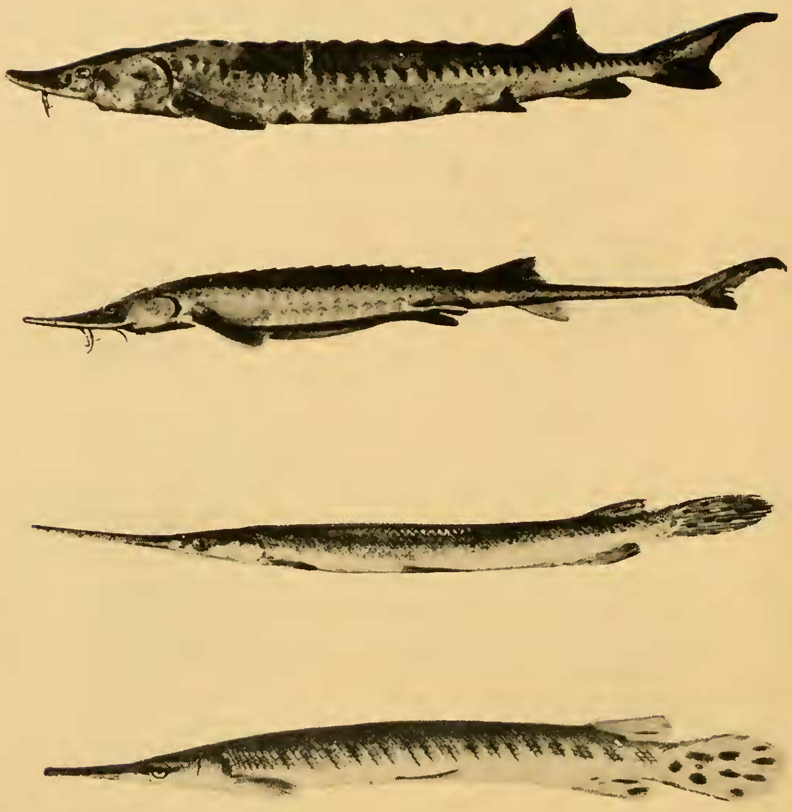


Figure 4. A. Rock sturgeon, *Acipenser fulvescens,* 23 inches long. B. Hackleback, *Scaphirhynchus platorynchus,* 20 inches long. C. Northern longnose gar, *Lepisosteus osseus oxyurus,* 24 inches long. D. Shortnose gar, *Lepisosteus platostomus,* 20 inches long.

200 pounds have been reported. The rock sturgeon may be distinguished from the shovelnose sturgeon by its more pointed snout and by the presence of a pair of spiracles, or openings, in the head, anterior to the gills. The peduncle of the tail is short and heavy.

In appearance rock sturgeon change greatly with age and size. The young have sharp snouts and very rough shields with the spines strongly hooked. The adults have blunt snouts and small, smooth shields, most of which disappear with age. The color also changes considerably: the young are usually dark olive above and paler with dark blotches on the sides; the adults are greenish olive or reddish and without spots. They commonly attain a length of 6 feet in Lake of the Woods, but what is probably the record sturgeon for this lake was procured off Long Point in June 1911. It weighed 236 pounds as caught and 120 pounds dressed and was about 8 feet long.

Rock sturgeon range through the drainages of the Red River of the North, Hudson Bay, and the St. Lawrence, and southward in the Mississippi drainage to northern Alabama and Missouri. They are a shoal-water fish occurring both in streams and lakes. In Lake Superior they are seldom if ever taken in the deep waters along the Minnesota shore but are said to be common in the comparatively shallow waters of Keweenaw Bay and in the vicinity of the Apostle Islands. They are occasionally taken in St. Louis Bay.

Rock sturgeon formerly occurred in some abundance in the Upper Mississippi River but are now becoming scarcer each year. In Minnesota they have been reported from Minneapolis (Cox, 1897), the St. Croix and Kettle rivers and Lake Pokegama in Pine County, and from Lake Pepin (Wagner, 1908), Red Lake River at Crookston (Surber, 1920), Red Lake, Lake of the Woods, and Rainy River and its tributaries. At present (1939), thanks to protective laws, rock sturgeon are increasing in the Snake, Cross, and Kettle rivers and in Pokegama Lake. Greene (1935) reported them from Lake Pepin, the Wisconsin River, and several localities in the Lake Michigan drainage. Occasionally sturgeon are caught on hooks but they are usually caught in pound nets and gill nets.

Rock sturgeon are said to frequent the shoal waters of lakes by preference and to ascend streams in the spring to spawn, but there are exceptions at Lake of the Woods. In 1911 they frequently spawned about some of the rocky islands not far south of Kenora (Surber), but their favorite spawning grounds were formerly at the Soo Rapids on Rainy River, to which point they at one time ascended in great numbers each spring at about the time the ice broke up. Spawning migrations have been noted as early as April 5, and they often last until the middle of June. At spawning time sturgeon are frequently seen in shallow water. Each spring in May and early June hundreds of sturgeon pass from the St. Croix River up the Snake River and gather under the dam at Cross Lake. The eggs are sticky and adhere to sticks and stones. The young at a length of three-fourths of an inch start feeding on Entomostraca or minute crustacea and continue this diet until they are 7 to 8 inches long.

Sturgeon are bottom feeders, their proctractile mouths being well fitted for sucking in the small animals and plants on which they feed. Their food consists principally of fresh-water snails, crawfish and insect larvae, an occasional minnow, and algae and other vegetable matter. The stomachs of 10 out of a total of 27 adults examined during June contained little but pebbles and sand. Mr. B. Arnesen of Lake of the Woods, who repeatedly kept sturgeon in confinement for long periods, found they apparently thrived on such grains as wheat and barley.

They were remarkably abundant at one time in Lake of the Woods, so much so that they were considered a nuisance by the pound-net fishermen, and many thousands were recklessly destroyed before a demand for their flesh was created. Some idea of the rapidity with which they were disappearing in this particular lake can be formed by the figures given by Evermann and Latimer (1910), who state: "In 1893 the catch in American waters amounted to 1,300,000 pounds. . . . By 1903 the sturgeon catch had dwindled to 45,239 pounds. . . . According to local fishermen there has been a slight increase in the number of sturgeon within the last few years." During the first nineteen days of September 1911 the catch of sturgeon at Curry's Fishery at the mouth of Rainy River was only 20 adult fish, that is, fish exceeding 15 pounds net weight. The number of undersized fish taken during the same period was 808; during the latter half of May 1912 the same fishery obtained 15 adults and 65 undersized fish. One 6-foot fish, a female procured by Curry in 1911, produced about 30 pounds of caviar, and the value of the fish and caviar netted the fisherman $54.80.

In this connection it is interesting to note the enormous increase in the price of caviar realized by the fishermen of Lake of the Woods. During the period 1888–91 sturgeon eggs sold at 10 cents a pound, in 1892–94 at 20 cents, in 1897 at 60 cents, in 1900 at 80 cents, and in 1909, at the peak, at $1.50 a pound. On the other hand, sounds, the swim bladder, used for the production of isinglass, maintained a steady price of $1.00 a pound from 1888 to 1902, in which year it dropped to 75 cents, and by the close of 1904 it had dropped to 50 cents, where it remained. Apparently the increasing use of various forms of celluloid and other substitutes was responsible for the drop in price.

Clearly some effort should be made to perpetuate the species. Yet it appears that it can be accomplished only by setting aside some lake where rock sturgeon now exist in numbers, if such a lake can be found, and drawing from this lake from time to time such numbers as may be needed to replenish other waters. The artificial propagation of rock sturgeon so far has been a decided failure, owing to inability to procure ripe fishes. The lake sturgeon grows very slowly, requiring 15 to 22 years to reach maturity (Borodin, 1925).

The artificial propagation of the lake, or rock, sturgeon has been the dream of fish culturists for upwards of 50 years. Efforts to procure ripe fishes have been made by successive generations, the results being the same in all but one or two instances. In 1911 Surber, who was then senior scientific assistant at the Fairport, Iowa, Biological Station, spent the entire summer and early fall at Lake of the Woods making a careful study of the problem, in both American and Canadian waters. Failing to procure any ripe fishes that season, Surber took a number of adults 5 to 6 feet long and wintered them at Le Claire Point in a specially constructed enclosure at the Curry Fishery and so continued observations on these penned fish during March, April, and May 1912.

Supplemental observations were made on additional fish procured at the mouth of Rainy River in April and May. The net result of these observations was the finding that the rock sturgeon spawned over a period of several months, depositing a few eggs at a time wherever it might be at the moment. This conclusion was based on the condition of the ovaries of upward of 40 adults which were examined critically. Eggs in all stages of development, from those scarcely one-fiftieth of an inch in diameter through all stages to those one-fifth of an inch in diameter and nearly ready for extrusion were found in the same fish.

In the early 1890's the Michigan Conservation Department succeeded in procuring ripe fishes from which they hatched several hundred thousand fry for two seasons. About 1903 the United States Bureau of Fisheries again procured some eggs and hatched them successfully at the Swanton, Vermont, Station (Carter, 1904). In the discussion following this report some interesting facts developed on the methods of handling eggs, the difficulty of procuring ripe fish, the size of the eggs, and the percentage of hatch.

GENUS *Scaphirhynchus* Heckel

This genus includes only one species, the characters of which are given below.

HACKLEBACK (Shovelnose Sturgeon, Switchtail)
Scaphirhynchus platorynchus (Rafinesque)

The hackleback or shovelnose sturgeon (Figure 4B) can be readily distinguished from the lake sturgeon by its longer snout and by the absence of a spiracle. It rarely exceeds a length of 3 feet or a weight of 5 or 6 pounds. The average is about 28 inches in length and approximately 3 pounds in weight. The body of this species is more slender than that of the lake sturgeon, the long slender tail extending fully twice as long as that of the lake sturgeon. The large caudal fin terminates in a long filament nearly if not quite equaling the rest of the fin. It also differs from young rock sturgeon of corresponding size in that small bony shields completely cover the tail, which is flattened from above. The snout is broad, flat, and shovel-shaped. Unlike that of the immature and adult rock sturgeon, its color is a uniform pale yellowish olive, without spots or blotches.

The hackleback ranges from the Hudson Bay drainage of the Canadian plains southward to New Mexico, Arkansas, and Kentucky. In Minnesota this species seems to be restricted to the Mississippi, Minnesota, and St. Croix rivers. Shovelnose sturgeon have never been able to ascend beyond the falls on any of these streams. Apparently Granite Falls on the Minnesota has prevented their distribution into the Red River but they are found in Lake Winnipeg. Although they are still taken by the commercial fishermen and an occasional angler in the St. Croix and in Lake Pepin, they are believed to be more or less uncommon at present. In Wisconsin Greene (1935) reported them from the Chippewa River and from the Mississippi River. Forbes (1908) stated that they spawn in Illinois between April and June. In Minnesota and Wisconsin they spawn in May and early June. At Taylors Falls each spring large numbers gather under the dam of the St. Croix River in an unsuccessful attempt to pass to their spawning beds. Although very little is known about their habits, it has been ascertained that they spawn in very rapid water and may therefore take advantage of the strong current created by the overflow of the newly built dams in the Upper Mississippi to maintain their relative abundance below Lake Pepin.

The hackleback finds ready sale in the market, either as steaks or smoked sturgeon. Owing to their small size most of them are smoked. In recent years the roe has been made into excellent caviar. It is often mixed with the roe of the paddlefish and even of suckers.

Comparatively little is known of their feeding habits. Stomachs examined by Surber at the Fairport laboratory indicated their food to be almost exclusively aquatic insect larvae including nymphs of dragonflies. Almost the same food habits were indicated in three stomachs secured from the Mississippi River below Winona in 1914.

Family LEPISOSTEIDAE

THE GAR FAMILY

The gars are a remnant of an ancient family. A number of species are found in the southern United States, the West Indies, Central America, and Mexico. At one time they were more widely distributed, for fossil gars are known from Europe.

They are all warm-water fishes. A species reaching a great size, the alligator gar, *Lepisosteus spatula* Lacépède, is found in the Gulf States. Gars are all distinguished by slender cylindrical bodies and thin, long, snoutlike jaws armed with sharp teeth. Teeth are present on the vomer and palatines. The body is clothed with heavy diamond-shaped ganoid scales covered by an enamellike substance, ganoin. The skeleton is partly cartilage and partly bone. The swim bladder is connected with the pharynx and may be used as a lung. The tail fin is of a modified heterocercal type (page 59).

Key to Common Species of Family LEPISOSTEIDAE

1. Beak long and slender; length of beak about 20 times least width.......... ....Northern Longnose Gar, *Lepisosteus osseus oxyurus* Rafinesque
   Beak short and broad; length of beak about 5 1/2 times least width or less. .2

2. Scales in lateral line usually 54–58; top of head with large round spots; body spotted; diffuse spots on fins......Spotted Gar, *Lepisosteus productus* Cope
   Scales in lateral line usually 60–64; top of head without spots; small round black spots on fins......Shortnose Gar, *Lepisosteus platostomus* Rafinesque

GENUS *Lepisosteus* Lacépède

Three species of gars occur in the Upper Mississippi drainage, all belonging to this genus. The single row of teeth in the upper jaw serves to distinguish these species from the alligator gar found in the south.

SHORTNOSE GAR
Lepisosteus platostomus Rafinesque

The shortnose gar (Figure 4D) is similar to the spotted gar except that the shortnose gar has no spots on top of its head and has more scales in the lateral line. It differs from the longnose gar chiefly in the length of the jaw. The back is short and broad compared to that of *L. osseus oxyurus* Rafinesque; the snout is broad and not much longer (about 1.3) than the rest of the head. A very young fish has short jaws and a wide black band on the sides. The scales in the lateral line usually number 60–64. The shortnose gar seldom exceeds 2 or 3 feet in length.

This species is distinctly southern in its distribution, occurring from

South Dakota through the Ohio Valley and south to Alabama and Texas. Cox (1897) reported only two specimens for Minnesota, both from the Mississippi River at Minneapolis. Wagner (1908) found it rather rare at Lake Pepin. Several examples were secured from sloughs in Goodhue County in 1921–23, and at least two examples were procured in a slough along the Minnesota River near Savage in 1920. Numerous specimens from sloughs near Winona are in the University of Minnesota collections. The farthest upstream record for the Mississippi is a specimen collected by Friedrich (1933) from the Mississippi River below St. Cloud. No specimens have been taken from the Mississippi River above St. Anthony Falls in recent years by the survey crews. Greene (1935) reports it from the Mississippi drainage in Wisconsin, including Lake St. Croix.

Although it differs in no essential from the longnose gar as far as breeding habits are concerned, the shortnose gar in southeastern Minnesota prefers grass-grown sloughs for its habitat, whereas the longnose gar prefers more open sloughs and backwaters where there is no vegetation. Gars spawn in the spring, usually in June, in shallow water and generally among grass and weeds. The eggs are a bright dark green and are said to be poisonous.

All species of gars frequently lie close to the surface, occasionally gulping in air. They are notoriously predacious, preying on all kinds of fish. Stealthily gliding alongside their prey, they seize it with an easy sideswipe of their long, vicious jaws. Small fishes are swallowed outright, but larger ones may be severed into two parts. Gars are very rapacious and destroy large numbers of both forage and game fishes. Their armor protects them from most other animals.

Fishermen wage ceaseless warfare on the gar wherever possible, but the cylindrical shape of their slender bodies, coupled with their activity, makes them hard to hold in any ordinary net, and most of them escape before a seine can be hauled. These predacious fishes occupy the place of more important game fishes, consuming food that could be used by northern pike, walleyes, and bass. Fortunately they seem to thrive best in waters not highly suited to these more desirable species.

The flesh of the gar is seldom used for food and has no commercial value in the north. In some of the southern states the flesh is eaten to a limited extent, and Dr. H. M. Smith (1907) stated that it is regularly sold in the markets at New Bern, North Carolina. The flesh is white and of rather fine grain, and there is no reason why it should not find a ready market.

In Louisiana a limited number of the skins are marketed annually; they are used by the jewelry and novelty trade for covering picture frames and boxes of various kinds. The horny cuticle of these skins is very hard and may be polished smooth and even, retaining an ivory-like finish (see *Report,* United States Commission of Fish and Fisheries, 1902, page 350). Before the days of the steel plow the skin of the gar was often used to cover plowshares, and it is even now used for this purpose in some sections of the rice-growing area of the United States.

SPOTTED GAR
Lepisosteus productus Cope

The spotted gar usually has from 54 to 58 scales in the lateral line. The snout is narrower than that of the shortnose but is not as narrow as that of the longnose. The snout is about 1.6 times longer than the rest of the head. The body is covered with large round spots, which become diffused on the fins. There are round spots on top of the head, whereas the shortnose has no spots on top of the head.

This species ranges from Minnesota eastward to Ohio and perhaps New York State, and southward to Florida and Texas. Our attention was directed to this fish by Professor C. L. Hubbs, who suggested that this species should be present in southern Minnesota. For many years we had been puzzled by finding gars that seemed to be intermediate between the shortnose gar and the longnose gar. This species is fairly common in clear, weedy lakes of southern Minnesota; the shortnose gar is more prevalent in the rivers.

NORTHERN LONGNOSE GAR (Gar Pike, Billfish, Billy Gar)
Lepisosteus osseus oxyurus Rafinesque

The longnose gar (Figure 4C) has a very elongate and subcylindrical body covered with regular rows of small, hard, enameled plates. The jaws are elongated, and both the upper and lower jaws are armed with long, sharp teeth. It is extremely variable in color, length of snout, and body proportions. The general color is greenish olive above, silvery on the sides, and white beneath; both body and fins are marked with numerous round, black spots. The scales in the lateral line number 60–63. In this species the snout is more than twice the length of the rest of the head. Some longnose gars attain a length of upwards of 5 feet, but the average for the species is much less. The young are very pretty little creatures, each marked with a broad black lateral band. They are especially noticeable for the evanescent lance-shaped upper lobe of the caudal fin.

This fish is found in all the streams tributary to the Mississippi River as far north as Minneapolis and in all the lakes of that drainage, but it is absent in collections from the Red River and Rainy River systems and from the northern lakes not properly in the Lower Mississippi drainage.

Woolman (1895) reported it from Ottertail River, a tributary of the Red River. It ranges from Montana eastward through the Mississippi and the Great Lakes and St. Lawrence drainages to Vermont, and southward to northern Alabama and Mexico. The longnose gars frequent the quieter waters and are probably more common in large sloughs along the Mississippi below St. Paul and in the Minnesota River sloughs than anywhere else, with the possible exception of certain lakes in the southern half of Minnesota. This species is very destructive of game and forage fishes and is not used extensively in the North for food.

Family AMIIDAE

THE BOWFIN FAMILY

The bowfins are primitive fishes with stout bodies covered with heavy, smooth scales. The head is covered with smooth plates. The mouth is horizontal and rather large. The jaws have two kinds of teeth: the larger and outer are conical; the vomer, palatines, and pterygoids bear small teeth. Only one genus and one species are known in North America today. Fossil forms are known outside of North America.

GENUS *Amia* Linnaeus

The characters of the genus are found in the following description of its one species.

BOWFIN (Fresh-water Dogfish) *Amia calva* Linnaeus

The bowfin (Figures 5 and 6) is a relic of an ancient family of which only one species remains today. It has a rather primitive skeleton, partly of bone and partly of cartilage. The head is covered by thin, bony plates. The dorsal fin is very long and low, reaching almost to the tail. The tail is rounded and of a modified heterocercal type. The body, which is rather stout, is covered by large, cycloid scales. The back and sides are an olive or a brownish green, and the belly is white. The dogfish has a pair of short nasal barbels. The male is distinctly marked by an ocellus, or eye spot, at the base of the caudal fin (Figure 5). The swim bladder is bifid in front and connected with the pharynx and may be used as a lung. The dogfish reaches a length of over 2 feet and a weight of 10 pounds.

Bowfin are very common in the Mississippi River and all its tributaries. They range eastward in the Great Lakes drainage, exclusive of Lake Superior, to Vermont and southward to Florida and Texas. They are found in some lakes of northern Minnesota and in almost every important lake of southern and central Minnesota. Some confusion in the northern distribution of this species has been caused by reports of dogfish in some of the boundary lakes, such as Lake of the Woods. Apparently this is due to the local application of the name dogfish to the burbot (*Lota lota maculosa*). *Amia calva* is apparently absent from Lake of the Woods and its connected waters (Hubbs, 1945). Greene (1935) reported them from many localities in Wisconsin.

They prefer sluggish water and often come to the surface to gulp in air. Dogfish kept in aquaria at the University of Minnesota come to the surface every few minutes, expelling air from the swim bladder

Figure 5. Fresh-water dogfish, *Amia calva*, male, 18 inches long.

Figure 6. Fresh-water dogfish, *Amia calva*, female, 20 inches long.

and gulping in a fresh supply. They are very tenacious of life; specimens have been kept out of water at low temperatures for 24 hours without apparent harm. Young dogfish have been highly recommended as bait because they will live for hours on a hook, but this practice should be discouraged to avoid introducing this destructive species into lakes where it is not now present.

The dogfish is voracious, feeding on all kinds of animal life, though fishes, including its own kind, form a large part of its diet. It is destructive of game fishes and forage fishes alike. It often feeds at night. Those in the aquaria at the University of Minnesota do not feed much during the winter, though in some northern lakes a dogfish will occasionally bite on a hook in the winter.

Spawning occurs in May or early June. Sometimes the dogfish migrate in large numbers up small streams or into weedy bays of lakes. The males at this time assume brighter colors, particularly of the fins, which become a bright green. A 5-pound female 19 inches long had 23,600 eggs in the ovaries. A 21-inch female had 64,000 eggs in the ovaries.

A nest is prepared by hollowing out a depression in the mud or sand until a firm bottom is obtained. Any plants present are torn away until the rootlets are exposed. Spawning usually takes place at night, the male guarding the nest. The young at first adhere to rootlets on the bottom of the nest by an adhesive organ on the snout. When the young can leave the nest they travel in dense schools, guarded for some time by the male. The young, like those of the gar, have at first a lance-shaped caudal fin, beneath which develops an inferior lobe which will become the permanent caudal fin (Reighard, 1900).

Although a very gamy fish when hooked, the dogfish has little value. It is occasionally eaten, but its flesh is soft and undesirable, though when properly cured and smoked the dogfish is reported to be excellent. Its destructive feeding habits make it highly obnoxious.

Family HIODONTIDAE

THE MOONEYE FAMILY

The mooneyes are silvery fishes with deeply compressed bodies, small heads, feeble mouths, and large eyes. They reach a length of over 12 inches. The dorsal and anal fins are without spines. The mouth is medium sized and obliquely set and has equal jaws; the maxillary bones are small. The teeth, on the jaws, tongue, vomer, palatines, and pterygoids, are well developed. The gill-membranes are free from the isthmus. The mooneyes have 8–10 branchiostegal rays and a straight lateral line. The few gill-rakers are short and thick. The stomach is horseshoe-shaped and has one pyloric caecum. The mooneyes have a large air bladder. The scales are large and cycloid. The head is naked, with a blunt snout. Two species are found in Minnesota and neighboring states.

Key to Common Species of Family HIODONTIDAE

Dorsal fin with 9 developed rays; belly keeled before and behind pelvic fins; anterior margin of dorsal fin inserted just above or slightly behind anal fin. . . . . .Goldeye, *Amphiodon alosoides* (Rafinesque)

Dorsal fin with 11 or 12 developed rays; belly scarcely keeled before pelvic fins; anterior margin of dorsal fin inserted in front of anal fin. . . . . .Mooneye, *Hiodon tergisus* LeSueur

GENUS *Hiodon* LeSueur

There are two species in this genus. Only one is found in Minnesota and neighboring states; the other occurs in the southern United States.

MOONEYE (Toothed Herring)
Hiodon tergisus LeSueur

The mooneye (Figure 7) is a silvery fish with a pale olive-buff back. It can be distinguished from the goldeye, or northern mooneye, by the keel, or ridge, on the belly, which is developed only between the ventral and anal fins. The eye is contained 3 times in the head. The maxillary reaches to the center of the orbit. The dorsal fin contains 11 or 12 developed rays, the anal fin 28. The anterior margin of the dorsal fin is inserted considerably in front of the anterior margin of the anal fin. The lateral line is complete and contains about 55 scales. The mooneye reaches a length of over 12 inches.

The common mooneye ranges from Hudson Bay to the St. Lawrence and southward to Alabama and Arkansas. It is common in the Mississippi River and its tributaries below St. Paul. It has been reported in

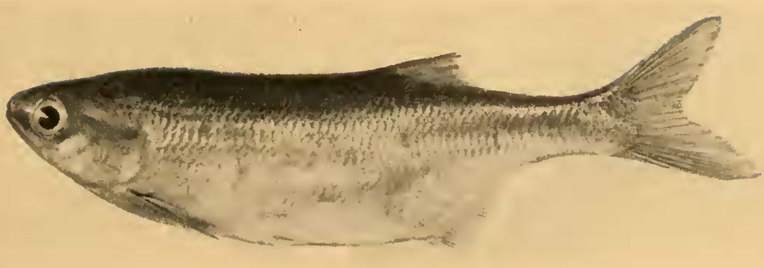


Figure 7. Mooneye, *Hiodon tergisus*, 11 inches long.

Lake of the Woods, Red Lake, and Red River (Cox, 1897). It usually frequents large lakes and streams.

Little is known concerning the spawning habits of this species. It feeds on insects, small crustacea, and minnows. Forbes and Richardson (1908) report it as a gamy biter on the hook. This species has little value as a food fish but is of some value as forage for game fishes.

GENUS *Amphiodon* Rafinesque

This genus contains only one species, which ranges from the Ohio River and Oklahoma northward into the prairie region of Canada. It is not present in the Great Lakes drainage.

GOLDEYE (Northern Mooneye, We-be-chee of the Red Lake Chippewas)
Amphiodon alosoides (Rafinesque)

The goldeye is bluish above; the sides and belly are silvery, with more or less golden luster forward. It is distinguished from the common mooneye by a sharp ridge, or carina, on the belly anterior to the ventral fins and by the number of rays in the dorsal fin. The dorsal fin has only 9 (rarely 10) developed rays, and the anal fin has 30. The anterior margin of the dorsal fin is inserted just above or slightly behind the anterior margin of the anal fin. The maxillary reaches past the middle of the orbit. The lateral line is incomplete and has 56–58 scales. The goldeye reaches a length of over 12 inches.

The goldeye is found in Lake of the Woods and is common in Red Lake and in the Mississippi River and its larger tributaries. Large quantities have been netted and sold commercially from Lake of the Woods and Red Lake, though at present the goldeye is rather scarce in Lake of the Woods. It is an excellent food fish and is often smoked. It feeds on minnows, insects, and snails, and will sometimes bite on a baited hook.

Family CLUPEIDAE

THE HERRING FAMILY

Herrings are rather elongated fishes of which numerous genera and species are found in both salt and fresh water. The Atlantic herring and the Pacific herring are members of this family, as are the common shad of the Atlantic Coast and the true sardines.

Key to Common Species of Family CLUPEIDAE

Last dorsal ray not elongated; snout sharp; lower jaw projecting. . . . . Skipjack, *Pomolobus chrysochloris* Rafinesque
Last dorsal ray greatly elongated; snout blunt; lower jaw not projecting. . . . . Gizzard Shad, *Dorosoma cepedianum* (LeSueur)

GENUS *Pomolobus* Rafinesque

This genus contains a number of species found in fresh water and in the sea, including the alewife of the Atlantic Coast. One species ascends the upper waters of the Mississippi River.

SKIPJACK (Blue Herring, Golden Shad)
Pomolobus chrysochloris Rafinesque

None of our fishes is more entitled to the appellation "streamlined" than the skipjack. The body is slender and elliptical, with a belly keeled like a torpedo-boat chaser. The head is slender and pointed. The lower jaw projects strongly. The caudal fin is deeply forked and powerful. The back is a bright steel blue, the sides have golden reflections, and the belly is silver. Though the skipjack often attains a length of 15 inches or more the average is considerably less—8 to 10 inches. Even in perfectly clear water its movements are so extremely swift that the eye can seldom follow them, and its coloration also helps to obscure its movements.

Before the construction of the Keokuk Dam this species was more or less abundant in the Upper Mississippi at least as far up as Minneapolis and in the St. Croix to Taylors Falls. It occurred in the Minnesota River and was at one time more or less common in Big Stone Lake, where Surber examined specimens in October 1920. During 1911–13 A. F. Shira obtained many specimens in Lake Pepin which he forwarded to the Fairport, Iowa, Biological Station for examination. There were both adults and young, which would indicate that they spawned somewhere in that vicinity. Specimens taken prior to 1910 from Lake Pepin and from the Minnesota River at Mankato are in the University of Minnesota collections. Specimens were obtained from the Mississippi

River by Surber in 1913–14 at Homer, Minnesota, but since then few have been reported. It might truthfully be said that the skipjack is the only strictly migratory fish occurring in the upper river. For several weeks after the waste gates at the Keokuk Dam were first closed during the spring of 1913 the skipjacks literally swarmed in the swift current below the powerhouse in a fruitless effort to reach the waters above.

The skipjack is a very active fish. Often it jumps clear of the water in play or in pursuit of its prey, for its favorite food is smaller fishes. Frequenting by preference the swiftest waters, it is more often found about the ends of the wing dams than elsewhere. The angler in pursuit of sport alone will find it a savage fighter on light tackle. It readily takes a small spoon hook and live minnows and occasionally takes flies (see *Forest and Stream*, November 1, 1913). Unfortunately it has no value as food, for it is excessively bony.

In accordance with the old rule that nothing exists in nature without a specific purpose, this fish performs at least one valuable function in the general scheme of nature. It was discovered in August 1912 (Surber, 1913) that this species was the only specific host of the niggerhead mussel, which supplied a shell valuable in the button industry. With the passing of the skipjack from the upper river the niggerhead mussel has become extinct and along with it part of the livelihood of a considerable number of people. At present the skipjack is very rare if not extinct above the Keokuk Dam.

GENUS *Dorosoma* Rafinesque

This genus contains four species, one of which ranges from Minnesota to New York and southward to Mexico and lives also in brackish water of the Gulf of Mexico and the Atlantic.

GIZZARD SHAD (Hickory Shad, Mud Shad, Hairy Back, Norwegian Herring)

Dorosoma cepedianum (LeSueur)

The gizzard shad (Figure 8) is silvery in color, with a bluish back. The young fish have a spot just posterior to the pectoral fin. The belly is sharply serrated, or keeled. This species is easily distinguished by the last ray of the dorsal fin, which is very long. Teeth are absent in the adult, though present in the young. The stomach is very muscular or gizzardlike, and the intestine is long and coiled. The gill-rakers are long and extremely fine. They reach a length of over 15 inches.

Gizzard shad frequent large rivers and muddy lakes. They are common in the St. Croix and Minnesota rivers and in the Mississippi River below St. Paul. They seldom reach a length of over 12 inches, though lengths of 18 inches have been reported. In quiet, muddy stretches of

Figure 8. Gizzard shad, *Dorosoma cepedianum*, 6 inches long.

the Lower Mississippi they are exceedingly abundant and are regarded as a nuisance by fishermen. They have little food value but are important as forage fishes, providing food for many game fishes. Dr. C. L. Hubbs states in a letter that they are sold for food in Washington, D.C.

Gizzard shad frequently travel in schools close to the surface and when surprised will skip over the surface of the water. This habit has caused local fishermen to apply the name skipjack to this species, though this name is applied to two other entirely different species (see pages 90, 245).

They secure their food by straining it from the water with their fine gill-rakers. They commonly feed on the small organisms composing the plankton and at times must secure their food close to the bottom because their stomachs often contain much mud. They feed on material not utilized extensively by other fishes and so serve as a natural means of converting this waste matter into food for highly prized game fishes.

Family OSMERIDAE

THE SMELT FAMILY

Smelts are small fishes, and most of them live in the sea, but many ascend rivers to spawn. They possess an adipose fin and well-developed teeth and are similar in form to the Salmonidae, but differ in having less than 100 scales in the lateral line.

GENUS *Osmerus* Lacépède

Several species occur in this genus, one of which has been introduced into inland waters.

AMERICAN SMELT

Osmerus mordax (Mitchill)

This smelt is a slender, silvery fish with an adipose fin. There are 2 to 4 large, strong teeth on the vomer. There are about 68 scales in the lateral line. The dorsal fin has 10 rays. These fishes are small, not exceeding 10 or 12 inches in length.

American smelt occur along the Atlantic Coast from New York northward, and migrate up rivers to spawn. They have become landlocked in some of the eastern lakes. They were originally introduced into a small lake in Michigan to provide food for introduced landlocked salmon and found egress from these waters into the Great Lakes (Creaser, 1925). They became very abundant in Lake Michigan, where they migrated up certain tributary streams in great numbers each spring. In 1942–43 they became scarce for some reason. However, they seem to be increasing again in 1946. For several years commercial fishermen have reported them from the Minnesota waters of Lake Superior, and in 1946 this report was verified by specimens sent to the Minnesota Department of Conservation from off the mouth of the French River. Smelt are excellent food fishes and large quantities are caught commercially during the spawning runs in eastern Wisconsin.

As smelt are carnivorous there has been much debate about their competition with the native trout and coregonids. Greene (1930) states that smelt become potential fish eaters at a very small size. They are cannibalistic, and larger smelt deprived of a plentiful supply of smaller smelt would tend to prey upon the young of other fishes.

Some people have requested that smelt be introduced into certain Minnesota lakes. It is possible that smelt might prove an undesirable addition to the fishes of such lakes even though they did no more than compete with all the smaller fishes for food. Every effort should be made to exclude smelt from new waters until it has been ascertained whether or not their value as dainty food fishes surpasses or compensates for their probable destructiveness to other fishes.

Family COREGONIDAE

THE WHITEFISH FAMILY

This family includes some of the most important commercial food fishes of the Great Lakes, such as the whitefish and the lake herring, or cisco. Several million dollars' worth of these fishes are caught and sold from the Great Lakes annually.

The fishes of this family are more or less silvery in color, with blue-green or pale-green backs. Most have rather long, slender gill-rakers. They have a single dorsal fin with soft rays and a small dorsal adipose fin, without rays, behind the dorsal fin. The mouth is small and either lacks teeth or has only a few small ones.

All members of this family are cold-water fishes and are widely distributed over the Northern Hemisphere. They constitute an important part of the fish population of Lake Superior and the other Great Lakes. They occur in many of the large, deep lakes of Canada, Minnesota, Wisconsin, Michigan, New York, and New England. They are widely distributed over Minnesota: tullibee or ciscoes of the genus *Leucichthys* occur in several of the deep south central lakes, and the larger, true whitefishes of the genus *Coregonus* occur from Mille Lacs northward. As a rule the deep-bodied ciscoes, or lake herrings, of inland lakes are called tullipee or tullibee.

The characters of the various species and subspecies of the genus *Leucichthys* are so variable that it is almost impossible to construct an analytical key of the genus. Hubbs agrees with Koelz in discarding several nominal species of the genus *Coregonus* and limiting this genus in the United States to the species *clupeaformis* with its several subspecies. The actual status of the members of this family found in the Great Lakes area is somewhat confused. More extensive studies are needed, particularly of those subspecies found in inland lakes. Koelz (1927, 1931) has done much to clear up the confusion of species in Lake Superior, and some of the data presented on this family have been obtained from his study.

It is well to note that as long ago as 1876 whitefish eggs taken in Lake Erie produced fry that were planted in many lakes in the central counties of Minnesota, even as far south as Clearwater Lake, Wright County. This planting may account for the presence of *Coregonus* in such waters as Mille Lacs and Leech Lake. In 1878, to complicate matters further, upward of 2,000,000 fry of the so-called tullibee hatched from eggs procured from Madison, Wisconsin were liberated in the south central lakes (*Annual Report*, Minnesota Fish Commissioners, 1878). Plantings were made in 1881 near the Twin Cities in White Bear Lake, Lake Gervais, and Lake Minnetonka, but no fishes survived.

Whitefishes hybridize, but to what extent is not at present known. Such hybridization accounts for some of the great difficulty in identifying the fishes of this family taken from different lakes. The common whitefish and the cisco, or lake herring, are the most common species found in Lake Superior. Five other species belonging to the same genus as the cisco and one species, the Menominee whitefish, belonging to the genus *Prosopium*, are also found in Lake Superior. Although several species of whitefish and tullibee have been described and reported for various Minnesota and Wisconsin lakes, it is doubtful whether more than one species of whitefish and one species of cisco occur inland. Many of the inland lakes of Minnesota, Wisconsin, and other northern states contain whitefish that are subspecies of the common whitefish and tullibee that are subspecies of the Great Lakes cisco, or lake herring.

Key to Common Species of Family COREGONIDAE*

1. Two flaps between openings of a nostril; gill-rakers of first arch more than 23 2
   Single flap between openings of a nostril; gill-rakers of first arch less than 20 .... Common Menominee Whitefish, *Prosopium cylindraceum quadrilaterale* (Richardson)
2. Premaxillaries longer than wide, not turned backward (antrorse) in position; premaxillary forms angle of less than 90° with horizontal axis of body; gill-rakers more than 31 (Diagram 4) 3
   Premaxillaries wider than long, turned backward (retrorse) in position; premaxillary forms angle in excess of 90° with horizontal axis of body; gill-rakers fewer than 32 (Diagram 4) ....Great Lakes Whitefish and subspecies, *Coregonus clupeaformis* (Mitchill)
3. Lower jaw more or less hooked (symphysial knob) 7
   Lower jaw not hooked (no symphysial knob) 4
4. Gill-rakers of first branchial arch usually more than 43.................. ....Lake Superior Cisco and subspecies, *Leucichthys artedi* (LeSueur)
   Gill-rakers of first branchial arch usually less than 43..................5
5. Body ovate (deeper anterior to center); mandible tip distinctly pigmented ....Bluefin, *Leucichthys nigripinnis cyanopterus* Jordan and Evermann
   Body elliptical (deepest at center); mandible tip never more than faintly pigmented 6
6. Gill-rakers of first branchial arch usually less than 39.................. ....Superior Shortnose Chub, *Leucichthys reighardi dymondi* Koelz
   Gill-rakers of first branchial arch usually 39 or more.................... ....Shortjaw Chub, *Leucichthys zenithicus* (Jordan and Evermann)
7. Body ovate; scales in lateral line usually more than 75; gill-rakers of first branchial arch usually less than 41.................................. ....Michigan Kiyi, *Leucichthys kiyi kiyi* Koelz
   Body elliptical; scales in lateral line usually less than 76; gill-rakers of first branchial arch usually more than 40.................................. ....Great Lakes Bloater, *Leucichthys hoyi* (Gill)

*The characters of the Coregonidae are variable and render a key difficult to use. Further reference should be made to Koelz (1929) and to Hubbs and Lagler (1941).

GENUS *Leucichthys* Dybowski

Members of this genus are characterized by two flaps between the openings of each nostril and by the terminal mouth. Usually more than 30 rather long and fine gill-rakers are present on the first branchial arch. Vestigial teeth may be present on the premaxillaries, palatines, mandible, and tongue. The premaxillaries are longer than they are wide. The mandible is seldom contained more than 3.1 times in the head. The males develop pearl organs on the head and sides during the spawning season.

This genus includes the common lake cisco, or herring, and the related tullibee of inland lakes, and the chubs, ciscoes, and bluefins of Lake Superior and other Great Lakes. For some species distinct subspecies have developed in different ones of the Great Lakes, and in some of the Great Lakes some species are found that are not present in the others. The species treated here include only those found in Lake Superior.

In various places local fishermen have applied the common names "cisco" and "tullibee" indiscriminately to different species of *Leucichthys*. Members of the genus are common in many of the northern lakes of America. Closely related species placed in the genus *Coregonus* are found in northern Europe and Asia.

LAKE SUPERIOR CISCO (Lake Herring, Blueback)
Leucichthys artedi arcturus Jordan and Evermann

The Lake Superior cisco, or herring,* is large, reaching a length of 12 inches or more. The body shape is subterete or elongate. The lower jaw is either equal to or slightly shorter than the upper. There are usually more than 43 gill-rakers. The lateral-line scales seldom number less than 80. Frequently confused with the common whitefish, the Lake Superior cisco can be readily distinguished by the absence of the overhanging snout and upper jaw characteristic of the whitefish and some other coregonids (Diagram 4).

This species is the most abundant member of the family Coregonidae found in the Minnesota waters of Lake Superior. The slender variety, *L. artedi arcturus,* is more common than the deeper and more compressed form, *L. artedi albus* (LeSueur). Other subspecies occur in the other Great Lakes. Ciscoes often run in schools and are commonly caught in gill and pound nets. They are pelagic, usually staying near the surface in deep, open water, where they swim down to a depth of several hundred feet. They feed largely on planktonic crustacea and occasionally on insects.

In late July and early August they migrate close to shore in Lake

*The name "herring" is a misnomer, for these fishes are in no way related to the true herring family.

Diagram 4. Mouth arrangement in two species of Coregonidae, showing overhanging snout in *Coregonus clupeaformis* (A) and shorter upper jaw in *Leucichthys artedi* (B).

Superior for spawning. They spawn during the last two weeks of November on almost any type of hard bottom from shoal water to a depth of 25 fathoms. Eggs taken from fishes procured November 21, 1921 off the mouth of the French River near Duluth ran 118,346 to the quart.

This species has great commercial value and large quantities are sold annually from Lake Superior and other Great Lakes. The flesh is excellent, and many are smoked or salted.

NORTHERN CISCO (Northern Tullibee, O-do-nee-bee of the Red Lake Chippewas)

Leucichthys artedi tullibee (Richardson)

This tullibee (Figure 9) is common in Lake of the Woods and Rainy Lake and probably in many other Minnesota and Wisconsin lakes. The tullibee found in inland waters is deeper bodied than the form found in Lake Superior. Koelz (1931) described 24 subspecies of *L. artedi,* mostly from inland lakes of the northern and eastern states and including fishes from only four Minnesota lakes. More subspecies could probably be described if tullibees from all Minnesota lakes could be studied. Koelz reports the subspecies *L. artedi tullibee* (Richardson) from Lake of the Woods and from Rainy Lake. Although it is less desirable as a food fish than the common whitefish found in inland waters, it exceeds the whitefish in commercial value.

TWIN LAKE CISCO (Inland Tullibee)

Leucichthys artedi woodi Koelz

Koelz (1930) identified as belonging to this subspecies two Minnesota specimens from Wolf Lake in Beltrami County and two others from Cass Lake. The body form and color of specimens from Wolf Lake

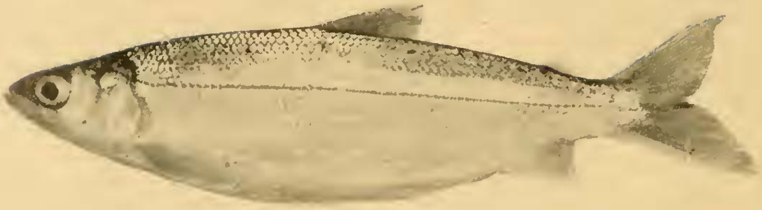


Figure 9. Northern cisco, *Leucichthys artedi tullibee*, 13 inches long.

examined by the authors appear to resemble closely those of the blackfin, *L. nigripinnis*. The system adopted by Koelz (1930) is so detailed that instead of simplifying matters it appears to complicate them by building up numerous additional subspecies of doubtful value.

If we accept Koelz's subspecies as valid, *woodi* is the common form of small tullibee occurring in numerous lakes in north central Minnesota and is the fish commonly designated as tullibee. Although ichthyologists have called the tullibees of Minnesota lakes by various names (Cox, 1897; Surber, 1920; Jordan, Evermann, and Clark, 1930), all specimens examined at the University of Minnesota show a close relationship to *L. artedi* and are either varieties or subspecies of *L. artedi* of the Great Lakes. Other subspecies are reported from various Wisconsin lakes by Greene (1935).

Tullibee are present in most of the larger lakes of northern Minnesota and are found in some of the central lakes, such as Mille Lacs. Tullibee are reported from some of the smaller lakes of central Minnesota, such as Lake Elmo in Washington County, Green Lake in Kandiyohi County, and Cedar Lake in Wright County. Some of them seem to be smaller and more slender than those found in other lakes and may belong to another subspecies, resulting from the early stocking, about 1878, when so-called Lake Superior herring and other coregonids were planted in many central Minnesota lakes. However, when specimens of these small, slender tullibee have been studied they have turned out to be merely young but normal individuals of the deep-bodied form.

Some ichthyologists have claimed that the deep-bodied tullibee was the result of the small lake environment. In certain lakes in the Superior National Forest slender-bodied *L. artedi arcturus* from Lake Superior have been introduced. It may be possible in the future to determine whether the environment has caused them to change their body form.

All the various members of this genus are cold-water fishes and do not thrive in warm water. Evidence of this fact is seen in many warm-water lakes like Mille Lacs, where the species does continue to exist but where thousands die each year during August.

The inland tullibee are excellent food fishes. They do not bite readily on a hook but must be taken in nets. In certain lakes, such as Ten Mile Lake near Hackensack, Minnesota they will occasionally rise to a fly. In many northern lakes they are heavily infested with the larvae of a tapeworm, *Triaenophorus*, which forms large cysts in the back muscles and renders the fish obnoxious. These worms are not injurious to man and die when cooked. However, owing to this infection large numbers of tullibee are annually condemned as unsuitable for food. Weights up to 8 pounds have been taken, but ordinarily the fish is much smaller.

SUPERIOR SHORTNOSE CHUB

Leucichthys reighardi dymondi Koelz

The chub is an elliptical fish which reaches a length of 12 inches or more. The gill-rakers of the first branchial arch usually number less than 39. The lower jaw is shorter than the upper and is unmarked or at most only faintly pigmented.

This species is found occasionally in the shallow water of Lake Superior, where it ranges along the shores and shoals down to a depth of about 65 fathoms, where such depths are found close to shore. Koelz (1929) states that this species probably spawns in November. The spawning grounds in Lake Superior are unknown. This species has been reported as spawning in May and June in Lake Ontario.

SHORTJAW CHUB (Cisco)

Leucichthys zenithicus (Jordan and Evermann)

The shortjaw chub is a large fish measuring 12 inches or more in length. It is a slender-bodied, large-headed cisco with color and fins much like *L. nigripinnis cyanopterus,* which it closely resembles, as it does *L. reighardi*. However, it spawns later than *L. nigripinnis cyanopterus* and has a longer snout than either of these other two species, from which it differs in other respects as well. The lower jaw is slightly shorter than the upper. The gill-rakers on the first arch usually number more than 39 but less than 43. The lower jaw is unmarked or only faintly pigmented. This species is much larger than *L. kiyi* and *L. hoyi* and may be distinguished from *L. artedi* by having fewer gill-rakers on the first branchial arch.

This fish is rather abundant in deep water off the entire Minnesota shore of Lake Superior. It is common around the Apostle Islands off the Wisconsin shore. According to Koelz (1929) it is found in Lake Superior at depths ranging from 10 to 100 fathoms or deeper, apparently ranging not far from shore or from shoals but rarely found in shallow water.

The shortjaw chubs are second to the lake herring, *L. artedi,* in commercial importance. Koelz reports that they spawn on the bottom in late November at a depth of from 20 to 40 fathoms. They feed on small planktonic crustacea and on small bottom insects and the crustacean *Pontoporeia.*

GREAT LAKES BLOATER

Leucichthys hoyi (Gill)

The bloater has an elliptical shape and is small, ranging from 6 to 8 inches in length. The lower jaw is longer than the upper and is more or less hooked. The gill-rakers of the first branchial arch usually number more than 40. It resembles *L. kiyi* but differs from it in usually having less than 75 scales in the lateral line, whereas *L. kiyi* has more than that number.

L. hoyi lives in deep water. Koelz (1929) reports it to be most abundant at depths ranging from 40 to 50 fathoms, but it has been taken in water as shallow as 15 fathoms and as deep as 90. This species is found on the slopes of the banks and shores of Lake Superior and Lake Michigan and according to Koelz apparently does not occur in the deep, open waters. It has little value commercially because of its small size. Koelz states that it probably spawns during the winter.

MICHIGAN KIYI (Chub)

Leucichthys kiyi kiyi Koelz

The kiyi, or chub, has an ovate shape and is small, reaching a length of 6 or 8 inches. The lower jaw is longer than the upper and is more or less hooked. The fish resembles *L. hoyi,* but the scales in the lateral line number more than 75.

The kiyi lives in the deep water of Lake Superior but is not common. Koelz reports taking them in nets at depths of not less than 20 fathoms and ranging down to 100 fathoms. They live in deeper water than *L. hoyi.* Most of the records reported by Koelz are from Michigan waters. Kiyis have no commercial value because of their small size. They feed on the small crustacean *Mysis.* Koelz reports this fish as spawning probably in deep waters in late November or early December.

BLUEFIN

Leucichthys nigripinnis cyanopterus Jordan and Evermann

The bluefin found in Lake Superior was originally described by Jordan and Evermann as *L. cyanopterus.* Koelz (1929) placed this fish as the Lake Superior variety of the blackfin, *L. nigripinnis* (Gill), found in Lake Huron and Lake Michigan. The blackfin was formerly called *L. prognathus* (Smith). The bluefin differs from the typical blackfin in its pale coloration and its bluish caudal and dorsal fins, on which the black is confined to the tips.

Like the kiyi, the bluefin is a deep-water species. Bluefins are sometimes abundant in Lake Superior from Duluth eastward to Two Harbors and intermittently to Beaver Bay, and thence to Grand Marais and slightly beyond. James Scott of Grand Marais is responsible for the report that these fish spawned offshore at this point in September (Koelz, 1929). Both the bluefin and the kiyi appear to inhabit depths where the water has a uniform temperature of 40° F. In midsummer, at least in the west end of Lake Superior, this habit would at times keep them deeper than 200 feet. Koelz states that they are seldom found in water shallower than 60 fathoms, or 360 feet, but this datum does not apply to the North Shore. They are commonly found in the stomachs of fat trout or siscowets caught at depths of 75 fathoms. Although they are caught in commercial nets, bluefins are not now abundant enough in Lake Superior to be of economic importance. Koelz states that fishermen report them as spawning in September at depths of 60 to 100 fathoms.

GENUS *Coregonus* Linnaeus

The genus *Coregonus* contains the true whitefishes, only one species of which is found in central North America, although other species have been recognized farther north. Other species of this genus are found in northern Europe and Asia.

GREAT LAKES WHITEFISH (Common Whitefish, Labrador Whitefish, Ah-de-com-egg of the Red Lake Chippewas)
Coregonus clupeaformis clupeaformis (Mitchill)

The common whitefish (Figure 10) is a large, more or less ovate fish with silvery sides that shade to a dark olive-brown back. It is characterized by the presence of two flaps between the openings of each nostril and by the snout which distinctly overhangs the lower jaw. The upper jaw is characterized by a wide premaxillary greater in width than in length. The mandible usually is contained from 2.4 to 2.7 times in the head. Vestigial teeth may be present on the premaxillaries, palatines, mandible, and tongue. The gill-rakers number more than 23 and less than 32. During the spawning season pearl organs are developed by both sexes on the sides of the body and on the head.

These fishes are among the most important of the commercial fishes in Lake Superior and in other Great Lakes, though they are not as abundant as formerly. Subspecies of the whitefish live in the open waters of some northern inland lakes and range to considerable depth. In Minnesota they have been taken at a depth of over 100 feet in Lake

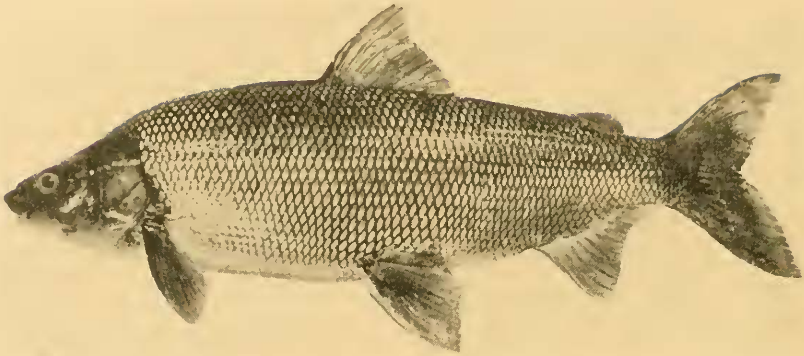


Figure 10. Great Lakes whitefish, *Coregonus clupeaformis clupeaformis*, 18 inches long.

Saganaga. In Lake Superior they range over the bottom to depths of several hundred feet.

In some of the inland lakes local sports fishermen confuse them with tullibee. The whitefish of the inland lakes can be readily distinguished from the tullibee usually found in the same lakes by the long, overhanging snout, which causes the mouth to be inferior.

This species is the largest of the coregonids. The largest examples, usually from Lake Superior, weigh upwards of 20 pounds, but the average weight hardly exceeds 4 pounds. Individuals weighing over 4 pounds are termed "jumbos" by the commercial fishermen. Koelz reports hybrids between the whitefish and the cisco as reaching the large size of 11 pounds.

In Minnesota, subspecies are found in lakes of the Arctic drainage, such as Red Lake, Lake of the Woods, and Rainy Lake, and in various boundary lakes as far east as Basswood, and in lakes of the Superior drainage, such as the lakes at the head of the Pigeon, including McFarland and Pine lakes in Cook County. This subspecies is the large whitefish of Leech Lake and Mille Lacs as well as Cass Lake, where it reaches a weight of 8 pounds.

Whitefishes are abundant in Red Lake and are next in importance to the walleyes in the commercial fisheries of that lake. Red Lake is also the source of supply of whitefish eggs for hatchery operations conducted by the State of Minnesota in cooperation with the Indian Service. Many thousands of fry from Red Lake have been planted in Lake Superior in an attempt to restore its fisheries, with some success. Although there seems to be little external difference between the whitefish from Red Lake and those from Lake Superior, the commercial fishermen on Lake Superior seem to differentiate between the two. Certainly there is a difference in the size of their eggs. Those from Lake Superior average

34,000 to a quart (0.125 of an inch in diameter) and those from Red Lake from 49,480 to 50,000 to a quart (0.111 to 0.104 of an inch in diameter). They spawn in Red Lake on gravel beds near shore at a depth of 6 to 8 feet at temperatures of 33° to 35° F. In the early fall the Lake Superior whitefish move inshore, where they spawn in November at a depth of 1 to 12 fathoms on bottoms of sand or smooth boulders.

Whitefish feed on planktonic crustacea and aquatic insects. They bite occasionally on baited hooks but are usually caught in gill or pound nets. They are taken throughout the summer by deep hook-and-line fishing in Ten Mile Lake near Hackensack, Minnesota. Minnows and small yellow perch are the favorite bait used. Commercially the whitefish has a greater value per pound than the cisco or tullibee. Whitefish roe or eggs are considered a delicacy; they are used to some extent for caviar. In many inland lakes many whitefish are heavily infected with the same larval tapeworm, *Triaenophorus,* as the tullibee.

Several subspecies, but probably only one species, occur in various lakes of Minnesota and have been reported under various names. Specimens of whitefishes have been collected from many inland lakes by the University of Minnesota and show no outstanding differences that might indicate a species different from those collected from Lake Superior. Other subspecies are reported from various lakes from Minnesota to Maine and northward.

INLAND LAKES WHITEFISH (Island Lake Whitefish)
Coregonus clupeaformis neo-hantoniensis (Prescott)

Koelz (1930) provisionally applies the name Island Lake Whitefish to the variety of whitefish found in Island Lake, Cook and Lake counties, Minnesota. There is no Island Lake on the boundary between Cook and Lake counties, but whitefish of large size do occur in numbers in Silver Island Lake in Lake County, just west of the boundary line of Lake and Cook counties. In late October these fishes run up the Island River well toward Harriet Lake to spawn.

GULLIVER LAKE WHITEFISH
Coregonus clupeaformis gulliveri Koelz

Specimens of this subspecies were collected by Friedrich (1933) from Whitefish Lake, Crow Wing County, Minnesota. They have large, nearly black pectoral fins. Hubbs states that he has specimens of this subspecies from the same lake. There are several specimens in the University of Minnesota collections.

GENUS *Prosopium*

The genus *Prosopium* is represented in the Great Lakes region by one species, which is apparently a subspecies of the Siberian whitefish (Berg, 1936). This genus is characterized by a single flap between the openings of each nostril, which differentiates it from the genus *Coregonus*. The absence of teeth also distinguishes it from the other coregonids.

COMMON MENOMINEE WHITEFISH (Pilot Fish, Round Whitefish)

Prosopium cylindraceum quadrilaterale (Richardson)

The Menominee whitefish is a more or less ovate fish with silvery sides and a dark-bronze back. The back is usually more deeply colored than those of the common whitefishes. The upper jaw contains a large premaxillary, which is greater in width than in length. The mandible is contained not less than 2.7 times in the head. The premaxillary is usually contained more than 3.8 times in the head. No vestigial teeth are present. The gill-rakers number 15–20. During the spawning season pearl organs are found on the sides of the bodies of both males and females, but not on the heads. They reach a weight of 3 to 4 pounds.

Menominee whitefish are found throughout northern North America from the Arctic Ocean to the Great Lakes and New England. They occur in all the Great Lakes but Erie and the tributary Nipigon. In Minnesota they occur occasionally in Lake Superior, where they move in schools along the shores. Apparently they do not go out into deep water. They were formerly abundant but are now caught only occasionally. Koelz reports that they spawn in late November or December at the mouths of the Devil Track and Cascade rivers. From December 14–23, 1923 they spawned in considerable numbers in shallow water off the mouth of the French River. The eggs were large for a whitefish, running 21,303 to the quart and having a diameter of 0.147 of an inch. Although an excellent food fish, this species is not abundant enough at present to be of great commercial value.

Family SALMONIDAE

THE SALMON AND TROUT FAMILY

The family Salmonidae includes the salmon and the trout and constitutes one of the most popular families of game and food fishes. These are long-bodied fishes with naked heads. They are characterized by relatively small cycloid scales and a well-developed adipose fin. The anal fin has from 9 to 16 rays. The dorsal fin is single and has from 10 to 12 rays; no spines are present. The ventral fins are located just below the dorsal. A slit is present behind the fourth gill; the pseudobranchiae are developed; the gill-membranes are not joined to the isthmus; the branchiostegal rays number 10–20. The air bladder is large. Many pyloric caeca are present.

These fishes are closely allied to the family Coregonidae but differ in the possession of stout gill-rakers and strong teeth lining the jaws, palatines, and margin of the tongue. The scales in the lateral line number more than 100. The fishes of this family are cold-water fishes, circumpolar in distribution. During the breeding season the males commonly develop secondary sexual characters, consisting usually of hooked jaws and sometimes, as in the salmon, of fleshy humps. Most of the members of this family lay their eggs in the fall, but the eggs do not hatch until early spring. The eggs can easily be kept alive on ice, and they have been shipped to many parts of the world.

Key to Common Species of Family SALMONIDAE

1. Tail deeply forked; no bright colors; body gray with light spots..........
....Common Lake Trout, *Cristivomer namaycush namaycush* (Walbaum)
Tail square or slightly forked; brown spots and frequently red or orange spots 2

2. Lateral line scales more than 200; light wormlike streaks on back; anal and paired fins with white margins......................................
..........Common Brook Trout, *Salvelinus fontinalis fontinalis* (Mitchill)
Lateral line scales less than 200; no wormlike streaks on back...........3

3. Rather large and diffuse dark spots, few on caudal; red spots ocellated with blue sometimes present on body ...Brown Trout, *Salmo trutta fario* Linnaeus
Rather small and distinct dark spots, profuse on caudal; red spots absent; longitudinal crimson streak on body varying in intensity ....
..................Coast Rainbow Trout, *Salmo gairdnerii irideus* Gibbons

GENUS *Salmo* Linnaeus

Members of this genus include the Atlantic salmon and many of the native trout. They are distinguished by a flat vomer bearing one or two rows of teeth on the shaft and by relatively large scales numbering not over 200.

ATLANTIC SALMON

Salmo salar salar Linnaeus

The Atlantic salmon is native to the Atlantic Ocean, from which it migrates up the rivers to spawn. It is distributed on the Atlantic Coast of northern North America, Greenland, and Europe, and has for centuries been a very popular game fish. In many parts of New England, the British Isles, and Europe it is now scarce. It is smaller than the Pacific salmon and averages about 15 pounds. This species has a brownish back and silver sides and is covered all over by numerous irregular X-shaped black spots. The young have red patches and 11 dusky bars. The dorsal fin contains 10–12 rays, the anal fin 9.

The Atlantic salmon has been introduced into many lakes of the North Central States with doubtful success. Since 1881 many attempts have been made to introduce this species into lakes and streams of Minnesota, including various deep lakes in Ramsey, Rice, Hennepin, Dakota, and other counties. There are no records of any mature fishes having been taken, although several hundred thousand were planted over a period of almost ten years.

LANDLOCKED SALMON

Salmo salar sebago Girard

In certain lakes of Maine the Atlantic salmon has become landlocked and has formed a subspecies called the Sebago salmon. A similar subspecies is the *ouananiche* of the Saguenay region of Quebec. The Sebago salmon has the same general characters as the Atlantic salmon but is smaller, averaging about 2 pounds. Although weights up to 35 pounds are known, the record catch on hook and line is 22 pounds and 8 ounces from Sebago Lake, Maine in 1907.

Since 1881 attempts have been made almost annually to introduce this species into lakes and streams in southern and central Minnesota. These attempts continued to as late as 1912 and 1913, when some were planted in Burnside Lake, St. Louis County. There is no authentic evidence that any of these numerous plants have been successful. Commercial fishermen report taking occasional individuals from Lake Superior near Ashland, Wisconsin.

BROWN TROUT

Salmo trutta fario Linnaeus

The brown trout (Figure 11A) can be distinguished by its square tail and large scales, which number 115–150 in the lateral line. It is usually heavily marked on the sides with dark and red spots, more or less ocellated.

This species was introduced into the United States from Europe in 1883 and immediately gained favor because of its rapid growth, gamy

Figure 11. A. Brown trout. *Salmo trutta fario.* 18 inches long. B. Common lake trout, *Cristivomer namaycush namaycush,* 17 inches long. C. Common brook trout, *Salvelinus fontinalis fontinalis.* 14 inches long.

qualities, and ability to withstand conditions untenable for native brook trout. When the Loch Leven or Scotch brown trout, *Salmo trutta levenensis* Walker, reached the United States we do not know, but eggs purported to be of this subspecies were secured from the United States Bureau of Fisheries in western Montana in 1923. Subsequently many thousands of the resulting fingerlings were planted in the streams and lakes of Minnesota. Apparently there are no strong characters separating the two forms, but *fario* seems to be a more robust fish, with the ocellated red spots well defined, whereas "*levenensis*" is inclined to slenderness, with the spots obscured, the red spots usually entirely so. Hubbs states in a letter that he can find no good evidence for separating Loch Leven trout from brown trout.

Brown trout were introduced into Lake Superior principally through the stocking of tributary streams, and are now fairly abundant. During October and November they ascend the mouths of many streams to spawn. Many of them spawn on rocky reefs alongshore. Some gorgeous individuals are secured at this season, when males, most of them highly colored, with sides a rich brick red, and weighing over 12 pounds, are taken. Four large females taken at Knife River north of Duluth November 12, 1923 produced 10,212 eggs, or 46 ounces.

For years it has been maintained by some that the brown trout is a serious competitor of the native brook trout. In 1902 Mr. William C. Harris stated: "The brown trout has lost popularity among numbers of American fishing clubs and anglers because of its rapid growth, large size, and consequent ability and inclination to devastate waters in which our smaller trouts live. Being able to exist and thrive in waters of a higher temperature than is adapted to other trouts, they should never be placed in streams which the latter inhabit. True, most, if not all, of our native salmonoids are cannibals, in fresh or salt water; but owing to the size of the brown trouts and the practice of putting them in comparatively small and shallow trout streams, where they can ravage at will on *fontinalis,* planting of them should be discountenanced and discontinued."

Mr. Harris took the extreme view, and he may be right in many particulars, but the fact remains that the brown trout is the only logical successor to the native brook trout. We should become reconciled to the fact that we have here a species that will perpetuate trout fishing in many localities for generations after the brook trout has ceased to exist there.

Brown trout are about the only trout that can exist under present-day conditions in many streams in the southern part of Minnesota. Consequently many have been planted in that section of the state, with excellent results. At present they are found more or less commonly in the White Water River and other streams in that region and have pushed their way up the St. Croix River into many of its larger tributaries in both Minnesota and Wisconsin. They are now common in many of the streams tributary to Lake Superior. Those ascending the French River near Duluth are numerous. An example from this stream measured 22 inches in length.

Brown trout are not nearly so delicately flavored as the native brook trout, but they grow to a much greater size, often reaching a weight of 12 pounds. Surber has seen one weighing slightly over 11 pounds, caught in Willow River a short distance from Hudson, Wisconsin. They rise freely to the artificial fly and put up a strenuous fight when once hooked, but the large ones are seldom taken except at twilight and sometimes after dark. The hybrid produced by crossing this species with the native brook trout is an extremely handsome fish, marked like a zebra, and apparently immune to many of the diseases that at times destroy whole stocks of brook trout. However, it is a "mule"; all attempts to breed it have proved futile.

YELLOWSTONE CUTTHROAT TROUT (Yellowstone Trout)
Salmo clarkii lewisi (Girard)

The cutthroat trout has a silvery-gray color, with black spots profusely scattered over the back and sides. The lower jaw is streaked with red in the crease along the jaw bone. The middle of the side has a rosy tinge. The scales are of moderate size and number 140–190 in the lateral line. The dorsal and anal fins each have 10 rays. The tail is slightly forked. This fish is native to streams of the Rocky Mountains. Various attempts have been made to introduce it into Minnesota streams, but without apparent success. Hubbs and Lagler (1941) state that there is one record of at least temporary establishment in Michigan.

LAHONTAN CUTTHROAT TROUT (Silver Trout, Tahoe Trout, Redfish)
Salmo clarkii henshawi Gill and Jordan

The silver trout has a green back and coppery silver sides. It is entirely covered by spots. The dorsal fin has 11 rays, the anal fin 12. The scales are of moderate size and number 160–170 in the lateral line. This fish is native to streams and lakes of the eastern slopes of the Sierras. Several hundred thousand small fingerlings of this species were planted in Big Trout Lake, St. Louis County, Minnesota, in 1921–23, but there is no record of any survival.

COAST RAINBOW TROUT (Steelhead Trout)
Salmo gairdnerii irideus Gibbons

The color of the rainbow trout (Figure 12) is either bluish or olive green above and silver on the sides, with a broad, pink lateral band. The back and sides and the dorsal and caudal fins are profusely spotted. The

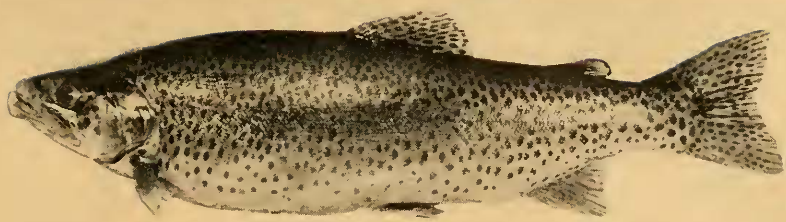


Figure 12. Coast rainbow trout. *Salmo gairdnerii irideus*, male, 18 inches long.

scales are rather large and number 120–140 in the lateral line. The tail fin is slightly forked. The dorsal fin contains 11 rays, the anal fin 10–12 rays.

This fish is native to the streams of the Pacific Coast, the steelhead variety being a seagoing type. Ichthyologists now agree that the steelhead and rainbow trouts are the same species, at least so far as those introduced into this region are concerned. Hubbs (1926) aptly stated that the variation is due entirely to conditions of water and development.

Early introductions of the Shasta rainbow trout, *S. gairdnerii stonei*, were made in Wisconsin, Minnesota, and other northern states. Later steelhead rainbow trout were successfully introduced into many waters of Minnesota and neighboring states and have now largely replaced the earlier planting. They are thriving in Lake Superior as a result of the stocking of tributary streams, which the trout are unable to reascend once they have reached the lake. In spring they run into the mouths of all the rivers to spawn. A few years ago one weighing 15 pounds was taken a short distance up the Knife River in Minnesota, and many others of nearly this size have been taken near Grand Marais. Casting and trolling alongshore in Lake Superior for this species as well as for brook and brown trout have increased in recent years. Some of the smaller interior lakes have responded quickly to plants of this fish, but efforts to maintain them in streams have too often ended in failure. The greatest success has been achieved by the introduction of a southern strain of this species into Minnesota waters. Most rainbow trout spawn in the spring, but this strain, for which the original stock was obtained from Missouri, spawns from the last part of October until early in February. Until the drought (1932) struck southern Minnesota, the strain was taking splendidly in several streams in which the maximum summer temperature was often as high as 85° F. During the protracted drought many streams almost ceased flowing and most of them were deserted by fishes of all kinds. The most successful attempts to acclimatize the species have been in the Cannon River, where it has lived in apparent harmony with smallmouth bass. It is also thriving in a number of spring-fed lakes in the northern counties. Rainbow trout have been introduced into some stone quarry pools near St. Cloud, Minnesota, where Professor George Friedrichs reports that they are thriving but do not reproduce.

The rainbow trout is regarded by many anglers as the most popular game fish. It will take various baits, including grasshoppers, salmon eggs, and even worms if they are moving. It strikes readily on a fly and on many trolling lures. It can be caught by amateur and expert alike, and its gamy qualities will satisfy the most discriminating.

GENUS *Salvelinus* Richardson

This genus includes the chars, represented by many species, only one of which, the brook trout, is found in Minnesota and neighboring states. The Dolly Varden trout, *S. spectabilis* (Girard), of the Western States is a related species. This genus is characterized by having over 200 small scales in the lateral line and by the vomer bearing teeth only on the head portion.

COMMON BROOK TROUT (Speckled Trout)
Salvelinus fontinalis fontinalis (Mitchill)

The brook trout (Figure 11C) has a dark-olive back and sides, with light wormlike or marbled streaks across the back. Numerous red spots margined with brown appear on the sides. The scales are very small, numbering about 230 in the lateral line. The dorsal fin has 10 rays, the anal fin 9. The caudal, or tail, fin is very slightly forked.

The brook trout originally ranged through the Great Lakes drainage, northward into Labrador, and southward in the Appalachians into Georgia. It was undoubtedly native to certain cold-water streams of Minnesota. The statement of Professor Cox (1897) that this species was native in the state only in streams flowing into Lake Superior is challenged by such men as C. A. Nelson of Lutsen, now 80 years old, who was born and brought up on the North Shore. These men claim that brook trout were originally found in several small lakes above Beaver Bay and back of Grand Marais, and in other small lakes between the Baptism and Manitou rivers, but that none were found in any of the rivers above the lower falls except the Reservation River until introduced by sportsmen. Apparently brook trout were always abundant about the mouths of these rivers and in Lake Superior. Also they have been claimed as native fish by the older residents living along the St. Croix and Mississippi rivers, who state that many small, spring-fed tributaries were inhabited by the species long before their introduction from hatcheries. They are native in the spring-fed streams of southeastern Minnesota. Parker in 1857 cites the abundance of speckled trout in the vicinity of Winona as an inducement to settlers. According to a letter from Dr. C. L. Hubbs, brook trout are native in northeastern Iowa.

Brook trout are cold-water fish, thriving best in clear, cold, spring-water streams and brooks in which the mean temperature rarely exceeds 50° F. Their food consists largely of insects, worms, and crustacea. There are certain lakes in the northern part of the state where the species is virtually landlocked, and here they grow much larger than they usually do in streams, as they do also around Isle Royale in Lake Superior. Although they reach a length of 18 to 24 inches, it is doubtful whether most of the brook trout taken in a majority of the streams in the state much exceed 8 to 10 inches in length. One of the largest specimens reported, taken in Nipigon River in Ontario by Dr. J. W. Cook, weighed 14 1/2 pounds and measured 31 1/2 inches.

Brook trout spawn in the fall, beginning early in September in some of the North Shore streams and continuing to the later part of November. At spawning time the fish move far up the smallest creeks, selecting gravel bottoms in shallow water for their spawning beds. There the eggs lie without hatching until the water begins to grow warmer the following spring (Jordan and Evermann, 1905).

The charge is often made that minnows and suckers destroy large numbers of trout eggs on their natural spawning beds, but the writers wish to take exception to this charge, claiming not that certain fishes do not destroy the eggs but that there is an entirely different side to the whole question. Years ago, by a systematic examination of many natural spawning beds in the mountains of western North Carolina and the Alleghanian region in West Virginia, in streams long famous for their magnificent brook trout fishing, it was proved beyond question that the actual damage done by most fishes is very small indeed. The natural spawning beds are in swift water, usually in midstream, and seldom over 2 feet deep, and therefore are more or less directly exposed to the rays of the sun for several hours daily. Invariably there were numerous dead eggs lying on top of the spawning beds or in the open crevices in the gravel just beneath, and only when a depth of about 2 inches below the surface of coarse gravel was reached were any live eggs discovered; but all or nearly all the eggs below this point, sometimes to a depth of 10 to 12 inches, were good.

The minnows and small suckers found in trout streams after the spawning season of the trout are of such size as to be unable to reach the good eggs in the crevices among the gravel. Therefore any eggs they obtain from the surface or just below must be dead before they eat them, for it is well known that exposure to the direct rays of the sun, at least during their early development, is almost invariably fatal to trout eggs. Consequently any consumption of eggs by minnows and small suckers, instead of being detrimental to the spawning beds, is actually a benefit, since the eggs are dead ones that would otherwise in due course of time gather fungus and, working downward among the good eggs, would in all probability spread the fungus and so during the winter destroy many of the good eggs. The only fish said to be positively detrimental to the trout spawn is the miller's-thumb, *Cottus cognatus*. However, this charge against the miller's-thumb requires further investigation.

The brook trout is a prime favorite with anglers in all parts of the country and is one of the choicest of food fishes. Trout streams are among the most valuable resources of a region, and it behooves the northern states to encourage the influx of sportsmen and tourists by keeping all suitable waters well stocked and protecting them in the interest of anglers. In many parts of Minnesota and Wisconsin good trout streams are scarce, and the few that exist are fished so heavily that continuous stocking is necessary. In recent years stocking with fingerlings and even larger trout has been practiced.

Brook trout bite readily on flies. Although worms are disdained by many trout anglers, brook trout will bite readily on angleworms, which are about the only bait one can use in some of the narrow brooks overgrown with brush. Like most other trout they are exceedingly wary, and the angler must exercise great caution, keeping out of sight as much as possible.

GENUS *Cristivomer* (Gill and Jordan)

This genus contains only one species, which is distinguished by its strongly forked tail and small scales. The vomer has a crest armed with strong teeth.

COMMON LAKE TROUT (Mackinaw Trout, Great Lakes Trout, Forktail Trout, Togue)

Cristivomer namaycush namaycush (Walbaum)

The lake trout (Figure 11B) is frequently called a "landlocked salmon" by anglers, but it is a misnomer, for this name properly belongs to the landlocked variety of the Atlantic salmon. The lake trout is dark gray, with round pale spots sometimes tinged with pink. Although the belly is usually pale, it may be dark and spotted. The length is about 4 times the depth. The dorsal and anal fins each have 11 rays. The tail is deeply forked. The scales are rather small, numbering 185–205 in the lateral line.

Lake trout are distributed through northern North America, extending as far south as the Great Lakes region and the New England States. Although this trout is widely distributed in certain types of northern lakes, it cannot be said to be abundant in any of them. The character of these inland lakes varies greatly, and we find a corresponding variation in the color, markings, and even the form and size of the fishes themselves, depending principally on whether the water is clear or brownish. The color of the flesh also varies from almost white in some inland lakes to a deep pink in Lake Superior.

In Minnesota lake trout are native in almost all the deeper lakes in the northern part of St. Louis, Lake, and Cook counties and in several lakes in Itasca and Koochiching counties, and are found in a few isolated lakes south of these, where they have probably been introduced. They are found in a few deep lakes in northern Wisconsin and in the Upper Peninsula of Michigan. They are common in Lake Michigan. They are still fairly abundant in Lake Superior, where angling for them is now pursued with increasing favor. In the inland and border lakes they seldom exceed 18 to 20 pounds in weight, but much larger ones, weighing up to 100 pounds, are sometimes secured in Lake Superior. In some of the small inland lakes the average fish does not exceed 3 pounds. Cox (1897) reported a specimen from Pokegama Lake near Grand Rapids, Minnesota (the southern limit of the range) weighing 25 pounds and measuring 42 inches.

Although they can be taken with the fly in shallow waters during the month of May, at all other seasons they can be secured only by deep trolling. The depths required vary according to water temperatures from 30 feet in June to 70 feet in the later part of July. When other methods fail still-fishing with live minnows at a depth of 70 feet or more is sometimes successful. In Lake Superior in midsummer it is sometimes necessary to troll at depths down to 200 feet to secure lake trout. Late in the summer they may be taken at the surface near shore. Lake trout are good fighters when handled with reasonably light tackle, but their fighting is generally confined to the depths. Under certain conditions in such Minnesota inland lakes as Cherokee and Little Saganaga they often clear the water in one or two leaps.

In Lake Superior they spawn from the later part of September into December, but in the inland lakes they spawn just at the closing of the lakes with ice, which usually occurs early in November. These fishes have been successfully reared to the age of 8 years in small cement ponds at one of the Minnesota hatcheries. They proved to be exceedingly hardy, more so than any other species of trout. Under confinement they did not mature until 5 years of age. Small females, 16 to 20 inches long, contained from 1500 to 2300 eggs.

Lake trout are caught and sold commercially from the Great Lakes, mostly from Lake Superior and Lake Michigan where they range at least to a depth of 800 feet. The commercial fishermen take them with large-mesh gill and pound nets and by long gangs of setlines, the hooks of which are baited with small ciscoes. The commercial fishermen often fish miles offshore.

Lake trout are cold-water fishes and do not thrive in waters over 65° F. The temperature of the water is probably the most important factor in determining the suitability of lakes for this species. To be suitable for this species a lake should have a depth of 100 feet or more, with rocky bottoms and shores. In such a lake oxygen is always abundant in the bottom water because very little oxygen is consumed by the decay of the scanty vegetation and organic matter. Although the surface water may become too warm for the trout, they can always find cold water with abundant oxygen at the bottom. Rocky lakes of less depth, unless fed by springs or cold bog drainage, often do not have a sufficient volume of cold water to carry many trout.

Many attempts to introduce lake trout in the deep lakes of central and north central Minnesota have failed because, though the bottom waters are cold enough to carry trout through the summer, the bottom oxygen becomes depleted because of the decomposition of large amounts of vegetation and organic matter. In several lakes of this type a few lake trout have survived, but not in sufficient numbers to warrant continued stocking. The warmth of the shoal waters and the absence of rocky reefs for spawning also prevent natural reproduction.

SISCOWET (Fat Trout)

Cristivomer namaycush siscowet (Agassiz)

The siscowet (Figure 13) is a form of the lake trout found only in the deeper waters of Lake Superior. In general it resembles the lake trout, but it differs in many details. The length of the siscowet is from 3 to 3 1/2 times its depth. The margin of the belly just anterior to the vent is very much swollen, forcing the vent to be directed posteriorly instead of ventrally as in the typical lake trout. The body cavity is lined with a very thick layer of fat. The color varies from light to dark, but the spots tend to be smaller than those of the lake trout. The scales of the siscowet are slightly larger, numbering about 175 in the lateral line.

The siscowet probably hybridizes with the lake trout, for all sorts of gradations in body form occur. Commercial fishermen call these intergrades "half-breeds" and sometimes sell them for typical lake trout. It is improbable that this fish is differentiated from the lake trout by its environment, since typical lake trout occur commonly at the same depths.

This deep-water trout is seldom taken except by commercial fishermen, and it is never taken on the comparatively shallow spawning beds of *C. namaycush namaycush*. Several commercial fishermen have recently fished for this trout off Grand Marais, Minnesota, setting their gill nets at depths from 600 to 800 feet. The eggs from four females taken off Grand Marais July 10, 1938 averaged 5000 per fish. Mr. R. G. Gale on November 29, 1923 took off Knife River, in deep waters of nearly 50 fathoms, a ripe male and a female of this subspecies which produced 3294 eggs (18 ounces, at 183 eggs per ounce). The female was estimated to weigh 20 pounds, so the eggs taken must have represented but a small proportion of the number actually produced, the loss occurring no doubt through the change in pressure when the fish came to the surface. The eggs were fertilized with lake trout milt and were held in river water for hatching, but did not hatch until May 22, 1924, a period of nearly six

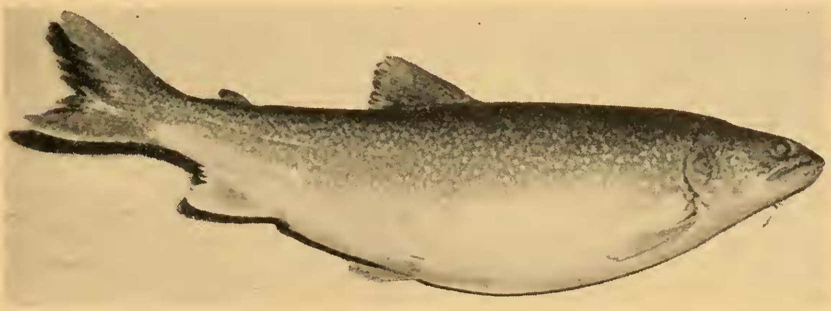


Figure 13. Siscowet, *Cristivomer namaycush siscowet,* 18 inches long, caught at 70 fathoms, Lake Superior.

months. The fry produced from these eggs were reared to yearlings before being released into Lake Superior.

A notable feature during the entire sojourn of these fishes in the hatchery was the position they assumed while not actively swimming about. The body was inclined at an angle of about 35 degrees from the horizontal, with head up and tail down. This position was maintained at all times except when the fish was darting about.

Several specimens caught off Grand Marais had smaller swim bladders than the lake trout, with much thicker walls. The viscera were coated with heavy layers of oily fat. This fish is extraordinarily fat and has a thick skin. It is not much esteemed locally as a food fish but is shipped East, where it is smoked and sold. Little is known of the habits of the siscowet, except that it frequents the deepest waters of the lake, seldom ascending above a depth of 300 feet. It feeds on sculpins and various species of *Leucichthys.*

GENUS *Oncorhynchus* Suckley

This genus contains the various species of Pacific salmon, all of which enter fresh water to spawn and die. At least one species has been unsuccessfully introduced into Minnesota and other northern states.

KING SALMON (Chinook Salmon)

Oncorhynchus tshawytscha (Walbaum)

The king salmon is a large fish weighing about 20 pounds, although weights up to 100 pounds are known. This fish has a dusky back and silver sides, and the back and tail are covered with small black spots. The dorsal fin has 11 rays; the anal fin usually has 16.

It is native to the northern Pacific Ocean from the Bering Sea to Japan and Southern California, and ascends coastal streams to spawn. Numerous attempts, dating back many years, have been made to introduce this species into Minnesota. In 1876 and for several succeeding years many plants of fry and fingerlings were distributed in the lakes of Rice, Blue Earth, Washington, Ramsey, Hennepin, Meeker, Wright, Faribault, and several other counties, and in the Cannon, Blue Earth, St. Croix, and Red rivers. There are records in the Annual Report of the Minnesota Fish Commissioners for 1878 of an occasional catch of some of the fish that had been planted about two years before. They had then reached a length of 10 to 13 inches. These reports came mostly from Rice County. Chinook salmon that had died in Sunfish Lake, Dakota County, had acquired a length of 16 1/2 inches and a weight of 2 pounds, 2 ounces. In 1881 many yearlings and several hundred thousand fry were planted even more widely, reaching as far south as lakes in Nobles County, and a generous supply was planted in the Upper Mississippi River at Brainerd. Many years later the United States Fish Commission made plants in Lake Superior, but with little apparent success.

Only one instance has been reported of this fish's ever having reached mature size in the smaller lakes. This specimen, 20 inches long, was taken in Lake Minnie Bell, Meeker County, Minnesota, in June 1919. Fingerlings had been planted in this lake in June 1916. An occasional fish has been reported from Lake Superior, but most of these fishes proved to be large steelheads. At least one authentic catch is recorded, that of a 12-pounder taken by Eben Falconer off Susie Island in late November 1921 and forwarded to Governor Preus of Minnesota, in whose office it was examined by Surber. Mr. R. G. Gale reported catching several salmon off the Minnesota shore of Lake Superior in nets set for lake trout, in 1934–35.

Family CATOSTOMIDAE

THE SUCKER FAMILY

The body of fishes of the sucker family is generally elongated and in some species is much compressed, but in others it is heavy and thick. The body is covered with smooth-edged scales; the head is scaleless. The mouth varies in size but is always so constructed that it can be drawn out to a considerable extent, thus enabling the fish to take food from the bottom of the stream or lake. No teeth are present on the jaws; the pharyngeal bones are set with numerous teeth that are somewhat similar to those of a comb. The gill-membranes are united to the isthmus (page 57). The dorsal fin contains 10 or more soft rays but no spines; the caudal fin is forked; the ventral fins are inserted far back on the abdomen; the pectoral fins are inserted on the lower part of the body. The air bladder is large and is in two or three parts. Nine genera and at least seventeen species probably occur in Minnesota and neighboring states.

The members of this family are largely American, though one species extends to Siberia and another occurs in China. None of the members of this family bite very readily on baited hooks. Some species are caught in seines and in other ways. They are used extensively for food, though they are all quite bony. Some species of the genera *Catostomus* and *Moxostoma* are sold commercially under the name "mullet."

Key to Common Species of Family CATOSTOMIDAE

1. Dorsal fin long, with 25–40 rays 2
   Dorsal fin short, with 10–18 rays 8

2. Eyes in front part of head; head large, not abruptly slenderer than the body: scales large, less than 40 in lateral line 3
   Eyes in back part of head; head small and slender; body 6–7 times length of head; scales more than 50 in lateral line .... Blue Sucker, *Cycleptus elongatus* (LeSueur)

3. Posterior fontanelle (soft spot at back of skull) present; anterior fontanelle (soft spot between eyes) absent or much reduced; cheek somewhat shallow and foreshortened (distance from eye to lower posterior angle of preopercle about three-fourths that of upper corner of gill-cleft); pharyngeal arch heavy, triangular in cross section; subopercle deepest at middle 4
   Posterior and anterior fontanelles both present; cheek relatively deep and long (eye about equidistant from upper corner of gill-cleft and lower posterior angle of preopercle; pharyngeal arch almost paper-thin; subopercle deepest below middle .... (Genus *Carpiodes*) 6

4. Mouth large, very oblique, protractile forward; upper lip about level with lower margin of orbit; lips thin and only faintly striated; gill-rakers on first arch as long as the gill-filaments of anterior row, nearly 100 (counted from posterior face of arch) ....

........Bigmouth Buffalofish, *Megastomatobus cyprinella* (Valenciennes)
Mouth small, lower and proctractile downwards; upper lip far below lower margin of orbit; lips rather thick and coarsely striated; gill-rakers on first arch all shorter than the longest gill-filaments of anterior row, less than 60 (counted from posterior face of arch) 5

5. Back elevated and compressed; distance from mandibular symphysis to extreme end of maxillary less than the length of orbit (between free rims of orbit); standard length more than 5 times thickness of head ....
................Smallmouth Buffalofish, *Ictiobus bubalus* (Rafinesque)
Back rounded and scarcely elevated; distance from mandibular symphysis to extreme end of maxillary more than length of orbit; standard length less than 5 times thickness of head ....
........................Black Buffalofish, *Ictiobus niger* (Rafinesque)

6. Mouth mostly anterior to the nostrils (Diagram 6) ....
............................Quillback, *Carpiodes cyprinus* (LeSueur)
Mouth mostly posterior to the nostrils (Diagram 6) 7

7. Adults with anterior rays of dorsal fin very much lengthened, sometimes equaling the length of the base of the fin............................
........................Highfin Sucker, *Carpiodes velifer* (Rafinesque)
Adults with anterior rays of dorsal fin scarcely elevated...............
............Northern Carpsucker, *Carpiodes carpio carpio* (Rafinesque)

8. Lateral line absent or incomplete in adult; greatest depth more than one-fifth standard length 9
Lateral line complete and continuous in adult; greatest depth less than one-fifth standard length 11

9. Lateral line wholly lacking at all ages; body oblong; scales in lateral line usually 36–41; markings consist of two longitudinal streaks in young, more or less combined with, or replaced by, narrow vertical bars in adult...
....(Genus *Erimyzon*) 10

10. Dorsal rays usually 11, sometimes 12; scale rows usually 36–38; depth in adult seldom more than one-third standard length (to last vertebra); size large, up to 10 inches in length ....
..........Western Lake Chubsucker, *Erimyzon sucetta kennerlii* (Girard)
Dorsal ray usually 10, sometimes 11; scale rows usually 39–41; in adults depth usually contained more than 3.4 times in standard length; length less than 6 inches...
.....Western Creek Chubsucker, *Erimyzon oblongus claviformis* (Girard)

11. Scales small and crowded anteriorly, 55–110 in the lateral line ....
....(Genus *Catostomus*) 12
Scales large and nearly equal all over the body, less than 50 in the lateral line 13

12. Scales very small, more than 80, about 100 in the lateral line; snout pointed
..Northern Sturgeon Sucker, *Catostomus catostomus catostomus* (Forster)
Scales larger, usually less than 80, about 65 in lateral line; snout not pointed
.... Common White Sucker, *Catostomus commersonnii commersonnii* (Lacépède)

13. Air bladder in 3 parts; scales in lateral line less than 50; head convex above
....(Genus *Moxostoma*) 14
Air bladder in 2 parts; scales in lateral line 46–50; head concave above.....
.........................Hog Sucker, *Hypentelium nigricans* (LeSueur)

14. Halves of lower lip meeting at a rather sharp angle, sometimes becoming

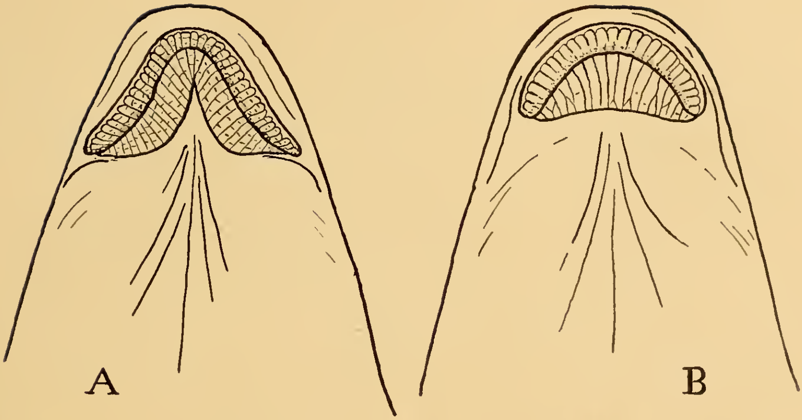


Diagram 5. Lower lip arrangement in *Moxostoma.* (A) *Moxostoma anisurum,* showing halves meeting in an acute angle. (B) *Moxostoma aureolum,* showing halves meeting in a straight line.

very obtuse in large adults, and obliterated when the mouth is protruded; mouth rather large; head rather squarish when seen from side, front, or above, and long (in adult contained 3.7–4.4 times in standard length; in young 1–3 inches long contained 3.3–3.7 times in standard length) 15

Halves of lower lip meeting in a straight line (in the very young at an obtuse angle; the margin often somewhat convex in adults); mouth small; head bluntly subconical and short (in adult contained 4.3–5.4 times in standard length; in young 1–3 inches long, about 3.5–3.8 times); developed dorsal rays usually 12–13; adults living chiefly in large rivers and lakes . . . . Northern Redhorse, *Moxostoma aureolum* (LeSueur)

15. Developed dorsal rays 11–15, usually fewer than 15; plicae of lips not broken up by transverse creases into papillalike elements; lips not much constricted; length of depressed dorsal fin less than two-thirds distance from dorsal fin to tip of snout; length of dorsal fin base decidedly less than distance from dorsal fin to occiput (back of skull) 16

Developed dorsal rays 14–17, usually 15 or 16; plicae of lips more or less completely broken up into papillalike elements; lips notably constricted; length of depressed dorsal fin more than two-thirds distance from dorsal fin to tip of snout; base of dorsal fin about equal in length to distance forward to occiput; found chiefly in large rivers or lakes . . . . Silver Redhorse, *Moxostoma anisurum* (Rafinesque)

16. With dark spots or crescents on the scale bases; caudal fin bright red; tip of dorsal fin whitish near margin in adult; size large, usually more than 15 inches long in adults; adults living mainly in large rivers and lakes except when spawning; lateral line 42–46 scales. . . . . Greater Redhorse, *Moxostoma rubreques* Hubbs

Without dark spots or crescents on the scale bases; caudal fin olive; tip of dorsal always black or blackish near margin; size smaller, probably not reaching 15 inches in length; adults living chiefly in smaller streams; lateral line 38–44 scales, usually 39–40 . . . . Golden Redhorse, *Moxostoma erythrurum* (Rafinesque)

GENUS *Megastomatobus* (Fowler)

This genus contains but one species, the characters of which serve for the genus.

BIGMOUTH BUFFALOFISH (Common Buffalofish, Redmouth Buffalofish)

Megastomatobus cyprinella (Valenciennes)

The body of the common buffalofish (Figure 14) is elliptical in shape and very robust. The head is large, with a blunt and broadly rounded snout. The general color is an olive brown, more or less coppery along the back and fading to a dull olive green on the sides and belly. The mouth is large and wide; it is protractile forward and very oblique. The upper lip is almost on a level with the lower margin of the orbit. The upper lip is very thin and nearly smooth. The lower lip is thicker and faintly but finely striated. The gill-rakers of the first arch, counted from the posterior face, number nearly 100. The dorsal fin has from 24 to 28 rays. The scales are large, those in the lateral line numbering 37–40.

The bigmouth buffalofish ranges from North Dakota to Lake Erie and southward to Alabama and Texas. The distribution of these fishes in Minnesota is peculiar. At one time there were countless numbers in the southern lakes, many of which have now become dry. Originally present in the Mississippi drainage below Brainerd, they reached the Red River of the North from the Minnesota River through Big Stone Lake and Lake Traverse. Hubbs and Lagler (1941) reported them at Winnipeg.

Buffalofish apparently became landlocked in the Upper Mississippi River at Brainerd about 40 years ago, and age determinations show that they very seldom reproduced. One example over 4 feet long weighed 65 pounds. This landlocked form probably is responsible for reports of buffalofish in lakes and in the Mississippi River near Grand Rapids. Greene (1935) reported this species as uncommon in Wisconsin and as reaching its northern limit in the southern part of that state.

Buffalofish prefer sluggish waters, for they feed largely on mollusks, insect larvae, and vegetation. The spawning season extends from the later part of April into June; the eggs are deposited among dead vegetation in shallow bays and sloughs, where they adhere to plants and other debris until hatched, which occurs at approximately 62° F. after a period of 9 or 10 days.

Jordan and Evermann (1905) stated that in former years in certain lakes of central and southern Minnesota extraordinary runs of very large buffalofish occurred occasionally. These runs took place in the spring, at spawning time, usually after a heavy rain, when the tributary streams were full and the connecting marshes were flooded. The buffalofish crowded in great numbers into the inlets and over the flooded

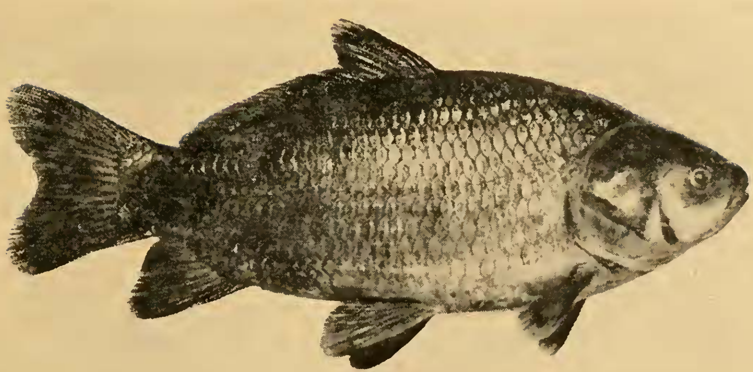


Figure 14. Bigmouth buffalofish, *Megastomatobus cyprinella*, 22 inches long.

marshes. After a few days they disappeared into the deeper waters. While the fish were congested in the shallow waters, farmers and others slaughtered vast numbers with clubs and pitchforks.

In the northern lakes buffalofishes seldom take the hook, nor can they be successfully gilled, but in more southern waters they are commonly taken on setlines baited with doughballs.

They are still fairly common in the Mississippi and Minnesota rivers and in some of the Minnesota lakes near the Iowa border. Buffalofish from clean water, though somewhat bony, have very well-flavored flesh. Those from dirty, weedy waters may have a muddy flavor. Many thousands of pounds are caught and sold annually from southern Minnesota waters by commercial fishermen during the removal of rough fish. The buffalofish thrives best in the same type of waters as the introduced carp, but its habits make it less obnoxious. The number of bigmouth buffalofish inhabiting some southern Minnesota lakes is enormous. Seine hauls have yielded nearly a thousand pounds of fish an acre.

GENUS *Ictiobus* Rafinesque

This genus has the mouth horizontal or only slightly oblique. The gill-rakers of the first arch, counted from the posterior face, number less than 60. The several species found in Minnesota and neighboring states reach a large size.

BLACK BUFFALOFISH (Mongrel Buffalo)
Ictiobus niger (Rafinesque)

The black buffalofish is larger and darker than the smallmouth buffalofish. Hubbs (1930) states: ". . . the slenderer but thicker body, and the less elevated and less sharpened back of *I. niger* serve to distinguish it from *I. bubalus.* In old specimens the nuchal region becomes much swollen, but the back is not sharpened and farther back does not become elevated. The depth of the body is contained 2.6 to 3.2 times in the standard length, as opposed to 2.2 to 2.8 times (except in young smaller than 80 mm.). This species further differs from *I. niger,* as pointed out by Forbes and Richardson (1908 and 1920; 71–72), in having a smaller eye, and a larger and less inferior mouth, with the mandible less included. These differences may be indicated by a single character index, a comparison of the greatest distance from mandibular symphysis to the extreme end of maxillary with the length of the orbit, between its free rims. In the larger young to smaller adults this measurement is greater, usually much greater than the orbit in *niger,* but less than or barely equal to the orbit in *bubalus.* In large adults, the mouth measurement becomes somewhat greater than the orbital length in *bubalus,* but at comparable sizes that measurement is twice the orbit in *niger.* In young, about two to four inches long, the mouth measurement in *niger* about equals the orbit, but in *bubalus* is only about two-thirds the orbit."

Separation of this species, *Ictiobus niger,* from the next species, *Ictiobus bubalus,* or even from *Megastomatobus cyprinella,* is somewhat difficult, for it is indeed a borderline form, and consequently at present we are forced to restrict our report of its range to the Mississippi River proper, where positive identifications have been made.

The black buffalofish is said to be the largest of the buffalofishes, but it is less common than the others. It has an elliptical and robust body. The head is thick and heavy, with a blunt and broadly rounded snout. The mouth is oblique. The lips are thin; the upper lip is faintly striated and the lower lip coarsely striated. The level of the upper lip is about halfway between the lower margin of the orbit and the chin. The dorsal fin has from 29 to 30 rays. The scales are large, numbering 36–40 in the lateral line.

The normal color of this fish is much darker than that of the other buffalofishes, but it is subject to much variation. Occasionally a red phase occurs, causing some individuals to resemble giant goldfishes.

The black buffalofish ranges from southern Minnesota to the Ohio Valley and southwestward to Mexico. It occurs rarely in a number of large streams and muddy lakes in southern Minnesota. In Wisconsin Greene (1935) reported this fish only from Lake Pepin and from bayous of the Mississippi River.

SMALLMOUTH BUFFALOFISH (Razorback Buffalofish)
Ictiobus bubalus (Rafinesque)

The smallmouth buffalofish has a compressed body with the back considerably elevated. The head is small and more compressed and pointed than that of the largemouth buffalofish. The mouth also is smaller and is slightly oblique and protractile downward. The lips are rather thick and coarsely plicate. The level of the upper lip is about halfway between the lower margin of the orbit and the chin. The dorsal fin has from 27 to 30 rays. The scales are large, numbering 37–39 in the lateral line. The color is dark, but there is no appreciable difference in color between the body and the fins. It is a somewhat smaller fish than the black buffalofish, but reaches a weight of over 20 pounds. Forbes and Richardson (1908) stated that about a fifth of the food of the specimens examined by them in Illinois was vegetation, mainly duckweed.

The smallmouth buffalofish occurs from southern Minnesota to southern Michigan and southward to Alabama and Mexico. It is apparently not nearly so common in Minnesota as the bigmouth buffalofish. Cox (1897) reported it from the Minnesota River. However, as it is said to prefer deeper, clearer waters for its habitat than the more common largemouth buffalofish and has been found in the Mississippi at Homer (Surber), it will no doubt be found to be more common in southern Minnesota than is now supposed. Wagner (1908) reported it as less abundant at Lake Pepin than the bigmouth buffalofish. In Wisconsin Greene (1935) reported it only from Lake Pepin sloughs along the Lower Mississippi River. It has also been reported from Waukesha County in Wisconsin and from Lake St. Croix. Commercial fishermen do not as a rule distinguish between the different species but market them all as buffalofish, and so much remains to be learned concerning the distribution of the various species.

GENUS *Carpiodes* (Rafinesque) CARPSUCKERS

This genus consists of silvery, deep-bodied fishes with long dorsal fins, the anterior rays of which are in most species more or less elongated. They are bottom feeders, feeding on almost any animal or plant matter they encounter. Their flesh is exceedingly bony and usually muddy in flavor. The name "carp" has been applied to them, and they are sometimes known as either American carp, carpsuckers, or river carp, though they are not in any way related to the introduced European carp. Considerable variation occurs among the species of this genus and sometimes renders their identification difficult.

QUILLBACK (Silver Carp, Nee-ge-jesh of the Red Lake Chippewas)
Carpiodes cyprinus (LeSueur)

There is so much difficulty as to the identity of the different species of this genus that it is hard to tell whether this species (Figure 15) is really common or whether casual observers have confused it with *C. carpio* or even with one of the other species. The body is ovate-oblong and compressed, and the back is much arched. The anterior rays of the

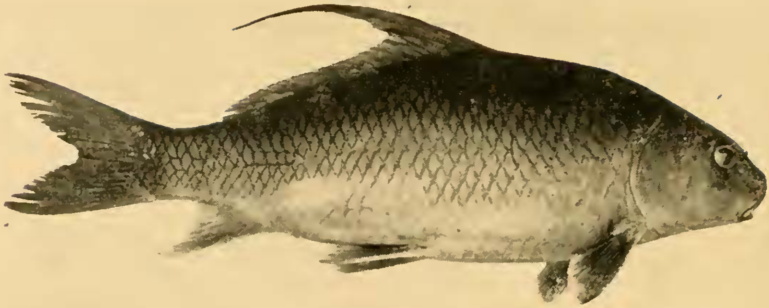


Figure 15. Quillback, *Carpiodes cyprinus,* 10 inches long.

dorsal fin are much elevated, nearly or more than equaling the length of the base of the fin. The lips are full, thick, and flesh colored in life, and the halves of the lower lip unite at an acute angle. The snout is long and bluntly pointed. The nostrils are posterior to the tip of the lower jaw. The distance from anterior nostril to end of snout is greater than the diameter of the eye. The color is light olive above, silvery on the sides, and pale on the fins. Minnesota specimens have from 26 to 30 dorsal rays, the number usually ranging from 27 to 29. The scales in the lateral line of local specimens range from 37 to 41, usually numbering 38–40. This species is usually small in southern Minnesota, seldom exceeding 12 inches in length, and has but little commercial value except in Red Lake and Lake of the Woods, where it reaches a larger size.

The quillback ranges from Lake of the Woods through all the Great Lakes except Lake Superior, and southward to Alabama and Kansas. It is also present in some of the Atlantic coastal waters. In Wisconsin Greene (1935) reported this species from the lower Wisconsin River, Rock River, and Lake Winnebago. Cox (1897) reported the quillback from the Minnesota, Blue Earth, and Pomme de Terre rivers. In Minnesota, quillbacks occur occasionally in the Mississippi and are probably even more abundant in its smaller tributaries than in the stream itself. A few have been taken in the Upper Mississippi River near Wolf Lake, but they are rare there (Surber, 1920). Wagner (1908) reported them from Lake Pepin. At present they are very abundant in Lake of the Woods and are the only members of this genus collected from there in recent years. Those from Lake of the Woods are much larger than those caught elsewhere and commonly reach a weight of 5 to 6 pounds. They have been called "quillback buffalo" at Lake of the Woods but are marketed there under the name of "carp."

In past years the pound-net fishermen found a ready market for these fish, which reached considerable commercial importance, bringing about the same price per pound as the introduced carp. At the Red

Lake fishery of the Minnesota State Fisheries the production of this species alone was 30,016 pounds for the period ending January 1, 1919.

RIVER SUCKER (Lake Carp, Carpsucker)
Carpiodes forbesi Hubbs

The adult river sucker is similar in body form and color to *C. carpio.* It differs in the position of the nostrils, which are considerably posterior to the tip of the lips. The lips are plicate and not very thin; the halves of the lower lip meet in a rather wide angle. The anterior rays of the dorsal fin are slightly elevated and are scarcely more than half the length of the base of the fin. The dorsal fin has from 25 to 30 rays, usually 27 or 28. The lateral line has 38–40 scales.

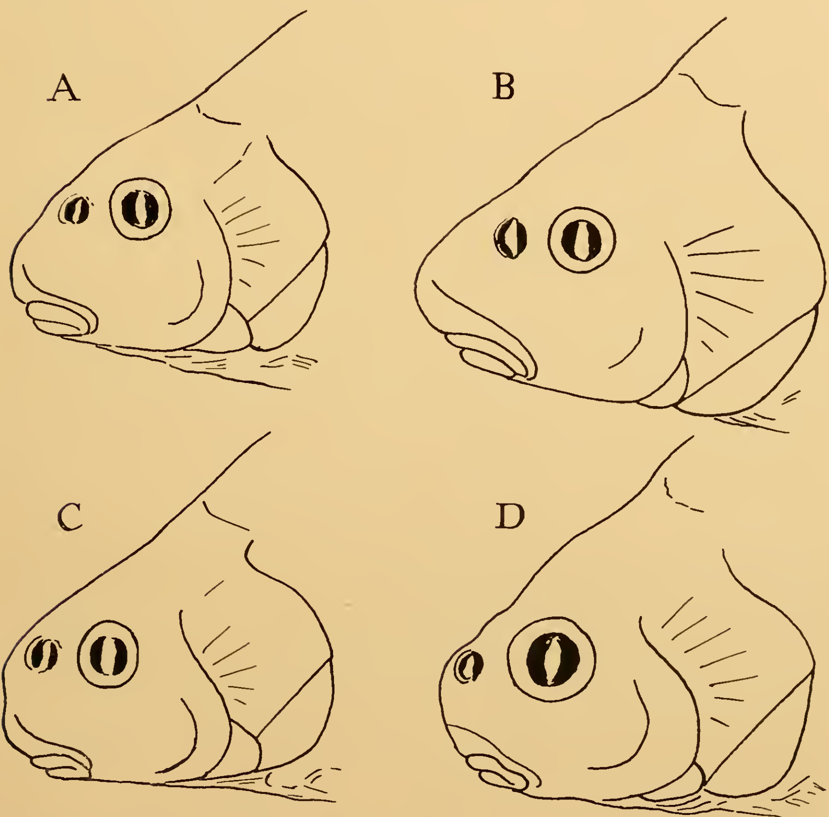


Diagram 6. Differences in the head structures of the four species of Carpiodes. (A) *Carpiodes cyprinus.* (B) *Carpiodes forbesi.* (C) *Carpiodes carpio.* (D) *Carpiodes velifer.*

The distribution of this species is not certain. Hubbs in a personal communication states that it is very common in Nebraska. It may occur in southern Minnesota and in Iowa and be overlooked because of the difficulty of identification. Greene (1935) does not report it for Wisconsin waters.

NORTHERN CARPSUCKER

Carpiodes carpio carpio (Rafinesque)

In the northern carpsucker the back is moderately compressed and slightly arched; the snout is not rounded. The nostrils are slightly posterior to the tip of the lower lip. The longest dorsal ray is two-thirds to three-fifths the length of the base of the fin and is never filamentous. The dorsal rays range from 23 to 27, though the dorsal rays of most Minnesota specimens usually range from 25 to 26, occasionally reaching 27. The scales in the lateral line number from 33 to 38. The lips are thin and silvery white in life, and the halves of the lower lip meet at a wide angle. The color is dull silver, sometimes brassy; often some of the scales are brownish at the base. The northern carpsucker sometimes attains a weight of 10 pounds.

The carpsuckers range from Montana to Pennsylvania and south to Tennessee and northern Texas. In Minnesota they are rather common in the Mississippi and Minnesota rivers. Greene (1935) found them along the Mississippi River and some of its larger tributaries in southern Wisconsin. They are probably restricted to a great extent to the sloughs and more sluggish parts of the streams. The carpsuckers, according to Forbes and Richardson (1908), are bottom feeders, swallowing a greater quantity of mud than the closely related buffalofishes. They are of little value for food.

HIGHFIN SUCKER (Bluntnose River Carp)

Carpiodes velifer (Rafinesque)

This species differs from *Carpiodes carpio* in having the back elevated. It closely resembles *C. cyprinus* in form, color, and the character of the dorsal fin, the anterior rays of which are considerably elongated; sometimes exceeding in length the base of the fin. The rays of the dorsal fin range from 24 to 28, the usual number being 25 to 27. The snout is short and very blunt. The nostrils are located over the anterior tip of the lower jaw. The distance from anterior nostril to end of snout is considerably less than the diameter of the eye. The scales in the lateral line range from 35 to 37. This species is small, seldom reaching a length of over 10 inches. It is of little value as food.

Highfin suckers range from southern Minnesota to Pennsylvania and southward to Tennessee. They have been reported from the Blue Earth River at Mankato, Minnesota (Cox, 1897). In Minnesota they are rather common in the Lower Mississippi River and its smaller tributaries in the southern part of the state. They have been taken in the Red Cedar River in Iowa, near the Minnesota line (Surber, 1920). Greene (1935) found them in the Mississippi and lower Wisconsin rivers in southern Wisconsin. Most of the specimens in the university collections are from the Minnesota and Mississippi rivers.

GENUS *Cycleptus* Rafinesque

This genus differs from the three preceding genera, *Megastomatobus, Ictiobus*, and *Carpiodes*, which are the only other North American genera having a long dorsal fin, in having the soft spot, or fontanelle, in the head obliterated, and in the slender body and rather small head. The genus *Cycleptus* contains only one species, restricted in its range to the Mississippi Valley.

BLUE SUCKER (Missouri Sucker, Gourdseed Sucker, Blackhorse, Sweet Sucker)
Cycleptus elongatus (LeSueur)

The body of the blue, or Missouri, sucker (Figure 16) is elongate and only slightly compressed. The color ranges from dusky to bluish black. The head is very small and slender, tapering to a fleshy snout with a bluntly pointed muzzle. The mouth is inferior. The protractile lips are rather thick and are directed downward. Each lip has five or six rows of tuberclelike papillae. The lower lip is incised behind. The long dorsal fin is elevated anteriorly and has from 30 to 32 rays. The anal fin has 7 or 8 rays. The scales are rather small and number 55–58 in the lateral line. This fish reaches a length of over 2 feet.

The Missouri sucker ranges from southern Minnesota and Wisconsin southward into Tennessee and northeastern Mexico, and possibly

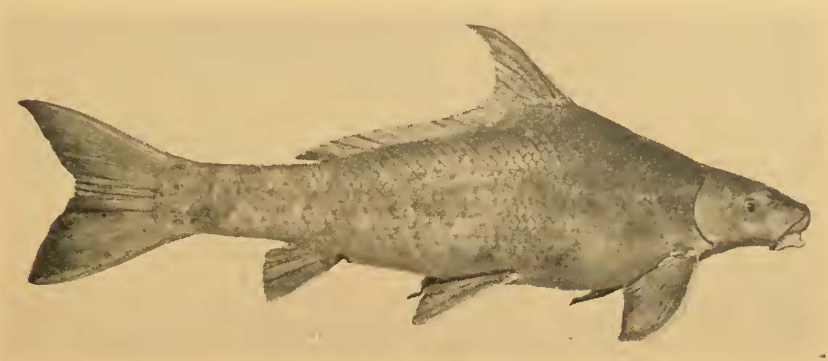


Figure 16. Blue sucker, *Cycleptus elongatus*, 25 inches long.

farther. It is a comparatively rare fish in Minnesota, where it is probably confined to the Mississippi River below St. Paul and to Lake St. Croix. It is highly esteemed as a food fish. The flesh is firm, flaky, and well flavored. Specimens in the University of Minnesota collections were taken from the Mississippi River below La Crosse in 1938 and from Lake St. Croix in 1941. Cox (1897) reported that it was taken at Minneapolis in 1880. Greene (1935) reported it as common in the Mississippi River near Lansing, Iowa.

GENUS *Catostomus* LeSueur

These are the fine-scaled suckers with short dorsal fins having less than 20 rays. Many species and subspecies are found in North America of which only two species occur in Minnesota and neighboring states.

COMMON WHITE SUCKER (Black Sucker, White Sucker, Mullet, Nah-way-bin of the Red Lake Chippewas)

Catostomus commersonnii commersonnii (Lacépède)

The common white sucker (Figure 17) has a slender cylindrical body with a rather blunt snout. The upper lip is thin, with two or three rows of papillae. The scales are larger than in the northern sturgeon sucker, numbering about 70 (60–80) in the lateral line. It is variable in coloration, particularly during the spawning season, when it is so dark as to receive locally the common name of black sucker. During the spawning season the males have a well-marked black lateral band, below which and parallel to it there is a salmon-colored or rosy one. At this time the back is nearly jet black and the belly cream colored, making a rather striking-looking fish. This breeding coloration is quickly changed for a more somber one at the close of spawning; in fact, the change from a dark color with black and rosy bands to a light color will occur within a few minutes at this season if the fish is caught and held in a net or confined in any manner.

The common white sucker ranges from the Mackenzie River to eastern Canada and southward to the Gulf States. It is abundant in all of the waters of Minnesota, Wisconsin, and nearby states. It occurs in enormous numbers in the headwaters of tributaries to the Mississippi River and in the streams and lakes of the Superior, Rainy, and Red River drainages. It reaches a length of over 20 inches.

Suckers spawn rather early in May. Although many suckers crowd the tributaries for spawning, vast numbers spawn in the shallow margins of almost all Minnesota lakes. Within a few weeks after the spawning these waters are cloudy with swarms of tiny golden-eye fry, which soon disappear, many undoubtedly contributing to the diet of the hungry, newly hatched fry of the game fishes. During the spring of 1917 suckers spawned in enormous numbers in the long series of rapids in the Mississippi River below the Bemidji power dam, and at one place, in an eddy, eggs had accumulated to a depth of 18 to 24 inches over an area of some 1500 square feet. Suckers have great reproductive potentials, producing from 36,000 to 130,000 eggs, depending on size. A large female 20 inches long contained nearly 140,000 eggs.

Suckers seldom bite on a baited hook but are frequently taken in nets and seines. Most of them are caught during spawning migrations, when they crowd into the shallow streams in such numbers that they can be literally scooped from the water and may even be caught with the bare hands. During the spring migration enormous numbers of this

Figure 17. Common white sucker, *Catostomus commersonnii commersonnii,* 14 inches long.

species are taken each year in the pound nets used in securing pike-perch for spawning. Sometimes the suckers amount to as much as two tons in a single night in the nets at Wolf Lake, near Bemidji, Minnesota. Many of them are used for food by the local people. They are prepared for use by salting, smoking, or "salmoning," and are rather highly esteemed. During recent years the common white sucker has become of considerable commercial value. The flesh, though bony, is firm and flaky and very sweet.

Anglers, particularly trout fishermen, accuse the suckers of destroying large quantities of trout spawn, and consequently they are in disrepute, but actual evidence of their destroying trout eggs is lacking. Suckers sometimes run up the trout streams to spawn, but they do so at a season when the trout eggs have already hatched. Even though some suckers should remain during the summer, they are always of limited number and all of them seek deeper water in the larger streams when the temperature of the water begins to drop, usually during the cool nights in August, a month or more before the trout begin to spawn.

In hatchery operations on the Upper Mississippi an enormous spring run of suckers follows that of the walleyes. They spawn shortly after the walleyes have finished spawning. During a spell of warm weather early in May the stomachs of some 500 or 600 of these suckers were examined, and not more than 50 contained any food. These suckers were taken from the natural spawning beds of the walleyes, and most of them had empty stomachs, though they had abundant opportunity to feed on the spawn. However, if they are feeding suckers will probably eat even their own eggs. Normally, aquatic plants form an important part of their diet, which is varied with insect larvae, mollusks, worms, and other small animals.

The young of this species and the next one, *C. catostomus catostomus,* are among the very important, if not actually the most important, forage fishes native to our waters. From the time they emerge from the egg until they reach a length of 8 inches, suckers are the natural food of the pikeperch, or walleye, and northern pike.

Suckers are the most easily handled of all our fishes under the usual methods of artificial production. They hatch about 95 per cent under normal conditions and in ordinary ponds grow to a length of 4 inches or more the first summer. It is predicted that they will eventually become one of the most important bait "minnows" if, as appears certain, it becomes necessary as a conservation measure to forbid the taking of minnows from public waters for sale as bait.

NORTHERN STURGEON SUCKER (Longnose Sucker, Red Sucker)

Catostomus catostomus catostomus (Forster)

This species can usually be distinguished from the preceding one, *C. commersonnii commersonnii,* by its long, pointed snout, which extends considerably beyond the mouth, and by its very small scales, much reduced and crowded anteriorly, and numbering more than 95 (95–114) in the lateral line. It is variable in coloration. The spring males are profusely tuberculate on head and anal fin and have a broad, rosy lateral band, which persists until late in the summer. This species reaches a length of over 2 feet.

The northern sturgeon sucker ranges from the St. Lawrence and Great Lakes basin westward into the Rocky Mountains and also northward. In Minnesota they are abundant in Lake Superior, Lake of the Woods, Rainy River and its tributaries, and Vermilion Lake. They have been taken in the St. Louis River at Fond du Lac, near Duluth, and also from Lake Saganaga and Kimball and Mink lakes in Cook County. In general they are distributed throughout the Arctic and Superior drainages and are inferior in numbers to the common sucker. They usually occur in large numbers wherever found in the northern part of Minnesota, but they have never been seen in the Mississippi drainage. Greene (1935) reported them from the drainages of Lake Michigan and Lake Superior in Wisconsin. In the deep northern lakes they often range to great depths. In Lake Superior they are taken occasionally at depths of 600 feet, but the commercial fishermen who fish at these depths claim that they seldom go this deep.

Sturgeon suckers have been observed migrating up tributary streams for spawning in the spring at the same time as the common suckers. In 1911 they spawned at Lake of the Woods during the first half of June. They were observed spawning in company with the common suckers at Fond du Lac, Minnesota, May 15, 1939. Their flesh, like that of the common sucker, is firm and well flavored but rather bony. They seldom bite on a hook and line but are usually taken by spearing during spawning migration.

GENUS *Hypentelium* (Rafinesque)

This genus contains but one species, the characters of which distinguish the genus. Its range is limited to the eastern section of the United States.

HOG SUCKER (Hog Molly, Spotted Sucker)
Hypentelium nigricans (LeSueur)

A description of this fish (Figure 18) is almost superfluous, for it is well known by its large head and dark cross blotches to almost every boy who has ever fished. The head is concave on top, the eye posterior

Figure 18. Hog sucker, *Hypentelium nigricans,* 10 inches long.

to the middle of the head. The scales are large and number 48–55 in the lateral line. The hog sucker is found most frequently in clear, rapid streams, where in midsummer it loves to bask in the sun, lying atop some large rock or in a shallow riffle.

Forbes and Richardson (1908) said: "The most striking peculiarities of this fish are related to its haunts and feeding habits. The large bony head and the unusually developed pectoral fins, together with the full lips and the papillose mouth, are all related to the fact that it seeks its food in the more rapid parts of streams, pushing about the stones upon the bottoms and sucking up the ooze and slime thus exposed, together with the insect larvae upon which it mainly depends for food. The slender body, the large pectoral fins and the comparatively high coloration of this species give it the aspect of a darter among the suckers, and its active habit and the peculiar character of its food resources is another point of affinity with that interesting group. It has also, like the darters, the habit of resting quietly on the bottom, supported by its paired fins, where its coarsely mottled colors serve well to conceal it among the surrounding stones."

The hog sucker ranges from central Minnesota eastward to New York and southward to northern Alabama and Oklahoma. It is probably common over most of southern Minnesota. Cox (1897) reported it from the Blue Earth and Minnesota rivers. The writers have found it in the Upper Mississippi near Wolf Lake, in Green Lake in Kandiyohi County, in the Kettle River and smaller tributaries of the St. Croix in Pine County, and in the tributaries of the Minnesota River and the Mississippi River south of St. Paul. This species has not been found in the Lake Superior drainage. Greene (1935) found it throughout the Mississippi and Lake Michigan drainages in Wisconsin.

The hog sucker sometimes attains a length of 2 feet, but its food value is slight.

GENUS *Erimyzon* Jordan

This genus is distinguished by the entire absence of the lateral line and by the plain coloration of the adult. The young have a broad black lateral band and are easily mistaken for Cyprinidae.

WESTERN LAKE CHUBSUCKER
Erimyzon sucetta kennerlii (Girard)

Although no records of the western lake chubsucker are known from Minnesota, it has been reported from southern Wisconsin (Greene, 1935) and may occur in southeastern Minnesota. It is reported (Hubbs and Lagler, 1941) as ranging from southern Wisconsin eastward through the lower Lake Michigan drainage to the tributaries of Lake Erie and southward to Alabama and east central Texas. It is a small fish, differing from the western creek chubsucker in having fewer scales, usually numbering 36–38 in the lateral line.

WESTERN CREEK CHUBSUCKER (Sweet Sucker, Pin Minnow)
Erimyzon oblongus claviformis (Girard)

The creek chubsucker is a small sucker rarely exceeding 10 inches in length, the average observed by the writers being about 6 inches. It varies greatly in color, but is usually dusky olive with a brassy luster on the lower sides; the fins are dusky. The dorsal fin typically has 10 rays. There are usually from 39 to 41 scales in the lateral line.

The western creek chubsucker ranges from southern Minnesota to

Pennsylvania and southward to southern Alabama and Texas. It is probably more or less common in the smaller streams in southeastern Minnesota. It was taken in 1918 and 1919 in Sand, Lower Tamarack, and Crooked creeks, all in Pine County, and in 1918 in Mill Creek, a tributary of the Root River in Olmsted County (Surber). Greene (1935) reports it as rare in southern Wisconsin and as found chiefly in the southeastern part.

The chubsucker is a bottom feeder and has the habit of supporting itself on the bottom by means of its paired fins, like the darters. It bites readily on a small hook but its flesh is bony and without flavor, and owing to its small size the species has no commercial value (Forbes and Richardson, 1908).

GENUS *Minytrema* (Jordan)

This genus has but one species, the characters of which serve to distinguish the genus.

SPOTTED SUCKER (Striped Sucker)
Minytrema melanops (Rafinesque)

The spotted sucker (Figure 19) is dusky, and coppery below. Each scale has a dark spot at its base. These spots form longitudinal stripes, which are most distinct in the adult though obscured in the breeding

Figure 19. Spotted sucker, *Minytrema melanops,* 17 inches long.

male. The males are tuberculate in spring. The spotted sucker reaches a length of 20 inches.

The spotted sucker ranges from southern Minnesota to Pennsylvania and southward to Florida, Texas, and Kansas. It is probably more or less rare in northern waters. It is found occasionally in the Minnesota River and in Lake St. Croix and Lake Pepin and occurs in some of the smaller tributaries of the Mississippi. It was secured in the Mississippi River at Homer by Surber in 1915, but is very uncommon there. Greene (1935) reported it from the Mississippi River at and below Lake Pepin and from the St. Croix River and several other tributaries of the Mississippi River in Wisconsin.

GENUS *Moxostoma* Rafinesque REDHORSES

These are suckers of large size, with large, coarse scales (less than 55) and bright coloration. They frequent clear streams and lakes and are among the first fishes to succumb to pollution or to continuously turbid water. This susceptibility probably accounts for their disappearance from many waters in southeastern Minnesota. Hubbs (1930) has made a critical analysis of this genus, but not much study has yet been made of the distribution of the various species in Minnesota. The genus is widely distributed over North America.

NORTHERN BLACK REDHORSE (Black Mullet)
Moxostoma duquesnii duquesnii (LeSueur)

The northern black redhorse is a rather large fish reaching a length of over 2 feet. In general form it resembles the other species of *Moxostoma*. The eye is usually small, less than two-fifths the snout in adults. The mouth is large. The scales number 42–49, but typically 44–47. The rays of the pelvic fin usually number 10. The northern black redhorse ranges from eastern Iowa to Pennsylvania and southward to Georgia and Oklahoma. This species occurs in southeastern Minnesota. It was collected by the Department of Conservation in 1945 from the Root River and identified by Dr. R. E. Johnson. Greene (1935) reported it from several areas in southern Wisconsin.

GREATER REDHORSE
Moxostoma rubreques Hubbs

This is a large fish reaching a length of over 2 feet. In general shape it is similar to *M. anisurum* but is usually not as deep. The least depth of the caudal peduncle is much more than two-thirds its length. The halves of the lower lip meet at a rather sharp angle. The mouth is rather large. The head is longer than in *M. aureolum* and squarish when seen from the side, top, or front. In adults the head in contained 3.7 to 4.4 times in the length, and in young, 1 to 3 inches, it is contained 3.3 to 3.7 times in the length.

The scales have dark spots or crescents on the scale bases. The caudal fin is bright red; in adults the tip of the dorsal fin is whitish near the margin. The eye is less than one-fourth the length of the head in young and less than one-seventh the length of the head in adults. The dorsal fin has from 11 to 15 rays. The scales number 42–46.

The greater redhorse ranges from Minnesota through the lower Great Lakes drainage to New York and southward to the Ohio River. This species is present in the larger streams of the Mississippi drainage in both Minnesota and Wisconsin. Greene (1935) found it also in Wisconsin tributaries of Lake Michigan.

GOLDEN REDHORSE
Moxostoma erythrurum (Rafinesque)

This species is similar to *M. rubreques,* but smaller. The halves of the lower lip meet at a rather sharp angle. The eye is more than one-fourth the length of the head in young and more than one-seventh the length of the head in adults. The scales number 38–44.

The golden redhorse ranges from southern Minnesota eastward to southern Ontario and southward to northern Alabama and the Red River basin in Oklahoma. It is found in small tributaries of the Mississippi and also in the St. Croix, Minnesota, and Mississippi rivers. It was collected from the Root River by the Minnesota Department of Conservation in 1945. Greene (1935) reported this species from many streams of Wisconsin, exclusive of the Lake Superior drainage.

SILVER REDHORSE (Whitenose Sucker, Silver Mullet)
Moxostoma anisurum (Rafinesque)

The silver redhorse (Figure 20) is pale in color; the caudal fin is smoky gray, with the upper lobe narrower and longer than the lower;

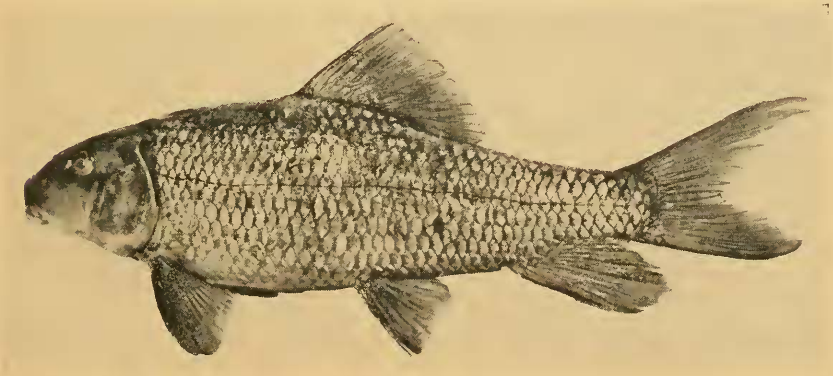


Figure 20. Silver redhorse, *Moxostoma anisurum,* 19 inches long.

the lower fins are red in the spawning season. It is distinguished by a large dorsal fin, which has 14 to 17 developed rays. The eye is large, more than one-fourth the length of the head in young and more than one-seventh the length of the head in adults. The scales number 38–44, usually 40–42. The halves of the lower lip meet at a rather sharp angle (Diagram 5). The fish reaches a length of 2 feet.

The silver redhorse ranges from the Hudson Bay drainage of Manitoba to Quebec and southward to northern Alabama and to Missouri. It is abundant in the Minnesota and St. Croix rivers and in the Mississippi River as far up as Grand Rapids, Minnesota. Cox (1897) reported it from the Des Moines River, and Surber in 1911 found it in the Red Cedar River. Evermann and Latimer reported it as "not uncommon" in Lake of the Woods. Our collections show it to be fairly common in Lake of the Woods, where it reaches a very large size. Wagner (1908) secured one adult and several young at Lake Pepin. It is well distributed over the state, though not nearly so abundant as *M. aureolum.* Greene (1935) reported it from many localities in Wisconsin, including tributaries of Lake Superior.

It is an excellent food fish, though somewhat bony. It sometimes bites on a baited hook but is more frequently caught in seines by commercial fishermen.

NORTHERN REDHORSE (Largescale Sucker, Redfin, May-squaw-she-gwah-nay-see of the Red Lake Chippewas) *Moxostoma aureolum* (LeSueur)

The northern redhorse (Figure 21) is very much like *M. anisurum,* but the tail as well as the lower fins are always red. The caudal lobes are subequal. The dorsal fin is rather low, is smaller than in *M. anisurum,*

Figure 21. Northern redhorse, *Moxostoma aureolum*, 18 inches long.

and has 12–14 developed rays. The mouth is small. The halves of the lower lip meet in a straight line in adults, at an obtuse angle in young. The head is bluntly subconical and short. In adults it is contained 4.3 to 5.4 times in the length, and in young, 1 to 3 inches long, it is contained 3.5 to 3.8 times in the length. The scales in the lateral line number about

45. It attains a length of 2 feet or slightly more and a weight of 8 or 10 pounds and is of considerable value as a food fish.

The northern redhorse ranges from Montana to eastern Canada and southward to New York and to Kansas. It is absent from the Ohio Valley except in the Wabash drainage (Hubbs and Lagler, 1941). It is common in many of the clear-water lakes and larger streams of Minnesota and in many of the creeks as well, but Wagner (1908) did not find it at all common at Lake Pepin in 1903–4. It is present in the Lake of the Woods and the Red River drainages and has been collected from the St. Louis River in the Superior drainage. It shows a decided preference for clear, swiftly moving streams. Greene (1935) reported it from all parts of Wisconsin.

Forbes and Richardson (1908) stated that this redhorse is not tenacious of life but dies quickly in the aquarium if the water is at all impure. In its native waters also it readily succumbs to impure conditions, which are likely to occur in midsummer. They sometimes perish in vast numbers and are found stranded along the banks when violent summer rains, following long periods of drought, overload the streams with mud and decaying vegetation.

In the Upper Mississippi in the region of Wolf Lake, Minnesota, the redhorses do not run up to spawn until about three weeks after the common suckers have spawned. At Lake of the Woods they always select clean sand and gravel bars in shallow waters for their spawning beds, and most of the eggs are deposited after sunset or very early in the morning. The northern redhorse frequently bites on a baited hook and is commonly caught and sold by commercial fishermen. Many regard this fish as the best of the suckers, for the flesh is white and flaky and, particularly when baked, is an excellent food.

Family CYPRINIDAE

THE MINNOW FAMILY

The minnows are usually fishes of small size, though the carp, which is not native, may reach a weight well over 50 pounds. Several American species reach a weight of several pounds and a length of 18 inches, but many species seldom reach a length of over 2 inches. Over 2000 species are known. Jordan, Evermann, and Clark (1930) list 307 species for North and Central America. With the exception of one Japanese species, all minnows are strictly fresh-water fishes.

The minnow family is represented by more individuals and species than any other family of fishes in Minnesota and neighboring states. Hubbs and Cooper (1936), describing the minnows of Michigan, state that the number of minnows in Michigan waters probably runs into many hundred millions. They attribute this abundance to at least three factors: Minnows as a group occupy a great variety of habitats and eat many types of foods; most species of minnows require a relatively short time to reach sexual maturity; a large number of minnows can occupy a small space and find sufficient food and shelter because they are usually small fishes.

Externally many species are so similar that it is difficult to distinguish them from one another. Consequently this family is extremely difficult to study. In addition the name "minnow" is often applied locally without discrimination to any small fish, and also there are a number of small fishes called minnows, such as the topminnow and mudminnow, which belong to other families.

In the spring the males often develop tubercles on the top of the head and sometimes on other parts of the body. In some species bright colors, particularly red, orange, and yellow, appear on the fins and in streaks along the body. Young individuals are usually more slender than the adults of the same species, and the eye is always much larger. The young fishes often show a black lateral stripe and caudal spot not possessed by the adults, though these marks are also common in the adults of many species.

All members of this family have the head naked in the nonbreeding state. One dorsal fin is present, and the spines are absent in all local species except the introduced carp and goldfish. Less than 10 soft dorsal rays are present in native minnows, but this number is exceeded in the introduced carp and goldfish. No teeth are present on the jaws. Pharyngeal teeth are well developed and form one of the most important characters for identification. The teeth are arranged in not more than two rows on each posterior branchial arch in all local species except the carp, which has three rows. The outer row contains 1 or 2 teeth, the inner or main row 4 or 5. The tooth, or dental, formula when given for a species means the number of teeth in each of the four rows from left to right. The formula 2, 5—4, 1 means that the left side has 2 outer and 5 inner teeth and the right side has 1 outer and 4 inner teeth.

In order to be observed the teeth must be carefully dissected out. The dissection is done by turning back the opercle and exposing the last gill-arch, which bears the teeth. This arch lies against and inside the shoulder girdle, which supports the pectoral fins. The last arch on each side must be carefully separated from the girdle by cutting, and then is removed by cutting at each end. The tissue must be dissected away from the teeth with needles and care taken not to injure the teeth, which are easily broken.

The various species of the family also show considerable difference in the selection of food from the general supply available to them. The minnows of Minnesota and neighboring states are mainly carnivorous, though they seldom eat fishes or the other larger aquatic animals. A few species eat largely of vegetation, and a few others feed almost wholly on the highly organic mud of the bottoms of ponds and streams, but the principal diet of most minnows consists of insects and crustacea (Entomostraca).

Forbes and Richardson in 1908 wrote: "In the general scheme of aquatic life, the native members of this family, taken together as a group, play a multiple role. They operate, to some extent, as a check on the increase of the aquatic insects, from which they draw a large part of their food supply; they make indirectly available, as food for their own most destructive enemies, these aquatic insects, many terrestrial insects also, which fall into the water and are greedily devoured by them, and the mere mud and slime and confervoid algae gathered up from the bottom of the waters they inhabit; and they rival the young to a great degree, of all larger fishes, their own worst enemies included by living continuously, to a great degree on the *Entomostraca* and insect life which these fishes must have, at one period of their lives, in order to get their growth. They also offer a considerable means of subsistence to certain aquatic birds . . . and, through their contributions to the support of the best food fishes, they form an important link in the chain of agencies by which our waters are made productive in the interest of man. . . .

"From the standpoint of the predaceous species, minnows are young fishes which never grow up, and thus keep the supply of edible fishes of a size to make them available to the smaller carnivorous kinds when the young of the larger species have grown too large to be captured or eaten. . . . Moreover, by their great numbers, by their various adaptations and correspondingly general ecological distribution, and by their permanently small size, the minnows must distract in great measure the attention of carnivorous fishes from the young of the larger species, upon which, without them, the adults of these larger species would fall with the full force of their voracious appetities. By offering themselves, no doubt as unconscious, but sufficient, substitutes, they thus help to preserve—for their own future destruction, however, be it noticed—the young of many species which would otherwise be forced to feed on each other's progeny. It is not too much to say, consequently, that the number of game fishes which any waters can maintain is largely conditioned upon its permanent stock of minnows."

Faced with such facts we should take steps to control and supplement, where possible, nature's effort to preserve a proper balance of game and forage fishes. At present there are hundreds of bait-minnow dealers scattered over the northern states, and their entire stock in trade is procured from public waters, in nearly every instance at the expense of game fishes. Several years ago certain streams and lakes in Minnesota had to be closed entirely to the taking of minnows for commercial purposes, and conditions have now reached an acute stage in which the natural food supply is so reduced as to curtail the game fish capacity of certain lakes and streams. Minnows have sometimes been hauled over 200 miles in an effort to supply the demand for live bait. When some dealer, without boasting, advises you that he has marketed over 100,000 dozen minnows in a single season, the magnitude of the industry and its effect upon fish life are manifest. And this is not the worst of it by any means, for it is safe to assert that for every minnow marketed by the dealer at least five others have been destroyed, either through careless handling when seined or assorted, in the course of transportation to the dealer's holding vats, or through improper facilities for the care of the minnows at the place of sale.

Some species of this family have played an important economic role besides that of being bait and food for other fishes, for many larger species, such as the carp, are important food fishes, particularly in the Old World. Some of the important European species of this family are the tench, roach, bleak, and bream. The crystalline, silvery coloring matter of various cyprinids is said to have been employed for ornamental purposes by the Chinese from time immemorial. The important artificial pearl industry has been carried on in France and Germany with the scales of the bleak.

In the following descriptions very little attempt is made to describe in detail the different species, but their ranges so far as shown by collections and records are indicated.

Key to Common Species of Family CYPRINIDAE*

1. Dorsal fin with a long base and more than 11 soft fin rays; dorsal and anal fins each with a strong spinous ray 2

*Adapted from Hubbs and Lagler, 1941.

Dorsal with a short base and fewer than 10 soft fin rays; no spinous ray in dorsal or anal fin 3

2. Upper jaw with 2 barbels on each side; lateral line with more than 32 scales (except in mirror and leather carps) ......Carp, *Cyprinus carpio* Linnaeus
No barbels; lateral line with fewer than 30 scales...............................Goldfish, *Carassius auratus* (Linnaeus)

3. Cartilaginous ridge of lower jaw prominent, separated by definite groove from lower lip; intestine spirally wound about air bladder..(Genus *Campostoma*) 4
Cartilaginous ridge of lower jaw hardly evident, not separated by a definite groove from lower lip; intestine not wound about air bladder 5

4. Scales in lateral line usually 43–47; scale rows around body just in front of dorsal fin usually 31–36; width of gape usually 4.3–4.8 in head............ Largescale Stoneroller, *Campostoma anomalum oligolepis* Hubbs and Greene
Scales in lateral line usually 49–55; scales around body just in front of dorsal fin usually 39–46; width of gape usually 4.6–5.5 in head ....Central Stoneroller, *Campostoma anomalum pullum* (Agassiz)

5. Premaxillaries nonprotractile; upper lip connected with skin of snout by a bridge of tissue across which the premaxillary groove does not pass 6
Premaxillaries protractile; upper lip separated from skin of snout by a deep groove continuous across the midline 7

6. Snout projecting far beyond the horizontal mouth; eyes superolateral ....Great Lakes Longnose Dace, *Rhinichthys cataractae cataractae* (Valenciennes) ....
Snout scarcely projecting beyond the somewhat oblique mouth; eyes lateral ....Western Blacknose Dace, *Rhinichthys atratulus meleagris* Agassiz

7. Maxillary with a barbel (usually requiring care to observe because it is small and often hidden in the groove about the upper jaw, which should be pulled out a little in searching for the barbel; the barbel is occasionally obsolete in *Semotilus* and *Margariscus*)..............................8
Maxillary without a barbel (a barbellike swelling occurs at the end of the maxillary in breeding males of *Hyborhynchus*)......................14

8. Barbel at or near end of maxillary and always slender; teeth in main row always 4—4 9
Barbel on lower edge of maxillary well in advance of posterior end (usually concealed in groove between maxillary and premaxillary and often flaplike or obsolescent); teeth in main row typically 5—4 13

9. Scales more than 55 in lateral line 10
Scales fewer than 45 in lateral line 11

10. Length of depressed dorsal fin more than two-thirds the distance from origin of dorsal to occiput; dorsal fin typically somewhat falcate; body moderately compressed; eye large ....Lake Northern Chub, *Couesius plumbeus plumbeus* (Agassiz)
Length of depressed dorsal fin less than two-thirds the distance from origin of dorsal to occiput; dorsal fin rounded or scarcely falcate: body terete; eye small ....Creek Northern Chub, *Couesius plumbeus dissimilis* (Girard)

11. Body marked with numerous x-shaped blotches...Spotted Chub, *Erimystax dissimilis* (Kirtland)
Body not marked with numerous x-shaped blotches..................12

12. Mouth somewhat oblique and slightly inferior, upper lip scarcely overhung by snout; eye shorter than upper jaw. Least suborbital width less than half

postorbital length of head, about half in largest adults; spot at caudal base round and blackish; caudal fin red in living young; teeth typically 1, 4—4, 1 ....Hornyhead Chub, *Nocomis biguttatus* (Kirtland)
Mouth horizontal and strictly inferior, upper lip considerably overhung by snout; eye longer than upper jaw; body without definite spots (beware of parasite specks); teeth typically 1, 4—4, 1; color silvery, without a dark lateral band; size large, 4–10 inches when adult; dorsal fin inserted distinctly in advance of pelvic fin.....Silver Chub, *Hybopsis storerianus* (Kirtland)

13. A black spot on dorsal fin near front of base, indistinct in young; mouth large, upper jaw extending at least to below front of eye; sides not mottled by specialized dark scales; scales in lateral line fewer than 60 .... .Northern Creek Chub, *Semotilus atromaculatus atromaculatus* (Mitchill)
No black spot on dorsal fin; mouth small, upper jaw not extending to below front of eye; sides mottled by specialized dark scales; scales in lateral line about 65–75 ....Northern Pearl Dace, *Margariscus margarita nachtriebi* (Cox)

14. Lateral line scales more than 60 15
Lateral line scales fewer than 55 19

15. Intestine short, with a single main loop, and less than twice as long as body; body with a single dusky lateral band; teeth in main row typically 5—4, sometimes 5—5, 4—5, or 4—4..................................16
Intestine elongate, with two crosswise coils in addition to the primary loops, and more than twice as long as body; body with two black lateral bands; teeth 5—5 or 5—4...18

16. Peritoneum black; lateral line incomplete; scales minute, more than 80 in lateral line, each with radii on all fields.............................. ....Finescale Dace, *Pfrille neogaea* (Cope)
Peritoneum pale; lateral line complete, except in young of *Margariscus;* scales fewer than 80 in lateral line, with radii only on exposed field......17

17. Head narrow; gape very wide, the upper jaw extending as far back as the front of the eye; nuptial tubercles small but numerous, developed on head and often also on nape; snout sharp.............................. ....Redside Dace, *Clinostomus elongatus* (Kirtland)
Head width moderate; gape much smaller, the upper jaw not extending as far back as the front of the eye; nuptial tubercles minute or undeveloped; snout blunt...................*Margariscus margarita nachtriebi:* see 13

18. Mouth strongly oblique and more curved; length of upper jaw less than one-fourth length of head; distance from tip of snout to back of eye usually about equal to rest of head...................................... ....Northern Redbelly Dace, *Chrosomus eos* Cope
Mouth little oblique, little curved; length of upper jaw more than one-fourth length of head; distance from tip of snout to back of eye distinctly longer than rest of head... ....Southern Redbelly Dace, *Chrosomus erythrogaster* Rafinesque

19. Abdomen behind pelvic fins with a fleshy keel over which the scales do not pass; lateral line much decurved; anal fin falcate ....Western Golden Shiner, *Notemigonus crysoleucas auratus* (Rafinesque)
Abdomen behind pelvic fins rounded over and scaled; lateral line not greatly decurved; anal fin scarcely falcate 20

20. First dorsal ray more or less thickened, separated by membrane from first well-developed ray, and with a thicker coating of adipose tissue; a dark

spot, faint in young and some females, at front of dorsal fin near but not at base; back flattish (these characters conspicuous only in adults) 21
First dorsal ray a thin splint, closely attached to first well-developed ray, and with a thinner covering of adipose tissue; no dark spot at front of dorsal near base (a dark spot is present at the very base in *Notropis umbratilis cyanocephalus*); back little flattened 23

21. Peritoneum silvery; intestine short (S-shaped)............................Bullhead Minnow, *Ceratichthys perspicuus* (Girard)
Peritoneum blackish or black; intestine somewhat elongated, with at least one short extra coil 22

22. Mouth terminal and oblique; caudal spot faint; lateral line very short (in Great Lakes subspecies)..Northern Fathead Minnow, *Pimephales promelas promelas* Rafinesque
Mouth inferior and horizontal; caudal spot conspicuous; lateral line complete ....Bluntnose Minnow, *Hyborhynchus notatus* (Rafinesque)

23. Mouth extremely small and nearly vertical; dorsal rays typically 9; teeth in main row 5—5 or 5—4, strongly serrate..Pugnose Minnow, *Opsopoeodus emiliae* Hay
Mouth larger and oblique to horizontal, except in *Notropis anogenus*; dorsal rays typically 8; teeth in main row 4—4............................24

24. Lower lip restricted to rather prominent lateral lobes....................................Suckermouth Minnow, *Phenacobius mirabilis* (Girard)
Lower lip normal, not restricted to lateral lobes.....................25

25. Anal rays 9–12, rarely 8; teeth 2, 4—4, 2...........................26
Anal rays usually 7 or 8, rarely 9; teeth in outer row usually 0 or 1, but often 2 in *Notropis heterodon*, *N. xaenocephalus*, and *N. hudsonius*..........30

26. Origin of dorsal as far, or slightly farther, forward than insertion of the pelvics...Northern Common Shiner, *Notropis cornutus frontalis* (Agassiz)
Origin of dorsal distinctly behind the insertion of the pelvics..........27

27. Body deep, the depth typically more than head length in adults or equal to head length in young; exposed portions of scales notably deeper than long; nuptial tubercles larger; breeding males with much red over entire body and fins; dorsal with prominent black spot at its extreme base, anteriorly ...Northern Redfin Shiner, *Notropis umbratilis cyanocephalus* (Copeland)
Body slender, the depth much less than the length of the head; exposed portions of scales not notably deeper than long; nuptial tubercles minute; breeding males with little or no red, or with red confined to the head region; dorsal fin lacking prominent black spot at its anterior base............28

28. Snout short and blunt, its length less than two-thirds the distance from the posterior margin of the eye to the posterior end of the head; body rather sharply compressed; form of body elliptical, deepest near middle of length 29
Snout produced and sharp, its length more than two-thirds the distance from the posterior margin of the eye to the posterior end of the head; body thicker and heavier; form of body somewhat ovate, deepest forward...............................Rosyface Shiner, *Notropis rubellus* (Agassiz)

29. Eye about four times in the head and located in the center of the head dorsoventrally ....*Notropis percobromus* (Cope)
Eye about three times in the head and located a little above the center of the head dorsoventrally ....Common Emerald Shiner, *Notropis atherinoides atherinoides* Rafinesque

30. Intestine greatly elongated, much coiled on right side...(Genus *Hybognathus*) 31
Intestine short, S-shaped 32

31. Dorsal fin rounded; color brassy; scales with focus less eccentric, and with about 20 radii in adult..Brassy Minnow, *Hybognathus hankinsoni* Hubbs
Dorsal fin somewhat falcate; color silvery; scales with focus very near basal edge, and with about 10 radii in adult....................................Western Silvery Minnow, *Hybognathus nuchalis nuchalis* Agassiz

32. Eye small, less than one-fourth length of head in adult; muzzle conical, the head subtriangular in outline; dorsal fin with a black blotch on membranes between the posterior rays, except in young; dorsal subquadrate in outline, the last rays in adults much more than half as long as the longest..................................Spotfin Shiner, *Notropis spilopterus* (Cope)
Eye large, more than one-fourth length of head in adult; muzzle bluntly rounded, the head not closely approaching a triangle in outline; dorsal fin without a black blotch on the membranes between the posterior rays; dorsal subtriangular in outline, the last rays less than half as long as the longest.33

33. A large, conspicuous, and well-defined black spot on the base of the caudal fin; size larger, commonly more than 3 inches in total length....................Northern Spottail Shiner, *Notropis hudsonius hudsonius* (Clinton)
No large, conspicuous, and well-defined black spot on the base of the caudal fin, spot when developed not sharply set off from lateral band; size small, maximum total length about 3 inches.............................34

34. Lateral band blackish, sometimes very indistinct in life, continued forward through eye and around muzzle; lateral line incomplete, except in *Notropis anogenus* 35
Lateral band dusky or obsolete, not definitely continued forward through eye and around muzzle; lateral line complete 38

35. Mouth extremely small, almost vertical; upper jaw extending only to below anterior nostril; teeth of inner row lacking; lateral line nearly or quite complete; peritoneum blackish.....Pugnose Shiner, *Notropis anogenus* Forbes
Mouth rather large, moderately oblique; upper jaw extending beyond anterior nostril almost to below eye; teeth of inner row frequently developed; lateral line incomplete; peritoneum silvery 36

36. Lateral band in surrounding muzzle confined to chin and premaxillaries; mouth more oblique, making an angle of less than 60 degrees with the vertical; teeth of outer row 1 or 2, usually developed; blackened borders to lateral-line pores not expanded into crescentic bars..................37
Lateral band in surrounding muzzle encroaching on snout above the premaxillaries but not on the chin; chin not black; mouth less oblique, making an angle of much more than 60 degrees with the vertical; teeth of outer row lacking; dark borders to lateral-line pores expanded to form prominent crescent-shaped black crossbars ....Northern Blacknose Shiner, *Notropis heterolepis heterolepis* Eigenmann and Eigenmann

37. Mouth more oblique, making an angle of decidedly less than 60 degrees with the vertical; jaws equal or nearly so; snout sharp; scales of next row above lateral line on trunk with dark bars alternating with the black marks on the lateral-line scales, producing a zigzag appearance; anal rays 8...........................Blackchin Shiner, *Notropis heterodon* (Cope)
Mouth less oblique, making an angle of little less than 60 degrees with the

vertical; lower jaw distinctly included; snout rather blunt; scales of next row above lateral line without definite dark bars; anal rays 7.......Northern Weed Shiner, *Notropis xaenocephalus richardsoni* Hubbs and Greene

38. Anal rays almost always 7.......................................39
Anal rays almost always 8.......................................41

39. Teeth usually 1 or 2, 4—4, 1 or 2; middorsal stripe not expanded at front of dorsal but surrounds base of that fin..................................
.............................River Shiner, *Notropis blennius* (Girard)
Teeth 4—4; middorsal stripe expanded in front of dorsal fin and interrupted at front of dorsal base...40

40. Length of depressed dorsal fin distinctly more than two-thirds distance from dorsal fin to occiput; scales usually 32–35; body more robust.............
............Southern Sand Shiner, *Notropis deliciosus deliciosus* (Girard)
Length of depressed dorsal fin about two-thirds distance from dorsal fin to occiput or less; scales usually 34–38; body less robust..................
........Northeastern Sand Shiner, *Notropis deliciosus stramineus* (Cope)

41. Mouth small; length of upper jaw about equal to diameter of eye; exposed surface of anterior lateral-line scales elevated more than twice as high as long; teeth 4—4.............................*(Notropis volucellus)* 42
Mouth large, upper jaw longer than eye; exposed surface of lateral-line scales not elevated, but of usual shape; teeth 1, 4—4, 1..................
...........Central Bigmouth Shiner, *Notropis dorsalis dorsalis* (Agassiz)

42. Color dark; exposed surface of anterior lateral-line scales about 2–3 times as high as long; scales in lateral line 35–38; fins rather small..............
...........Northern Mimic Shiner, *Notropis volucellus volucellus* (Cope)
Color pale; exposed surface of anterior lateral-line scales about 3–5 times as high as long; scales in lateral line 31–35; fins high, sharp, and fragile.......
...............Ghost Mimic Shiner, *Notropis volucellus buchanani* Meek

GENUS *Cyprinus* Linnaeus

This genus is represented by one introduced species, the carp, now widely spread in the United States.

CARP (German Carp, European Carp)
Cyprinus carpio Linnaeus

The carp (Figures 22 and 23) are large, fresh-water fishes of Asia, introduced first into Europe and then into America. The mouth of the carp has two pairs of barbels, one of which is very short and extends downward from the edge of the snout. The dorsal fin is long and has a stout spine, which is serrated posteriorly. The anal fin also has a spine. The carp has three rows of pharyngeal teeth arranged as follows: 1, 1, 3—3, 1, 1. As a result of long cultivation several varieties have become established. Those most commonly observed in waters of the Upper Mississippi drainage are designated, according to the prevalence or absence of scales, as scale carp, mirror carp, and leather carp. The scale carp are uniformly covered with heavy scales, the mirror carp have

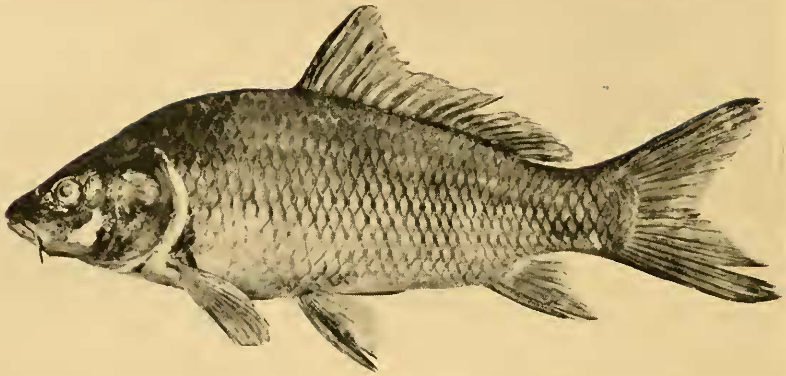


Figure 22. Carp, *Cyprinus carpio*, scale variety, 20 inches long.

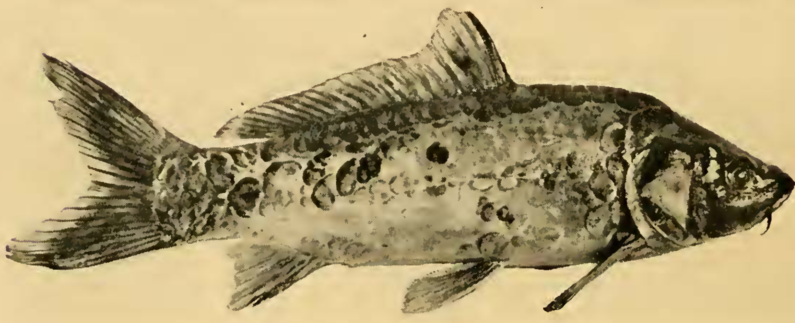


Figure 23. Carp, *Cyprinus carpio*, mirror variety, 18 inches long.

only a few very large scales, and the leather carp have none at all. The scale carp is the most common variety.

Carp, like the English sparrow among birds, have proved to be a nuisance in many waters and are universally condemned by sportsman anglers, but apparently they have come to stay and we must make the best of a bad situation. They have been a big item in the commercial fisheries of the midwestern states, particularly in Iowa, Illinois, and southern Wisconsin and Minnesota. Many millions of pounds are produced annually, 90 per cent or more finding a market in Chicago and New York. Most of them are shipped alive. The meat when properly prepared is excellent. Carp are prepared for cooking by skinning them and cutting out and discarding the dark streak running along each side. The meat should be soaked in salt water from two to six hours and may then be cooked by any of the usual methods. Carp are sometimes salted and smoked.

Although carp are not very popular as food fish in this country they have been highly esteemed for centuries in the Old World. In some parts of Europe they are reared and fattened in ponds in a state of semi-domestication. It is not certain when carp reached Europe, but they were introduced into England just before 1490. Carp were first introduced into the United States in 1872 by J. A. Poppe and planted in California. In 1877 the United States Commissioner of Fish and Fisheries introduced carp which were at first maintained in ponds at Washington, D.C. Soon after, they were planted in the Mississippi drainage. The date of the introduction of carp into Minnesota waters was about March 17, 1883, but they came also by way of the Mississippi River from the waters below. They have now become so widely distributed over the southern part of the state that there is hardly a lake connected in any manner with the Mississippi, Minnesota, or Des Moines rivers or their tributaries that is not stocked with myriads of them. So far they appear to have been unable to ascend beyond the dam at Little Falls on the Mississippi or Taylors Falls on the St. Croix, but it is feared they will eventually do so or that they will be accidentally introduced by some careless angler, dumping his minnow pail after a day's fishing. Carp are abundant in most shallow lakes and sluggish rivers in the central states.

The carp spawn in late April or in May, depending on the temperature of the water. They enter shallow bays or pass up tributary streams to shallow headwaters in vast numbers. The females attended by the males crowd into water so shallow that their backs are entirely exposed. There they spawn with a great deal of splashing and commotion. The act is sometimes called "rolling."

Carp are among our most prolific fishes, producing over 2,000,000 eggs each in females weighing 15 to 20 pounds. The eggs hatch in 10 to 20 days, depending on the temperature. If food is abundant the young may reach a length of 8 inches or even more in one year. They grow more rapidly than most native fishes.

Carp are omnivorous feeders, eating some animal matter, much plant material, and mud. They root up the bottoms, overturning and destroying the vegetation. If sufficiently abundant they may render the water turbid and the bottom unfit for the feeding and spawning of native game fishes, as they have done in many shallow lakes in Minnesota.

Carp will often leap and splash on the surface of the water, apparently playing. They are exceedingly wary and can be seined only with great care. They will bite on hooks baited with doughballs or with corn. Sometimes a weighted sack of green corn is used to lure them to the bait.

GENUS *Carassius* Nilsson

This genus is native to Europe and Asia, but one eastern Asiatic species has been widely introduced elsewhere.

GOLDFISH

Carassius auratus (Linnaeus)

The goldfish differs from the carp principally in dentition and in the absence of barbels. The teeth are 4—4 and are compressed. In its native state in China and Japan the fish is olivaceous in color and has habits similar to those of the carp. When goldfish are introduced into natural waters they usually revert to their original color. In very early times goldfish were domesticated in China, and some elaborate varieties have been developed. Just when they were introduced into Europe is not certain, but they were present in England as early as 1690.

Goldfish have been introduced into Silver Lake, North Saint Paul, Ramsey County, where they are apparently thriving, though large numbers died in 1939 in a heavy winter-kill. They have been caught occasionally from Lake Minnetonka and from sloughs along the Minnesota River south of Fort Snelling. Several other small lakes in central and southern Minnesota have been reported to contain goldfish. Greene (1935) reported them from several lakes in Waukesha County, Wisconsin.

Goldfish should never be placed in lakes or streams because they may thrive and become a nuisance, owing to their carplike habits. In Lake Erie and certain waters of New York State they have become fairly abundant and are used to some extent for food, since they reach a weight of several pounds.

GENUS *Couesius* Jordan

LAKE NORTHERN CHUB (Chub Minnow)

Couesius plumbeus plumbeus (Agassiz)

This minnow (Figure 24D) is characterized by protractile premaxillaries and an oblique terminal mouth rising anteriorly to the level of the eye. It is a rather elongated minnow with a small head and mouth. The body is dusky and has a lateral band. The scales are 11–68–7. The pharyngeal teeth are 2, 4—4, 2. It reaches a length of over 5 inches.

The lake chub, as a species, ranges from the Pacific Coast drainage in British Columbia and from the Rocky Mountains eastward through Wyoming and Nebraska to Maine and northward. It seems to be absent from the Mississippi drainage in the Central States. In Minnesota it is confined to the Lake Superior and Arctic drainages. Specimens in the University of Minnesota collections are from Lake Kabetogama, Brule River in Cook County, and Lake Superior, including Grand Portage Bay. Greene (1935) found it in Wisconsin only in tributaries of Lake Superior and Lake Michigan. Hubbs has found the western subspecies *C. plumbeus dissimilis* (Girard) in streams tributary to Lake Superior.

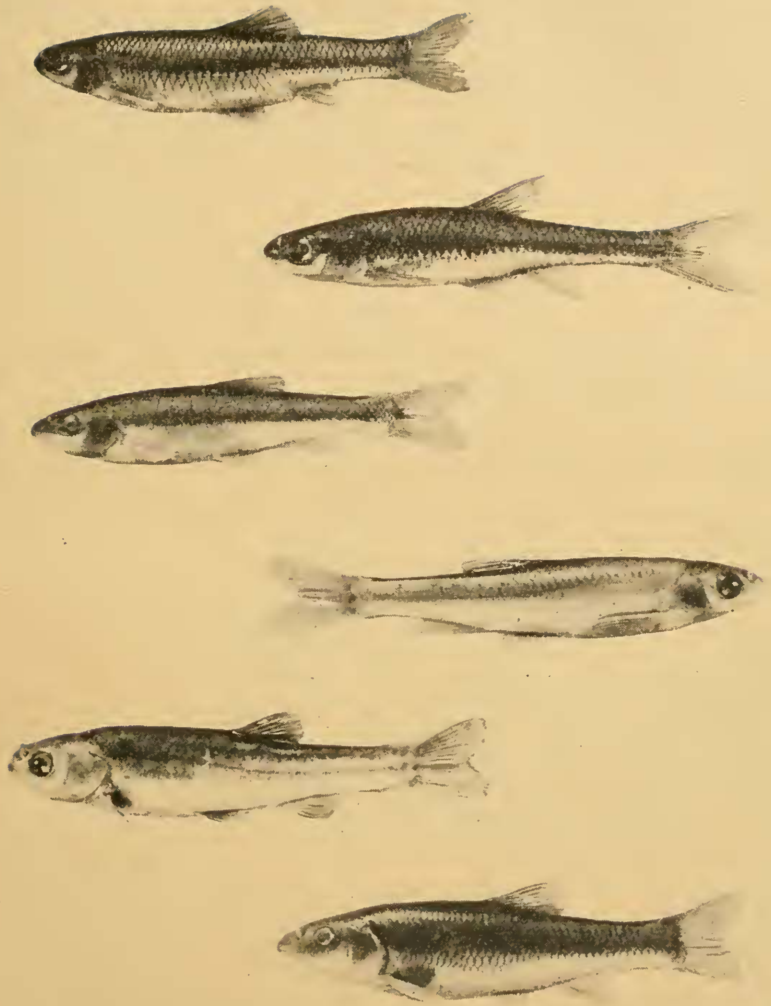


Figure 24. A. Bluntnose minnow, *Hyborhynchus notatus*. B. Northern blacknose shiner, *Notropis heterolepis heterolepis*. C. Central stoneroller, *Campostoma anomalum pullum*. D. Lake northern chub, *Couesius plumbeus plumbeus*. E. Finescale dace, *Pfrille neogaea*. F. Hornyhead chub, *Nocomis biguttatus*.

GENUS *Nocomis* Girard

HORNYHEAD CHUB (Jerker)
Nocomis biguttatus (Kirtland)

The hornyhead chub (Figure 24F) is a large species, sometimes reaching a length of 10 inches. It is one of the best live-bait minnows for bass, pickerel, and other game fishes. The head is large and broad. Barbels are present at the end of the maxillary. The scales are 6–41–4, with 18 rows before the dorsal fin. A black spot is at the base of the caudal fin. The pharyngeal teeth are 1, 4—4, 1, or 1, 4—4, 0, or rarely 4—4.

The hornyhead chub ranges from North Dakota and Colorado eastward to the Hudson River drainage and southward to Oklahoma and the Ohio Valley. It is widely distributed in Minnesota, and is common in the Mississippi and Minnesota rivers and their tributaries and also in Red Lake River and Pelican Lake, Crow Wing County (Cox, 1897). It is common in small tributaries of the St. Croix River in Pine County (Surber, 1920). It builds its nest in fine gravel (Hubbs and Cooper, 1936).

GENUS *Hybopsis* Agassiz

SILVER CHUB (Storer's Chub)
Hybopsis storerianus (Kirtland)

The silver chub is an elongated minnow with a short, broad back. The back is greenish and the sides silvery. There is sometimes a faint lateral band on the sides. The scales are 5–42–4 with 14 to 16 rows in front of the dorsal fin. The pharyngeal teeth are 1, 4—4, 0. Barbels are present. This fish reaches a length of over 8 inches.

The silver chub ranges from the Red River drainage in Canada to the southern shore of Lake Ontario and southward to northern Alabama, Oklahoma, and Wyoming. This species is very common in the Minnesota and Lower Mississippi drainages. It has been reported from the Ottertail River at Breckenridge and the Red Lake River at Crookston, Minnesota, both in the Red River drainage (Cox, 1897), and from the Mississippi at Lake Pepin (Wagner, 1908). Greene (1935) reported this species from Lake Pepin southward. It prefers large muddy rivers.

GENUS *Extrarius* Jordan

SPECKLED DACE (Long Minnow)
Extrarius aestivalis hyostomus (Gilbert)

The speckled dace is a very slender minnow with a long snout projecting halfway beyond the mouth. It has a barbel on each maxillary and about 37 scales in the lateral line. The pharyngeal teeth are 4—4. This minnow reaches a length of 2 1/2 inches.

The speckled dace ranges from southern Minnesota and Ohio to Alabama. Cox (1897) reported this species from Blue Earth River at Mankato. Several specimens in the University of Minnesota collections are from a slough near Winona (1900). Greene reports this species from the Mississippi below La Crosse.

GENUS *Erimystax* Jordan

SPOTTED CHUB
Erimystax dissimilis (Kirtland)

The spotted chub is a slender minnow, olivaceous in color with silvery sides marked with a bluish lateral band more or less broken into blotches. The back and sides are marked with x-shaped splotches. The head is blunt with the mouth slightly inferior. The teeth are 4—4. The scales are 5–6; 38–47; 4–5, with 14–17 rows behind the dorsal fin. A barbel, shorter than the diameter of the eye, is on the maxillary.

The spotted chub ranges from Lake Erie to the Ohio River drainage exclusive of the Tennessee and Cumberland portion, and west to Arkansas, northeastern Oklahoma, southeastern Kansas, central Iowa, and southern Minnesota. The only Minnesota record is from specimens collected in 1945 by the Minnesota Department of Conservation from the Root River in Fillmore County.

GENUS *Rhinichthys* Agassiz

WESTERN BLACKNOSE DACE (Striped Dace)
Rhinichthys atratulus meleagris Agassiz

This minnow (Figure 25D) is similar in form to the following species, *R. cataractae cataractae,* but the snout does not extend far beyond the mouth. The barbels are small or absent. The dorsal fin has 7 rays. The body is dusky, splotched with black; the belly is silvery. Breeding males have bright red sides.

The western blacknose dace ranges from Lake of the Woods to Ohio and southward to the Ohio Valley, Iowa, and Nebraska. It is confined mostly to the Great Lakes and the Upper Mississippi drainages. Collections at the University of Minnesota show this species to be rather common in clear brooks in northern and eastern Minnesota. It occurs occasionally in lakes and large rivers.

Evermann and Latimer (1910) reported it as more common than *Rhinichthys cataractae* in Rapid River and Falls River in the Lake of the Woods drainage. Cox (1897) found it common in lakes and streams

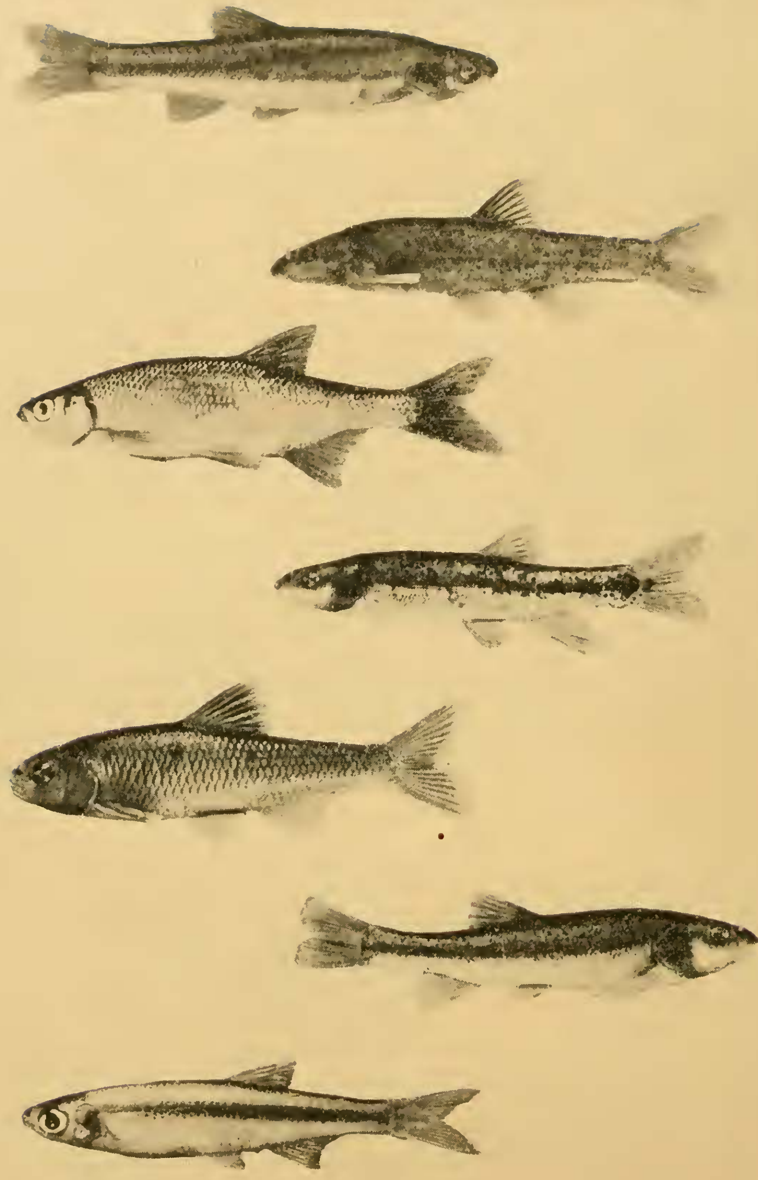


Figure 25. A. Northern redbelly dace, *Chrosomus eos.* B. Great Lakes longnose dace, *Rhinichthys cataractae cataractae.* C. Western golden shiner, *Notemigonus crysoleucas auratus.* D. Western blacknose dace, *Rhinichthys atratulus meleagris.* E. Northern common shiner, *Notropis cornutus frontalis.* F. Northern creek chub, *Semotilus atromaculatus atromaculatus,* immature. G. Common emerald shiner, *Notropis atherinoides atherinoides.*

of the Upper Mississippi but uncommon in the Des Moines River. Jordan, Evermann, and Clark (1930) mentioned it from Rainy River as *Rhinichthys lunatus* (Cope). Greene (1935) reported it as common throughout Wisconsin. According to Hubbs and Cooper (1936) this minnow scatters its eggs on gravel and sand bottoms in creeks.

GREAT LAKES LONGNOSE DACE (Black Minnow)
Rhinichthys cataractae cataractae (Valenciennes)

The body of the Great Lakes longnose dace (Figure 25B) is elongate and cylindrical. The snout projects considerably beyond the mouth. Barbels are present on the maxillaries. This dace is rather olivaceous in color, with dark splotches. During the spring the males have considerable red on head, sides, and fins. The dorsal fin has 8 rays. The scales are 14–65–8. The teeth are 2, 4—4, 2. This species reaches a length of 5 inches.

This species ranges from coast to coast in southern Canada and southward to North Carolina, Iowa, Mexico, and Oregon. It is rather common in small streams and lakes in northern and eastern Minnesota. Greene (1935) reported it from the St. Croix River, the St. Louis River, and numerous areas in northern Wisconsin. Not much is known about the spawning habits.

GENUS *Semotilus* Rafinesque

NORTHERN CREEK CHUB (Northern Horned Dace)
Semotilus atromaculatus atromaculatus (Mitchill)

The northern creek chub (Figure 25F) is one of the larger minnows; it reaches a length of 12 inches. It is characterized by a small barbel a little above the end of each maxillary and a black spot at the anterior base of the dorsal fin. It is dusky silver in color. The teeth are 2, 5—4, 2. The scales in the lateral line vary from 50 to 60.

The creek chub ranges from Montana to the Gaspé Peninsula and southward to the Gulf States. Greene (1935) reported it as common in all parts of Wisconsin. It has a wide distribution over Minnesota, principally in the smaller streams of central and southern Minnesota. In many localities the drain upon it as a bait minnow has nearly ended in extirpation. The young closely resemble several other black-sided minnows, but the adult is easily distinguished from others by its size and, during the spring at least, by the coarse tubercles present on the head.

This species prefers small rivers and large creeks but is occasionally found in lakes. It is a nesting fish. On clean gravel the male makes a nest in which more than one female deposits eggs, and the male then covers the eggs with small stones.

GENUS *Margariscus* Cockerell

NORTHERN PEARL DACE (Leather Back, Nachtrieb's Dace)
Margariscus margarita nachtriebi (Cox)

This minnow has a rather heavy body, a short head, and a blunt snout. It is dusky in color and has faint black lateral stripes. The lateral line contains about 72 scales. The teeth are 2, 4—5, 2.

The northern pearl dace ranges from the Rocky Mountains through the Dakotas, Minnesota, and Wisconsin, to Maine, and northward to the tundra. Originally described from specimens obtained in Mille Lacs, it is found to be common in lakes over most of central and north central Minnesota. It is scarce in or absent from the northeastern and extreme southern parts of Minnesota. It occurs also in bog streams and rarely in small, clear, cool, rocky streams. Greene (1935) found it common in northern and central Wisconsin. It has not been reported from the tributaries of Lake Superior.

GENUS *Pfrille* Jordan

FINESCALE DACE (Bronze Minnow)
Pfrille neogaea (Cope)

This species (Figure 24E) is a medium-sized, robust minnow with a large, broad, blunt head. It is blackish bronze in color, with dark lateral bands. The lower parts are crimson in spring males. There are more than 80 scales in the lateral line. The teeth in the main row are typically 5—4, but sometimes 4—4 or 4—5 or 5—5.

The finescale dace ranges westward through southern Canada to Minnesota and southward through parts of the Great Lakes basin. Relict populations occur in the Black Hills and western Nebraska (Hubbs and Lagler, 1941). In Minnesota it has been found in Brule Lake and several other waters in the Lake Superior drainage in Cook and St. Louis counties. Greene (1935) reported this species from Wisconsin in streams in the Great Lakes drainage and gives one record of occurrence in the Mississippi drainage.

GENUS *Chrosomus* Rafinesque

SOUTHERN REDBELLY DACE
Chrosomus erythrogaster Rafinesque

The southern redbelly dace is a small, brownish-olive minnow with black spots on the back, a blackish stripe along the sides from above the eye to the tail, and another band below running through the eye and ending in a black spot at the base of the caudal fin. The belly and the space between the bands are usually silvery, but in spring males they are a bright scarlet. The dorsal fin has 8 rays. The scales are 16–85–10. The teeth are 5—5 or 5—4. The mouth is slightly oblique and curved and is more than one-fourth the length of the head.

The southern redbelly dace ranges from Iowa through southern Wisconsin to Pennsylvania and southward to Alabama and Oklahoma. It is a southern species. Its distribution in Minnesota is not well known. The Minnesota Department of Conservation collected it from the Root River in 1945. Cox (1897) reported it as having been taken at Austin by Dr. Meek. Several specimens have been found in a minnow dealer's stock, but their origin was unknown. Greene (1935) reported it from many streams in southern Wisconsin and from several streams not far from Lake Pepin.

NORTHERN REDBELLY DACE

Chrosomus eos Cope

This minnow (Figure 25A) is similar to the southern redbelly dace except that the jaws and snout are shorter. The mouth is strongly oblique and curved, reaching less than one-fourth the length of the head. The teeth are 5—5 or 5—4. In Michigan it was reported by Hubbs and Cooper (1936) as favoring acid waters, such as bog pools and streams. They report that this minnow spawns in filamentous algae. During spawning the female is attended by several males.

The northern redbelly dace ranges across southern Canada from Winnipeg eastward and southward to Colorado, Nebraska, and Minnesota, and into New Jersey. In Minnesota this species occurs occasionally in many of the smaller nonacid tributaries of the Mississippi, especially above Minneapolis. It is found in many of the smaller tributaries of the Minnesota, St. Croix, and Rum rivers. Greene (1935) found it well distributed over Wisconsin and along the Mississippi below Lake Pepin.

GENUS *Clinostomus* (Girard)

REDSIDE DACE

Clinostomus elongatus (Kirtland)

The redside dace is a medium-sized minnow with a broad, black lateral band, the front half of which is bright crimson in spring males. The head is long and pointed and the mouth proportionately larger than that of any other minnow. There are less than 80 scales in the lateral line. The teeth are typically 5—4 but may be 5—5 or 4—5 or 4—4.

Hubbs and Lagler (1941) reported the redside dace to be rather discontinuous in range. In general it ranges from Minnesota and Iowa eastward through southern Ontario and into New York, and does not range far southward. It is found in some of the small streams in the

Mississippi drainage in Minnesota and Wisconsin. Greene (1935) reported it in central and southern Wisconsin. He believes this species to be in process of extirpation in Wisconsin because of its widely scattered distribution, and also reports numerous cases of hybridization with other minnows.

GENUS *Opsopoeodus* Hay

PUGNOSE MINNOW
Opsopoeodus emiliae Hay

The pugnose minnow has a slender body and a short head with a small, upturned mouth. The back is yellowish; the sides are silvery, with dark lateral stripes. There is a black spot on the back of the dorsal fin. The dorsal fin has 7 to 10 rays, the anal fin 8. The scales are 5–40–3. The pharyngeal teeth are 5—5 or 4—5, with serrated edges. This species reaches a length of over 4 inches.

The pugnose minnow ranges from southern Minnesota to the western end of Lake Erie and southward to Florida and Texas. Greene (1935) reported it from the Lower Mississippi River and from elsewhere in southern Wisconsin. There are no specimens from Minnesota in the University of Minnesota collections.

GENUS *Notemigonus* Rafinesque

WESTERN GOLDEN SHINER (Bream, Roach)
Notemigonus crysoleucas auratus (Rafinesque)

The western golden shiner (Figure 25C) is a deep-bodied minnow with a large eye. The back is greenish, and the sides are pale with a golden tinge. The lateral line is curved downward. There are about 51 scales in the lateral line. The teeth are 5—5. This species commonly ranges up to 5 inches in length, but occasionally up to 12 inches.

The western golden shiner is distributed from North Dakota to southern Ontario and southward to Oklahoma and the Ohio Valley. Greene (1935) reported it from all parts of Wisconsin. In Minnesota golden shiners are more common in lakes than in streams. They prefer shallow lakes and ponds. Golden shiners are the only fish that survive in some ponds and sloughs where the oxygen is completely exhausted in winter. Laboratory experiments at the University of Minnesota indicate that at freezing temperatures this fish can live with very little oxygen but at higher temperatures requires as much oxygen as any other fish.

GENUS *Notropis* Rafinesque

This genus contains a large number of species, which are widely spread. At least seventeen species are reported from Minnesota.

NORTHERN COMMON SHINER

Notropis cornutus frontalis (Agassiz)

The northern common shiner (Figure 25E) is a large, slender, steel-blue minnow with gilt lines. The spring males are tuberculate and have bright rosy bellies and lower fins. This minnow reaches about 8 inches in length. The scales are 6–41–3. The teeth are 2, 4—4, 2. The scales of adults often assume a roughened appearance.

This subspecies ranges from Saskatchewan to Quebec and southward to Colorado, Nebraska, and Iowa, and through the northern part of the Ohio basin. It is very common in the collections from lakes and streams over Minnesota and Wisconsin (Greene, 1935). It is one of the most important bait minnows in Minnesota.

Notropis percobromus (Cope)

This minnow is pale without any red color. It closely resembles *N. atherinoides* but differs in many details. The body is elliptical rather than oval in shape. The eye is smaller (about four times in the depth of the head instead of three times), and is located in the center of the head dorsoventrally rather than a little above the center dorsoventrally. The length of the head is usually greater than one-fourth the standard length. The lips are not pigmented as much as in *N. atherinoides*.

This minnow was identified by Hubbs (1945) from material collected by the University of Minnesota from a small stream at Lake City, Minnesota and from the Mississippi River at Whitman, Minnesota. Hubbs gives its range as extending from the Red and Arkansas river systems on the Great Plains of Oklahoma and Kansas to the Mississippi River in Tennessee, northward to the Missouri River system in the Dakotas and up the Mississippi River to Lake Pepin.

COMMON EMERALD SHINER

Notropis atherinoides atherinoides Rafinesque

This species (Figure 25G) has a compressed, elliptical body and a short, blunt snout. It has a greenish back and silvery sides. There are about 38 scales in the lateral line. The teeth are 2, 4—4, 2.

The common emerald shiner is distributed throughout most of the Mississippi drainage, Lake Erie, and parts of southern Canada. Greene (1935) reported it from the larger streams and lakes of Wisconsin. In Minnesota it is commonly found in the Mississippi, Lake of the Woods, and Lake Superior drainages. This species is very common in Lake of the Woods and was reported as very common in Red Lake River by Woolman (1895).

This minnow shows a preference for lakes and is not uncommon in many of the central and northern lakes of Minnesota, where it moves and feeds in large schools at the surface of open water. Enormous schools of the tiny fry may often be seen on the surface in the center of a lake and are often mistaken for fry of game fishes or tullibee.

ROSYFACE SHINER

Notropis rubellus (Agassiz)

This minnow is characterized by a rosy tinge on the top and sides of the head and at the base of the dorsal fin. It has a dusky stripe on the back and a dark dotted line at the base of the anal fin. There are about 33 to 39 scales in the lateral line. The teeth are 2, 4—4, 2.

The rosyface shiner ranges from North Dakota to southern Ontario and southward to Virginia, the Ohio Valley, and Missouri. It is common over most of Minnesota. Cox (1897) reported it as rather common in various streams and lakes in the Upper Mississippi and as present in the Des Moines River at Windom. Evermann and Latimer (1910) erroneously reported this species from Lake of the Woods. Their specimens on re-examination by Hubbs (1945) proved to be *Notropis atherinoides atherinoides*. Greene (1935) reported it as well distributed over most of Wisconsin but absent from the Lake Superior drainage.

According to Hubbs and Cooper (1936) this species spawns in midstream and not on the bottom.

NORTHERN REDFIN SHINER (Blueheaded Minnow)

Notropis umbratilis cyanocephalus (Copeland)

During the spawning season the northern redfin shiner (Figure 26B) is very striking, with its steel-blue back and bright red fins and belly. It is deep-bodied, with a dark spot near the front of the dorsal fin. There are about 50 scales in the lateral line. The teeth are 2, 4—4, 2. This species reaches a length of 3 1/2 inches.

In life the northern redfin shiner is a perfect gem of a minnow, for both its coloration and its perfect form. The breeding males are highly, but delicately, colored. All their fins, including the caudal, are red at the base, shading to rose pink toward the distal two-thirds; the top of the head, back to the dorsal fin, is a deep, cerulean blue. The narrow, black vertebral line is very prominent, but the broader lateral stripe is much paler. These colors, except in the vertebral line, quickly fade out in formalin.

The northern redfin shiner ranges from Minnesota through southern Ontario to New York and southward to Kentucky and Iowa. It probably is one of the most common minnows in Minnesota. It is common in the Cannon River and other clear streams in the southern half of Minnesota. It was reported as common in the Rapid River of the Red Minnesota. Evermann and Latimer (1910) erroneously reported this species from Lake of the Woods and the Rapid River. Hubbs (1945) re-examined their material and found their single specimen from Lake of the Woods to be *Hyborhynchus notatus* and the specimens from Rapid River to be *Notropis cornutus frontalis*. This species was secured by Dr. Meek (1890) from the Cedar River at Austin. It is not uncommon in streams of the Mississippi drainage and occurs occasionally in lakes. It is absent from the Lake Superior drainage.

This species was very common in Dobbins Creek a few miles east of Austin on July 23, 1940. Dobbins Creek, a tributary of the Cedar River, is a spring-fed stream with numerous deep pools and clear water. The bottom is of sand and gravel. It flows rather swiftly in places. The shiners were most numerous in the heads of the deeper pools, where, in the swift current, they imparted a bluish shimmer before the outline of the fishes themselves was visible. This coloration was due to the reflection of the blue from the heads and dorsal halves of the minnows' backs.

SPOTFIN SHINER

Notropis spilopterus (Cope)

The spotfin shiner (Figure 26A) is dark silver in color and has a black spot at the posterior end of the dorsal fin. The scales are 5, 38–40, 3. The pharyngeal teeth are 1, 4—4, 1, with serrated edges. This minnow reaches a length of about 4 inches.

The spotfin shiner ranges from North Dakota and Iowa to Lake Champlain and southward to Maryland and Alabama. This minnow is rather common in Minnesota but seems to be most abundant in the Upper Mississippi and Minnesota rivers and their tributaries. It is found occasionally in lakes. It is widely distributed over Wisconsin (Greene, 1935) but absent from the Lake Superior drainage.

According to Hubbs and Cooper (1936) the eggs are laid in the crevices of boards and logs.

REDFIN

Notropis lutrensis lutrensis (Baird and Girard)

This minnow is deep-bodied and has a small eye. The fins are distinctly reddish. The body is olivaceous above with greenish-gray and silver sides. Spring males are brightly colored with orange and red on the body and head. The teeth usually number 4—4, though 0, 4—4, 1 and 1, 4—4, 1 have also been reported. The scales are 6, 34–37, 3–4. The dorsal fin has 8 rays, the anal fin usually 9. The redfin is similar to *Notropis spilopterus* but does not have the black spot on the dorsal fin.

The redfin minnow ranges from South Dakota to Illinois and southward to Texas (Jordan, Evermann, and Clark, 1930). Specimens in the

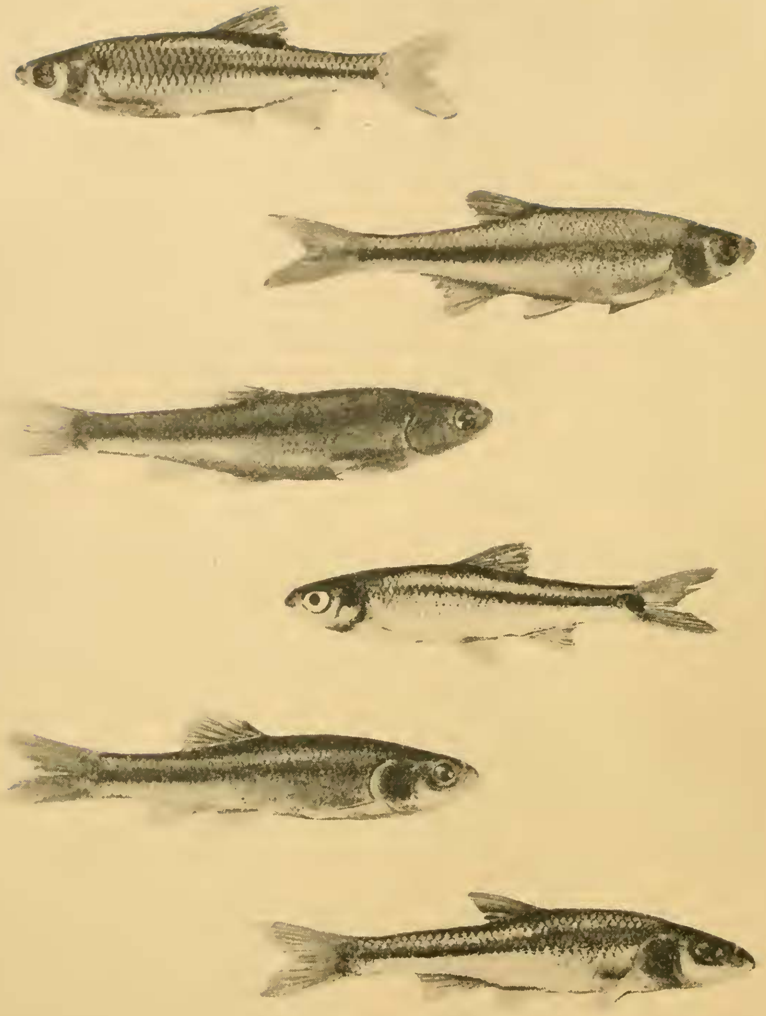


Figure 26. A. Spotfin shiner, *Notropis spilopterus.* B. Northern redfin shiner, *Notropis umbratilis cyanocephalus.* C. Brassy minnow, *Hybognathus hankinsoni.* D. Spottail shiner, *Notropis hudsonius.* E. Fathead minnow, *Pimephales promelas promelas.* F. Central bigmouth shiner, *Notropis dorsalis dorsalis.*

University of Minnesota collections were collected from the Rock River near Luverne in 1939. It apparently is absent from Wisconsin, for Greene (1935) did not report it.

RIVER SHINER
Notropis blennius (Girard)

This slender minnow is rather pale and has a silvery lateral band. There are about 37 scales in the lateral line. The teeth are 2, 4—4, 1.

The river shiner ranges from Manitoba through Wisconsin and Ohio to Pennsylvania and southward to Oklahoma. In Minnesota Evermann and Latimer (1910) reported this species as common in Lake of the Woods and the Rainy River. Woolman (1895) secured it in the Red Lake River and Red River of the North. Cox (1897) reported it as common in all the streams and lakes and stated further that if it was more abundant in one place than another that place was the northern part of Minnesota. Greene reported this species from the St. Croix and Mississippi rivers. There are specimens in the University of Minnesota collections from Lake of the Woods and from the Mississippi River at Winona. This species prefers large streams.

SPOTTAIL SHINER (Spawneater)
Notropis hudsonius hudsonius (Clinton)

This species (Figure 26D) has a well-defined spot at the base of the caudal fin. The color varies from yellow to dusky, with a silvery lateral band. The scales are 5–39–4. The pharyngeal teeth are 1, 4—4, 0–2. This species reaches a length of slightly over 4 inches.

The spottail shiner is apparently distributed through the Great Lakes basin except for Lake Superior, the Upper Mississippi Valley, and the Hudson River. It is fairly common in lakes and large streams in the eastern and northern parts of Minnesota. It was reported by Cox as being fairly common in Minnesota. Evermann and Latimer (1910), in speaking of it in their report on Lake of the Woods fishes, stated that perhaps it is the most abundant minnow in these waters and doubtless forms a large part of the food of the carnivorous species.

Cox (1897) included the subspecies *N. hudsonius selene* (Jordan) from specimens obtained in Lake Superior at Bayfield, Wisconsin. This subspecies name was not recognized by Jordan, Evermann, and Clark except as a synonym of *N. hudsonius*. Greene (1935) attempted to restore the name and reported the subspecies to be common in Wisconsin along the Mississippi River, St. Croix River, and Lake Superior. Hubbs and Lagler (1941) reported the northern spottail shiner, *N. hudsonius selene,* to be distributed northward through the Red River Valley into Canada. Specimens of this species from various parts of Minnesota have been submitted to Hubbs, who states that they are similar to *N. hud-*

sonius hudsonius (Clinton) of the Hudson River. Apparently there is still some confusion to be cleared up in the taxonomy of this species.

According to Hubbs and Cooper (1936) this species scatters its eggs over sandy shoals in lakes.

PALLID SHINER

Notropis amnis Hubbs and Greene

The northern pallid shiner ranges from southern Minnesota and Wisconsin southward to Texas. Greene (1935) reported this species from the Mississippi River and its larger tributaries at Hastings and southward. There are no specimens of this species in the University of Minnesota collections.

CENTRAL BIGMOUTH SHINER

Notropis dorsalis dorsalis (Agassiz)

This minnow (Figure 26F) is greenish in color, with a dark lateral band on the side. The head is long and flat, the tail long and slender. There are about 35 scales in the lateral line. The teeth are 1, 4—4, 1.

The bigmouth shiner ranges from Wyoming and North Dakota eastward to New York and Pennsylvania. Friedrich (1933) reported this species from the Mississippi River at St. Cloud. It was reported by Greene (1935) from the St. Croix and Mississippi rivers and their tributaries. It is widely distributed in small rivers in central and southern Minnesota and has also been collected from Leech and Cass lakes. It prefers sandy streams.

NORTHERN WEED SHINER

Notropis xaenocephalus richardsoni Hubbs and Greene

This minnow has a slender, dark-olive body, a dark lateral band, and a spot on the tail. The anal rays number 7. There are about 37 scales in the lateral line. The pharyngeal teeth are 2, 4—4, 2; some are denticulate. The mouth is not as oblique as in *N. heterodon* and the snout is more blunt. This species reaches a length of 2 inches.

The northern weed shiner ranges through southern Minnesota, Wisconsin, northern Iowa and Illinois, and western Michigan. It was reported by Greene (1935) from the St. Croix and Mississippi rivers as Richardson's shiner, *Notropis nux richardsoni.* It prefers sluggish waters. There are specimens in the University of Minnesota collections from sloughs near Winona and Fountain City.

BLACKCHIN SHINER

Notropis heterodon (Cope)

The blackchin shiner is moderately stout and has a lateral band which in surrounding the muzzle is confined to the chin and the premaxillaries. The scales of the first row above the lateral line have dark bars which alternate with the black marks on the lateral-line scales, producing a zigzag appearance. The scales are 5–36–3; 12 to 14 scales are in front of the dorsal fin. The jaws are equal or nearly so, the maxillary reaching the posterior nostril. The mouth is oblique, making an angle of decidedly less than 60 degrees with the vertical. The pharyngeal teeth vary from 4—4 to 1, 4—4, 1. This species reaches a length of 2 1/2 inches.

The blackchin shiner ranges through the glacial lake districts of Ontario, Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, Ohio, and New York. In Minnesota Woolman (1895) reported it from the Pomme de Terre River at Appleton. It has been collected from many places in the Mississippi drainage and from some of the small streams of the Superior drainage. Greene (1935) reported this species to be especially characteristic of lakes in Wisconsin. Collections at the University of Minnesota indicate that it is rare in streams but occurs occasionally in lakes throughout the state.

SOUTHWESTERN SAND SHINER

Notropis deliciosus deliciosus (Girard)

This fish has a stout body with a dusky lateral band and 7 anal rays. There are 35 to 38 scales in the lateral line. The pharyngeal teeth are 4—4. This species reaches a length of 2 1/2 inches.

The southwestern sand shiner ranges from the Dakotas through Illinois and part of Indiana and southwest into Mexico and Texas. This minnow was identified by Hubbs from a creek 16 miles east of Austin, Minnesota. There are no specimens of this subspecies in the University of Minnesota collections.

NORTHERN SAND SHINER

Notropis deliciosus stramineus (Cope)

This subspecies of *Notropis deliciosus* is the most common form found in the Great Lakes area. It is found in streams throughout Minnesota but is most common in the northern part.

The northern sand shiner ranges from southern Ontario and Minnesota southward to Iowa and the Ohio Valley. Greene (1935) reported it from the Mississippi and St. Croix rivers and from numerous streams throughout Wisconsin, including the Lake Superior and Lake Michigan drainages.

TOPEKA SHINER

Notropis topeka (Gilbert)

This shiner has a stout body with a lateral band ending in a black caudal spot. The scales are 5–35–6. It reaches a length of 3 3/5 inches.

The Topeka shiner ranges from southern Minnesota through Iowa into Kansas. Hubbs reports that he has identified specimens of the Topeka shiner from a creek 16 miles east of Austin. There are no specimens in the University of Minnesota collections. This fish is rather southern in distribution and in Minnesota is probably restricted to the extreme southern part.

NORTHERN MIMIC SHINER

Notropis volucellus volucellus (Cope)

This is a rather slender minnow with a lateral band which is somewhat broken anteriorly. The lateral-line scales number 35–38. The exposed surface of the lateral-line scales is about two to three times as high as long. The mouth is small, the length of the upper jaw being about equal to the diameter of the eye. The pharyngeal teeth are 4—4. This minnow reaches a length of over two inches.

The northern mimic shiner ranges through southern Canada southward into Minnesota, Kentucky, and both drainages of North Carolina. This species is common in lakes of north central Minnesota, such as Leech Lake, Cass Lake, Cut Foot Sioux Lake, and Lake of the Woods. It has been found also in Cottonwood County in southern Minnesota. Greene (1935) reported it from the St. Croix and St. Louis rivers and as widespread in Wisconsin.

CHANNEL MIMIC SHINER

Notropis volucellus wickliffi (Trautman)

This subspecies ranges in the Mississippi drainage from Minnesota and Iowa eastward to Ohio and Kentucky. Greene (1935) reported the channel mimic shiner as confined to the Mississippi River, but it has been collected also in other major rivers of Minnesota.

GHOST MIMIC SHINER

Notropis volucellus buchanani Meek

The ghost mimic shiner is another subspecies reported by Greene (1935) from the Mississippi River in Iowa just below Minnesota. Greene reported this shiner as ranging in the Mississippi River below Iowa and Wisconsin and from southern Ohio to the Rio Grande. It has been collected from the Mississippi River just above the Iowa line.

NORTHERN BLACKNOSE SHINER

Notropis heterolepis heterolepis Eigenmann and Eigenmann

The northern blacknose shiner is a rather slender minnow with a lateral band running over the snout. The dark borders of the lateral-line pores are expanded to form prominent crescent-shaped black crossbars. The mouth is somewhat oblique but not as much so as in

N. heterodon. The pharyngeal teeth are 4—4, those of the outer row being absent. This minnow reaches a length of over two inches.

This species ranges from Saskatchewan eastward through the Great Lakes region to Maine and southward to Iowa. It is found in small streams and lakes of northern Minnesota, including North Shore streams of the Lake Superior drainage. Greene (1935) reported it from the St. Croix River and from some of the Wisconsin tributaries of the Mississippi River farther south.

PUGNOSE SHINER
Notropis anogenus Forbes

This minnow has a rather stout body with a distinct lateral band and a spot on the tail. There are 34 to 37 scales in the lateral line. The pharyngeal teeth are 4—4. It reaches a length of 1 1/2 inches. The mouth is very small and oblique.

This species occurs in the glacial lake regions from eastern North Dakota through Minnesota, Wisconsin, Michigan, northern Illinois, Indiana, and Ohio, and into the St. Lawrence drainage of New York. Cox (1897) reported it as probably rare in Minnesota and stated that it had been taken in the Cedar River at Austin by Dr. Meek. Greene (1935) reported it from the upper St. Croix River in Wisconsin. Hankinson (1929) reported it from the Red River drainage. It prefers and is found in the small streams of the Mississippi River and Lake Superior drainages. There are no specimens in the University of Minnesota collections.

GENUS *Phenacobius* Cope

SUCKERMOUTH MINNOW
Phenacobius mirabilis (Girard)

This minnow has a distinctly suckerlike mouth with thick lips. The cylindrical body is colored an olivaceous silver and has a black spot at the base of the caudal fin. The scales are 6, 43–51, 5. The teeth are 4—4 and are generally hooked.

This species ranges from South Dakota to western Ohio and southward to Texas and Tennessee. It is apparently rare in Minnesota, for it has been collected only from southeastern counties. Greene (1935) reported it from the Mississippi River below La Crosse.

GENUS *Dionda* Girard

OZARK MINNOW (Forbes's Minnow)
Dionda nubila (Forbes)

The Ozark minnow is a dusky, silvery minnow with a yellow belly. It is marked with a dark lateral band, which extends from a slight spot at the base of the tail through the eye and around the snout. The intestine is much coiled. The teeth are 4—4 and are slightly hooked. The scales are 36–38.

Greene (1935) reported the range of this minnow as from southern Wisconsin to Oklahoma and Arkansas. This species was reported by Greene from the driftless area of southwestern Wisconsin. It is a southern species. Hubbs has identified specimens from the Cedar River in Minnesota, but none have been collected by the University of Minnesota. It probably occurs in the small streams of the southeastern part of the state.

GENUS *Hybognathus* Agassiz

BRASSY MINNOW

Hybognathus hankinsoni Hubbs

The brassy minnow (Figure 26C) is difficult to distinguish from *Hybognathus nuchalis*, which it closely resembles. The scales have many weak radii instead of a few strong ones and the head is more blunt and the fins more rounded than in *nuchalis*. The dorsal fin is rounded instead of pointed. The intestine is more than twice the length of the body.

The brassy minnow ranges from North Dakota through southern Ontario to the Lake Champlain region and southward to Colorado, Nebraska, Iowa, and southern Michigan. This species was reported by Greene (1935) from many streams in the Mississippi, Lake Michigan, and Lake Superior drainages in Wisconsin. It seems to be common in many small streams throughout Minnesota, including the Lake Superior drainage.

WESTERN SILVERY MINNOW

Hybognathus nuchalis nuchalis Agassiz

The western silvery minnow has a very slender, silvery body. The dorsal and anal fins each have 8 rays. The scales are 5–38–4. This minnow, which reaches a length of 6 inches, is distinguished by an extremely long intestine, 7 to 10 times the length of the body.

This species ranges from Montana to Ohio and southward to the Gulf States. It is common in small streams throughout Minnesota, especially those with muddy bottoms. It occurs occasionally in lakes, particularly those in the southern part of Minnesota. Greene (1935) reported this species from the Mississippi River and numerous tributaries of the Mississippi in Wisconsin. It was reported by Jordan, Evermann, and Clark (1930) for the Red River of the North as *Hybognathus argyritis* (Girard).

GENUS *Pimephales* (Rafinesque)

FATHEAD MINNOW (Blackhead Minnow)
Pimephales promelas promelas (Rafinesque)

The fathead minnow (Figure 26E) is heavy-bodied and varies in color from olivaceous to black. The dorsal fin has a horizontal black bar in adults. There are 9 dorsal rays; the anterior one is thickened. The anal fin has 7 rays. The scales are 7, 43–47, 6. The pharyngeal teeth are 4—4. This species reaches a length of 2 1/2 inches.

The northern fathead minnow ranges from southern Canada southward to Colorado, Tennessee, and Maine. This species is common everywhere in Minnesota in both lakes and streams. It is abundant in the northern part of the state, especially in mud-bottom streams and lakes. Greene (1935) reported it from all drainage systems in Wisconsin and as most abundant in the southwestern portion of the state.

The eggs are laid under stones or boards and are guarded by the male, which strokes them with a pad developed on its back.

GENUS *Ceratichthys* Forbes

BULLHEAD MINNOW
Ceratichthys perspicuus (Girard)

This minnow has a rather stout body with a heavy, blunt head. It is a light olive in color and has a lateral stripe ending in a spot at the base of the caudal fin. There is a black spot on the front of the dorsal fin. The teeth are 4—4. They have grinding surfaces and are slightly hooked. There are 39 to 44 scales in the lateral line and usually 7 above and 4 below. The dorsal fin has 9 rays; the anterior ray is thickened. The anal fin has 7 rays. The intestine is shorter than that of *Hyborhynchus notatus*, which this minnow closely resembles. This species reaches a length of 3 inches.

The bullhead minnow ranges from eastern Nebraska and South Dakota through the Ohio drainage of Indiana and Ohio into Pennsylvania and south into Alabama, Oklahoma, and Texas. This species is common in the larger streams of southern Minnesota. It was reported by Greene (1935) from the Mississippi River and its tributaries from Lake Pepin southward.

GENUS *Hyborhynchus* Agassiz

BLUNTNOSE MINNOW
Hyborhynchus notatus (Rafinesque)

The body of the bluntnose minnow (Figure 24A) is elongate. It is olivaceous silver in color. There is a prominent spot on the tail fin and also on the front of the base of the dorsal fin. In breeding males the head is black and there are three rows of large tubercles across the snout. The dorsal fin has 9 rays; the anterior ray is thickened. The anal fin has 7 rays. The scales are 6–45–5. The predorsal scales (about 23) are small and crowded. The pharyngeal teeth are 4—4. This minnow reaches a length of 4 inches.

This species, which is an important forage minnow, ranges from Winnipeg through the Great Lakes region to Quebec and southward to Virginia and the Gulf States. It is more common than the preceding species in small brooks and pools. It is widely distributed over Minnesota in lakes and streams, especially in the central and southern part. It occurs in the Lake of the Woods drainage (Evermann and Latimer. 1910). Greene (1935) found it widespread in Wisconsin and reported it from the Lake Superior, Lake Michigan, and Mississippi River drainages.

Spawning occurs from early May until late June. With its tail the male fans out a cavity under a stone or board. The female deposits the eggs in the cavity, and the male guards them.

GENUS *Campostoma* Agassiz

CENTRAL STONEROLLER (Doughbelly, Rotgut Minnow, Stonelugger)

Campostoma anomalum pullum (Agassiz)

The central stoneroller (Figure 24C) is a pale-brown minnow with a dark bar behind the opercles and across the dorsal and anal fins, which are bright orange in spring males. The lips are thick and fleshy. The intestine is very peculiar; it is wrapped many times around the swim bladder. The scales are 7, 49–55, 8. The dorsal fin has 8 rays, the anal fin 7. The teeth are 4—4. This species reaches a length of 8 inches. It is a bottom feeder living largely on vegetable matter. Forbes and Richardson (1908) reported finding large quantities of mud in the intestine.

The central stoneroller occurs from Minnesota eastward through the Great Lakes region and southward in the Mississippi Valley to Mexico. In Minnesota it is more common in the central and southern parts. It has been reported from the Minnesota, Blue Earth, and Pomme de Terre rivers (Cox, 1897) and from the Root and White Water rivers (Surber, 1920). It is common in southern Wisconsin (Greene, 1935).

The largescale stoneroller, *Campostoma anomalum oligolepis* Hubbs and Greene, may occur in Minnesota, though no Minnesota material has been identified as this subspecies. It differs from the central stoneroller in having 43 to 47 scales in the lateral line. Greene (1935) found this subspecies common in many parts of Wisconsin and reported it also from eastern Iowa.

Family AMEIURIDAE

THE NORTH AMERICAN CATFISH FAMILY

Catfishes are distinguished by their smooth, scaleless bodies, dorsal adipose fins, stout spines in the dorsal and pectoral fins, and barbels on the upper and lower jaws. The head and mouth are broad; the upper jaw is formed in front by the premaxillaries. The numerous teeth are slender and weak and are arranged in bands. Catfishes are among the largest of the fresh-water fishes.

About 35 species of this family are known from the United States and Mexico. None occur in the Pacific drainage of the United States except where introduced, but some are found in the Pacific drainage of Mexico. A closely related family, Siluridae, includes several species of Europe and Asia, such as the great wels, *Silurus glanis,* of the Danube, which reaches a length of 13 feet. Other closely related families include the sea catfishes, the South and Central American catfishes, including some cave species, and the electric catfishes of Africa.

All the larger species are important food fishes. The larger ones keep well in cold storage and may be shipped great distances alive, each frozen in a cake of ice.

Forbes and Richardson (1908) wrote of the catfishes as follows: "By their ability to live contentedly in situations commonly avoided by most other fishes, they organize into their living substance much food material which would otherwise disappear as a mere natural waste, and, in so far as they are themselves eaten by other fishes, they thus increase the general supply of fish food in the waters they enter and inhabit. By their services as scavengers, they help to protect more sensitive fishes from the effects of the pollution of the water through a decomposition of objects which they are themselves very willing to devour, and in this way also they may convert into a form acceptable to other fishes food substances otherwise useless. As we have found them to be eaten more or less by both our species of black bass, by the sand-pike *(Stizostedion canadense),* and by the yellow bullhead and the mud-cat, their utility in this sense seems appreciable.

"On the other hand, it must be noticed they have appeared very rarely in the food of fishes, in comparison with their numbers and general distribution. . . . They devour other fishes much more generally than others devour them. . . . Their partial immunity is doubtless due in considerable measure to their remarkable defensive apparatus of stiff, acute, projecting, poisoned spines in the pectoral and dorsal fins, weapons capable of inflicting really painful punctures in animals as large as man.

"The nocturnal habits of catfishes must also contribute to their protection from predaceous enemies. . . . Their habit of leading and guarding their young greatly increases their chances of survival."

Key to Common Species of Family AMEIURIDAE

1. Caudal fin deeply forked....................2
   Caudal fin not deeply forked, generally rounded....................3

2. Anal fin of 24–29 rays including rudiments....................
   ....Channel Catfish, *Ictalurus lacustris punctatus* (Rafinesque)
   Anal fin of 30–35 rays....................
   ....Blue Catfish, *Ictalurus furcatus furcatus* (Valenciennes)

3. Adipose fin free, not connected with caudal fin....................4
   Adipose fin connected wholly or partly to caudal fin....................7

4. Anal rays less than 16, usually 13....................
   ....Shovelhead Catfish, *Pilodictis olivaris* (Rafinesque)
   Anal rays more than 16....................5

5. Anal rays 17–24; barbels under jaw gray to black....................6
   Anal rays 23–27, usually 23–25; barbels under jaw whitish....................
   ....Northern Yellow Bullhead, *Ameiurus natalis natalis* (LeSueur)

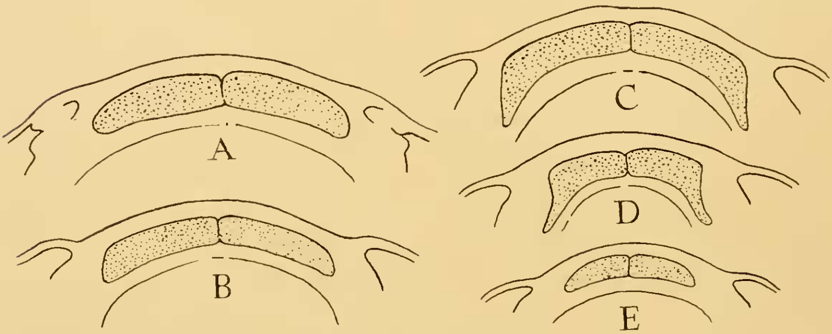


Diagram 7. Arrangement of teeth in upper jaws of the five genera of Ameiuridae. (A) *Ictalurus lacustris punctatus*, no backward extensions. (B) *Ameiurus nebulosus nebulosus*, no backward extensions. (C) *Pilodictus olivaris*, with backward lateral extensions. (D) *Noturus flavus*, with backward lateral extensions. (E) *Schilbeodes mollis*, no backward extensions.

6. Pectoral spines strongly barbed (except in very old individuals); no light bar across base of tail; fins seldom with jet-black membranes; body often mottled ....
   ......Northern Brown Bullhead, *Ameiurus nebulosus nebulosus* (LeSueur)
   Pectoral spines not strongly barbed; light bar usually across base of tail; fins with jet-black membranes; body not mottled....................
   ....Northern Black Bullhead, *Ameiurus melas melas* (Rafinesque)

7. Band of teeth on premaxillary without any backward lateral extensions (Diagram 7) 8
   Band of teeth on premaxillary with distinctly backward lateral extensions (Diagram 7) ....Stonecat, *Noturus flavus* Rafinesque

8. Pectoral spine smooth on posterior edge, but with longitudinal groove; no acute notch between caudal and adipose fins..Tadpole Madtom, *Schilbeodes mollis* (Hermann)
Pectoral spine with fine teeth, or serrae, on posterior edge; notch between caudal and adipose fins more or less acute............................9

9. Pectoral spine short, 3 in head; the length of posterior serrae not one-half diameter of spine; color light brown, sometimes faintly mottled.................................Slender Madtom, *Schilbeodes insignis* (LeSueur)
Pectoral spine long; less than 2 in head; the posterior serrae strong and length nearly equal to diameter of spine; color grayish with specks and large blotches.........................Brindled Madtom, *Schilbeodes miurus* (Jordan)

GENUS *Ictalurus* Rafinesque

The species of this genus are characterized by their large size, deeply forked tail fins, and silvery or plumbeous coloration. The bony bridge between the dorsal fin and the head is sometimes complete. These species prefer the deeper river channels and the clear lakes, and in general avoid muddy waters. They are distributed in the Mississippi, Great Lakes, and Gulf of Mexico drainages and southward to Guatemala.

NORTHERN CHANNEL CATFISH (Great Lakes Catfish)
Ictalurus lacustris lacustris (Walbaum)

This catfish is the large one found in the Great Lakes and connected waters. The separation of this subspecies from the following subspecies, *Ictalurus lacustris punctatus,* is difficult and questionable. It is said to differ in sometimes having the supraoccipital processes unjoined so that they do not form a continuous bony bridge between the head and the dorsal fin. The tail is forked, but somewhat less so than that of the following subspecies. The head is heavier and broader. The body is a dark, slaty blue and may or may not be spotted.

Hubbs and Lagler (1941) gave the range of this catfish as from the Prairie Provinces of Canada and the Hudson Bay region through the Great Lakes drainage. This subspecies was listed for Minnesota by Cox (1897), but no records were reported. It is possible that it occurs in Lake Superior or the Lake Superior drainage. In the summer of 1941 catfishes, apparently of the following subspecies, were collected from the St. Louis River by the Minnesota Department of Conservation. Greene (1935) did not find it in Lake Superior, but reported it from Lake Michigan.

CHANNEL CATFISH (Speckled Catfish, Fiddler)
Ictalurus lacustris punctatus (Rafinesque)

The channel catfish has a rather slender body and a very large, deeply forked caudal fin, or tail, fitting it eminently well for life in the swift water in which it usually lives. The mouth is rather small, for a catfish, and has very long barbels. In color it is a light bluish olive, lighter on the sides, and more or less thickly covered with circular spots of a bluish-ash color. The anal fin has 24 to 29 rays. Under favorable conditions this catfish attains a length of 3 feet and a weight of more than 25 pounds, but the weight of those usually called "fiddlers" rarely exceeds 3 or 4 pounds, and they are often much smaller.

The channel catfish ranges from Montana to the Ohio Valley and southward through the Mississippi Valley to the Gulf of Mexico, into Mexico, and into Florida. In Minnesota this catfish is common in most of the larger clear, swift tributaries of the Mississippi, such as the St. Croix and other streams to the southward. Cox (1897) reported it from the Red River at Moorhead and Grand Forks, and from the Ottertail and Red Lake rivers. It prefers large streams with strong currents.

Its occurrence in Lake Superior and its tributaries is uncertain; Greene (1935) did not find it in the Lake Superior drainage in Wisconsin, though he reported its probable occurrence in the Lake Michigan drainage. However, the specimens collected in 1941 from the St. Louis River and tentatively identified as *I. lacustris punctatus* may definitely assign this subspecies to the Lake Superior drainage. Cox (1897) reported it from the Red River of the North and its main tributaries, but investigations conducted by Olson and Slager in 1932 throughout this stream and numerous tributaries as far down as Fargo failed to indicate its presence at that time. It still occurs in the Minnesota and Blue Earth rivers and is common in the Mississippi and St. Croix and their larger tributaries.

Little is known of its spawning habits in Minnesota, beyond the fact that it spawns in very swift waters, usually sometime during early spring and never later than July 1. Efforts to propagate it under artificial conditions have so far resulted only in failure. However, it has recently responded to some degree to propagation under seminatural conditions (Morris, 1939) in Missouri, where the eggs are said to hatch in seven days at a temperature of 78° to 83° F.

Channel catfish, like others of their kind, are omnivorous in diet, nothing apparently coming amiss to them. They seem to eat more clams and water snails than any of the other catfishes do. In Illinois Forbes and Richardson showed that their principal food, 44 per cent of all they eat, consists of insect larvae. They bite readily on live minnows and crayfishes and are often caught at night by still-fishing or on setlines. Most of the catfishes are nocturnal in habits, but the channel cat is an exception, at least during certain seasons of the year. In June and early July it will often rise during the day to the fly of the bass fisherman. This species is a very desirable food fish, for the flesh is fine, white, and of excellent flavor.

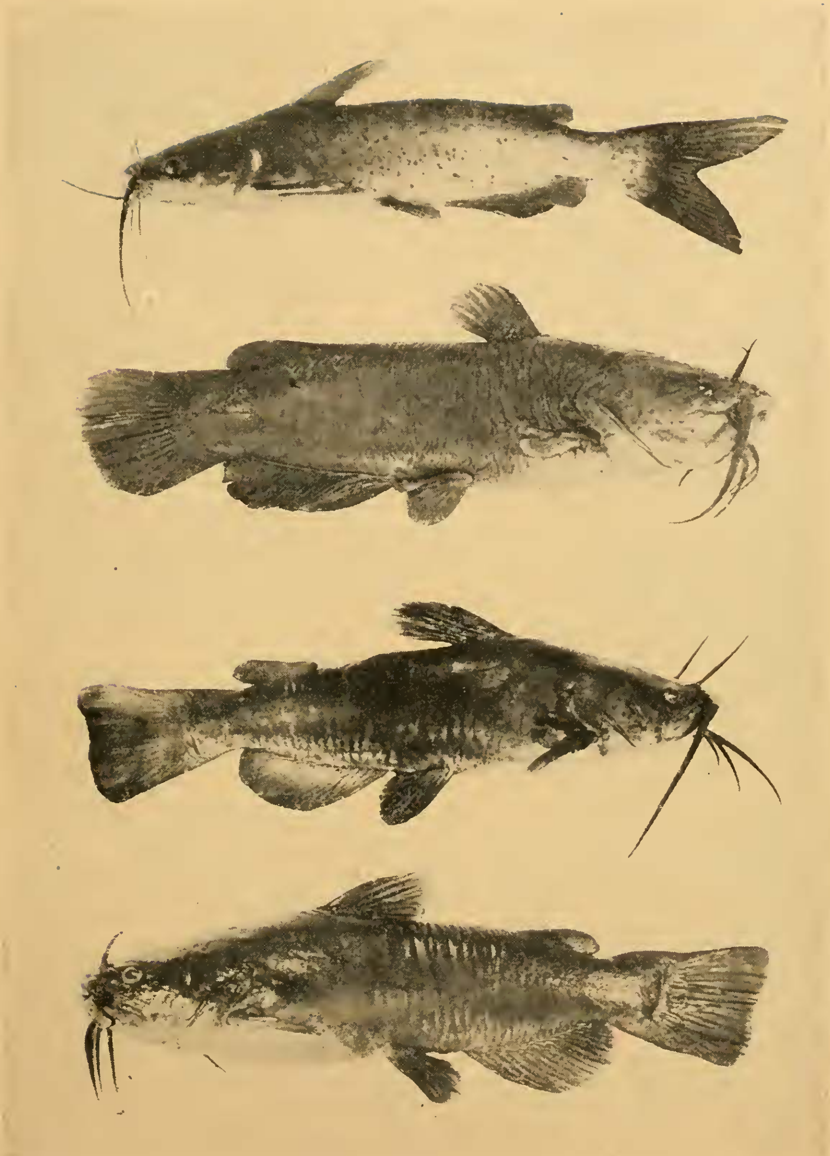


Figure 27. A. Channel catfish, *Ictalurus lacustris punctatus,* 15 inches long. B. Northern yellow bullhead, *Ameiurus natalis natalis,* 12 inches long. C. Northern brown bullhead, *Ameiurus nebulosus nebulosus,* 9 inches long. D. Northern black bullhead, *Ameiurus melas melas,* 10 inches long.

BLUE CATFISH (Great Forktail Cat)

Ictalurus furcatus furcatus (Valenciennes)

This catfish is distinguished by its bluish or slaty-gray back, the color fading to silver white on the belly, and has no spots. The anal fin has 30 to 35 rays. The blue catfish is by far the largest catfish found in American waters. It ranges from Kansas and Minnesota eastward through the Ohio Valley and southward to the Gulf and northeastern Mexico. In the Upper Mississippi it is believed to be more or less migratory in habits, occurring most frequently during the summer months when the water is warmest and no doubt moving south with the advent of cold weather.

The blue catfish formerly occurred in the Mississippi River and larger tributaries from Minneapolis southward. It is now very rare in Minnesota waters, and no specimens have been taken in recent years. A very large catfish weighing 160 pounds from the Minnesota River at Hanley Falls is probably this species.

Jordan and Evermann (1905) stated that in spite of the popular prejudice to the contrary, the flesh of this catfish is of excellent quality, firm and flaky, of a very delicious flavor, nutritious to a high degree, and always commands a fair price. In some localities on the Lower Mississippi it is highly esteemed as a food fish. It is usually caught on setlines during the night, with minnows and crayfishes as bait.

GENUS *Ameiurus* Rafinesque

BULLHEADS (Horned Pouts)

There are four species in this genus, distributed from the Gulf of Mexico through the eastern United States and into the Arctic drainage. Members of this genus are moderate in size and are characterized by a square or slightly rounded caudal fin, yellowish, mottled, or blackish coloration, and mud-loving habits. When skinned or dressed their flesh is reddish or pink, in contrast to the white flesh of the other catfishes. They can inhabit lakes so shallow and weed-grown that few, if any, other fishes can exist there. It is not unusual for these shallow lakes to freeze almost solid, yet we find at least some of the bullheads surviving. At low temperatures these fishes can endure lower oxygen conditions than most other fishes. With regard to their hardihood, Forbes and Richardson (1908) said: "These fishes will live where no others can survive, and when the air supply is bad far past the point of supporting life in ordinary fishes, they have merely to come leisurely to the surface and renew the supply in their swim-bladders. In the late fall they become sluggish and cease feeding, often 'mudding up,' or burying themselves more or less in soft leafy ooze along shore. They will lie dormant in the mud at the bottom of dried-out shallows for weeks at a time without harm, and have even been found, according to some (Dean), in cocoon-like clods of nearly dried mud, still alive." They can live out of the water for many hours when on ice.

Jordan (1904) described the horned pouts as dull and blundering fellows, fond of the mud, and growing best in weedy ponds and rivers without current. They stay near the bottom, moving slowly about with their barbels widely spread, feeling for anything edible. Jordan further stated that they will take any kind of bait, from an angleworm to a piece of tin tomato can, without coquetry, and that they seldom fail to swallow the hook. Bullheads are very tenacious of life, and open and shut their mouths for half an hour after their heads have been cut off. They spawn in spring. The old fishes lead the young in great schools near the shore, seemingly caring for them as the hen for her chickens.

Bullheads are naturally gregarious and usually go in schools. Sometimes two or three species congregate. The original range of the different species of bullheads in Minnesota waters will always remain a matter of conjecture. Many shallow lakes once frequented by them have dried up completely. The Red River of the North from Lake Traverse downstream nearly to the Canadian border has been almost dry for considerable periods, and at least one species reported there many years ago is now unknown. Over a period of years the United States Bureau of Fisheries has transplanted hundreds of thousands of these fishes from Mississippi River sloughs to waters in various sections of the state. Consequently it is impossible to work out the original dispersal of the various species.

For stocking small, muddy ponds or even lakes so shallow and weedy that there is a constant threat of severe losses through winter freezing or summer evaporation, there is no better fish than one or another of the three species of bullheads belonging to this genus.

Bullheads are omnivorous and eat large quantities of both vegetable and animal matter. When confined with other fishes they will eat many of the small ones. However, studies made on the stomachs of several hundred bullheads from various Minnesota lakes show that they eat very few fishes. The stomachs of 80 per cent of the bullheads examined were filled largely with vegetable matter. Insect remains occurred in 70 per cent of the stomachs. Entomostraca occurred in 43 per cent of the stomachs and in several composed enough bulk to indicate that they were not always incidental. Sunfishes were found in 4 per cent, perch in 3 per cent, and minnows and unidentified fish remains in 5 per cent. Twelve per cent contained remains of small fishes. A very small percentage contained remains of frogs, leeches, crayfishes, and amphipods. Their feeding habits probably vary with the type of food available. Cable (1928) made a study of the food of bullheads in South Dakota and found that they ate vegetable matter and decayed material only when forced to it. She concluded that bullheads prefer animal food in the form of insect larvae, crustacea, and molluscs, but are able to use other food such as vegetable matter if necessary.

NORTHERN BLACK BULLHEAD (Wah-wah-see-se of the Red Lake Chippewas)

Ameiurus melas melas (Rafinesque)

Although it closely resembles the brown bullhead, *A. nebulosus,* the black bullhead (Figure 27D) is smaller in size, usually reaching a length of 6 to 10 inches, and never exceeding 15. It differs also in being of stouter build. In well-nourished adults the body is very plump and the head flat, and there are rather prominent shoulders on each side of a median groove. The young are more slender. The pectoral spines are relatively smooth and without strong barbs. The caudal fin is never more than slightly emarginate. The anal fin is short and deep; its rays number 17–22, usually 17–20; its base is nearly one-fifth of the body length, the pale rays forming a sharp contrast to the black membranes. The barbels under the jaw range from gray to black. The body is variable in color, ranging from greenish brown to black above; the sides vary in luster between green and gold; the under parts of the head and body as far back as the anal fin are greenish, plumbeous, yellowish, or bright yellow, but never satiny white. A light bar across the base of the tail fin is a distinguishing character in adults.

The northern black bullhead ranges from North Dakota to northern New York and southward into Kentucky and Iowa, where it intergrades with another subspecies. This bullhead is quite common in shallow lakes and muddy streams over most of southern and central Minnesota. It is absent from the Lake of the Woods drainage and so far has been found only in the St. Louis River system of the Lake Superior drainage. Notwithstanding the adverse conditions prevailing in the Red River Valley, it still persists in tributaries of the Red River, ready to resume its former natural habitat when water conditions permit its return to the main stream. Nor have the droughts entirely eliminated it from the more or less intermittent waters tributary to the Rock River of the Missouri drainage in the southwest counties of Minnesota. Greene (1935) reported it as very common in Wisconsin and gave one record for the Lake Superior drainage. It is very common in Iowa and South Dakota.

It differs very little, either in habits or habitat, from other members of the genus. It bites readily, night and day, on worms, liver, or almost any kind of meat. Its flesh is firm and well flavored when the fish has been taken from clean water. Bullheads from muddy water sometimes have a disagreeable, muddy flavor. The flavor can be improved by keeping the bullhead alive in clean waters for a week.

Its spawning habits are the same as those of the other bullheads. It makes a nest on shallow sand or mud bottoms, often utilizing a natural depression or a muskrat burrow. The young remain for some time in dense schools attended by the male.

NORTHERN BROWN BULLHEAD (Speckled Bullhead)
Ameiurus nebulosus nebulosus (LeSueur)

The body of the brown bullhead (Figure 27C) is typically elongate but becomes more robust northward. The anal fin is moderately long and has 17 to 24 rays, usually 18 to 21. Its base is one-half the length of the body. The barbels under the jaw range from gray to black. The body shows a wide range of color, from yellowish to black, but is usually a dark yellowish brown mottled with dark green. It can be distinguished from the black bullhead, *A. melas,* by the absence of a light bar from the base of the tail and often by the somewhat higher dorsal fin and except in old individuals by the strong barbs on the pectoral spines. This species usually does not exceed a foot in length, but sometimes attains a length of 18 inches and a weight of 3 or 4 pounds.

The range of the northern brown bullhead is from North Dakota into New England, southward to the northern part of the Ohio Valley, and along the Atlantic Coast to Virginia. Although present in the Great Lakes drainage, it is absent from the Lake Superior drainage. It intergrades with another subspecies in the Ohio Valley southward. Of the three bullheads occurring in Minnesota the brown bullhead is perhaps the most common. It frequents by preference the quieter waters of both lakes and streams. It occurs abundantly in the backwaters of the Mississippi below St. Paul. It is found in the Minnesota and Blue Earth rivers and their tributaries and at one time occurred in the Red River (Woolman, 1895), but it has not been reported recently. Surber (1920) found it in certain Pine County lakes tributary to the St. Croix, in Green Lake in Kandiyohi County, and in Four Mile Bay near the mouth of the Rainy River. Friedrich (1933) reported it from the Mississippi River above St. Anthony Falls and in the Sauk River. It occurs in Lake Pepin and certain backwaters above and below the lake. It is widespread in Iowa and in Wisconsin, except in the Lake Superior drainage.

Like other bullheads, it spawns rather early in the spring, from April to June, and great schools of the jet-black young are often seen in the warm, stagnant pools and sloughs, swimming at the surface in summer, usually guarded by the parent male fish. They make nests six inches deep, and according to Forbes and Richardson (1908) up to two feet deep, on shallow sand or mud bottoms, sometimes using mouths of muskrat burrows or natural depressions. The cream-colored eggs are deposited in masses and are guarded by the male. Females 11 to 13 inches long were found to have 6000 to 13,000 eggs in their ovaries. Both this species and the black bullhead have thick skins and are more easily dressed than the thin-skinned yellow bullhead.

NORTHERN YELLOW BULLHEAD (Paperskin)
Ameiurus natalis natalis (LeSueur)

The yellow bullhead (Figure 27B) is yellowish, clouded or mottled with a darker color, and often has a bright yellow belly. The body is short and heavy, the head short and broad, the mouth wide. The long anal fin has 23 to 27 rays, usually 23–25, counting rudiments. Its base is more than one-fourth the length of the body. The caudal, or tail, fin is somewhat rounded when spread. The whitish barbels under the jaw distinguish it from other bullheads. The length is 12 to 18 inches.

The northern yellow bullhead ranges from North Dakota to New York and southward to Texas and Tennessee. Although present in the Great Lakes drainage it seems to be absent from the Lake Superior drainage. Other subspecies occur coastwise from the Hudson River drainage southward (Hubbs and Lagler, 1941). There is hardly a shallow lake tributary to the Upper Mississippi River where this species is not abundant, and it occurs with other bullheads in most of the lakes and sluggish streams of southern Minnesota. It does not occur in the Red River drainage, nor is it found in the deep northern lakes. It is widespread in Wisconsin, except in the Superior drainage, and is common in Iowa, especially in the larger streams.

In common with other bullheads it has exceedingly interesting spawning habits. Examination of a few females 10 to 11 inches long showed an average of about 4000 eggs in their ovaries. From the time the eggs are deposited in May or June until the young have attained a length of nearly 2 inches they are closely guarded by the parent male fish. In quiet water schools of several hundred young are found feeding and moving in a compact group near the surface, with the guardian parent a foot or two away actively engaged in warding off all intruders.

Like all the catfishes this species is a scavenger, eating everything dead or alive found in the water, such as minnows, crayfishes, insect larvae, and water snails. Water plants often form a large part of its diet. The young feed principally on Entomostraca and insect larvae. Notwithstanding their coarse food habits bullheads are excellent pan fishes, the flesh being fine, firm, and of delicious flavor. The bullhead bites readily on almost any kind of bait. Owing to its thin skin this species is probably more difficult to skin than any of the other bullheads.

GENUS *Pilodictis* Rafinesque

These are large catfishes with slender bodies and much-flattened heads. The lower jaw is much projected. The anal fin has 12 to 15 rays. Only one species, which ranges in the Mississippi drainage, occurs in this genus.

Figure 28. Shovelhead catfish. *Pilodictis olivaris,* 24 inches long.

SHOVELHEAD CATFISH (Mud Catfish, Yellow Catfish)
Pilodictis olivaris (Rafinesque)

The shovelhead catfish (Figure 28) is characterized by a slender body, much depressed anteriorly. The head is large, broad, and much depressed, with the lower jaw projecting. The barbels are short. The dorsal spine is weak; the strong pectoral spines are serrated on both edges. The adipose fin is nearly as long and half as high as the anal fin. The anal fin has 12 to 15 rays. The caudal fin is almost rounded, being scarcely emarginate. In color this fish is yellowish and much mottled with brown.

This catfish is not uncommon in Lake St. Croix and the Minnesota River and in the Mississippi below St. Paul. It does not range northward past St. Anthony Falls on the Mississippi or past the St. Croix Falls on the St. Croix. It inhabits large, sluggish rivers and consequently is mostly confined to the larger tributaries of the Mississippi. Wagner (1908) reported it as not as numerous as the blue cat in Lake Pepin. Weights over 40 pounds are not uncommon. It is very abundant in the Lower Mississippi Valley and there attains a very large size, sometimes reaching a length of 5 feet. Evermann reported a maximum weight of 100 pounds for the species, and Forbes and Richardson (1908) reported weights of 50 to 75 pounds as not uncommon.

It is frequently caught on setlines and by commercial seiners. Live minnows and crayfishes are the best bait. The flesh is excellent although somewhat coarse in large individuals. Farther south the shovelhead catfish is sometimes found in submerged hollow logs, from which it is often taken by hand. It feeds mostly on aquatic animals and eats small fishes of all kinds.

GENUS *Noturus* Rafinesque STONECAT

Stonecats are small, slender, flat-headed catfishes, with the adipose fin keellike and continuous with the dorsal fin except for a shallow notch.

There are lateral backward extensions on the premaxillary band of teeth. Although the wounds caused by the pectoral and dorsal spines of other members of this family are more irritating than would be expected, the members of this genus and the following one, *Schilbeodes*, have much better developed poison glands, particularly on the bases of the pectoral spines. A slight prick from a spine may be exceedingly painful. The skin is thick and villose. The anal rays number 16. One species occurring in this genus ranges east of the Rocky Mountains from Montana to New York, and southward to Oklahoma and Alabama.

STONECAT

Noturus flavus Rafinesque

This species is easily distinguished from the bullheads of the genus *Ameiurus* by the fact that the long, low adipose fin is continuous with the caudal except for a shallow notch, whereas these fins are entirely separate in the bullheads. The body is moderately elongate, broad and flat in front of the dorsal, and subcylindrical behind it. It is yellowish brown in color, the sides of the head shade to yellow, and the belly is whitish. This species seldom exceeds a length of 9 inches.

This little fish is very common under stones and logs in swift water. Cox (1897) reported this species in Minnesota from the Blue Earth River at Mankato, but its distribution in the state is a matter of conjecture. Apparently it is a southern fish, for all records in the University of Minnesota collections are from the southernmost counties. Greene (1935) reported it from swift streams with stony bottoms in central and southern Wisconsin, including the Lake Michigan drainage.

GENUS *Schilbeodes* Bleeker — MADTOMS

The madtoms are small, tadpolelike catfishes having subcylindrical bodies with more or less broad heads. All the members of the genus *Schilbeodes* can be readily distinguished from the bullheads of the genus *Ameiurus* by the character of the adipose fin, which is continuous with the caudal. They can be distinguished from the genus *Noturus* by the absence of the backward lateral extensions of the band of teeth on the premaxillary. As in the preceding genus, there is a poison gland beneath the epidermis surrounding the base of the pectoral spine. There are a number of species in this genus, all of which occur east of the Rocky Mountains.

TADPOLE MADTOM

Schilbeodes mollis (Hermann)

The body of the tadpole madtom (Figure 29) is robust, short, and deep; it is deepest just in front of the dorsal fin. The color is purplish olive to dark brownish, without noticeable speckling. There are three dark streaks on the sides. The adipose fin is continuous with the caudal. The premaxillary bands of teeth are truncate laterally and without backward lateral extensions. The pectoral spines are smooth and unserrated. The species reaches a length of 3 to 5 inches. Hubbs and Raney (1944) have shown that the former name of the tadpole madtom, *Schilbeodes gyrinus* (Mitchill) should be replaced by *Schilbeodes mollis* (Hermann).

The tadpole madtom ranges from North Dakota to New York and southward as far as Texas and Florida. It is common in both the Upper Mississippi and the Red River drainages in Minnesota and is probably often mistaken by local fishermen for the young of the bull-

Figure 29. Tadpole madtom, *Schilbeodes mollis*, 3 inches long.

heads. It has been collected in the St. Louis River in the Lake Superior drainage. It seems to prefer still, muddy waters where it can hide under vegetation and debris. In 1911 H. Walton Clark and Surber found it in the sloughs of the Mississippi River near Muscatine, Iowa, where it was often found in dead mussel shells. It is occasionally found along weedy lake shores and is very abundant in sluggish, shallow, weedy streams in Minnesota, Wisconsin, and Iowa. It is very common in Lake Itasca at the headwaters of the Mississippi River.

According to Forbes and Richardson (1908) the tadpole madtom, like other species of this genus, is provided with poison glands, which are just beneath the epidermis surrounding the spines of the pectoral and dorsal fins; these glands are ductless and the poison they secrete is liberated only when the epidermis of the spine is torn. The wound from these spines is quite as painful as a bee's sting. None of the madtoms are of any importance as food fishes, but owing to their tenacity of life they are said to serve as excellent bait for black bass. They are seldom found in the stomachs of any other fishes.

SLENDER MADTOM

Schilbeodes insignis (LeSueur)

The slender madtom is much more slender than the preceding species, *S. mollis*. It is light brown and sometimes faintly mottled, and has a large, squarish spot of lighter color on the back before the dorsal fin and a smaller crescentic spot behind it. The pectoral spines are serrated. This species reaches a length of 3 to 4 inches. Hubbs and Raney (1944) have shown that the former name of the slender madtom, *Schilbeodes exilis* (Nelson) should be replaced by *Schilbeodes insignis* (LeSueur).

The slender madtom ranges from Iowa and southern Wisconsin southward to Alabama, Arkansas, and eastern Oklahoma. Cox (1897) reported this species from the Blue Earth River at Mankato, Minnesota, and as found in riffles under stones. However, since *insignis* is a southern species it is possible that this record was due to a misidentification. This species has not been found in any recent collection from Minnesota waters. Greene (1935) reported it only for southeastern Wisconsin.

BRINDLED MADTOM

Schilbeodes miurus (Jordan)

This species is very similar in shape to the preceding one, *insignis*. The color is grayish with black specks and larger blotches; there are four saddlelike blotches on the back, the last one extending to the edge of the adipose fin. At a glance, viewing it from above, an observer might mistake it for a muddler, or sculpin. It probably never exceeds 3 inches in length. According to Forbes and Richardson (1908), "Hay, in his list of Indiana fishes, mentions its occurrence in Minnesota and North Carolina."

The brindled madtom is reported as ranging from Iowa through southern Wisconsin, to Lake Erie and its tributaries in Michigan and Ontario, and to the Allegheny drainage in New York, and southward to Mississippi, Louisiana, Arkansas, and northeastern Oklahoma. This species was reported July 7, 1911 in the Red Cedar River at St. Ansgar, Iowa just south of the Minnesota line (Surber, 1920). It is a southern species, and it is very doubtful that it occurs as far north as Minnesota. It has not been found in any recent collection from Minnesota waters. Greene (1935) referred to two records of this species from southern Wisconsin by Cahn (1925), but questioned their authenticity.

Family UMBRIDAE

THE MUDMINNOW FAMILY

Mudminnows are soft-rayed fishes with rather heavy bodies, compressed posteriorly. The large head is flattened above; the mouth is medium sized, with teeth on the jaws, vomer, and palatine bones. The upper jaw is not protractile; the maxillary bones form the posterior part of the margin of the upper jaw. The gill-rakers are not well developed. The branchiostegal rays number 6 to 9. The pseudobranchiae are not well developed. The cycloid scales cover the head and body; no lateral line is present. Only one genus and one species are found in Minnesota.

GENUS *Umbra* Müller

This genus contains two American and one European species. One of the American species is found in the Great Lakes and Upper Mississippi drainages.

WESTERN MUDMINNOW
Umbra limi (Kirtland)

The western mudminnow (Figure 30) is dark, sometimes rich brown in color, and much mottled. The body has 14 narrow, light crossbars and a dark bar at the base of the caudal fin. The head is contained 3.75 times in the body length and the depth is contained 4.25 times in

Figure 30. Western mudminnow, *Umbra limi*, 3 inches long.

the length. The dorsal fin, which has 14 rays, is inserted rather posteriorly, but the first ray is farther forward than the first ray of the anal. The anal fin has 8 rays, the ventral fins 6. This species seldom exceeds 4 inches in length.

The mudminnow ranges from Minnesota through the Great Lakes drainage and south to Kansas and Tennessee. It is widely distributed in all parts of Minnesota, including the Red River and the Lake Superior drainage. Greene (1935) reported it to be widely distributed over Wisconsin. It is fond of muddy streams and pools with aquatic vegetation. Loving muddy bottoms and living in the mud as it does, it is no doubt often overlooked. It may be mistaken for the young of the dogfish, *Amia calva*, which it closely resembles in color and shape. However, it can always be recognized by the short dorsal fin, for in the dogfish the dorsal fin extends almost to the caudal fin. The mudminnow is carnivorous; it feeds on small crustacea, worms, and insects. It has the interesting habit of quickly concealing itself when frightened by wriggling downward into the bottom mud, tail first. It is very hardy. It has the habit of burrowing into the mud when the water in a pond evaporates. For this reason it is often the only fish inhabiting swamps, shallow ponds, and bog pools. It is very common in ditches in some of the swamps and muskegs of northern Minnesota.

Mudminnows spawn in the spring; ripe females have been found in the middle of April. They are reported as migrating up small streams and depositing their eggs singly on the leaves of aquatic plants.

Family ESOCIDAE

THE PIKE FAMILY

The family Esocidae includes the true pikes, or pickerels, all of which are included in the genus *Esox,* which is represented also in northern Europe and Asia. All members of this family have elongated bodies and heads. They are distinguished by very long, depressed jaws. A single soft-rayed dorsal fin is inserted far back on the body. No spines are present in any of the fins. The jaws are armed with large canine teeth.

Five species are found in the United States. The muskellunge, *Esox masquinongy* Mitchill, and its subspecies are found in the Upper Mississippi Valley, the Great Lakes region, and Lake of the Woods. The northern pike, *Esox lucius* Linnaeus, in Minnesota sometimes called "great northern pike," or "pickerel," is found throughout northern Europe and in North America north of the Ohio River. The eastern common, or chain, pickerel, or green pike, *Esox niger* LeSueur, a slender species with chainlike markings on the body, is found in the southern and eastern United States. The bulldog (barred) pickerel, *Esox americanus* Gmelin, a small pickerel, is likewise confined to the eastern and southern United States. The little mud pickerel, *Esox vermiculatus* LeSueur, which is considered a subspecies of *americanus* by many ichthyologists, is a small pickerel rarely reaching a length of over 12 inches. It is marked with wormlike wavy bars. It is distributed in the Ohio Valley and the Lower Mississippi drainage. The only species of the family definitely known to occur in Minnesota are the northern pike, *Esox lucius,* and the muskellunge, *Esox masquinongy.* Both these fishes have received numerous common names, which have been listed by Weed (1927).

Key to Common Species of Family ESOCIDAE

1. Opercle entirely scaled; markings of wavy dark bars; size small............ ....Mud Pickerel, *Esox vermiculatus* LeSueur
   Opercle naked on lower half; markings variable; size large...............2

2. Cheeks completely scaled; body markings of adult, light spots on dark background; immature markings consist of light, irregular bars; mandibular pores 5 or less on each side................Northern Pike, *Esox lucius* Linnaeus
   Cheeks may have lower half naked or partially or even largely scaled; body marking ranges from solid color to dark spots or bars on light background; mandibular pores more than 5 on each side ....Muskellunge, *Esox masquinongy* Mitchill

GENUS *Esox* Linnaeus

Esox is the only genus of this family found in America.

MUD PICKEREL (Grass Pike)
Esox vermiculatus LeSueur

Esox vermiculatus is a small pickerel rarely reaching a length of over 12 inches. The body is olive green and is marked with dark, wormlike wavy bars. The branchiostegals usually number 11–13. There are about 105 scales in the lateral line. The opercle is entirely scaled.

The mud pickerel is distributed from Iowa across southern Wisconsin and Michigan into southern Ontario, and southward into the Gulf States. Greene (1935) reported it for southern Wisconsin and gives a record from the Mississippi between Iowa and southern Wisconsin. Although this species was reported for Minnesota from a very early record (Surber, 1920) the evidence for this record is not conclusive. No specimens have been reported in Minnesota in the last fifty years and it is doubtful that it is present except perhaps in the extreme southeastern corner of the state. Because of its small size this pickerel has little value as a pan or game fish.

NORTHERN PIKE (Pickerel, Great Northern Pike, Jackfish, Ke-no-shay of the Red Lake Chippewas)
Esox lucius Linnaeus

The northern pike (Figure 31) is a more or less elongated fish. It has a dorsal fin far back on the body. The depth varies considerably. The head is more or less elongated and depressed forward into a pair of ducklike jaws. The top and front of the head are without scales. The cheeks are entirely covered by scales. The upper half of the opercle is covered by scales, but the lower half is naked. The branchiostegals number 11–16, usually 14–16. The depth of the body is contained 5 to 7 times in the length. The dorsal fins have 16 to 19 rays. The ventral fins are located halfway between the anal and pectoral fins. The sensory pores of both sides of the ventral surface of the mandible number 10 or occasionally fewer.

The color is bluish and greenish gray, the belly white or yellow. In adults the sides are more or less covered by light spots against a darker

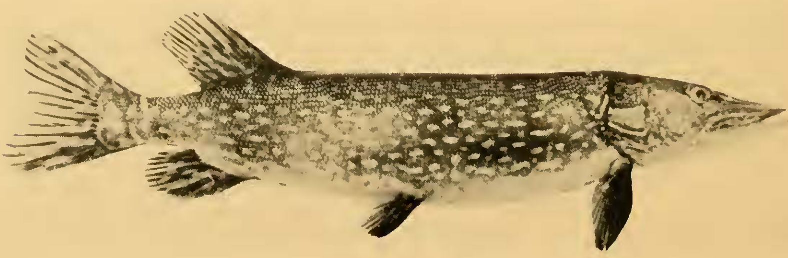


Figure 31. Northern pike, *Esox lucius*, 28 inches long.

background. The young have light bars upon a dark background. These bars gradually break up into light spots when the fish is about 6 inches long, though specimens over 12 inches long have been found still bearing the juvenile bars. The fins are more or less spotted.

The northern pike may reach a large size and weigh from 25 to 30 pounds. Weights of over 50 pounds have been reported. Northern pike grow very rapidly and some reach a length of 8 to 12 inches at the end of the first summer. Pike 36 inches long were found to be about 9 years old.

This species is found in nearly all the streams and lakes of Minnesota. It prefers sluggish streams and seems to be fond of the warm, muddy waters of shallow, weedy lakes, but is equally abundant in most of the clear, cold waters of the deep, rocky lakes of the north. It is common in most of the waters of Wisconsin (Greene, 1935).

In Minnesota and parts of Wisconsin the northern pike is often called "pickerel" or "great northern pike." Some fishermen in Minnesota claim that the great northern pike is a different species from the fish locally called the common pickerel and that they differ mainly in the depth of the body. Others have added to this misunderstanding by confusing juvenile northern pike with the eastern common, or chain, pickerel of the East. The size, markings, and proportions of the northern pike show a great deal of variation. Hundreds of specimens have been examined at the University of Minnesota and no differences sufficient to indicate the existence of two different species have been found.

The claim that northern pike lose their teeth in August has been carefully investigated at the University of Michigan by Trautman and Hubbs (1935), who have found no foundation for it. Hundreds of examples examined at the University of Minnesota show no sign that they shed their teeth entirely at any one time. Apparently worn-out or broken-off teeth are replaced as they are lost by new ones, which grow alongside the larger ones. "Sore gums" attributed to loss of all the teeth at one time are probably due to exposure to the air and hemorrhages caused by death struggles. The fact that northern pike do not bite well in August is probably attributable, not to loss of their teeth, but to the fact that food production is then at its peak for the year and that they are consequently well fed, and also to the fact that they are likely at this time to seek the cooler and deeper waters.

The northern pike feeds largely on other fishes, sometimes on its own kind. Large quantities of perch and suckers, insects, and even large leeches form a part of its diet. It is a voracious feeder and consumes enormous quantities of food throughout the year.

Though somewhat bony, northern pike, especially the smaller ones, are excellent food fishes. A strong flavor may be imparted to the flesh by the large secretions of mucus in the skin, but this flavor can be avoided by skinning the fish. Though some consider the northern pike obnoxious because of its slime and its voracity, it ranks high as a game fish, for it offers great resistance and fight when hooked.

Northern pike are occasionally caught by still-fishing when live minnows are used for bait. However, trolling and casting, with plugs, spoons, or live minnows as bait, are the most successful methods of fishing for them. They are often speared through the ice in winter.

Northern pike spawn in the spring immediately after the ice melts. They may ascend small streams or move into the flooded grassy margins of lakes, where they deposit their eggs, which hatch in about two weeks. Spawning in Minnesota and Wisconsin usually occurs in April or early May. A large female may deposit over 100,000 eggs. A 6-year-old female 26 inches long and weighing about 4 pounds had nearly 60,000 eggs in the ovaries. The young northern pike feed the first week or two on tiny water fleas and small aquatic insects, but they are soon ready for a fish diet. They feed at first on small fish fry, such as young suckers, which are hatched at about the same time and in the same place. If there is a scarcity of food they readily resort to cannibalism. Northern pike are easily propagated artificially and considerable numbers are produced in the hatcheries of some of the northern states, although cannibalistic habits render the rearing of fingerlings difficult.

In recent years a striking variation (Figure 32A) of the northern pike has appeared in several places in northern Minnesota. This variant has the morphological characters of *E. lucius* but lacks spots or other markings. The body is usually colored a dark silver or gray, sometimes flecked with gold. The fins are finely speckled with black. The opercle is scaled on the upper half only and the cheek is entirely scaled. Occasionally specimens with faint light spots on the caudal peduncle, identical with the caudal markings of *E. lucius,* have been found. The total number of pores on both ventral surfaces of the mandible does not exceed 10. The writers have never seen specimens weighing over 10 pounds.

This fish was first observed about 1930 in Lake Belletaine near Nevis, Minnesota, where it is common. The local fishermen report that it did not appear in their catches until about that year. It was named "silver muskellunge" by the fishermen, though it is undoubtedly related to *E. lucius* rather than to *E. masquinongy.* For several years this fish and the true muskellunge have been propagated in the Nevis Hatchery and planted in nearby lakes, and consequently it has become fairly widespread.

A specimen of this fish has been collected from Detroit Lakes, where none have been planted. A report of its occurrence in a Lake County lake has been received. Many specimens have been reared at the University of Minnesota, some to 3 years of age. Apparently they breed true, for all the offspring are marked like the parents. When they are crossed with the northern pike the resulting hybrids have a peculiar

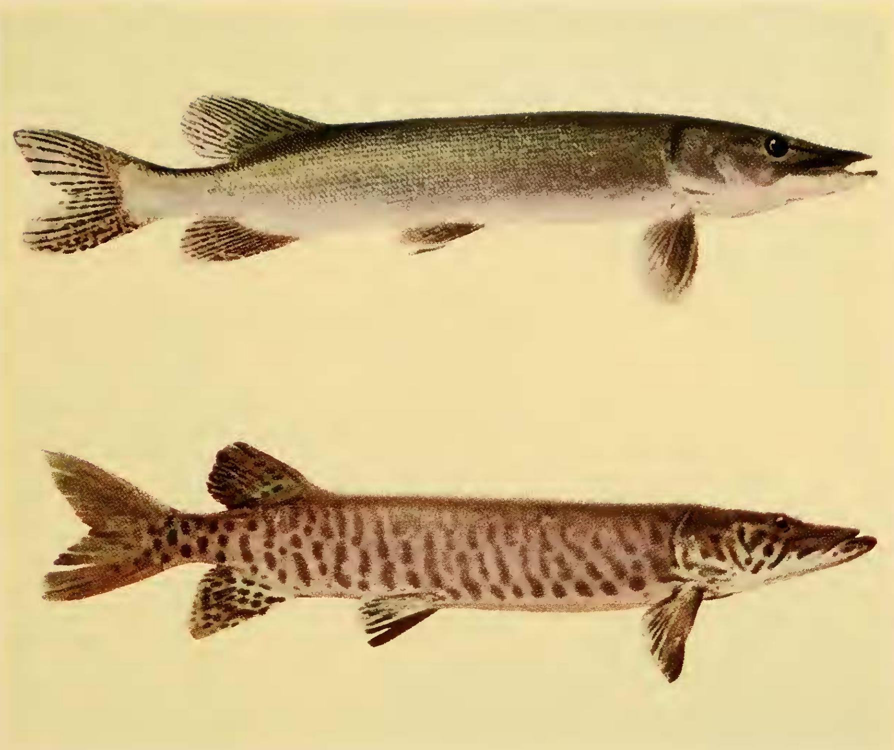


Figure 32. A. Northern pike, *Esox lucius*, silver variety, 23 inches long. B. Northern muskellunge, *Esox masquinongy immaculatus*, 24 inches long.

black mottling on the body. Undoubtedly, as proved by the experimental evidence, this type is breeding true in nature, for in the lakes where this fish occurs pure silver-colored individuals of all ages continue to appear and possible hybrid types are uncommon. This fish is apparently a true-breeding mutant of *Esox lucius* and has definitely established itself in several lakes, where it breeds with others of its kind rather than with the accompanying northern pike and muskellunge. Properly, the common name should be "silver pike" rather than "silver muskellunge."

NORTHERN MUSKELLUNGE (Wisconsin Muskellunge)
Esox masquinongy immaculatus (Mitchill)

The general shape of the muskellunge is very similar to that of the northern pike. The species is said to be readily distinguishable because of the absence of scales on the lower part of the cheek, but many Minnesota specimens show more or less developed scales on the lower cheek. As in the northern pike, the opercle bears scales on the upper half only and the lower half is naked. The branchiostegals number 16–19. The dorsal fin has from 19 to 21 rays. The body is usually more or less silvery, though some muskellunge from the Lake of the Woods drainage are dark brown. The markings vary considerably, but always consist of dark markings on a light background. The total number of pores on the ventral surfaces of both mandibles varies from 11 to 18, but always exceeds 10. Minnesota specimens have from 130 to 157 lateral-line scales, but most specimens counted ranged from 147 to 155.

Three subspecies of muskellunge have been described by various authorities. Of these the subspecies *immaculatus* (Figure 32B) is assigned to the region of Minnesota and Wisconsin. The subspecies *E. masquinongy masquinongy* (Mitchill) is reported to range through the Great Lakes but at present seems to be absent from the Minnesota waters of Lake Superior. Greene (1935) reported it from the Apostle Islands in Lake Superior and from Lake Michigan.

The markings and other characters of the muskellunge in this region indicate that further study is needed to determine the relations of the various types. The typical markings consist of a more or less silvery background with broad and more or less distinct dark bars on the sides. This variety is called locally the "tiger musky." On some older specimens the bars become so faint as to be almost indiscernible. Other muskellunge are marked with more or less distinct spots on a light background and are called locally "leopard muskies." Whether they constitute distinct varieties is doubtful, for all are sometimes found in the same lake and many individuals showing intergradations are found.

Muskellunge are seldom abundant in any one lake in Minnesota. They are found in Lake of the Woods and tributary waters and in certain lakes in the vicinity of Grand Rapids, Park Rapids, and Leech Lake. Muskellunge have been found occasionally in Lake Pepin and in the Mississippi between Minneapolis and Brainerd. They are found in a number of lakes and streams of northern Wisconsin. In both Minnesota and Wisconsin their range is increasing through artificial propagation.

Because of its reputation for fighting, the muskellunge is one of the most highly prized game fishes. It is also one of the most rapidly growing fishes in the northern states. Minnesota specimens reach a length of 12 inches in the first 4 months of life. Muskellunge often reach 25 to 30 pounds in weight, and records of muskellunge weighing well over 50 pounds occur annually.

Muskellunge are entirely carnivorous. Their food consists largely of suckers, perch, and other fishes. Muskellunge reared in tanks at the University of Minnesota fed on water fleas for the first week of life, but thereafter refused such small fry and would feed only on small suckers and other fishes. If they were without food for an hour they would start slashing at one another. Almost the only losses that occurred in the rearing experiments were due to cannibalism. In two months they had reached a length of 6 inches and were each consuming from 10 to 15 minnows a day. Their movements were exceedingly swift. They would stalk their prey, poise, and then dart faster than the eye could follow and swallow their prey with one gulp. If the victim happened to be a large fish one slash was sufficient to sever the tail of the unlucky victim.

The muskellunge spawn later than the northern pike, usually during the first part of May. Ordinarily they spawn in tributary streams and shallow lake channels, rather than in weeds as the northern pike does.

Late-maturing northern pike have been reported as spawning with muskellunge. Further evidence of hybridization has been found in the occasional appearance of specimens bearing muskellunge markings but having ten mandibular pores. In 1939–41 a large number of muskellunge eggs were successfully fertilized with northern pike milt at the Nevis Hatchery. Northern pike eggs were likewise successfully fertilized with muskellunge milt. Part of the resulting young fish were reared in the vicinity of the Nevis Hatchery. Others were removed to the University of Minnesota and reared in tanks and ponds. This experiment indicated that muskellunge easily hybridize with northern pike and probably often do so in nature. The hybrids grew much faster for the first year than either the purebred muskellunge or the northern pike, but in subsequent years little difference in growth was noted. However, the hybrids always exhibited much greater vitality and had a much lower mortality rate.

A comparison of the hybrids with 39 Minnesota specimens of muskellunge and 200 northern pike showed that the hybrids had some distinctive morphological characters. Ninety-one per cent of the hybrids were entirely scaled on their cheeks, whereas only 22 per cent of the muskellunge had entire scalation. Approximately 75 per cent of the hybrids had 10 mandibular pores and the rest had 11–12 pores. Muskellunge often had as high as 18 pores. The number of lateral-line scales of the hybrids was usually less than for the muskellunge and more than for the northern pike. The lateral-line scales of the muskellunge ranged from 130 to 157, but most of them had from 147 to 155. The lateral-line scales of the northern pike ranged from 117 to 132. The lateral-line scales of the hybrids ranged from 119 to 145, but most of them had from 129 to 141. The anal fin rays of the hybrids numbered 16 to 19, the same range as for the muskellunge, but somewhat higher than for the northern pike, which ranged from 14 to 18, usually 14 to 16. The dorsal fin rays of the hybrids numbered 18 to 21, the same as for the muskellunge but slightly more than for the northern pike, which ranged from 17 to 19. The branchiostegal rays of the hybrids ranged from 17 to 18 and were within the limits for those of the muskellunge rather than for the northern pike.

Artificial propagation is now being carried on in Minnesota and Wisconsin. The voracity and cannibalistic tendencies of this fish may explain why it is seldom abundant in any one lake and also why it is found in only a few scattered places in Minnesota. Through artificial propagation it may be possible to bring about a wider distribution.

Muskellunge are usually caught by casting or trolling with large spoons or other active lures. Large spinners baited with large live minnows are often used.

Family ANGUILLIDAE

THE EEL FAMILY

The long, snakelike body of the eel is covered with minute, elongated scales, which are imbedded in the skin. Some of the scales are arranged at right angles to one another. The head is small and conical. The bones are much modified from those of the typical fish. The preopercle and premaxillary bones are present. The maxillaries are absent. The ventral fins are absent; the pectoral fins are present; the dorsal fin is long and its rays are short. Many species of eels belonging to related families are found in the sea, but only one species of one genus is found in fresh water in the United States.

GENUS *Anguilla* Shaw

This genus contains but one American species, which is restricted to waters east of the Rockies. Closely related species are found in Europe and Asia.

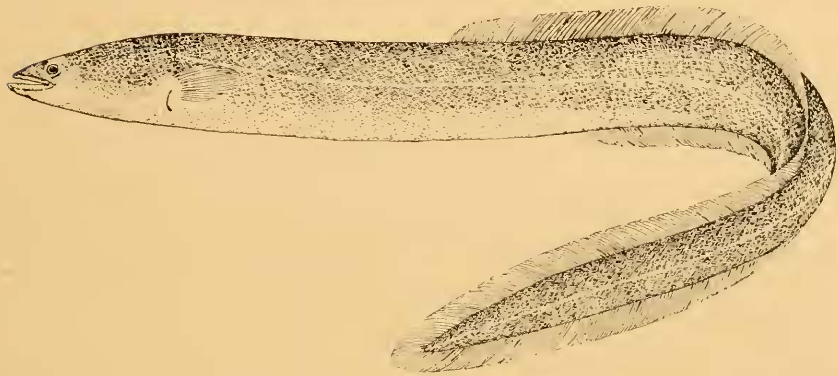
AMERICAN EEL (Common Eel, Fresh-Water Eel)
Anguilla bostoniensis (LeSueur)

The body of the eel needs little description. The tail is somewhat compressed, and the lateral line is well developed. The head is rather long and has small eyes located well forward. The jaws and vomer are well set with teeth that are somewhat unequal in length. The lower jaw projects beyond the upper. The outer end of the tongue is free. The opercular openings are slitlike. The dorsal fin is continuous with the caudal and anal fins. The upper parts of the body are dark brown in color, and the lower parts are light. Female eels reach a length of 4 feet.

The only animals ever confused with the eel are the lampreys, and there is no reason for this confusion, for the lampreys lack jaws and pectoral fins and have seven pairs of gill-clefts.

The eel was at one time fairly common in the Mississippi and its larger tributaries at least as far up as St. Anthony Falls. It has now become almost extinct in Minnesota and Wisconsin. A few are taken occasionally in the Mississippi and the St. Croix. The fact that all eels must come from the sea and that the route has now been obstructed by many dams is undoubtedly responsible for their scarcity in Upper Mississippi waters.

Eels spawn in the sea and the adults are never seen after they leave the coast. The young eels, after passing through larval stages, ascend the rivers and live for several years in quiet, poollike stretches, where they reach maturity. Only females journey far inland. Males, which never exceed 18 inches, remain near the river mouth. On reaching maturity they return to the sea to spawn and die. They are omnivorous and voracious feeders. They feed mostly at night, on both dead and live animal food. During the day eels usually hide under stones or bury themselves in the mud. At night they become very active. They travel readily over short stretches of land and have been reported as making forays into swamps and wet meadows to catch frogs and other small animals. Eels kept in aquaria at the University of Minnesota climb from



American eel, *Anguilla bostoniensis*.

tank to tank with ease and have remained out of water over 24 hours without apparent harm.

Eels bite readily on baited hooks, particularly at night. The flesh of the eel is excellent and in some places is considered a delicacy. Most of the eels sold commercially in the United States are caught in the East. In former years their skins had considerable value. They were used for many things, including the manufacture of fine buggy whips and book bindings.

Family CYPRINODONTIDAE

THE KILLIFISH FAMILY

Fishes of this family have somewhat elongate bodies, compressed posteriorly. The head is considerably depressed. The cycloid scales are rather large. The lateral line is very imperfect. The mouth is very small. The lower jaw is projecting and the upper jaw protractile in all American species. There are teeth in the jaws and sometimes on the vomer. The gill-membranes are free from the isthmus; the gill-rakers are short. The branchiostegal rays number 4–6. The pseudobranchiae are not developed. The dorsal fin, composed of soft rays, is single and usually inserted far back. The caudal fin is not forked. The ventral fins are inserted on the abdomen. The air bladder is sometimes absent.

Many genera and species, including topminnows, are known in the brackish and fresh waters of the southern states, the Atlantic Coast, Mexico, and Central America. Some species found in the southeastern United States are ovoviviparous, i.e., give birth to living young. Only one genus is found in Minnesota and neighboring states.

Key to Common Species of Family CYPRINODONTIDAE*

1. Dorsal fin originating distinctly in advance of anal; body with crossbands in both sexes..
   Western Banded Killifish, *Fundulus diaphanus menona* Jordan and Copeland
   Dorsal fin originating distinctly behind front of anal; body with crossbands in male only..2
2. Body rather deep and compressed, depth 3.5–4.3; males with vertical bars, females with about 10 horizontal streaks; a black blotch below the eye......
   ....Northern Starhead Topminnow, *Fundulus dispar dispar* (Agassiz)
   Body slender and scarcely compressed anteriorly, depth 4.4 or 5.3; a purplish black lateral band with irregular edges in the male; no black blotch below eye.....Northern Blackstripe Topminnow, *Fundulus notatus* (Rafinesque)

*Modified from Hubbs and Lagler (1941).

GENUS *Fundulus* Lacépède

This genus contains a number of southern and eastern species, some of which live in brackish water. Only one species is known from Minnesota, though closely allied topminnows, *Fundulus notatus* (Rafinesque) and *Fundulus dispar* (Agassiz), are known from Wisconsin and Illinois.

WESTERN BANDED KILLIFISH

Fundulus diaphanus menona Jordan and Copeland

The western banded killifish (Figure 33) is olivaceous with the sides barred with olive and silver crossbands; the back is sometimes spotted.

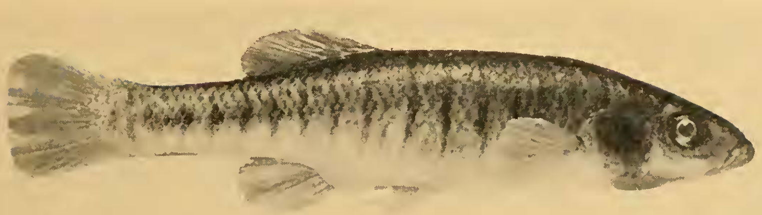


Figure 33. Western banded killifish, *Fundulus diaphanus menona,* 2 inches long.

The fins are not much marked except in breeding males, which have the dorsal fin strongly marked with a longitudinal stripe. The head is contained 4 times in the length, the depth 4.8 times. The eye is contained 3.5 times in the head. The dorsal fin has 13 rays and is inserted far back. The first rays of the dorsal fin are before the first rays of the anal or over them. The anal fin has 11 rays. The scales are cycloid and number 43–45. This species reaches a length of 4 inches.

This little fish is fond of muddy brooks and ponds where there is aquatic vegetation. It is fairly common in the shallow waters of Minnesota lakes. Numerous specimens have been reported from the various streams and lakes in the vicinity of Mankato, from the St. Croix River, and from the streams and lakes of the Upper Mississippi and Minnesota rivers (Cox, 1897). There are specimens in the University of Minnesota collections from all parts of Minnesota except the northeastern portion. This species has been reported from a number of localities in Wisconsin (Greene, 1935) but is common only in the southeastern portion.

This fish feeds on small crustacea, insects, algae, and the seeds of aquatic plants. Ripe females containing large eggs are found in midsummer, indicating a late spawning date. It is a poor bait fish, for it will not stand handling and confinement in a minnow pail.

NORTHERN STARHEAD TOPMINNOW

Fundulus dispar dispar (Agassiz)

The northern starhead minnow is a small fish reaching a length of about 2 1/2 inches. The body is rather deep and compressed. The males are bluish olive and are marked with vertical bars. The females are marked with about 10 horizontal streaks. There is a black blotch below the eye. The dorsal fin has 7 rays, the anal fin 9. There are about 35 scales in the lateral line.

This minnow ranges from Iowa to southern Michigan and southward to Arkansas and Tennessee. It has never been found in Minnesota waters. Greene (1935) reported it from southeastern Wisconsin. It is reported as preferring quiet, shallow waters.

NORTHERN BLACKSTRIPE TOPMINNOW

Fundulus notatus (Rafinesque)

The blackstripe topminnow is a small, slender fish reaching a length of about 3 inches. It is marked with a broad blue-black lateral band. There is no black blotch below the eye. The dorsal fin has 9 rays, the anal fin 11. There are about 34 scales in the lateral line.

This species ranges from Iowa through southern Michigan to central Ohio and southward to Texas. Greene (1935) reported it from southeastern Wisconsin. It has never been found in Minnesota. It is reported as preferring the quiet waters of lakes and streams.

Family PERCOPSIDAE

THE TROUTPERCH FAMILY

These fishes have elongate bodies, which are rather heavy anteriorly and compressed posteriorly. The head is rather pointed, the mouth small, the eye large, and the maxillary bones small. The premaxillaries border the upper jaw, which is protractile. The jaws are set with weak teeth. The gill-membranes are free from the isthmus; the pseudobranchiae are developed. The branchiostegal rays number 6. The gill-rakers are tuberclelike. The bones of the head are cavernous; the scales are ctenoid; the lateral line is present. This family contains but two genera—*Columbia,* found in the Columbia River basin, and *Percopsis,* found in eastern North America.

GENUS *Percopsis* Agassiz

This genus contains only one species, the troutperch, *Percopsis omiscomaycus* (Walbaum).

TROUTPERCH

Percopsis omiscomaycus (Walbaum)

Although this fish (Figure 34) bears a general superficial resemblance to a perch or to a small walleye, it may be distinguished from these species by the presence of an adipose fin somewhat like that of a trout or whitefish. When freshly caught from the water it has a peculiar translucent appearance and is more or less mottled with light and dark colors, with many small blackish spots on and above the lateral line. The head is conical and is free from scales. The head is contained 3.8 times in the length and the depth 4.3 times. The dorsal fin is inserted about the middle of the body and has 2 spines and 9 soft rays. The anal fin has 1 spine and 7 soft rays. The ventral fins each have 1 spine and 8 soft rays. There are about 50 scales in the lateral line. This species reaches a length of 8 inches.

The troutperch ranges from Alberta to Quebec and southward to Kansas, Missouri, Kentucky, and Virginia. Greene (1935) reported it from only a few widely scattered areas of Wisconsin. This species occurs in large numbers in many of the clear, deep-water lakes and larger streams of Minnesota, where it forms no inconsiderable amount of food for the larger game fishes. A large number of specimens have been collected in the streams and lakes of the Upper Mississippi and from many places in southern Minnesota. Cox (1897) reported taking five hundred specimens at one haul with a small seine in the St. Louis River

Figure 34. Troutperch, *Percopsis omiscomaycus*, 3 inches long.

at the mouth of the Cloquet River. Troutperch are common in larger lakes, such as Mille Lacs and Lake of the Woods.

Troutperch spawn late in May or early in June. They usually select sand bars in lakes for this purpose, but where the lake environment is unsuitable they may ascend rivers instead. The troutperch may be a cold-water fish, for large numbers of them die in warm weather. Fully 10 per cent of the fishes that died in Mille Lacs during the severe losses in the summer of 1921 were of this species, but were misidentified by the local residents as young walleyes. Larger individuals are occasionally utilized as pan fish. The troutperch may be readily taken on a hook baited with angleworms. It feeds largely on small insects and crustacea.

Family APHREDODERIDAE

THE PIRATEPERCH FAMILY

The body of the pirateperch is considerably compressed, the back somewhat elevated, and the head flattened above. The mouth is of medium size and rather oblique, with the lower jaw projecting beyond the upper. The jaws, vomer, palatines, and pterygoids bear teeth; the upper jaw is not protractile; the maxillary bones are well developed. The edges of the preopercle and preorbital are toothed or serrated. There is a spine on the opercle. No pseudobranchiae are present. There are 6 branchiostegal rays. No lateral line is present. In adults the vent is located just back of the lower jaw. The air bladder is simple; the pyloric caeca number 12. This family contains but one American genus.

GENUS *Aphredoderus* LeSueur

This genus contains one species, found from Minnesota eastward to New York and south to Texas.

WESTERN PIRATEPERCH

Aphredoderus sayanus gibbosus (LeSueur)

The western pirateperch (Figure 35) is a very dark, purplish fish. The caudal fin has two black bars at its base with a lighter bar between. This species becomes somewhat iridescent and yellow-bellied in the spawning season. The body is oblong, rather heavy anteriorly, and compressed posteriorly. The back is somewhat elevated in the region of the dorsal fin. The dorsal fin is rather high and has 2 spines and 6 soft rays. The ventral fins have 1 spine and 7 soft rays. The head is contained 3 times in the length, the depth 3 times. The scales are

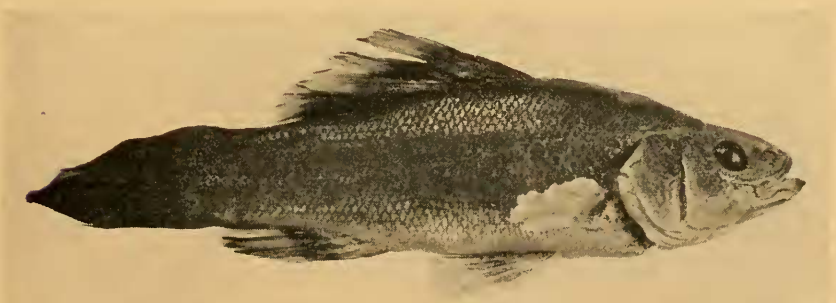


Figure 35. Western pirateperch, *Aphredoderus sayanus gibbosus*, 5 inches long, preserved specimen.

ctenoid, varying from 45 to 60 in a direct line from the opercle to the base of the caudal fin. This fish reaches a length of about 5 inches. An interesting point about this little fish is the location of the vent, which in the young is situated in about the natural position, but gradually passes forward as the fish matures, until in the adult it is located just back of the jaw.

The western pirateperch is a southern species and probably reaches its northern limit in southern Minnesota and Wisconsin. Greene (1935) reported it as uncommon in Wisconsin and listed it from five localities. It is rare in Minnesota; the only records are of several specimens collected from sloughs in the vicinity of Winona, Minnesota.

This species spawns early in the spring and builds a nest. The female is reported as helping to guard the nest. This species feeds on insects and small fishes.

Family SERRANIDAE

THE SEA BASS FAMILY

This family includes a large number of marine fishes. Several species are found in fresh water. Some authors divide the species in this family into several families, placing the local species under the family Moronidae.

Members of the sea bass family are moderately deep-bodied and more or less compressed. The dorsal fins contain spines. The ventral fins are thoracic, and each usually has 1 spine and 5 soft rays. The anal spines if present number 3. The lateral line does not extend on to the caudal fin. The members of this family differ from those of the Centrarchid family in a number of characters. They possess well-developed pseudobranchiae (gill-like structures on the inside of the opercle) which are very minute in the Centrarchids. The ribs are mostly attached to the ends of transverse processes instead of on the body of the vertebrae. They possess a small plate of bone—the subocular shelf—which extends under the eyeball from the second circumorbital. The fresh water species lack the supplementary maxillary bone.

Several genera and many species occur in this family. Some live in the sea and enter rivers to spawn. The two species found in Minnesota and neighboring states are strictly fresh-water fishes.

KEY TO COMMON SPECIES OF FAMILY SERRANIDAE

Dorsal fins separate; anal fin III, 11–13 .... White Bass, *Lepibema chrysops* (Rafinesque)

Dorsal fins slightly joined; anal fin III, 10 .... Yellow Bass, *Morone interrupta* Gill

GENUS *Lepibema* Rafinesque

This genus contains one species, which occurs in the Mississippi drainage as far north as southern Minnesota.

WHITE BASS (Striped Bass, Silver Bass)
Lepibema chrysops (Rafinesque)

The general color of the white bass (Figure 36) is silvery with yellowish under parts; the sides are streaked with narrow, dusky, longitudinal lines, five of which are above the lateral line. The body is compressed and deep; the back is elevated; the head is rather conical and scaly. The mouth is medium sized and horizontal; the jaws are about equal in length; the maxillary extends to the middle of the eye with no supplemental bone. There is a deep notch in the subopercular bone and the preopercle is serrated. The gill-rakers are long and slender. The depth is contained 3.5 times in the length. The dorsal fins have 9 spines anteriorly and 1 spine and 13 or 14 soft rays in the posterior portion. The longest dorsal spine is contained 2 times in the head. The anal fin has 3 spines and 11 or 12 soft rays. The scales number 10, 55–65, 15. The base of the tongue as well as the jaws, vomer, and palatines bear teeth. This species reaches a length of over 18 inches.

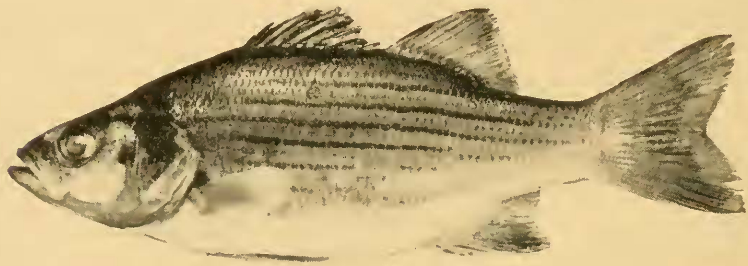


Figure 36. White bass, *Lepibema chrysops,* 13 inches long.

The white bass is often called a "striped bass." It ranges from southern Minnesota eastward through the Great Lakes region to New York and southward to Kansas and Tennessee. It is absent from the Lake Superior drainage. It is common in the St. Croix River, the Minnesota River including Big Stone Lake, and in the Mississippi River from St. Paul southward, and also in many southern Minnesota lakes. Greene (1935) reported it from many localities in the Lake Michigan and Mississippi drainages of southern Wisconsin. It is an excellent game fish; it rises to a fly and bites on minnows. This species feeds on insects and small fishes. It is not a nest builder. It migrates upstream in the spring to spawn in shallow waters and takes no care of the eggs or young. It is probably a great traveler. In the December 1921 issue of *Fins, Feathers and Fur* there is a report of a fish of this species traveling downstream a distance of 140 miles. It was tagged in Lake Pepin in September and caught later at Clayton, Iowa.

GENUS *Morone* Mitchill

This genus contains several species, one of which lives in brackish waters of the Atlantic Coast and ascends streams. Another species in the Lower Mississippi drainage occurs as far north as southern Minnesota.

YELLOW BASS

Morone interrupta Gill

This fish has an oblong-ovate body with an elevated back. The dorsal fins are connected and contain 9 spines anteriorly and 1 spine and 12 rays in the posterior portion. The anal fin has 3 spines and 9 or 10 soft rays. There are 51 to 55 scales in the lateral line.

In general appearance this fish is very similar to the white bass, but the sides are more yellow or brassy and have about 7 very distinct black stripes. The stripes are offset, or broken, about midway on the body, thus giving rise to the specific name *interrupta*. This species can be distinguished from the white bass by the smaller number of anal rays. It reaches a length of about 15 inches.

The yellow bass ranges from southern Minnesota, Wisconsin, and Indiana southward to Texas and Louisiana. It is a southern fish and is rare in Minnesota and Wisconsin. Occasionally it is found in the Mississippi from Lake Pepin southward. Its feeding and spawning habits are similar to those of the white bass. It is reported to be an excellent game and food fish.

Family PERCIDAE

THE PERCH FAMILY

The perch family includes the perch, the walleye, the sauger, and numerous species of darters. The body is more or less elongated or elliptical. The lateral line is complete. The mouth may be either terminal or inferior. Teeth are present on the jaws and usually on the vomer and palatines; sharp pharyngeal teeth are present. The opercle ends in a flat spine. Seven branchiostegals are present. The gill-membranes are free from the isthmus; a slit occurs behind the fourth gill-arch; the gill-rakers are slender and toothed. The dorsal fin is completely divided, the anterior usually containing about 13 spines. The anal fin has 1 or 2 spines. The ventral fins are thoracic, with 1 spine and 5 soft rays. The larger species found in Minnesota consist of the common perch, the walleye, and the sauger. The darters, belonging to the subfamily *Etheostominae*, are all small and rather difficult to study. Members of the family Percidae occur in Europe, Asia, and North America.

Key to Common Species of Family PERCIDAE*

1. Six branchiostegal rays, tail not forked or weakly forked, pseudobranchiae rudimentary or lacking, small size 4
   Seven or rarely eight branchiostegal rays, tails forked, pseudobranchiae well developed, large size (except stunted perch) 2
2. Canine teeth (unusually long teeth) present on the jaws and palatine bones 3
   No canine teeth present, bars on sides ....
   ....Yellow Perch, *Perca flavescens* (Mitchill)
3. Rays of the soft dorsal fin about 20 (19–22); a large black blotch at the base of the last dorsal spines; no distinct black spot at the base of the pectoral fins; tip of lower lobe of caudal fin usually whitish; pyloric caeca usually 3.............Walleye, *Stizostedion vitreum vitreum* (Mitchill)
   Rays of soft dorsal fin 17 to 20; no distinct black blotch at the base of the last dorsal spines; a black spot at the base of the pectoral fins; tip of lower lobe of caudal fin not whitish; pyloric caeca usually 5 to 8................
   ....Eastern Sauger, *Stizostedion canadense canadense* (Smith)
4. Body very elongate, pencil-shaped; depth 7.8–9.0 in length; flesh pellucid in life; a single anal spine; scales of trunk confined to median sides..........
   ....Western Sand Darter, *Ammocrypta clara* (Jordan and Meek)
   Body less extremely elongate; depth 5.0–7.0; flesh opaque; 2 anal spines; squamation of body almost or quite complete........................5
5. Premaxillaries fused to preorbitals at the sides and overhung slightly by a very gibbous snout; color largely green in life.........................
   ....Northern Greenside Darter, *Etheostoma blennioides blennioides* (Rafinesque) ....
   Premaxillaries free from the preorbitals at the sides...................6

*Modified from Hubbs and Lagler (1941).

6. Premaxillaries distinctly protractile, even the midline separated by a deep groove from the snout..7
Premaxillaries scarcely protractile, bound down to the snout by a fleshy frenum, which, especially in *Imostoma,* may be crossed by a shallow groove when the mouth is tightly closed....................................9

7. Lateral line lacking on posterior part of body; dorsal fins widely separated; snout very blunt and rounded ....Bluntnose Darter, *Bolcosoma chlorosomum* (Hay)
Lateral line nearly or quite complete; dorsal fins little separated; snout more or less sharp *(Boleosoma nigrum)*..................................8

8. Nape, cheeks, and breast well scaled...................................... ....Scaly Johnny Darter, *Boleosoma nigrum eulepis* Hubbs and Greene
Nape, cheeks, and breast scaleless.. ....Central Johnny Darter, *Boleosoma nigrum nigrum* (Rafinesque)

9. Midline of belly with a definite single file of scales more or less enlarged, thickened, deciduous, and separated by a slight groove from the scales on either side; these scales may be only weakly specialized in *Imostoma* and sometimes little modified in females of other genera; one such scale between pelvic fins; pelvics separated by a space at least three-fourths as wide as base of either fin; anal fin usually almost as large as the second dorsal, sometimes even larger; body typically elongate and little compressed........10
Midline of belly without a median file of specialized scales; no specialized extra-spiny scale between pelvic fins; pelvics separated by a space less than three-fourths as wide as base of either fin; anal fin smaller in area than second dorsal fin; body typically deeper and more compressed.........14

10. Snout extended forward as a small conical protuberance beyond the upper lip; mouth horizontal; anal spines very flexible; scales 78–103 in lateral line; crossbars numerous and narrow... ....Northern Logperch, *Percina caprodes semifasciata* (De Kay)
Snout not extended beyond upper lip; mouth more or less oblique; anal spines stiff; scales fewer than 80; crossbars either broad or obsolete.....11

11. Belly largely scaleless medially, but crossed before anus by a bridge of scales; scales of midline only incipiently modified; premaxillary frenum usually hidden by a shallow furrow behind upper lip........................... ....River Darter, *Imostoma shumardi* (Girard)
Belly mostly scaled and with the scales of the midline strongly modified, at least in males; premaxillary frenum usually not hidden by cross furrow..12

12. Gill-membranes united into a broad curve distinctly more distant from tip of snout than is the back of the eye; lateral blotches small; spinous dorsal with a submarginal orange band in life.................................... ....Slenderhead Darter, *Hadropterus phoxocephalus* (Nelson)
Gill-membranes not united, but meeting at a sharp angle and on the midline scarcely farther from tip of snout than is the back of the eye; lateral bars or blotches large; spinous dorsal without orange stripe..................13

13. Scales in lateral line 52–67; cheeks naked; bands broad, large, and squarish; color gilt in life....Gilt Darter, *Hadropterus evides* (Jordan and Copeland)
Scales in lateral line 65–85; cheeks at least partly scaled; bands narrower; not gilt in life.........Blackside Darter, *Hadropterus maculatus* (Girard)

14. Lateral line obsolete; dorsal spines usually 6; lower fins much produced and pointed in breeding males; adults seldom as long as 1 1/2 inches.......... ....Northern Least Darter, *Microperca microperca microperca*

(Jordan and Gilbert) ....
Lateral line at least partly developed; dorsal spines usually 8 or more; lower fins not greatly developed; adults usually over 1 1/2 inches long.......15

15. Conspicuously marked with longitudinal rows of spots or dashes; head completely scaleless; males not brightly colored; dorsal spines of breeding males ending with fleshy knobs ....
...........Striped Fantail Darter, *Catonotus flabellaris lineolatus* Agassiz
Not conspicuously marked with longitudinal rows; head partly sealed; males brightly colored; dorsal spine without knobs........................16

16. Gill-membranes very broadly connected; color greenish in life............
..............Eastern Banded Darter, *Poecilichthys zonalis zonalis* Cope
Gill-membranes not broadly connected; not green....................17

17. Body rather slender; depth 5.4–6.8 in length; soft dorsal rays 9–11, occasionally 12...................Iowa Darter, *Poecilichthys exilis* (Girard)
Body rather deep; depth 4.5–5.4; soft dorsal rays 12–14...............18

18. Cheeks covered with ctenoid scales; scales 49–57 in lateral line...........
............Northern Mud Darter, *Poecilichthys jessiae asprigenis* Forbes
Cheeks scaleless or with a few embedded scales around the eye; scales 43–53 in lateral line..
.....Northern Rainbow Darter, *Poecilichthys caeruleus caeruleus* (Storer)

Subfamily PERCINAE

GENUS *Perca* Linnaeus

This genus contains but one species, which is common in northeastern North America.

YELLOW PERCH (Common Perch, Ringed Perch, Ah-sah-waince of the Red Lake Chippewas)
Perca flavescens (Mitchill)

The yellow perch (Figure 37) varies greatly in color. Usually the sides are golden yellow, with 6 to 8 broad, dark crossbars from the back to below the middle of the sides. The upper fins are dusky, the lower fins orange or bright red in males during the spawning season. This species reaches a length of 12 to 15 inches and a weight of about a pound. The mouth contains many small teeth but no large canine, or tearing, teeth. This last characteristic serves to distinguish the perch from the young walleye, the only fish it resembles.

Perch range through southern Canada south to Kansas, northern Missouri, Illinois, Indiana, and Ohio, and into Pennsylvania. They are present in the Atlantic drainage from Nova Scotia to South Carolina. They have been widely introduced elsewhere. Perch are generally abundant throughout Minnesota and neighboring states in lakes and large streams, but they are seldom found in small streams. In some of the smaller northern lakes perch occur in immense numbers, but in only a few lakes do they exceed a weight of one-half pound. They are

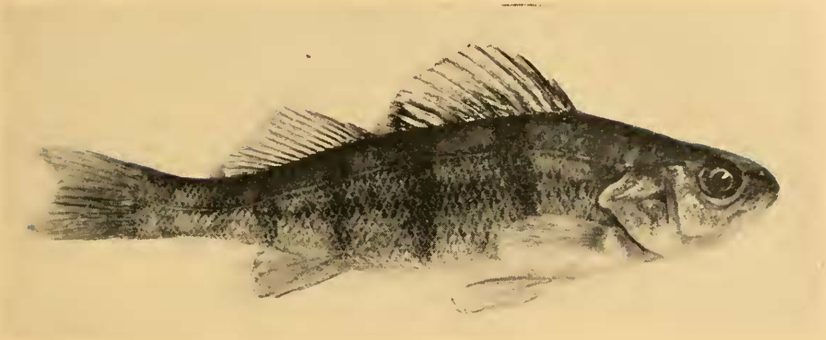


Figure 37. Yellow perch, *Perca flavescens*, 6 inches long.

wholly carnivorous and prefer a diet of minnows, but eat aquatic insects, the young of other fishes, crayfishes, and other animal matter as well. Their extreme voracity makes them a nuisance in many waters.

When free from parasites perch are excellent food fishes, but they are not very popular with anglers in most parts of Minnesota. Incredible numbers of them can be easily caught in most Minnesota and Wisconsin lakes. They bite readily on worms, minnows, and other baits, and are often termed "bait stealers." In some lakes they apparently compete with the more desirable game fishes to such an extent that such lakes have been termed "perch-bound." Where they are excessively abundant they are very small, probably because of crowded conditions. The competition for food in such cases retards growth. Cannibalism, which would be a welcome antidote for such a condition, does not occur because of the similarity in size of the individuals comprising the perch population. Undoubtedly perch are an obstacle in artificial stocking, for they may consume newly introduced fry as fast as they are placed in the lake.

Perch usually spawn early in May, though spent females have been found in central Minnesota lakes as early as the first part of April when the ice was just beginning to melt. The spawning season lasts from 2 to 4 weeks. When the water temperatures are between 45° and 50° F. the eggs are deposited in the water and settle in heavy, adhesive bands over sticks and water weeds on sandy bottoms. Spawning usually occurs at night. The spawn is deposited in hollow, ribbonlike bands several inches wide and plaited like the bellows of an accordion. These masses may be drawn out to a length of some feet. Smith (1907) stated that one fish in an aquarium at the Bureau of Fisheries in Washington, D.C., deposited a string 88 inches long, the weight of which after fertilization was 41 ounces, although the weight of the fish before discharging the eggs had been only 24 ounces. The relative heaviness of the fertilized eggs was obviously due to water absorbed through the egg membranes. The number of eggs produced in the ovaries varies from 10,000 to over 48,000, depending on the size and age of the fish.

This species is one of the very best of pan fishes. The flesh is white, firm, and of excellent flavor. As a game fish the yellow perch can be commended chiefly because of the fact that anybody can catch it. It can be taken with hook and line any month in the year and with any sort of bait — grasshoppers, angleworms, grubs, small minnows, pieces of mussel, or pieces of fish. It will even rise on occasion, and freely, too, to the artificial fly. In summer it is frequently heavily parasitized by several kinds of worms, which form cysts in the skin and muscles. These parasites, though harmless to man, have been a factor in making the perch unpopular in many localities.

Subfamily SANDRINAE

GENUS *Stizostedion* Rafinesque

This genus contains two species, both found in Minnesota and neighboring states. At least one subspecies, the blue pikeperch, *S. vitreum glaucum* Hubbs, occurs in the East.

EASTERN SAUGER (Sand Pike)
Stizostedion canadense canadense (Smith)

The eastern sauger (Figure 38) is a smaller and more slender fish than the walleye, or pikeperch, but otherwise its resemblance to the walleye is very strong indeed, so much so that when faded in color it

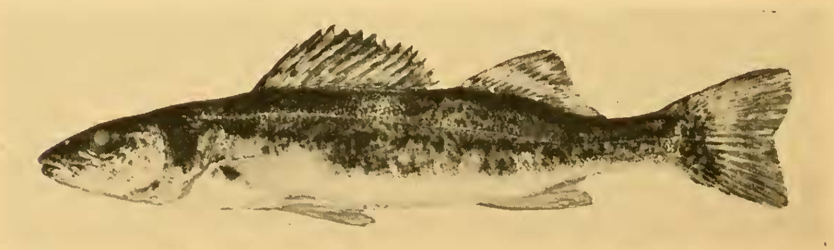


Figure 38. Eastern sauger, *Stizostedion canadense canadense,* 11 inches long.

is difficult to distinguish one from the other by casual examination. This similarity has virtually nullified the enforcement of the Minnesota law on the size limits of walleyes. Violators of this law when caught with undersized walleyes almost invariably claim they are saugers, and once the entrails have been removed it is difficult for any but an expert to determine the species. The fin rays in both species vary to such an extent that they too are of doubtful diagnostic value. Examples from the Mississippi and St. Croix rivers are sometimes similar to the walleye in color and even in markings, though more mottled.

In the walleye the pyloric caeca are 3 in number, subequal, and about as long as the stomach. In the sauger these appendages are 4 to 7 in number and unequal. But even here there is a variation, the walleye sometimes possessing 4 or 5 caeca, and saugers that otherwise appear typical may have a like number.

The usual color of the eastern sauger is grayish with brassy reflections and with dark mottlings on the sides. The absence of a black blotch on the last dorsal spine and the presence of a black spot at the base of each pectoral fin help to distinguish it from the walleye The length of this species averages about 12 to 14 inches, but may reach 18 inches.

The sauger is found from southern Canada southward to Arkansas, northern Alabama, and West Virginia. It is not common in Wisconsin; Greene (1935) reported it only from the Mississippi below Lake Pepin. It has been reported from the Lake Michigan drainage, where it may be present as a result of introduction. Greene believes its scarcity in Wisconsin is due partly to the competition of its very common near relative, the walleye. The distribution of this fish in Minnesota is rather spotted and indicates its preference for large, clean streams and lakes. Cox (1897) reported it from the Mississippi and its tributaries above St. Anthony Falls. However, it seems rather odd that, of more than a hundred thousand *Stizostedion* handled over a period of ten years at the Wolf Lake spawning station on the Mississippi near Bemidji, Minnesota, not a single example of this species was noted. Cox reported it also from Big Gull Lake and a tributary stream. It is more or less common in the Mississippi from Hastings southward, in the Minnesota River, and in the St. Croix River and even in its tributaries in Pine County, Minnesota. Evermann and Latimer (1910) reported it as not common in the Rainy River. It is very abundant in Lake of the Woods and Lake Kabetogama.

The catch of saugers in the commercial fisheries at Lake of the Woods is combined with that of walleyes, and all are sold as yellow pike. The sauger is an excellent food fish and is valued highly by sportsmen in the several places where it is at all abundant. It feeds almost exclusively on aquatic insects and small fishes. Very little is known about its spawning habits, but they are probably the same as those of the walleye.

WALLEYE (Yellow Pikeperch, Yellow Pike, called Pickerel in Ontario, O-gah of the Red Lake Chippewas)
Stizostedion vitreum vitreum (Mitchill)

The walleye (Figure 39), commonly called walleyed pike in Minnesota, pickerel in Canada, and pikeperch in the eastern states, varies

Figure 39. Walleye, *Stizostedion vitreum vitreum,* 16 inches long.

considerably in color. It ranges from a dark silver to a dark olive brown mottled with brassy specks. Those of the brown waters of the northern lakes are the darkest in color. A large black spot is always present at the base of the last dorsal spine, though it may fade in dead walleyes. The lower lobe of the tail, or caudal, fin has a wide white margin. The jaws contain large canine, or tearing, teeth.

The walleye is found from southern Canada to southern Alabama and Georgia. It ranges south on the Atlantic Coast to North Carolina (Hubbs and Lagler, 1941). It has been widely introduced elsewhere. It is primarily a fish that thrives best where it has a wide range, and consequently seems most at home in lakes several miles or more in length. It is a fish of clean, cold lakes and clear rivers, and retires to deep water during the hotter months of the year. The walleye is a great traveler. Tagged individuals have been caught within a few months from 70 to 100 miles away from where they were tagged. A subspecies, the blue pikeperch, *Stizostedion vitreum glaucum* Hubbs, is found in Lake Erie.

The walleye is widely distributed over Wisconsin (Greene, 1935) and the larger streams of the Dakotas. In Minnesota this abundant and valuable food and game fish has never occurred anywhere in the Lake Superior drainage except in the St. Louis River system and in Lake Superior itself. However, it has pushed up through the chain of lakes drained by tributaries of Rainy River, which is in the Hudson Bay drainage, and through such chains as the Kawishiwi to within a hundred yards of the watershed separating the Hudson Bay basin from that of Lake Superior. For instance, it has occurred in numbers in Harriet Lake at the extreme head of Island River, which is in the Hudson Bay drainage, whereas a stone's throw away in Sister Lake of the Lake Superior drainage it was unknown until introduced. It originally occurred in streams and lakes in every part of Minnesota with the exception of a limited area in the southern part of Lake County and the southern and eastern parts of Cook County. In the larger lakes it is still abundant, particularly in lakes around the headwaters of the Mississippi. It is one of the most abundant fishes in Red Lake, and with the possible exception of tullibee and sauger the walleye is still the most abundant fish in Lake of the Woods. Some idea of its abundance in Rainy Lake can be gained from the results of the egg-gathering operations in Rat Root River carried on by the Minnesota Division of Game and Fish. Rat Root River is only one of many tributaries of Rainy Lake up which these fish migrate each spring to spawn. The catch in a single night with a single pound net has been as high as 36,000 fully adult fishes, with some of the females weighing as high as 12 to 14 pounds. Pollution of the Lower Mississippi and almost all of the Minnesota River accounts for a gradual decrease in the number of walleyes in those streams. Thanks to remedial measures and the construction of dams raising the water to a permanent low level we can shortly expect an increase in the number of walleyes to something like the normal population of forty years ago.

Minnesota has been the leading state in the propagation of walleyes. More than 825 lakes are stocked annually with fry of this species by the Minnesota Department of Conservation. The annual output fluctuates, but in favorable seasons the fry reaches the enormous number of approximately three quarters of a billion. Phenomenal success attended the introduction of fry of this species into a number of Cook County lakes that by reason of their comparative shallowness were unsuitable for lake trout and contained no other game fishes except northern pike. One of these, Brule Lake, has an area of over 4000 acres; yet three years after the initial stocking with walleye fry it was possible to catch the legal limit in any part of the lake. Although there are no tributary streams entering the lake up which the walleyes may run to spawn, they are reproducing in large numbers. The stocking of walleye fry at Brule Lake is only one example of many similar successful introductions. It is believed that at present more walleyes exist in Minnesota waters than at any previous time; for though walleyes have become scarce in many southern lakes because of adverse conditions prevailing over a period of years, this deficiency has been compensated for by the extension of their range into many lakes in which they did not formerly exist.

The walleye may reach a length of over 3 feet and a weight ranging from 15 to 18 pounds. However, weights over 10 pounds are rare. The average fish caught by the angler usually ranges from 1 to 4 pounds and is from 3 to 5 years old (Eddy and Carlander, 1939). The larger lakes, such as Mille Lacs, Cass Lake, Leech Lake, Lake Vermilion, and Lake Winnibigoshish, are ideal for this species. Some of these lakes have long been somewhat overfished, with the result that there is now a scarcity of large walleyes and an abundant supply of small ones weighing from 1 to 2 pounds. Walleyes are no longer taken commercially in inland waters, except in Red Lake, where the Indians make a livelihood principally from this fish. In international waters the principal commercial sources of supply are still Lake of the Woods and Rainy Lake.

With anglers this species is one of the most popular fishes in Minnesota. It is a fish of clear, cold lakes and clean rivers and a clean feeder, with flesh of the finest quality, and it is no wonder that it has long been the favorite of epicures. It can be truthfully asserted that in Minnesota it is everyman's fish, because rich and poor alike find it available. During the hotter months it retires into deep water and may be somewhat more difficult to catch on the usual tackle. During May and June, and again in September, October, and even November, it provides more sport to the average angler than all other species combined, with the exception of the crappie and sunfishes. It may be caught either by still-fishing with live minnows for bait or by trolling and casting with live minnows, artificial minnows, or spinners.

The walleye spawns shortly after the ice melts. The spawning run starts when water temperatures range from 38° to 44° F. The spawning season is apparently determined by the temperature of the water and may come early in April or, if the season is cold, may be delayed until the first part of May. During the spawning season great numbers of walleyes migrate up tributary streams, where the eggs are usually deposited in riffles. The adults usually stay in the headwaters from three to six weeks after spawning, and then return to the main body of water. However, large numbers of walleyes do not leave the lake, but deposit their eggs on gravel reefs in the shallow waters of the lake (Stoudt and Eddy, 1939).

On the spring run to the spawning grounds the males usually precede the females by a few days. The reverse is true toward the close of the run. It is sometimes difficult to determine the sex of walleyes less than 13 to 14 inches long, even at the spawning season. Consequently many erroneous estimates of the relative numbers of males and females have been given. The length of the males rarely exceeds 15 inches, but the females are uniformly larger, and ripe ones usually exceed the male's maximum by several inches. A large female weighing 12 pounds, taken on the Upper Mississippi above Wolf Lake in 1918, produced 388,000 eggs, from which 270,000 fry were hatched. This fish was taken in several successive seasons and became locally famous as "Old Silver Spot." Careful records kept at the Bemidji spawning station indicate, on the basis of several thousand records, that the average production of eggs per female is 49,614. However, it must be noted that this figure does not represent the total number of eggs that might be deposited under natural conditions over a period of several hours or days, for no efforts were made to take all the eggs; only those flowing freely were taken. Average counts of the eggs in the ovaries indicate that there are about

26,000 eggs per pound of fish. The individual variation is high, the number in 3- to 3 1/2-pound females varying from 72,000 to 110,000.

The proportion of males to females varies little from season to season. At the Bemidji station it was found that during the course of a season's run, which usually covers a period of two to three weeks, depending on weather conditions, the proportion of males to females was on the average two males to one female. This finding agrees with the records kept at other stations.

Even in nature the production of walleyes is not economical. An enormous quantity of natural food is required to produce a pound of this strictly carnivorous fish. Forbes and Richardson (1908) estimated that, reckoning the average life of a walleye at three years, the smallest reasonable estimate of food for each one would fall somewhere between 1800 and 3000 fishes, and this estimate is probably conservative. Adult walleyes kept in the aquaria at the University of Minnesota will eat from 10 to 20 small fish a day. During the winter the walleye, like the perch, remains active and continues to feed. Consequently it is readily caught through the ice during the winter months. It bites less readily during the last half of February and usually ceases to bite in March as the spawning season approaches.

Subfamily ETHEOSTOMINAE

THE DARTERS

The darters comprise a variety of forms difficult to identify unless thoroughly studied. All darters are American fishes, and they are found only east of the Rockies. They differ distinctly from other members of the family Percidae and have therefore sometimes been placed in a separate family called Etheostomidae. They are differentiated from the other Percidae by their small size, unforked or weakly forked caudal fin, usually 6 branchiostegal rays, and slightly developed pseudobranchiae (false gills on the under side of the opercle), and by the character of the serrations on the opercles, which are very slight if present at all. They are all small, perchlike fishes of slender form with fins, particularly the pectorals, highly developed. The colors of the males during the spawning season are the most brilliant found in any of our fresh-water fishes. This brilliant coloring and the unusual habits of the darters make them by far the most interesting small fishes we have.

Many years ago Jordan (1888) wrote of the darters: "Any one who has ever been a boy and can remember back to the days of tag-alders, yellow cowslips, and an angleworm on a pin-hook, will recall an experience like this: You tried some time to put your finger on a little fish that was lying, apparently asleep, on the bottom of the stream, half hidden under a stone or a leaf, his tail bent around the stone as if for support against the force of the current. You will remember that when your finger came near the spot where he was lying, the bent tail was straightened, and you saw the fish again resting, head upstream, a few feet away, leaving you puzzled to know whether you had seen the movement or not. You were trying to catch a Johnny Darter. Nothing seems easier, but you did not do it."

The largest darters reach a length of 8 inches, but the average is about 2 1/2 inches. Most of the species usually prefer clear running water, where they rest on the bottom among the stones. When frightened or hungry they dart swiftly for a short distance, coming to rest suddenly on their large pectoral fins. As they rarely leave the bottom when resting they are never seen suspended in the water. A few species seek a sand bottom, where they lie buried with only the eyes visible. Darters feed chiefly on Entomostraca and the larvae of insects.

Upon the origin of the group as a whole Forbes (1884, quoted from Jordan, 1904) wrote: "Given a supply of certain kinds of food nearly inaccessible to the ordinary fish, it is to be expected that some fishes will become especially fitted for its utilization. Thus *Etheostoma* is to be explained by the hypothesis of the progressive adaptation of the young of certain *Percinae* to a peculiar place of refuge and a peculiarly situated food supply. These are the mountaineers among fishes. Forced from the populous and fertile valleys of the river beds and lake bottoms, they have taken refuge from their enemies in the rocky highlands, where the free waters play in ceaseless torrents, and there they have wrested from stubborn nature a meagre living. Although diminished in size by their constant struggle with the elements, they have developed an activity and hardihood, a vigor of life and a glow of high color, almost unknown among the easier livers of the lower lands. Notwithstanding their trivial size, they do not seem to be dwarfed so much as concentrated fishes."

GENUS *Imostoma* Jordan

RIVER DARTER

Imostoma shumardi (Girard)

The body of the river darter (Figure 40A) is robust, the head broad and thick, and the mouth large. The scales number 6–56–11. The cheeks, opercles, and nape are scaly; the breast is naked. The dorsal spines number 10 and the soft dorsal rays 15. The anal spines number 2 and the soft rays 11. The color and markings are dark olive blotched with even darker olive; the sides have 8 to 10 vague bars. The river darter may be readily identified by the black spots between the first and second spines and between the last three spines in the first dorsal fin. The fins are barred; the suborbital stripe is large and black. The river darter reaches a length of 3 inches.

This species ranges from southern Manitoba and western Ontario to Ohio and southward to eastern Oklahoma and northern Alabama. In Minnesota it is apparently restricted to the larger rivers over most of the state. Greene (1935) reported it from Lake St. Croix and various points along the Mississippi and from several of the large tributaries of the Mississippi in Wisconsin. Hankinson (1929) reported it from the Red River drainage. It is one of the most common darters in Lake of the Woods. Hubbs (1928) demonstrated that *Alvordius guntheri* (Eigenmann and Eigenmann) is a synonym of this species.

GENUS *Hadropterus* Agassiz

BLACKSIDE DARTER

Hadropterus maculatus (Girard)

The body of the blackside darter is fusiform and rather elongate. The head is not very slender; the muzzle is moderate; the maxillary reaches just past the front of the eye. The scales number 9–56–17. The cheeks are usually covered with small scales; the nape may be scaly or not; the breast is naked. The dorsal spines number 13–15 and the soft dorsal rays 12; the anal spines number 2, the rays 9. The color and markings are greenish yellow with dark, more or less confluent blotches along the side; the fins are barred. A small black spot is present at the base of the caudal fin. The blackside darter reaches a length of 3 to 4 inches.

The blackside darter ranges from southern Manitoba into New York and southward to Oklahoma and Alabama. It is rather common in southern Minnesota streams but is rare northward. It has been found in the Sturgeon and Red Lake rivers but does not occur in the collections from the Mississippi above St. Anthony Falls. It has been found in Minnesota in small streams in Rock County, in the Mississippi at Winona, and in the Cannon River. Greene (1935) reported it as common over most of Wisconsin and absent only from the Lake Superior drainage. Although present in lakes it is essentially a stream fish.

SLENDERHEAD DARTER

Hadropterus phoxocephalus (Nelson)

The body of the slenderhead darter is thin and elongate. This darter has a very slender head and a long acuminate snout. The jaws are subequal; the mouth is large; the maxillary reaches the eye. The scales number 12–68–12. The nape is scaly and the breast naked. The dorsal spines number 12, the soft rays 13. The anal fin has 2 spines and 9 soft rays. The color and markings are yellowish brown. The lateral spots

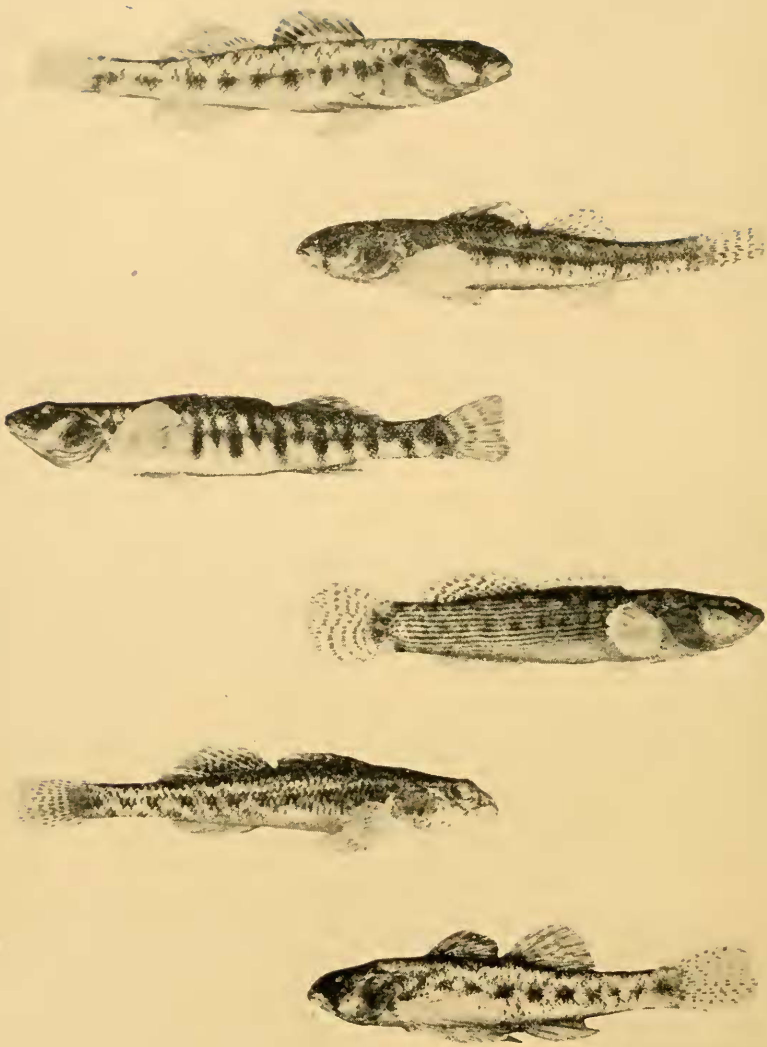


Figure 40. A. River darter, *Imostoma shumardi.* B. Iowa darter, *Poecilichthys exilis.* C. Northern logperch, *Percina caprodes semifasciata.* D. Striped fantail, *Catonotus flabellaris lineolatus.* E. Scaly Johnny darter, *Boleosoma nigrum eulepis.* F. Northern least darter, *Microperca microperca microperca.*

are smaller and more numerous than in *Hadropterus maculatus* and are quadrate in form. There is a small dark spot on each end of the lateral line. This species reaches a length of 3 to 4 inches.

The slenderhead darter ranges from Iowa and eastern Minnesota to western Pennsylvania, and southward to Oklahoma and Tennessee. It is rare in Minnesota and is apparently confined to the Mississippi drainage in the eastern limits of the state. Greene (1935) reported it from the upper St. Croix River, from the Mississippi below Lake Pepin, and from several large tributaries of the Mississippi and of Lake Michigan in Wisconsin. Forbes and Richardson (1908) state that they found this darter most abundant in smaller rivers and creeks, but only rarely in large rivers and lakes. They found females greatly distended with eggs in June. This darter prefers swift water with bottoms of sand and gravel.

GILT DARTER
Hadropterus evides (Jordan and Copeland)

The body of the gilt darter is stout and compressed. The heavy head is blunt forward, with a small mouth; the maxillary reaches the eye, which is large. The scales number 9–65–9. The cheeks, nape, and breast are naked. The dorsal fin has 11 spines and 11 soft rays, the anal fin 2 spines and 8 rays. The color and markings are dark olive and the markings are tessellated above. The back has 7 broad transverse bars extending below the lateral line. These bars in the male are deep blue green, the interspaces are yellow with copper-red blotches. The throat, cheeks, upper fins, and the two spots at the base of the caudal fin are orange; the anal and ventral fins are blue black. This species reaches a length of 3 inches.

The gilt darter ranges from southern Minnesota to New York and southward to Oklahoma and Tennessee. It is absent from most of the Great Lakes drainage. Greene (1935) reported the gilt darter from the St. Croix River both above and below the St. Croix Falls and stated that it appears to be rather rare in Wisconsin. It prefers swift streams.

GENUS *Percina* Haldeman

NORTHERN LOGPERCH (Zebra Fish, Manitou Darter)
Percina caprodes semifasciata (De Kay)

The body of the northern logperch (Figure 40C) is elongate. The head is broad between the eyes and has a piglike snout projecting beyond the inferior mouth. The scales are small; there are about 92 in the lateral line. They number 9–11, 83–93, 12–14. The cheeks and opercles are scaly; the breast is naked. The dorsal fin has 15 spines and 15 soft rays. The anal fin has 2 spines and 9 soft rays. The color and markings are yellowish green, with about 15 dark crossbands alternating with fainter and shorter bands. There is a black spot at the base of the caudal fin. The fins are barred. This species reaches a length of 6 to 8 inches.

The northern logperch, the largest and one of the most common of the darters, ranges from Minnesota to Vermont and intergrades southeastward with *Percina caprodes caprodes* (Rafinesque) and with *Percina caprodes carbonaria* (Baird and Girard); Greene (1935) reported such intergrading in southeastern Wisconsin. The logperch is widely distributed in the lakes and larger streams of Minnesota and Wisconsin.

The larger logperch may be taken by hook-and-line fishermen when they are fishing for perch and sunfishes, and when fried is just as desirable a food fish. It is sometimes used as a bait minnow; the 3- or 4-inch logperch is a very desirable bait for pike.

The food of small logperch, like that of the other darters, consists principally of Entomostraca and the amphipod crustacea *Hyalella;* this diet is augmented as the fish increases in size by insect larvae, principally Chironomids. In certain specimens from Big Sandy Lake, Kidd (1927) found the food to consist largely of algae, and no doubt algae often supplement the animal food of this species.

GENUS *Ammocrypta* Jordan

WESTERN SAND DARTER

Ammocrypta clara (Jordan and Meek)

The body of the sand darter is subterete and extremely long. The lateral line is complete. The head is long and pointed and the eye large. The scales number 6–75–10. The cheeks and opercles are scaly, the nape is thinly scaled, and the belly is mostly naked. The dorsal fin has 10 spines and 10 soft rays, the anal fin 1 spine and 8 soft rays. The color and markings are translucent and finely dotted above; there is a series of small, square, olive blotches along the back and another along the lateral line; the latter series is connected by a gilt band; the fins are pale. This species reaches a length of 2 1/2 inches. It has the habit of burying itself in the sand by a sudden plunge, leaving only the eyes visible.

The western sand darter ranges from Minnesota and Wisconsin southward. In Minnesota it is apparently restricted to the clear, sandy-bottomed streams of the southern part of the state and to the clean, sandy lakes of the central counties as far north as Aitkin and Itasca counties. Greene (1935) reported that the areas it selects for its habitat seem to be barren of other fishes. Hubbs in a recent letter states that the darter formerly called *Ammocrypta pellucida* consists of three species, and that the true *A. pellucida* is found in the Great Lakes and

Ohio River drainages and *A. clara* in the Mississippi River system from Minnesota southward.

Specimens of the sand darter taken in Big Sandy Lake, Minnesota appeared to be living to a great extent on small insects and crustacea, chiefly Chironomid larvae, *Corixa*, and *Hyalella* (Kidd, 1927).

GENUS *Boleosoma* De Kay

CENTRAL JOHNNY DARTER

Boleosoma nigrum nigrum (Rafinesque)

The body of the central Johnny darter is slender and fusiform. The lateral line is often incomplete behind. The head is long, with a decurved snout and a small mouth. The scales number 5–50–9. The cheeks are nearly always naked; the breast is naked; the opercles are scaly. The dorsal fin has 9 spines and 12 soft rays, the anal fin 1 spine and 8 soft rays. The color and markings are usually pale olive, but sometimes the markings are entirely black; the back is speckled with brown; the sides are covered with numerous W-shaped blotches. The Johnny darter reaches a length of 2 1/2 inches.

This darter ranges from Saskatchewan to western Quebec and southward west of the Alleghenies to Oklahoma and Virginia. It is more common in and more widely distributed over Minnesota than any of the other darters. It occurs in both lakes and streams. There are specimens in the University of Minnesota collections from over 125 localities. Greene (1935) reported it as widely distributed over Wisconsin.

Midge larvae, *Hyalella*, and Entomostraca, with a considerable percentage of algae, constitute the principal food of this species.

SCALY JOHNNY DARTER

Boleosoma nigrum eulepis Hubbs and Greene

The scaly Johnny darter (Figure 40E) differs from the typical form principally in having the breast, nape, and cheeks fully scaled. Hubbs and Lagler (1941) reported this subspecies as occurring in glacial lake districts of portions of Minnesota, Iowa, Wisconsin, and northern Illinois; eastward through the Great Lakes basin, but only in and about the base-level lakes marginal to Lake Michigan in Wisconsin, Indiana, and both peninsulas of Michigan, in Lake St. Clair and the Detroit River, and in the bays and around the islands of Lake Erie in Ontario, Ohio, and Pennsylvania. In Minnesota this subspecies has been found only in the northern part, mostly in glacial lakes. It is the subspecies found in the Lake Superior drainage. Many intergrades between this subspecies and *B. nigrum nigrum* occur in central and southern Minnesota.

BLUNTNOSE DARTER
Boleosoma chlorosomum (Hay)

This darter resembles the Johnny darter, but is completely scaled and much smaller. The head is much more blunt. The dorsal fin usually has 9 (8–10) spines and 10 (10–11) soft rays. The scales number 6, 52–60, 6–7 (7–10). The cheeks, opercles, and breast are fully scaled. The nape has a median naked strip and the belly is covered with ordinary scales. The lateral line is lacking posteriorly.

This darter ranges from Indiana to southern Minnesota and south to the Alabama River system of Alabama and to Texas. A few specimens were collected by Dr. R. E. Johnson of the Minnesota Department of Conservation from an overflow pool of the Root River, Houston County, Minnesota, on September 10, 1945. This darter was also collected by Dr. John Greenbank from a slough near the Mississippi River at the Iowa-Minnesota line. These are the northernmost records known for this species.

GENUS *Poecilichthys* Agassiz

EASTERN BANDED DARTER (Belted Darter)
Poecilichthys zonalis zonalis Cope

The body of the banded darter is slender. The head is small and short, the snout obtusely decurved. The scales are 6, 43–59, 12. The cheeks and opercles are scaly; the breast is scaly or naked. The dorsal fin has 11 spines and 12 soft rays, the anal fin 2 spines and 7 soft rays. The color and markings are olivaceous, with six brown, quadrate spots on the back connected by alternating spots with a broad, brown lateral band, from which eight narrow, dark bluish bands nearly or completely encircle the belly. The pectoral, anal, and caudal fins are golden, speckled with brown; the middle half of the first dorsal is crimson; the base of the second dorsal has round red spots; there is a black spot on the opercle and one at the base of the caudal. The female is duller in color than the male. This darter reaches a length of 2 1/2 inches.

The banded darter ranges from Minnesota to western New York and southward to Arkansas and Alabama. It is probably rare in Minnesota. It was reported from the Blue Earth River at Mankato (Cox, 1897), and there is one specimen in the University of Minnesota collections from the Mississippi at Red Wing. This darter was collected in 1945 from the Root River by Dr. R. E. Johnson of the Minnesota Department of Conservation. Greene (1935) reported it to be common in the Mississippi and Lake Michigan drainages in Wisconsin but absent from the Lake Superior drainage. It prefers swift streams with rock or sand bottoms.

NORTHERN MUD DARTER

Poecilichthys jessiae asprigenis Forbes

The body of the northern mud darter is fusiform, rather stout, and compressed. The head is moderately pointed, with a terminal mouth. The scales number 6–47–7. The cheeks and opercles are more or less scaly. The dorsal fin has 12 spines and 12 soft rays, the anal fin 2 spines and 9 soft rays. The color and markings are brownish, with greenish crossbars or blotches; the sides are covered with dark-blue, quadrate crossbars; the fins are speckled with gold. This darter reaches a length of 2 1/2 inches.

The northern mud darter ranges from southern Minnesota and Wisconsin to Arkansas. Greene (1935) reported it from the St. Croix and Mississippi rivers and called attention to its preference for the muddy sloughs and river mouths near the Mississippi and its larger tributaries. It has been collected from Hay Creek near Red Wing, Minnesota.

NORTHERN RAINBOW DARTER (Blue Darter, Soldier Fish)

Poecilichthys caeruleus caeruleus (Storer)

The body of the rainbow darter is stout. The head and eye are large. The mouth is moderate; the lower jaw is the shorter; the maxillary reaches to the front of the orbit. The scales number 5–45–8. The cheeks, neck, and breast are usually naked; the opercles are scaly. The dorsal fin has 10 spines and 12 soft rays, the anal fin 2 spines and 7 soft rays. The color and markings of the male in the spawning season are olivaceous, blotched above with darker olive; the sides have about twelve oblique bars of indigo blue running downward and backward, with the interspaces a bright orange; the cheeks are blue; the breast is orange; the fins are chiefly orange and bright blue. The females are much duller in color. This species reaches a length of 2 1/2 inches.

The northern rainbow darter ranges from southern Minnesota and Wisconsin to southern Ontario and southward to Alabama and Arkansas. Wherever found this species shows a preference for clear spring brooks. In Minnesota it was observed in Shady and Bear creeks of the Root River system in September 1918. It was reported by Cox (1897) from the Blue Earth River and from ponds, presumably spring-fed quarry ponds, near the Minnesota River around Mankato. There are specimens in the University of Minnesota collections from the Mississippi near Red Wing (1938) and from Houston County (1945). Greene (1935) reported it from numerous localities in Wisconsin.

IOWA DARTER

Poecilichthys exilis (Girard)

The Iowa darter (Figure 40B) is similar to *P. jessiae* in size and form, but has reverse coloration. Its body is more slender than that of most other Minnesota darters. It is bright green, blotched with dark brown, and has about 11 reddish spots on the sides. The belly is greenish yellow to almost white and is overlaid between the base of the anal and pectoral fins with an orange band; there is a band before the eye and one below it. The upper half of the spinous dorsal fin, except the margin, is a brilliant orange, with a very dark edge. The scales number 5–59–9. The dorsal fin has 9 spines and 11 soft rays. The anal fin has 2 spines and 7 soft rays. This darter reaches a length of 2 inches. Spring males have exceedingly brilliant and beautiful coloration.

This species has been a difficult one to describe and delimit, for most of its characteristics are variable. In all the specimens examined by Carlander (1941), who has made a detailed study of this species, the cheek, opercles, and nape were completely scaled, but the breast was naked; the gill-membranes were slightly or not at all connected. In about half the Minnesota specimens studied the lateral line was almost straight; in other specimens there was considerable anterior arching. The number of scales in the lateral line varied from 49 to 69, a larger range than is reported elsewhere for this species.

In no case was the lateral line complete. Usually about half the scales were without pores. Dividing the number of pored scales, together with the unpored scales to the last pored scale, by the number of unpored scales gave a measure of the completeness of the lateral line. The frequency distribution of this measure was as follows:

Completeness of lateral line	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.6
Number of fishes	1	1	6	5	7	9	10	3	1	2	1	1

The dorsal fin had 7 to 10 spines, usually 9. The variation in this character was as follows: 7 spines in 3 fishes, 8 in 27, 9 in 62, and 10 in 12.

A general characteristic often used in separating this species from others is the number of soft rays in the dorsal fin. This species has 9 to 11, whereas others have 12 to 15. Some Minnesota specimens were found to have 12 rays; however, in counting these rays the last, a forked ray, was counted as one, though at times it was difficult to determine whether it was one forked ray or two separate rays. These Minnesota specimens with 12 rays were collected with other specimens having fewer rays, from which they were undistinguishable except for this difference. The Minnesota specimens had from 9 to 12 rays. There were 9 rays on 4 fishes, 10 on 33, 11 on 63, and 12 on 9.

This species ranges from Saskatchewan to Quebec and southward to Colorado, Iowa, Illinois, Indiana, and Ohio. The Iowa darter is very common throughout the lake region of Minnesota, from the Iowa line northward. It is found in Lake of the Woods and Lake Vermilion. It is commonly found in the weedy margins of lakes as well as streams. It is common in all parts of Wisconsin (Greene, 1935). Forbes and Richardson (1908) reported it as spawning in April and May.

GENUS *Catonotus* Agassiz

STRIPED FANTAIL DARTER

Catonotus flabellaris lineolatus Agassiz

The striped fantail darter (Figure 40D) has a rather heavy body with a long, pointed head and a projecting, prowlike lower jaw. It is dark brown, with a dusky spot on each scale, so arranged that the whole body seems covered with lengthwise stripes. The spines of the dorsal fin are very low, and in the male each of them ends in a little fleshy pad of a rusty-red color — the fish's only attempt at ornamentation. The dorsal fin has 8 spines and 12 to 14 soft rays, the anal fin 2 spines and 7 to 9 soft rays. The scales number 9, 40–65, 14. The head is naked. The gill-membranes are broadly connected. This species reaches a length of 2 1/2 inches.

Jordan (1888) referred to the fantail as the darter of darters, the hardiest, wiriest, wariest of them all, and the one most expert in catching other creatures. It is the one that most surely evades your clutch; you can catch a weasel when you can put your fingers on one of these. Jordan further stated that the fantail darter chooses the coldest and swiftest waters, where, as befits his form, he leads an active, predatory life and is the terror of water snails, caddis worms, and mosquito larvae.

The striped fantail darter ranges from northern Minnesota and Michigan to northern Arkansas and Oklahoma. Greene (1935) reported this species from all parts of Wisconsin except in the Lake Superior drainage. It is very common, and many have been collected from lakes and small streams of southern and central Minnesota.

GENUS *Microperca* Putnam

NORTHERN LEAST DARTER

Microperca microperca microperca (Jordan and Gilbert)

The body of the northern least darter (Figure 40F) is short, deep, and compressed. The lateral line is absent. The head is rather short and bluntly rounded, with a somewhat decurved snout. The pelvic fins are very large in the males. The scales number 34–39, 9. The dorsal fin has 6 or 7 spines and 10 soft rays, the anal fin 2 spines and 6 soft rays. The color and markings are olivaceous and much speckled with brown. There are many zigzag markings; the soft dorsal and caudal fins are barred; there is a dark spot on the shoulder. This darter reaches a length of 1 to 1 1/2 inches. It may be recognized by the absence of the lateral line.

The northern least darter ranges from Minnesota to southern Ontario and southward to Kentucky, Arkansas, and Oklahoma. It is the smallest darter and probably the smallest of our native fishes. Because of its small size it is probably often overlooked in collecting. It is said to prefer small brooks and ponds and usually lives in dense vegetation.

Cox (1897) considered it rather common in Minnesota in the streams and lakes of the Upper Mississippi and reported it from Pine Creek in Crow Wing County and from Grand Rapids. There are specimens in the University of Minnesota collections from Crow Wing County. Greene (1935) reported it from the St. Croix River above Taylors Falls and from all the major drainages in Wisconsin.

GENUS *Crystallaria* Jordan and Gilbert

CRYSTAL DARTER

Crystallaria asprella (Jordan)

This is a slender translucent darter with 3 or 4 saddle marks across the back. The cheeks may be naked or partly covered with thinly scattered scales. The opercles have a few pectinate scales on the upper portion. The nape is scaled but the throat, breast, and belly are naked except sometimes for part or all of the space in front of the ventral fins directly under the pelvic girdle. The dorsal fin has 7 to 8 spines and 13 to 15 soft rays. The dorsal spinous and soft portions are widely separated. The scales are 8–10, 89–97, 9–11 (12–16). It reaches a length of 3 to 4 inches.

This is a southern darter, ranging from Arkansas and Alabama into Indiana and Illinois. A few specimens of this species were collected by Dr. John Greenbank from the Wisconsin side of the Mississippi River below Winona on August 2, 1945. This is the most northern record known.

GENUS *Etheostoma* Rafinesque

NORTHERN GREENSIDE DARTER

Etheostoma blennioides blennioides Rafinesque

The body of the northern greenside darter is elongate and little compressed. The head is thick, with a very convex profile. The eyes are set high and close together. The mouth is small and inferior. The scales number 65–78. The cheeks, opercles, and neck are scaly; the breast is naked. The dorsal fin has 13 spines and 13 soft rays, the anal fin 2 spines and 8 soft rays. The color and markings are olive green, mottled above. On the sides there are eight double transverse bars, each pair forming a Y-shaped figure of a deep-green color. The sides are covered with orange dots; the fins are bluish green with orange-red markings. This darter reaches a length of 5 inches.

The northern greenside darter ranges from Illinois eastward into northern Michigan and southern Ontario, and southward into the northern Ohio drainage. It was tentatively identified in the field by Surber (1920) from the White Water River in Winona and Olmsted counties, Minnesota in September 1918. Its occurrence in Minnesota is doubtful, for Greene (1935) found it only in the southeastern part of Wisconsin. There are no specimens in the University of Minnesota collections.

Family CENTRARCHIDAE

THE SUNFISH FAMILY

The sunfish family is one of the most important families of game fishes, for it contains the sunfishes, the crappies, and the largemouth and smallmouth basses. About 24 species are known for this family. Ten species of the sunfish family, or Centrarchidae, are more or less common in Minnesota. These species are the rock bass, the warmouth, the largemouth bass, the smallmouth bass, two species of crappies, and five species of sunfishes. Numerous variations of the name "bass" have been applied to various members of this family, as well as to those of the family Serranidae.

The members of the sunfish family are characterized by having more or less deep, flattened bodies, with two dorsal fins in the middle of the back. These fins are confluent or joined together. The front, or anterior, fin is supported by 5 to 13 sharp spines; the hind, or posterior, fin is supported by soft rays. The ventral fins are thoracic and typically have 1 spine and 5 rays. The anal fin has 2 to 8 spines.

All the various species are considered more or less warm-water fishes and prefer fertile lakes of moderate temperatures with abundant vegetation growing on firm sand and mud bottoms. They are widely distributed from southern Canada to the Gulf of Mexico. More species occur in the southern than in the northern states. The members of this family are all native to North America, though some, such as the largemouth bass, have been introduced into Europe, South America, and elsewhere. Only one species, the Sacramento perch (*Archoplites interruptus*) of California, is native west of the Rockies.

All members of the family are nest builders. The males perform the important duties of building the nest and caring for the young. The male prepares the nest in shallow water by fanning out a depression on the bottom with his tail. He then hunts up a female, who lays eggs in the nest. After laying the eggs the female is often chased away by the male, who guards the eggs and watches over the young until they are able to look after themselves. In some cases one female may serve several males and may even spawn several times during the summer. The male is very pugnacious during the spawning season and will dart viciously at any fish or object approaching the nest.

Members of the sunfish family sometimes use the nests of other fishes that have finished spawning. In the case of sunfishes it has been reported that they may spawn again later in the season and use the same nest. In the northern states most of the species of the sunfish family with the exception of the crappies usually go into semihibernation during the winter and feed little or not at all. This reduction in food intake may be due partly to the low temperature of the water. Bass and various sunfishes kept in aquaria at the University of Minnesota also feed much less in winter when the temperature is lowered.

Sunfishes are the most widespread and abundant members of this family in the northern states. Five species of sunfishes are found more or less commonly in Minnesota: the bluegill, the pumpkinseed or common sunfish, the green sunfish, the longear sunfish, and the red or orange spotted sunfish. Numerous cases of hybridization between these species have been reported. They hybridize extensively in many Minnesota lakes. Often specimens that show characters of two species and lack the complete characters of either are found. All sunfishes are more or less brightly colored, and the males are especially so during the spawning season.

Key to Common Species of Family CENTRARCHIDAE

1. Dorsal fin about equal to anal in length............................2
   Dorsal fin much longer than the anal............................3

2. Length of dorsal fin much less than distance from origin of dorsal fin to eye; dorsal spines usually but not always 6............................ ....White Crappie, *Pomoxis annularis* Rafinesque
   Length of dorsal fin about equal to distance from origin of dorsal fin to eye; dorsal spines usually 7 or 8............................ ....Black Crappie, *Pomoxis nigro-maculatus* (LeSueur)

3. Scales large, 53 or fewer in lateral line; body short and deep, its depth usually more than two-fifths the length; dorsal fin not deeply notched between the spinous and soft-rayed portions; usually with a black spot on flap of the opercle............................4
   Scales small, 58 or more in lateral line; body rather long, the depth in the adult one-third the length; dorsal fin more or less deeply notched.......10

4. Anal spines usually 6......Rock Bass, *Ambloplites rupestris* (Rafinesque)
   Anal spines usually 3............................5

5. Teeth present on tongue ....Warmouth, *Chaenobryttus coronarius* (Bartram)
   Teeth absent from tongue 6

6. Pectoral fins short and rounded, about one-fourth standard length.....7
   Pectoral fins long and pointed, about one-third standard length........8

7. More than 44 scales in lateral line; gill-rakers long and slender; body stout ....Green Sunfish, *Lepomis cyanellus* Rafinesque
   Less than 40 scales in lateral line; gill-rakers short and knoblike; body deep.................Longear Sunfish, *Lepomis megalotis* (Rafinesque)

8. Gill-rakers short and knoblike; opercular bone stiff behind.............. ....Pumpkinseed, *Lepomis gibbosus* (Linnaeus)
   Gill-rakers long and slender; opercular bone flexible behind 9

9. Soft anal rays usually 10 to 12; distinct black blotch near base of last dorsal rays; size usually large ....Bluegill, *Lepomis macrochirus* Rafinesque
   Soft anal rays usually 7 to 9; no single black blotch near base of last dorsal rays; size small......Orangespot Sunfish, *Lepomis humilis* (Girard)

10. Maxillary bone in the adult not extending beyond the posterior margin of the eye; mouth of medium size; scales about 11–74–17, 15–18 rows of scales on cheek........Smallmouth Bass, *Micropterus dolomieu* Lacépède
Maxillary bone in the adult extending beyond the posterior margin of the eye; mouth large; scales about 7–68–16, 10 or 11 rows of scales on cheek; young with a black stripe along side, which becomes somewhat indistinct in large adults............Largemouth Bass, *Huro salmoides* (Lacépède)

NOTE: The five sunfishes described are known to hybridize with one another, so that many a sunfish caught in nature represents a hybrid. This key is based on pure-type characters and does not attempt to separate these hybrids.

GENUS *Micropterus* Lacépède

This genus includes four species (Hubbs and Bailey, 1940, 1944), only one of which is found in the latitude of Minnesota. The other three, including the spotted or Kentucky bass, *Micropterus punctulatus* (Rafinesque), are southern.

NORTHERN SMALLMOUTH BASS (River Bass)
Micropterus dolomieu dolomieu Lacépède

In the northern smallmouth bass (Figure 41B) the mouth is of moderate size, the maxillary not extending beyond the eye. The young are more or less barred or spotted and never have a black lateral band. In the young the caudal fin has a yellow or orange base, black center, and a white tip. The very young fry are jet black. The color of the adult varies above from a dark green flecked with gold to a pale olive brown; it is white below. The body is sometimes a uniform color, but often it is mottled with vermiculations of a darker olive green. This mottling is most often noted just after a smallmouth bass has been landed after putting up a brave fight. The eyes are more or less reddish. There are 15 to 18 rows of scales on the cheeks and 11 to 14 longitudinal series between the middorsal and the lateral line. The dorsal fin has 9 or 10 spines and 13 to 15 soft rays; the spinous portion is low. The anal fin has 3 spines, rarely 4 or 2, and 10 to 12 soft rays. The lateral line has 66 to 78 scales. The pyloric caeca on the intestine where it leaves the stomach are single, but are branched at their base in the largemouth. This species commonly reaches a length of 1 to 2 feet. Weights run up to about 7 pounds, though smallmouth bass weighing over 4 pounds are seldom caught.

It seems rather odd that in certain Minnesota lakes it is difficult to distinguish the adult smallmouth bass from the largemouth, though the young of the two species, until they are yearlings at least, are so radically different that they can be distinguished at a glance. Hybrids have never been reported.

The northern smallmouth bass ranges from the Lake of the Woods region to Quebec and southward to northern Alabama and eastern

Oklahoma. It has been introduced extensively elsewhere. It is widely distributed in Wisconsin. Originally the range of the smallmouth bass in Minnesota was virtually limited to the Mississippi drainage. It is extremely doubtful that it occurred in the Red River drainage except where introduced. It occurs with the largemouth bass in several lakes at the headwaters of the Ottertail River and also in the headwaters of the Mississippi. In the Mississippi the smallmouth bass is sometimes quite abundant above Minneapolis, but it is perhaps most abundant in the main river channel above and below Lake Pepin. It seldom occurs in the connected sloughs. It is still common in the Kettle River, where it is supplied largely by runs from the St. Croix River. It is found also in the Snake River and Lake Pokegama. It occurs more or less sporadically in tributaries of the Mississippi in the southeastern counties and more commonly in tributaries of the St. Croix. For many years Lake Miltona in Douglas County was probably one of the most noted smallmouth lakes in the United States, but in recent years intensive fishing has destroyed much of its reputation. Both the smallmouth and the largemouth bass are found in many other lakes in the same area, but less abundantly. The smallmouth bass now occurs in Lake of the Woods and in certain nearby small lakes north of the Canadian border. The writers are informed by H. H. Mackay of the Ontario Game and Fisheries Department that smallmouth bass are not native to Lake of the Woods. He states that in 1901 and thereafter smallmouth bass were planted in Long Lake, which is separated from Lake of the Woods by a small channel and dam. The dam was destroyed soon afterward, and the bass escaped into Lake of the Woods. Bass were planted also in other small lakes of that region.

Most of the repeated efforts made to extend the range of the smallmouth in Minnesota waters have had doubtful success, even when adult fishes were used. The records of stocking in the files of the Minnesota Game and Fish Department prior to 1920 offer little information about the distribution of the smallmouth, for the entries are as "black bass," with no separation into species. Since 1920 the records give the species and indicate that all attempts to stock the northern coffee-colored streams have failed. Attempts to stock clear-water lakes in the border counties, where all conditions appeared favorable, also usually ended in failure. In a few northern waters where smallmouth were successfully introduced and reproduced in large numbers, as in Bear Lake in Lake County, they never exceeded 6 inches in length, regardless of age. The habitat preference of smallmouth would therefore appear to be clear, moderately cold, swift-flowing streams and moderately sized, clear-water lakes with clean gravel bottoms.

Dr. Henshall (1891), whose writings did more than anything else to draw attention to the superb fighting qualities of this fish, said: "He is plucky, game, brave and unyielding to the last when hooked. He has the arrowy rush of the trout and the 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." In many of the clean, cold lakes of the central counties of Minnesota, where both species intermingle, it is doubtful whether the fighting ability and tactics of the two species can be distinguished.

The sites selected by the smallmouth bass as spawning grounds are invariably over clean gravel and sand bottoms where there is a decided current. The smallmouth spawns at about the same temperatures as the largemouth—that is, at 60° to 65° F. It is even more susceptible than the largemouth to sudden drops in temperature. Consequently eggs deposited early in the season are often killed, and in this event a second and even a third spawning occur, sometimes as late as August. Nests are usually placed a considerable distance apart, because the males do not tolerate nearby neighbors. In the care of the nest, the eggs, and the fry the male smallmouth shows an attention to duty even stricter than that manifested by the largemouth.

In pond culture operations a curious phenomenon has been repeatedly noted by Surber. Shortly after darkness has set in the fry spread out promiscuously over the spawning bed and assume a light-gray color which is retained until sunrise the following morning, when they resume the normal jet-black color of healthy fry. The same change occurs when the fry are being carried in cans for transplanting during a cold night. Whether it occurs as a result of temperature change, since the water is several degrees cooler at this time, or as a result of darkness has not been definitely determined.

For the most part the smallmouth frequents deeper waters than the largemouth, except when feeding. On the approach of winter smallmouth bass retire to the depths, where, under overhanging rocks and logs, they undoubtedly remain semidormant during the entire winter, for few are ever caught in winter. The bulk of their food consists of minnows, small suckers, and even small bullheads. During September they may be found feeding on crayfishes, which may form almost their exclusive food during the month of October. In most waters they indicate very little preference for frogs, which the largemouth prefers at certain seasons.

A 3-pound smallmouth bass kept at the University of Minnesota showed a natural appetite for mice from the janitor's traps. However, he would not touch a dead one unless it was moved. The young of both species of bass feed largely on *Daphnia* or water fleas during the first weeks of their existence. Then they are ready for aquatic insects and small fishes. If these are not abundant they will start feeding on one another. When not crowded young bass grow rapidly and may reach a length of 6 inches or more the first season. In the south they grow much more rapidly than in the north, and in rearing ponds where only a few

Figure 41. A. Largemouth bass, *Huro salmoides*, 9 inches long. B. Northern smallmouth bass, *Micropterus dolomieu dolomieu*, 14 inches long.

bass are produced they are much larger in size than they would be if more were produced.

Although both species of bass occur in both lakes and streams, the smallmouth bass is preeminently a fish of rivers of moderate size, whereas the largemouth is most at home in moderate sized lakes with weedy shores. The smallmouth also seems to flourish in moderately deep, boulder-lined lakes.

GENUS *Huro* Cuvier

This genus contains only one species, which was formerly included in the preceding genus, *Micropterus,* but was set apart in a separate genus by Hubbs (1926).

LARGEMOUTH BASS (Black Bass, Green Bass, Oswego Bass, Ah-she-gun of the Red Lake Chippewas) *Huro salmoides* (Lacépède)

The largemouth bass (Figure 41A) has suffered many name changes in the past twenty years. For many years it was called *Micropterus salmoides* (Lacépède); then it successively became *Aplites salmoides* (Lacépède), *Huro floridana* (LeSueur), and finally *Huro salmoides* (Lacépède).

The largemouth bass was originally found east of the Rockies from Canada southward to Florida and Mexico. It has been widely introduced elsewhere. In the northern states the largemouth reaches a weight of over 8 pounds; it reaches double this weight in the southern states. It differs from the smallmouth largely in the position of the angle of the jaw, which reaches back to below the hind margin of the eye, and in the number of scales on the cheek. It differs also in the absence of vertical bars and dark mottlings on the sides. A faint, dark, horizontal stripe may be present on the sides. In fingerlings and young this stripe is very distinct.

Environmental differences exert a powerful influence on the appearance of the largemouth bass. Those from clear-bottom lakes are a rather bright dark green on the sides and silvery below, and the broad, blackish band on the sides is almost as distinct as it is in the young. Adults from mud-bottom lakes may shade from dark olive brown to deep black, with the markings scarcely discernible, and the fry and very young are almost colorless.

The cheeks have about 10 or 11 rows of scales. There are 8 or 9 rows of scales above the lateral line. The scales of the lateral line number 62–68. The dorsal fin has 10 spines, occasionally 9, and 12 or 13 soft rays; the spinous portion is separated from the soft portion by a deep notch. The anal fin has 2 to 4, usually 3 spines and 10 to 12 soft rays.

Beyond any question the largemouth bass is one of the most popular game fishes in the central states, not because its fighting ability is superior to that of the smallmouth, but because of its wide distribution in lakes and the larger streams. In Minnesota it is, or was, common in the muddy lakes of the southern and central counties and in sloughs along the Mississippi. However, it is most abundant in the clear-water lakes, particularly around the headwaters of the Mississippi. It occurs also in many small, isolated lakes near the Canadian border, but how it got there no one knows. It is present in several lakes in the Quetico Provincial Park north of the Canadian border. It is found in only a few lakes in Lake and Cook counties, and in most of them it has been introduced.

In Minnesota fewer largemouth bass than crappies, sunfishes, walleyes, and northern pike are caught; but more largemouth bass than smallmouth bass or some species of trout are caught. Probably this situation is not due to any scarcity of bass but to the fact that most anglers do not fish for bass, though they are the favorite fish of a relatively few anglers, who sometimes seek them exclusively. Bass fishing requires a special technique. Largemouth usually feed in shallow, weedy waters. At certain times they will rise to a fly. Casting into weed beds with frogs, minnows, or plugs forms part of the favorite technique of many bass fishermen. Even after seizing the bait, bass often are not hooked because they will run some distance with it before swallowing it far enough for hooking. Skill is often required to hook and land a bass.

From a purely epicurean point of view, bass from mud-bottom lakes in some sections of Minnesota and Wisconsin are rather unpalatable, particularly in the early part of the fishing season, before they have been able to throw off the muddy taste acquired from the lake bottom during their partial hibernation. On the other hand, those taken from lakes with sand and gravel bottoms are entirely free from this disagreeable muddy flavor.

The spawning of bass is largely controlled by weather conditions. A sudden drop of but 10 or 12 degrees below the normal temperature for the spawning season, which is 60° to 65° F., is sufficient to kill the eggs or the newly hatched fry. Reighard (1906) made the same finding in Michigan. In Minnesota bass spawn any time between May and July when the water reaches 60° to 65° F. The prevailing winds at that time are usually from the south, but should there be a sudden shift to the northwest the temperature usually drops abruptly. As a rule spawning areas are found in more or less sheltered bays in waters 2 to 6 feet deep. If such areas happen to be located on the southern or southeastern side of a lake we can usually expect a severe loss of eggs or fry or both, for bass desert their nests in short order when the water reaches 48° F. Turbid waters may also disturb the spawning. A light deposit of silt on the eggs will cause bass to desert their nests. Such an event seldom happens in lakes, except in the immediate vicinity of cultivated lands, where the surface soil can be carried by heavy rains down steep slopes to the spawning grounds.

The largemouth bass do not always use the same care as the smallmouth in selecting nesting sites. Where good beds are available they follow much the same procedure as the smallmouth bass, but usually a mass of dead vegetation or an accumulation of roots will suffice. Such a nest is cleaned before the eggs are deposited. Depressions 2 to 3 feet in diameter and about 6 inches deep are fanned out by the tail of the male. The male removes small pebbles by carrying them away in his mouth.

Bass exercise the same care and courage in defending their nests against all enemies, fancied or real, as do the other members of the Centrarchidae. From the time the male bass clears off an area for the female to deposit the eggs until the eggs are hatched and the fry leave the nest, every object appearing in the vicinity, within a radius of at least 20 feet, is immediately attacked and driven off. The male even drives off other bass, except those of his own species performing similar duties, of which he apparently takes cognizance. Bass usually nest about 30 feet apart and seem to exercise territorial rights. They never nest in colonies as the sunfishes often do.

In pond culture operations Surber has tried time and again to induce the guarding males to take such food as minnows and frogs. They would immediately strike, but after chewing savagely on the minnow or frog for a few seconds they would eject it with considerable force. When a frog was taken it was carried some distance away before it was ejected, and immediately afterward the bass resumed his sentry duties. The newly hatched bass go in schools, which usually do not break up until the fry reach a length of an inch or more. Although at this stage the guardian parent does not defend them as vigorously as before, his attendance is manifested as a protector and is continued until the schools of young finally scatter.

Because of the popularity of the largemouth bass as a game fish and because of its ability to thrive under many conditions of environment and temperature not enjoyed by other fishes, there is a constant and ever-increasing demand on the fish hatcheries for largemouth fry for stocking ponds and lakes throughout the northern states. This demand far exceeds any hope of supply in the near future. The bass do not respond to artificial expression and fertilization of the eggs as do the walleye, perch, and trout, but have to be liberated in ponds and allowed to attend to their domestic affairs in their own way. Consequently the output of bass by the state fish hatcheries is limited to the amount of pond room available for this purpose. For the best results the adults should be removed as soon as nesting duties are over, for otherwise they may devour part of the young. If nestings boxes built like stalls are provided bass may be induced to nest close to one another in the ponds. In this way production may be increased. Artificial propagation by stripping is possible but has never been considered practicable. Several states have experimented with artificial propagation of bass, but it is not practiced extensively.

Counts of eggs in female largemouth bass show from 2000 to 26,000 eggs in the ovaries. A 3-pound female contained nearly 40,000 eggs. Needham (1938) reported that from 2000 to 7000 eggs are produced per pound of fish. Carbine (1939) in his investigations on Michigan lakes reported an average of 4000 fry per nest.

The adult largemouth bass eat a wide variety of food. Insects and small fishes, mostly minnows and perch, form a large part of their diet, and crayfishes and frogs also are found in their stomachs.

GENUS *Chaenobryttus* Gill

This genus contains one species, which ranges through the eastern United States south of the Great Lakes.

WARMOUTH (Warmouth Bass)
Chaenobryttus coronarius (Bartram)

The warmouth (Figure 42) resembles the rock bass and may easily be mistaken for it. It has a robust body of mottled olivaceous or gray color mixed with chocolate and purplish shades and sometimes flecked with gold or green. The belly is pale green or yellow speckled with dark dots or with gold. The cheek and opercle are streaked and have a short black opercular flap. The dorsal fin has 9 to 11 spines, usually 10, and 9 to 11 soft rays. The anal fin has 3 spines and 8 to 10 rays, whereas the rock bass has 6 anal spines. The scales are 6–7, 39–43, 11–12. This species reaches a length of 8 to 10 inches.

The warmouth is supposed to range as far west as the Dakotas and should occur in southern Minnesota, though only one record has been reported and there are no specimens in the University of Minnesota collections. A specimen collected in 1934 near Winona, Minnesota by the Minnesota Division of Game and Fish was kept in the pond at the St. Paul hatchery for several years. Greene (1935) reported it from several localities on the Mississippi in Wisconsin.

Forbes and Richardson (1908) described the warmouth as essentially a fish of lakes, ponds, and smaller rivers, but as sometimes occurring in creeks and large rivers; they describe it as preferring mud bottoms. The warmouth feeds largely on insects and small fishes. Although small, it is frequently caught with hook and line and utilized as a pan fish. It sometimes has a rather muddy flavor. Its spawning habits are the same as those of the sunfishes.

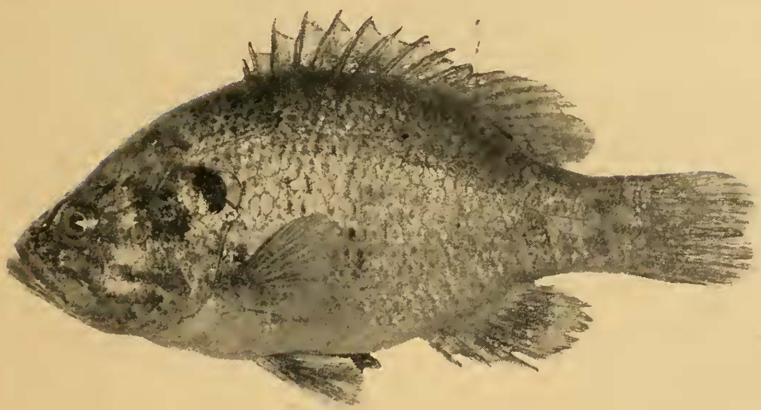


Figure 42. Warmouth, *Chaenobryttus coronarius,* 5 inches long.

GENUS *Lepomis* Rafinesque

This genus includes many of the sunfishes found in the central and eastern United States. They were formerly distributed in several genera but have recently been grouped into the single genus *Lepomis* by Bailey (1941). In Minnesota they are rare or absent from most of the Lake Superior drainage except where introduced.

GREEN SUNFISH

Lepomis cyanellus Rafinesque

The green sunfish (Figure 43) is rather dull in color. When it is just freshly removed from the water the sides and back are colored olive green and each scale is flecked with yellow. The body is rather robust, particularly in old specimens. This sunfish is not as deep-bodied as the pumpkinseed and the black opercular lobe is shorter. The mouth is large; the maxillary is one-fifth to one-fourth longer than the distance from the lower margin of the orbit to the lower posterior corner of the preopercle. The gill-rakers are long and slender. The dorsal fin has 9 or 10 spines and 10 to 12 soft rays. The spinous portion of the fin is less than one-half the height of the soft portion. The pectoral fins are short and rounded; their length is contained 4 times or more in the standard length of the body. The anal fin has 3 spines and 9 or 10 soft rays. There are more than 44 scales in the lateral line.

The green sunfish occurs from Colorado and South Dakota eastward to western New York and southward to Mexico and the Gulf States. It is found in certain lakes in all parts of Minnesota. Although widespread

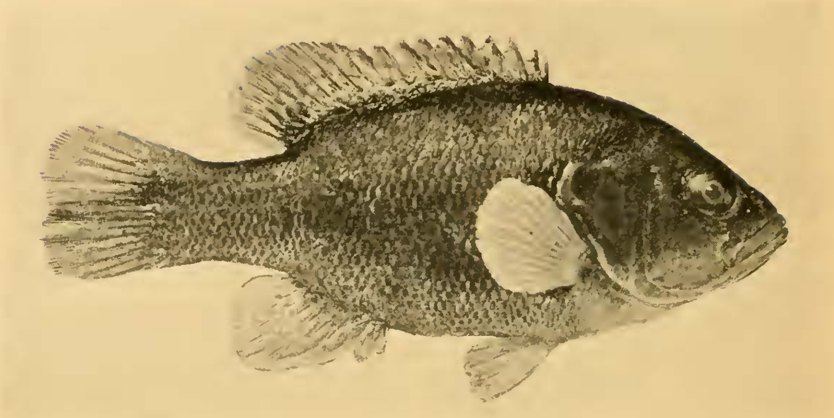


Figure 43. Green sunfish, *Lepomis cyanellus,* 4 inches long.

it is not always common and is absent from many lakes. It is common and sometimes very abundant in the shallow waters of many lakes near St. Paul and in many small streams of southern Minnesota. Greene (1935) reported it as common in southern Wisconsin.

In the northern states this sunfish is usually small; its length here seldom exceeds 4 or 5 inches. Consequently it has little value as a pan fish and may be regarded as a nuisance when it becomes abundant. In several lakes in northern Minnesota it is the only sunfish present and consequently is responsible for the reports that these lakes contain stunted sunfishes. Not much is known about its spawning habits in this state, but they are probably the same as those of the bluegill. It has often been mistaken for the bluegill because it has a black spot at the posterior base of the dorsal fin, which, however, is at the base and not above as in the bluegill. Many people have transplanted this fish to other lakes under the impression that it was the bluegill. In the transplanting of sunfishes care should be taken to avoid planting this species, for it seldom reaches desirable pan-fish size.

ORANGESPOT SUNFISH

Lepomis humilis (Girard)

This small, rather slender sunfish (Figure 44) may be recognized by the bright-orange spots scattered over the body. The opercular lobe has a pale margin and may be tinged with red or orange. Sometimes there are longitudinal orange bars on the cheek. The pectoral fins are long and pointed; their length is contained slightly more than 3 times in the standard length. The anal fin has 3 spines and 7 to 9 soft rays. The opercular bone is flexible posteriorly and extends to the middle of the

Figure 44. Orangespot sunfish, *Lepomis humilis,* 3 inches long.

opercular flap. The gill-rakers are long and slender. This species has little value as a pan fish because its length seldom exceeds 4 inches.

The orangespot sunfish is found from North Dakota and western Ohio southward to Texas and the Gulf States. This species has not been reported often from Minnesota. The writers have collected it from many small streams and lakes in southern and central Minnesota and from backwaters of the Mississippi south of St. Paul. It occurs also in the shallow waters of a few lakes south of Minneapolis. Little is known of its spawning habits in Minnesota. Greene (1935) reported it as occurring sparingly in the southwestern corner of Wisconsin, and possibly in the southeastern corner.

GREAT LAKES LONGEAR SUNFISH

Lepomis megalotis peltastes Cope

The Great Lakes longear is a small sunfish with a short, deep body colored with brilliant blue streaks and orange spots. The extremely long opercular flap is bordered with red. No black spots are present on either the dorsal or anal fin. The fins are orange with blue rays. The pectoral fin is short and rounded and is contained 4 times in the standard length. The gill-rakers are short and knoblike. The opercle is flexible posteriorly. The lateral line contains 39 scales or less. This sunfish reaches a length of about 6 inches.

This subspecies ranges from Minnesota into lower Ontario and western Pennsylvania, and intergrades southward with *L. megalotis megalotis.* Greene (1935) reported it only for eastern Wisconsin. The presence of this species in Minnesota is doubtful. The specimens referred to in the previous edition of this book have since proven to be other species. Dr. R. E. Johnson of the Minnesota Department of Conservation has since (1945) reported taking a single specimen of what seems to be this species from Little Rock Lake in Morrison County, Minnesota. Cox (1897) reported specimens from Big Stone Lake and from the Pomme de Terre River. If found in Minnesota, this species is not common and is restricted to the southern part. Because of its small size it is not an important pan fish.

PUMPKINSEED (Common Sunfish)
Lepomis gibbosus (Linnaeus)

The pumpkinseed (Figure 46A), or common sunfish, is characterized by a very deep, compressed body with a bright-orange belly. The back is usually raised or humped more than in the other sunfishes. An outstanding character distinguishing this species from the bluegill is the bright-orange spot on the long opercular lobe. The yellow bellies of the young aid in distinguishing them from young bluegills. The body may be covered with orange spots, and bars may be absent from the sides. Wavy bright-blue bars are sometimes present on the lower sides of the head. The mouth is small; the maxillary reaches only a little past the front of the orbit. The pectoral fins are long and pointed and are contained less than 3 times in the standard length. The dorsal fin has 10 spines and 11 or 12 soft rays. The opercular bones are not flexible posteriorly. The gill-rakers are short and stout.

The pumpkinseed is found from the Dakotas and southern Canada southward to the Gulf States. Greene (1935) reported it as widespread over Wisconsin except in the Superior drainage, from which he has but one record. It is almost as common in Minnesota as the bluegill. The pumpkinseed is found in most lakes and streams of the southern and central counties, but it is not as common in the northern areas and is absent from most of the rocky lakes of northeastern Minnesota. In many lakes it has apparently hybridized with the bluegill to such an extent that it is impossible to determine the species of many individuals. The pumpkinseed reaches almost the same size as the bluegill and has about the same value as a pan fish. Its spawning habits are the same as those of the bluegill, and both spawn at the same time.

COMMON BLUEGILL (Redbreasted Sunfish)
Lepomis macrochirus macrochirus Rafinesque

The bluegill (Figures 45, 46B) has had many changes of name during the past twenty years. For years it was called *Lepomis pallidus* (Mitchill). Then discoveries of priority led to the successive use of the names *Helioperca incisor* (Cuvier and Valenciennes), *Helioperca macrochira* (Rafinesque), and *Lepomis macrochirus* Rafinesque.

This sunfish has faint bars on the sides, which fade quickly after the fish is removed from the water. It may be distinguished by a black spot above the base of the posterior dorsal fin and by short, black opercular, or "ear," lobes on the gill covering. Some very old individuals have longer opercular lobes and a very vivid purplish hue. The lower sides of the head and the opercle are blue, sometimes bright blue. The bluegill is the largest of Minnesota sunfishes. It reaches a weight of well over a pound, and weights of 2 pounds have been reported. The mouth

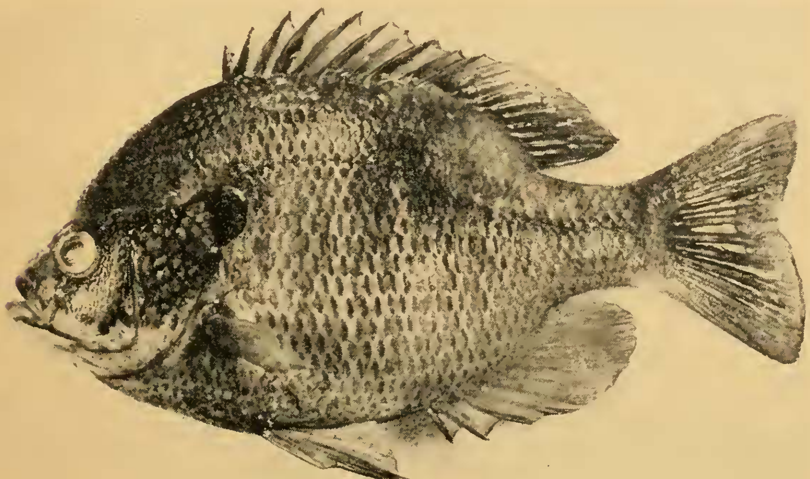


Figure 45. Common bluegill, *Lepomis macrochirus macrochirus*, an old male, 8 inches long.

is small; the maxillary barely reaches the front of the orbit. The dorsal fin has 10 rather long spines and 10 to 12 soft rays. The anal fin has 3 spines and 10 to 12 soft rays. The pectoral fins are long and pointed and are contained slightly more than 3 times in the standard length. The opercular bone is flexible posteriorly and extends almost to the margin of the opercular lobe. The gill-rakers are long and slender.

The bluegill is found from North Dakota through southern Canada and southward to the Gulf States. It is the most common and widely spread of all the sunfishes in Minnesota and neighboring states. It is common over most of Wisconsin and has been reported several times from the Lake Superior drainage (Greene, 1935). It is found in most lakes and streams of Minnesota, but is absent from some of the cold, rocky lakes and streams in the northeastern part. It is rare in or absent from most of the Minnesota area of the Lake Superior drainage.

It nests from the middle of May until the first of August. Bluegills frequently move about in schools. During the spawning season they usually have their nests close together or even side by side. Carbine (1939) reported finding as high as 51,000 eggs in a single bluegill nest in Michigan. At the University of Minnesota counts of eggs from the ovaries showed as many as 67,000 eggs in a single female. Twenty-seven females, weighing from 8 to 10 ounces, each contained from 15,000 to 58,000 eggs. It is probable that many nests contain eggs deposited by more than one female, and females have often been reported as spawning several times during the summer.

The bluegill is one of the most popular pan fishes, and it is not a bad game fish when it will rise to a fly. It is an excellent pan fish, for the meat is well flavored and relatively free from bones. It is very popular with many cane-pole anglers and small boys, for it bites readily on worms, grasshoppers, and even pieces of perch. According to recent creel censuses on Minnesota lakes more bluegills than any other species are caught by anglers. In fact, they constitute nearly half the total catch of the summer anglers.

GENUS *Ambloplites* Rafinesque

This genus contains several species, only one of which occurs in the northern states.

NORTHERN ROCK BASS (Redeye, Goggle-eye)
Ambloplites rupestris rupestris (Rafinesque)

The body of the rock bass (Figure 47) is thicker than the body of the crappie or sunfish. The rock bass is more or less oblong, the back is considerably elevated, and the forehead is considerably rounded. The dorsal fin contains 10 or 11 spines, the anal fin 6. The back and sides are ordinarily an olive-brown color, and each scale has a dark spot. The eye is more or less red. The young fishes may be readily recognized by the broad, irregular, black vertical bars on their sides. The rock bass can change color with great rapidity; in a few minutes it can change from silver to almost solid black or to silver with black splotches. It reaches a length of 8 to 10 inches.

The northern rock bass is found from the Dakotas and southern Canada southward in the Mississippi drainage to North Carolina and northern Arkansas. It is widely distributed in lakes and clear streams throughout most of Minnesota, Wisconsin, and neighboring states. Although it is supposed by some to inhabit rocky streams only, it is found commonly as well in many lakes of moderate size and even occurs in some of the rocky lakes of northeastern Minnesota. It has been reported from the Rainy River drainage and from such large lakes as Mille Lacs and Lake of the Woods. It is rather rare in much of the

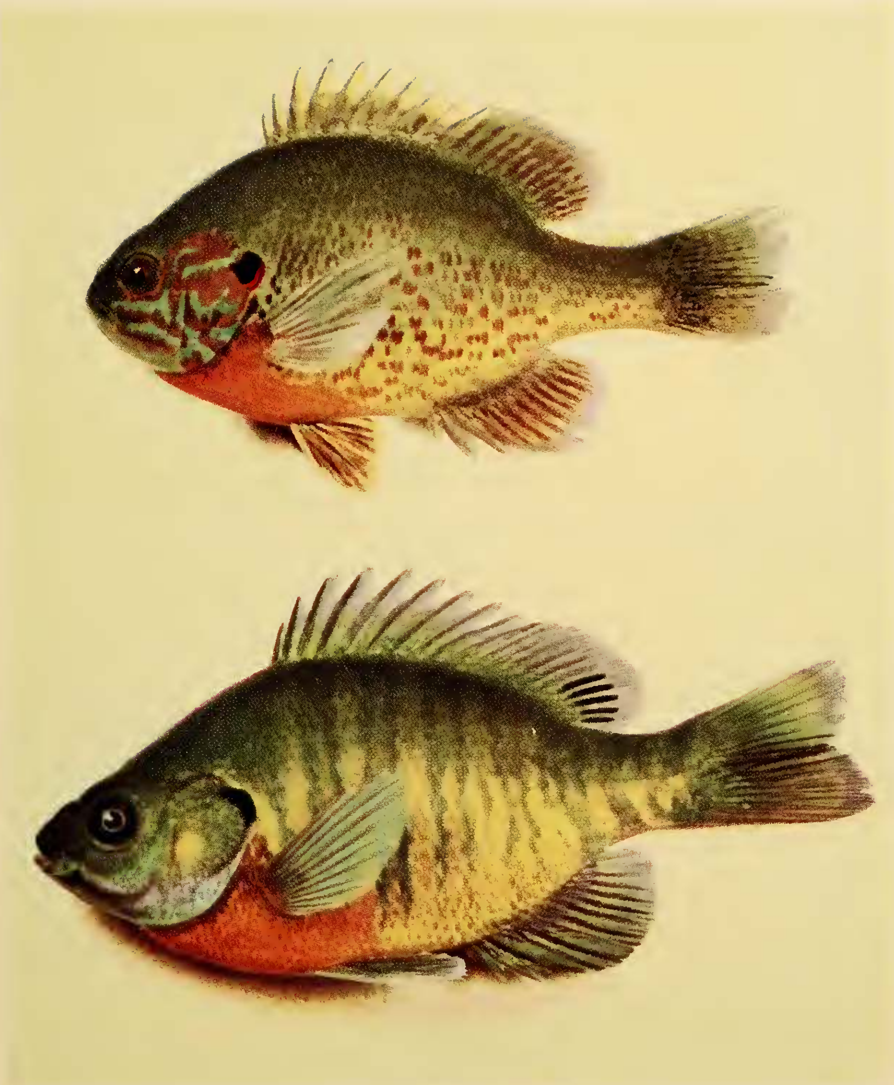


Figure 46. A. Pumpkinseed, *Lepomis gibbosus,* 6 inches long. B. Common bluegill, *Lepomis macrochirus macrochirus,* 7 inches long.

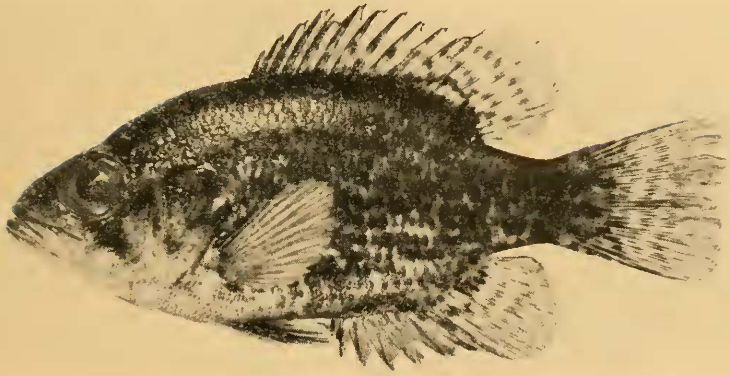


Figure 47. Northern rock bass, *Ambloplites rupestris rupestris,* 5 inches long.

Lake Superior drainage in Minnesota, though Greene (1935) found it in this drainage in Wisconsin.

The rock bass spawns from late May until early July on gravel beds in streams or on shallow sand bottoms in lakes. Some of the females examined from lakes near St. Paul contained as high as 11,000 eggs, though most of them contained about 5000.

This fish reaches a weight of over 2 pounds. It is a good game fish and has considerable value as a pan fish, though the flesh sometimes has a muddy flavor. It bites readily on grasshoppers, worms, and minnows, and at times it will rise to a fly. It travels in schools, and once a school is located the angler can often catch his limit in a short time.

GENUS *Pomoxis* Rafinesque

This genus contains two species of crappies, both of which are found in Minnesota and neighboring states. Both species have many names.

WHITE CRAPPIE (White Bass)
Pomoxis annularis Rafinesque

The shape of the white crappie (Figure 48) is about the same as that of the black crappie, though in some specimens the head is more dished and the back is not as high. The anal fin of the white crappie has less conspicuous dark mottlings than that of the black crappie. The color is silvery, more or less mottled with dark green. Usually there are dark bars on the sides, particularly in young ones. This species is usually lighter in color than the black crappie, with which it is easily confused. It may be often distinguished by the dorsal spines, which usually number 6, as compared with 7 or 8 in the black crappie. However, some in-

Figure 48. White crappie. *Pomoxis annularis.* 6 inches long.

dividuals may have 7 dorsal spines, like the black crappie. The dorsal fin is always shorter in the white crappie. Its length is much less than the distance from the origin of the dorsal to the eye. Five or 6 anal spines are present. The length seldom exceeds 12 inches. Adults may weigh from 1 to 2 pounds, though weights up to 4 pounds have been reported.

The white crappie is found from southern Minnesota eastward to southern Ontario and southward to the Gulf. It occurs in the Atlantic drainage of Alabama and South Carolina. Minnesota records for this fish are largely from lakes and streams in the southern part of the state. This species is virtually absent from lakes in northern Minnesota and is rare in or absent from many lakes of central Minnesota. It is rather common in western and southern Wisconsin (Greene, 1935).

This fish reaches about the same size as the black crappie and is an excellent pan and game fish. Spawning occurs in the late spring and early summer. The spawning habits are like those of the black crappie.

BLACK CRAPPIE (Calico Bass, Strawberry Bass, Grass Bass)
Pomoxis nigro-maculatus (LeSueur)

The black crappie (Figure 49), formerly known as *Pomoxis sparoides* (Lacépède), is elliptical in shape, though somewhat elongated and much compressed laterally. The forehead is somewhat dished but usually not as much as in the white crappie. The color is more or less silvery, with numerous black or dark-green splotches. There are no bars on the sides of adults, though bars are prominent on juveniles. The black crappie is usually much darker in general color than the white crappie. It is usually distinguished from the white crappie by the dorsal

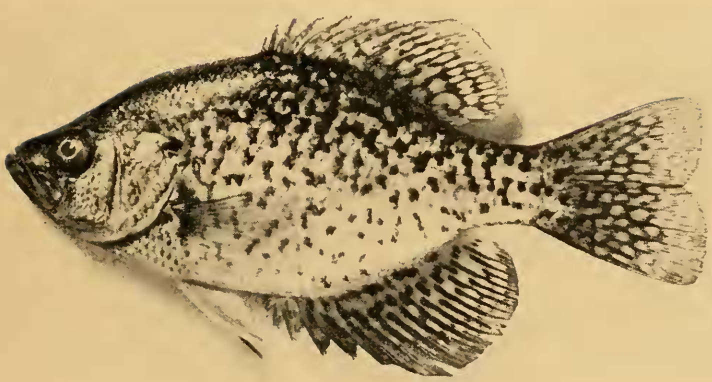


Figure 49. Black crappie, *Pomoxis nigro-maculatus*, 8 inches long.

spines, which number 7 or 8, as compared with 6 in the white crappie. It can also be distinguished by the length of the dorsal fin, which is about equal to the distance between the dorsal and the eye. The dorsal fin contains 15 soft rays. The anal spines number 6. The length seldom exceeds 12 inches. The black crappie often weighs up to 2 pounds, and weights of 4 pounds have been reported.

The black crappie is common in lakes and large streams over most of the eastern United States and southern Canada. It has been introduced on the Pacific Coast. It is abundant in many lakes of Minnesota, Wisconsin, and neighboring states, and is absent only from the deep, rocky lakes of northeastern Minnesota, particularly those of the Lake Superior drainage. It is present in the Lake Superior drainage in Wisconsin (Greene, 1935). In Minnesota it prefers large streams and medium-sized lakes, and is rare in many of the largest lakes. It is much more common and widespread than the white crappie.

Crappies may spawn at 1 or 2 years of age. Large ones of 1 1/2 pounds may have as many as 140,000 eggs in their ovaries. Smaller females of half-pound weight contain from 20,000 to 60,000 eggs. In most Minnesota waters spawning usually occurs in May and June, though occasionally one may be found spawning in July. The nests are often close together and are sometimes built on bottoms that are softer and muddier than those usually chosen by members of this family. Crappies are easy to propagate in ponds, and they also increase rapidly in lakes. Recent studies on fish populations indicate that they have become overabundant in certain Minnesota lakes, with the result that there are numerous stunted ones. Crowded populations of stunted crappies are caused by the removal of the larger fishes through selective fishing. This same condition frequently occurs with sunfishes in overfished lakes.

Aquatic insects, crustacea, small minnows, and other small fishes form the diet of the black crappie. This species is one of the few members of the Centrarchidae family that continue to feed during the winter and do not go into semihibernation. The stomachs of black crappies caught in winter show that they feed extensively on small fishes and insects, though many caught in late winter had their stomachs filled with tiny water fleas, or *Daphnia*.

Both species of crappies rank high as pan and game fishes in Minnesota. They bite readily on minnows and at times may even rise to a fly. The flesh is very palatable, though it may sometimes be slightly muddy in flavor. Next to the bluegill more crappies than any other fish are caught by Minnesota anglers. During the winter the black crappie forms about 75 per cent of the catch of anglers fishing through the ice. In December enormous numbers, even exceeding the total summer catch, are caught from some lakes.

Family ATHERINIDAE

THE SILVERSIDE FAMILY

The silverside family includes many species found in both salt and fresh water in various parts of North America and other continents. Only one genus and one species occur in Minnesota and neighboring states.

GENUS *Labidesthes* Cope

This genus contains but one species, the brook silverside, *Labidesthes sicculus* (Cope).

NORTHERN BROOK SILVERSIDE (Skipjack)
Labidesthes sicculus sicculus (Cope)

The northern brook silverside (Figure 50) is a slender, beautiful little fish of a transparent greenish color. It has a prominent and brilliant silver lateral band with a dark lateral streak above it. The back is dotted with black. The body is elongate and compressed; the head is long and flattened above; the snout is slender and is considerably drawn out and longer than the eye. The premaxillaries are very protractile; the edge of the upper jaw is concave. The scales are cycloid. The head is contained 4.5 times in the length and the depth 6 times. The eye is very prominent. The anterior dorsal fin has 4 very small, weak spines; the

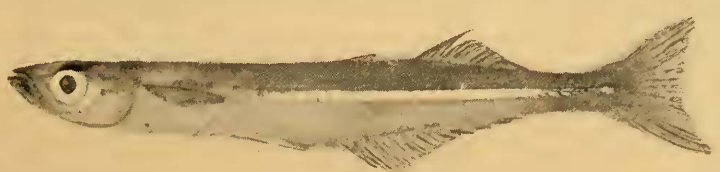


Figure 50. Northern brook silverside, *Labidesthes sicculus sicculus,* 2 1/2 inches long.

posterior dorsal fin has 1 spine and 11 soft rays. The anal fin has 1 spine and 23 soft rays. No lateral line is present. There are 75 scales in a line from the opercle to the base of the caudal. The caudal fin is forked. This fish seldom, if ever, exceeds 4 inches in length.

The brook silverside is distributed from Minnesota eastward through southern Ontario and southward to the Gulf. It is fairly widely distributed over the southern half of both Minnesota and Wisconsin. It occurs in both lakes and streams. It assembles in large schools and swims and feeds near the surface.

This rather delicate fish feeds extensively on planktonic crustacea and small insects, and also on insect larvae (principally of gnats and mosquitoes), surface insects, and copepods and other Entomostraca. Its breeding habits and life history have been studied in detail by Hubbs (1921) and Cahn (1927). It spawns among aquatic plants. The eggs become attached to the plants by the long filament with which each egg is provided. The eggs are widely scattered, an egg here and another there. The silverside has little value as a bait minnow but is utilized for food by many game fishes.

Family SCIAENIDAE

THE DRUM FAMILY

In this family of fishes the body is compressed and somewhat elongate, and the shape much like that of a bass. All parts are covered with ctenoid scales, which extend over the bases of the vertical fins. The lateral line is well developed and extends across the caudal fin. The head is large and covered with scales. There are teeth on the jaws. There is no supplemental maxillary bone on the upper jaw, which is somewhat protractile. The pseudobranchiae are well developed. There is a slit behind the fourth gill. The gill-membranes are free from the isthmus. The dorsal fin is deeply notched, and the soft part is much longer than the spinous part. The anal fin has 1 or 2 spines. The ear bones, or otoliths, are well developed. The air bladder is large; the pyloric caeca are few.

These fishes are carnivorous. They have the power of producing a peculiar grunting sound, which is supposed to be made by forcing air from the main portion of the air bladder into one of its smaller divisions. This family contains many genera and species, most of which are marine. The marine species include the fishes known as croakers, drummers, yellowtails, and some of the sea basses. Only one genus is found in the fresh waters of North America.

GENUS *Aplodinotus* Rafinesque

There is only one species of this genus, which occurs in the fresh waters of the central United States and ranges northward into Canada and southward to Guatemala.

FRESHWATER SHEEPSHEAD (White Perch, Freshwater Drum, Mah-nah-she-gun of the Red Lake Chippewas)
Aplodinotus grunniens Rafinesque

The freshwater sheepshead (Figure 51) is a large, coarse fish with a body form similar to that of the carpsucker. The body is oblong with an elevated, compressed back. It is silvery in color. Some specimens are almost white, others quite dark. The upper parts are darker than the lower. Commercial fishermen distinguish between white and black sheepsheads. The snout is blunt. The mouth is large and horizontal; the lower jaw does not extend beyond the upper. The ordinary teeth are slender and closely crowded into velvety bands; the pharyngeal teeth are well developed and are blunt and closely set, or paved. The preopercle is slightly serrate. The dorsal spines are strong and high and are

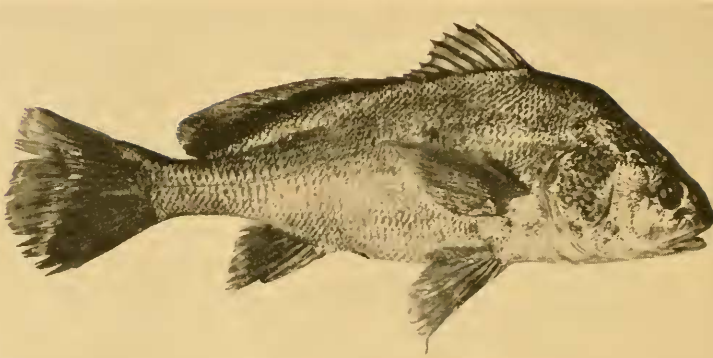


Figure 51. Freshwater sheepshead, *Aplodinotus grunniens,* 18 inches long.

covered with scales at the base. The anal fin has 2 spines, of which the second is very strong. The head is contained 3.5 times in the length and the depth about 3 times. The anterior part of the dorsal fin has 8 or 9 spines; the posterior part has 1 spine and 25 to 31 soft rays. The anal fin has 2 spines and 7 soft rays. The ventral fins terminate in fine filaments. The lateral line has about 55 (50–56) scales. This species reaches a length of over 2 feet.

The sheepshead is found throughout most of the Mississippi drainage, in part of the Hudson Bay drainage, in the Great Lakes drainage except Superior, and southward to the Gulf. It occurs in certain streams in Mexico and Central America. In Minnesota it is widely distributed in the Mississippi and its tributaries below St. Anthony Falls and in the St. Croix and its tributaries, particularly in Pokegama Lake. It is present in large numbers in Red Lake and Red Lake River, but its occurrence in other parts of the Arctic drainage of Minnesota is doubtful, notwithstanding the report of one sheepshead at the Bigsby Island Fishery in Lake of the Woods during the summer of 1922 by the late Paul Marschalk, manager of the Booth Fisheries at Warroad. In Wisconsin Greene (1935) reported it to be restricted to the Mississippi River and Lake Winnebago.

It is an interesting fish in that it has the power of producing a peculiar grunting sound. This noise is usually made in the evening, and coming from the water without any apparent source as it does, it is somewhat weird. The ear bone furnishes the famous lucky stone so prized by many youthful fishermen. The ear bones are so hard that they often remain intact long after the rest of the skeleton has disintegrated. Forbes and Richardson (1908) reported this species as reaching a weight of 50 to 60 pounds, but the average is probably 2 or 3 pounds.

The sheepshead is a rather grotesque and sluggish fish. It lives on the bottom of muddy waters, where it feeds especially on mollusks, first crushing the shells with the powerful, paved, millstonelike pharyngeal jaws. When examined the stomach is often found to contain only the soft bodies and opercula of gastropod mollusks, the crushed shells evidently having been thrown out. Crayfishes are sometimes found in the stomach. Although the sheepshead is seldom caught on hook and line by sportsmen, it is caught in seines and sold in large numbers by commercial fishermen, under the name of white perch. As a food fish it ranks with suckers and carp.

This species has become of added significance as an intermediary host for several species of mussels, which pass through their metamorphosis on the gills of the sheepshead. Sometimes this fish carries an almost incredible number of glochidia (Surber, 1913). Unfortunately the species it carries are of little commercial value.

Family COTTIDAE

THE SCULPIN FAMILY

This family contains many genera and species, many of which are known as sculpins, muddlers, and miller's-thumbs. Many species live in the sea, though a number have taken up their abode in fresh waters, apparently to escape competition, and are found throughout North America, Asia, and Europe. Three or four species are found in Minnesota.

The sculpins are grotesque fishes. The body is elongate, the head very large and much depressed. The eyes are placed high in the head, and the space between them is narrow. The edge of the preopercle has one or more spinous processes. Teeth are present on the jaws and usually also on the vomer and palatines; the upper jaw is protractile, and the maxillary is without a supplemental bone. Gill-rakers are either short and tuberclelike or absent. The body is naked or partially covered with scales, prickles, or bony plates, but never entirely scaled. The lateral line is present. The pectoral fins are very large, and the ventral fins are thoracic. Pseudobranchiae are present. There are usually 4 to 8 pyloric caeca.

Key to Common Species of Family COTTIDAE

1. Gill-membranes free from isthmus; dorsal fins widely separated; head long; body slender; eyes very large; small but definite slit behind last gill........ ....Deepwater Sculpin, *Triglopsis thompsonii* Girard
   Gill-membranes not entirely free from isthmus; dorsal fins scarcely separated; head broad; body fusiform; eyes smaller; no slit behind last gill..........2
2. Lateral line complete............Spoonhead Muddler, *Cottus ricei* Nelson
   Lateral line incomplete, extending back to region of second dorsal fin......3
3. Pelvic rays typically I, 3;* palatine teeth few or absent.................. ....Slimy Muddler, *Cottus cognatus* Richardson
   Pelvic rays typically I, 4; palatine teeth well developed.................. ....Northern Muddler, *Cottus bairdii bairdii* Girard

*A sheath encloses the spine with the first soft-ray and the spine is not visible without dissection.

GENUS *Triglopsis* Girard

The fishes of this genus are restricted mostly to the deep waters of the Great Lakes.

DEEPWATER SCULPIN

Triglopsis thompsonii Girard

This sculpin differs from those of the following genus, *Cottus,* in having a very slender body and a long, narrow head. The gill-membranes are free from the isthmus. The eye is very large. The skull is cavernous.

The dorsal fin has 8 spines and 18 rays, the anal fin 15 soft rays, and the ventral fin 1 spine and 3 soft rays. There are 4 short spines on the preopercle. This species reaches a length of about 3 inches.

The deepwater sculpin lives only at great depths in the Great Lakes and in the streams of Arctic Canada. Jordan (1929) regarded it as a rare relic of a marine group. Greene reported one record from deep waters of Lake Superior off the Wisconsin shore. There are specimens in the University of Minnesota collections, which were caught in nets at a depth of 600 feet in Lake Superior off Grand Marais. Many were also secured from stomachs of siscowets.

GENUS *Cottus* (Artedi) Linnaeus

The members of this genus are widespread in cold streams and lakes of the Northern Hemisphere. Although many species have been described, many of them are probably only subspecies.

SPOONHEAD MUDDLER
Cottus ricei Nelson

The spoonhead muddler has a stout body with a large, flat head and a tapering tail. The skin is very prickly. It is olivaceous in color and finely speckled. The dorsal fin has 8 spines and 17 soft rays; the anal fin has 12 soft rays. This species reaches a length of nearly 3 inches.

This fish can be distinguished from the other local muddlers, *Cottus*, which it closely resembles, by the complete lateral line. It is distributed from Hudson Bay to the Great Lakes. Although it has never been collected in Minnesota waters it probably occurs in the deep waters of Lake Superior. It has been found off Isle Royale (Hubbs and Lagler, 1941). Greene (1935) reported it from Lake Michigan and stated that it lives in somewhat shallower waters than *Triglopsis*.

NORTHERN MUDDLER (Miller's-Thumb, Blob, Common Sculpin)
Cottus bairdii bairdii Girard

The general color of the northern muddler (Figure 52) is a mottled dark brown or grayish, somewhat lighter below. The body is rather stout and tapers toward the tail fin. The head is large, much flattened above, and wide through the opercular region. The preopercle has a sharp, short spine, which is directed backward and upward; the subopercle has a spine that is directed forward. The skin is smooth except just behind the pectoral fins, where it is often covered with sharp prickles. The lateral line is present. The first dorsal fin is low and weak; the pectorals are very large and are about equal to the head in length. The head is contained 3.3 times in the length, the depth 4 to 6 times. The dorsal fin has 6 to 8 spines and 16 to 17 soft rays. The anal fin has

Figure 52. Northern muddler, *Cottus bairdii bairdii,* 3 inches long.

about 12 soft rays. The pelvic fins each have 1 spine and 4 soft rays. According to Hubbs and Lagler (1941) the pelvic spine is a slender splint within the membrane of the first ray and must be dissected to be observed. This species is usually small; it reaches a length of 3 to 7 inches.

The northern muddler is found in the eastern United States from southern Canada southward to the Ohio River and West Virginia, and in the Atlantic drainage from Pennsylvania to Virginia. Other subspecies occur south of this range. It is common in small streams throughout Minnesota and Wisconsin. It prefers the riffles over gravel bottoms. It is fairly common also in some of the northern lakes with boulder-lined shores. This grotesque fish is rarely seen or caught, partly because of its protective coloration, which matches closely that of the bottom on which the fish always rests. Its habit of wriggling under stones and pebbles further aids it in escaping minnow seines.

The northern muddler commonly rests on the bottom on its enormous, fanlike pectoral fins. It swims short distances with a darting movement that resembles a hop. Although no extensive studies of its food habits have been made in Minnesota, it is considered carnivorous. It supposedly feeds on small fry and insects and is accused of gorging on trout eggs, but since such eggs as may be eaten are probably loose eggs that have no chance of hatching, the accusation that it is harmful to trout is not supported by much tangible evidence. Surber (1920) found no evidence of trout eggs in muddlers taken from trout spawning beds, and his findings are supported by evidence obtained by Koster (1937) in New York. The eggs are deposited in a cavity under a stone in swift water and are guarded by the male.

GREAT LAKES MUDDLER (Sculpin)
Cottus bairdii kumlieni (Hoy)

This subspecies was reported in Wisconsin from Lake Superior and Lake Michigan by Greene (1935). It is more slender than *C. bairdii*

bairdii. The distance between the tip of the snout and the anus is nearly equal to the distance between the anus and the tip of the caudal fin rather than the base of the caudal fin.

SLIMY MUDDLER (Northern Miller's-Thumb)
Cottus cognatus Richardson

The slimy muddler (Figures 53 and 54) is similar to *Cottus bairdii* in appearance and habits. It differs largely in having 1 spine and 3 rays in the pelvic fin, instead of 1 spine and 4 soft rays as in *C. bairdii.* It has 8 spines and 16 to 18 soft rays in the dorsal fin. This species ranges from Alaska and Canada into the Great Lakes drainage and east of the Alleghenies to West Virginia. It has been found in the shallow waters along the Minnesota and Wisconsin shores of Lake Superior and in many of the streams tributary to Lake Superior. There are specimens in the University of Minnesota collections from the Temperance, Devil

Figure 53. Slimy muddler, *Cottus cognatus,* 3 inches long.

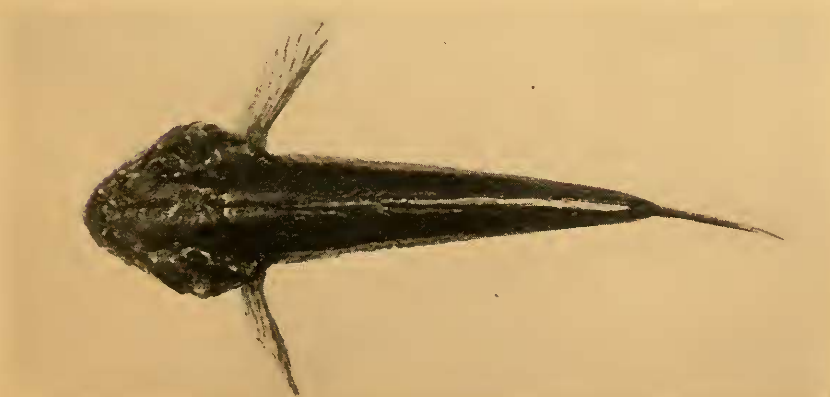


Figure 54. Slimy muddler, *Cottus cognatus,* dorsal view showing large pectoral fins.

Track, Baptism, and Little Isabella rivers in the Lake Superior drainage and from Big Sandy Lake in Aitkin County in the Mississippi drainage. A separate population of this species occurs in Iowa and extends up into southeastern Minnesota where it has been taken by the Minnesota Department of Conservation from the Root River and the Whitewater River. The nesting habits are probably the same as those of the northern muddler.

Family GASTEROSTEIDAE

THE STICKLEBACK FAMILY

In this family of fishes the body is somewhat compressed and the caudal peduncle, or portion before the caudal fin, is very slender. The head is medium sized. The mouth is moderate; the lower jaw projects beyond the upper. The maxillary is bent and overlaps the premaxillary at the corner of the mouth. The jaws are set with sharp, even teeth, and the upper jaw is protractile. There are no true scales. The dorsal fin is preceded by several free spines. The branchiostegal rays number 3. The ventral fins each have a stout spine, and the pectoral fins are inserted far back. The air bladder is simple. A small number of pyloric caeca are present.

The sticklebacks are small, carnivorous fishes of which several genera and species are found in both fresh and salt waters. Most or all of them build nests. They are represented in Minnesota by two genera and two species.

Key to Common Species of Family GASTEROSTEIDAE

Dorsal fin preceded by 4–6 free spines.................................. ....Brook Stickleback, *Eucalia inconstans* (Kirtland)

Dorsal fin preceded by 8–11 free spines................................ ....Ninespine Stickleback, *Pungitius pungitius* (Linnaeus)

GENUS *Eucalia* Jordan

This genus contains only one species, distributed from Kansas to New York and throughout the Great Lakes region.

BROOK STICKLEBACK
Eucalia inconstans (Kirtland)

The brook stickleback (Figure 55) is a graceful little fish mottled in colors that vary from brown to black, with the under parts usually lighter; there is some red on the anterior parts of the spring males. The body is somewhat elongate and moderately compressed; the portion before the caudal fin is very small. No scales are present. The gill-membranes are somewhat free posteriorly; the gill-rakers are short. No ridge, or keel, is present along the caudal peduncle. The head is contained 3.5 times in the length, the depth 4 times. The dorsal fin has 4 or 5 free spines anteriorly and 9 or 10 soft rays posteriorly. The anal fin has 1 spine and 9 or 10 soft rays. This species seldom exceeds 2 1/2 inches in length.

Figure 55. Brook stickleback, *Eucalia inconstans,* 1 1/2 inches long.

The brook stickleback is found from Kansas to Maine and northward into southern Canada. This little fish is abundant in almost every small spring-fed brook in Minnesota and Wisconsin (Greene, 1935). It feeds on tiny insects and crustacea. Brook sticklebacks spawn in Minnesota about the first week of May, depending on the seasonal conditions. The nest is a hollow spherical or cylindrical mass of grass and small twigs, several inches long. It is bound together by secretions of the male and is fastened to some object in shallow water. Only a relatively few eggs are deposited and these are large for the size of these fishes. Sticklebacks are very pugnacious; they readily attack fishes much larger than themselves.

GENUS *Pungitius* Costa

This genus contains the ninespine stickleback found in both salt and fresh waters in northern Europe, Asia, and North America.

NINESPINE STICKLEBACK
Pungitius pungitius (Linnaeus)

The ninespine stickleback (Figure 56) is olive above and much speckled. The sides have dark bars, and the belly is silvery. The body is slender and a little compressed; the portion before the caudal fin is extremely slender. The head is short and blunt, and the eye is wider than the length of the snout. The gill-rakers are long and slender. A ridge or keel is developed along the caudal peduncle. The dorsal fin has 9 or 10 free spines and 9 rays. The dorsal spines do not all point in the same direction. The pelvic spines are larger than the dorsal spines. The anal fin has 1 spine and 8 rays. This species reaches a length of about 3 inches.

The ninespine stickleback is very common in the shallow waters of Lake Superior, where it was described by Agassiz (1850) as *Gasterosteus nebulosus.* A specimen was taken in Lake Superior at Grand

Figure 56. Ninespine stickleback, *Pungitius pungitius*, 1 1/4 inches long.

Marais, Minnesota by T. S. Roberts in 1879. It is abundant in the lower parts of most of the Minnesota streams flowing into Lake Superior and has been collected from Lake Vermilion in the Arctic drainage. In Wisconsin Greene (1935) found it in Lake Superior and Lake Michigan. This species inhabits both fresh and brackish waters and is found throughout northern Europe and North America from the Great Lakes northward. Its habits are similar to those of *Eucalia inconstans*.

Family GADIDAE

THE CODFISH FAMILY

In fishes of the codfish family the body is slender, heavy anteriorly and compressed posteriorly. The scales are small and are cycloid. The long dorsal fin extends almost the entire length of the back, and in some species is divided into two. No spines are present in any of the fins. The caudal is rounded; the ventral fins are inserted far forward. Four gills are present; there is a slit behind the fourth one; no pseudobranchiae are present. Pyloric caeca are numerous in some species, and the air bladder is generally well developed.

This well-known family includes many marine fishes, such as the cod, the haddock, and many other related species. It is represented in the fresh waters of Minnesota and neighboring states by only one genus and one species. The same species occurs in the freshwaters of northern Europe and Asia.

GENUS *Lota* (Cuvier)

This genus includes one species and several subspecies found throughout northern North America and in Europe and Asia.

EASTERN BURBOT (Lawyer, Ling, Eelpout, Spineless Catfish, Me-zi-e of the Red Lake Chippewas)
Lota lota maculosa (LeSueur)

The eastern burbot (Figure 57) is a large, dark-olive fish, thickly marbled and reticulated with blackish markings of a decidedly reptilian appearance. The body is long and heavy anteriorly but is compressed posteriorly. The head is rather small, depressed, and broad, and has a barbel on each of the anterior nostrils. The eye is very small. The head is contained 4.6 times in the length, the depth 6 times. The mouth is moderate; the lower jaw does not project; the maxillary extends to the posterior edge of the eye. A small median barbel hangs under the lower jaw. The jaws are set with numerous weak teeth, arranged in bands; the vomer bears a crescent-shaped band of teeth; the palatines are toothless. The very small scales are imbedded in the skin. The gill-openings are wide, and the gill-membranes are free from the longest openings. The divided dorsal fin has 13 and 76 rays, the anal fin 68. The ventral fins each have 7 rays. The pyloric caeca number 30. The burbot reaches a length of 30 inches and a weight of 10 pounds.

The eastern burbot ranges through central and eastern Canada southward to Connecticut and westward through the Great Lakes basin and the Missouri River basin. It occurs in the Columbia River watershed and probably intergrades with *L. lota leptura,* the subspecies found in Alaska and eastern Siberia, in the Fraser and Mackenzie basins (Hubbs and Schultz, 1941). It is common in Lake Superior where it ranges to depths of over 600 feet. It is more or less common in all the larger streams and most of the lakes of Wisconsin and northern Minnesota. Evermann and Latimer (1910) reported it as one of the most abundant fishes in Lake of the Woods. Although rarely found south of Mille Lacs, it is taken occasionally as far south as Lake Pepin and the Whitewater River. On the Upper Mississippi at Wolf Lake near Bemidji, Minnesota it is often incorrectly called a dogfish. It is not particularly abundant there. It is very destructive to other fishes, particularly to white-

Figure 57. Eastern burbot, *Lota lota maculosa,* 21 inches long.

fishes. It will kill whitefishes of its own size or even larger. Professor George W. Friedrich of St. Cloud State Teachers College caught a 15-inch burbot attempting to swallow a 12-inch walleye. At Red Lake during the fall of 1918 it was taken on the whitefish spawning beds, and the burbots examined had stomachs distended with whitefish eggs. Stomachs collected in winter and examined at the University of Minnesota contained perch and minnows.

The burbot spawns in midwinter or in early spring before the ice has melted. A number of females caught February 15, 1938 had already laid their eggs. Fry with traces of yolk sac still persisting have been secured at Lake Vermilion about the middle of April when the water temperature was still at 35° F. Young burbot are sometimes found in streams tributary to lakes, and it is possible that some adults enter streams to spawn. Olson (1945) found burbot spawning in midwinter in the swift water of a stream near Ely, Minnesota. The fact that many newly hatched young are found on the shallow, sandy bottoms of lakes indicates that some burbots spawn in lakes. Commercial fishermen claim that they spawn in the spring in Lake Superior. During the summer adult burbots are usually found only in deep water.

Some years ago, about 1913 or 1914, Mr. S. P. Wires, the late veteran superintendent of the Duluth federal hatchery, had had in his possession for some time a live albino of this species. It was a pale straw color and had pink eyes.

This fish has assumed considerable economic importance in recent years, since the oil produced from the liver was found to be similar to that from the liver of the salt-water cod. Countless thousands of these fishes have been wantonly destroyed. It is to be hoped that the value of the remaining ones will be recognized and that they will be treated accordingly. A small plant at Lake of the Woods is now processing burbot livers on a considerable scale for the extraction of oil.

Only a few people use the burbot for food. Otherwise, except for the recent demand for oil, this fish has been discarded as useless. Its snake-like markings coupled with its slender form doubtless account for the prejudice against using its flesh, which is very well flavored and not as strong as that of many popular species of game fishes. It has a slightly coarse texture and in large ones may be rather firm. Burbot should be skinned before cooking and may be made into fillets. Moore (1917) stated that the meat of the burbot resembles that of the cod and the haddock and, with due consideration of its smaller size, may be cooked like those fishes.

Bibliography

Adams, Charles C., and Hankinson, Thomas L.
1928. The Ecology and Economics of Oneida Lake Fish. Bull. N.Y. State Coll. Forestry Syracuse Univ., Vol. 1, No. 4a (Roosevelt Wild Life Annals, Vol. 1, Nos. 3 and 4), pp. 235–548.

Agassiz, Louis
1850. Lake Superior, Its Physical Character, Vegetation, and Animals Compared with Those of Other and Similar Regions, with a Narrative of the Tour by J. E. Cabot. Gould, Kendall, and Lincoln, Boston, 428 pp.

Aitken, Walter W.
1936. Some Common Iowa Fishes. Iowa State Coll. Extension Circ. 224, pp. 1–33.

Alexander, M. L.
1914. The Paddlefish. Trans. Am. Fish. Soc., Vol. 44, pp. 73–78.

Allen, William F.
1911. Notes on the Breeding Season and Young of *Polyodon spathula*. Jour. Wash. Acad. Sci., Vol. 1, No. 10, pp. 280–82.

Avery, Carlos
1919. Report of the Minnesota State Fisheries to December 31, 1918. Minn. Dept. Game and Fish Circ., pp. 1–16.

Bailey, Reeve M.
1941. The Scientific Name of the Black Crappie. Copeia, No. 1, pp. 21–23.

Bennett, G. W., Thompson, David H., and Parr, Sam A.
1940. Lake Management Reports 4. A Second Year of Fisheries Investigation at Fork Lake, 1939. Nat. Hist. Survey Biol. Notes No. 14, pp. 1–24.

Berg, Leo S.
1931. A Review of the Lampreys of the Northern Hemisphere. Ann. Mus. Zool. Acad. Sci. U.R.S.S., Vol. 32, pp. 87–116.
1936. Note on *Coregonus (Prosopium) cylindraceus (Pallas)*. Copeia, No. 1, pp. 57–58.
1940. Classification of Fishes, Both Recent and Fossil. Trav. Inst. Zool. Acad. Sci. U.R.S.S., Vol. 5, No. 2, pp. 85–517.

Borodin, Nicolas
1925. Biological Observations on the Atlantic Sturgeon. Trans. Am. Fish. Soc., Vol. 55, pp. 184–90.

Cable, Louella E.
1928. Food of Bullheads. Appendix 2, Rept. U.S. Comm. Fish., 1928, pp. 27–41.

Cahn, A. R.
1927. An Ecological Study of Southern Wisconsin Fishes, the Brook Silverside *(Labidesthes sicculus)* and the Cisco *(Leucichthys artedi)* in Their Relations to the Region. Ill. Biol. Monogr., Vol. 11, No. 1, pp. 1–151.

Carbine, W. F.
1939. Observations on the Spawning Habits of Centrarchid Fishes in Deep Lake, Oakland County, Michigan. Trans. 4th N. Am. Wildlife Conf., pp. 275–87.
1944. Egg Production of the Northern Pike, *Esox lucius* L., and the Percentage Survival of Eggs and Young on the Spawning Grounds. Papers Mich. Acad., Sci., Arts, and Letters, Vol. 29, pp. 123–37.

Carlander, Kenneth D.
1941. The Darters (Etheostominae) of Minnesota. Proc. Minn. Acad. Sci., Vol. 9, pp. 41–48.

Carter, E. N.
1904. Notes on Sturgeon Culture in Vermont. Trans. Am. Fish. Soc., Vol. 34, pp. 60–75.

Churchill, E. P., and Over, W. H.
1933. Fishes of South Dakota. S.D. Game and Fish Comm., Pierre, pp. 1–87.

Coker, Robert E.
1930. Studies of Common Fishes of the Mississippi River at Keokuk. Bull. U.S. Bur. Fish., Vol. 45, 1929, pp. 141–225.

Cox, Ulysses O.
1896. A Report Upon the Fishes of Southwestern Minnesota. Rept. U.S. Fish Comm., 1894, pp. 605–16.
1897. A Preliminary Report on the Fishes of Minnesota. Geol. and Nat. Hist. Survey Minn. Zool. Ser. 3, pp. i–viii, 1–93.

Creaser, Charles W.
1925. The Establishment of the Atlantic Smelt in the Upper Waters of the Great Lakes. Papers Mich. Acad. Sci., Arts, and Letters, Vol. 5, pp. 405–24.

Creaser, Charles W., and Hann, Clare S.
1929. The Food of Larval Lampreys. Papers Mich. Acad. Sci., Arts, and Letters Vol. 10, 1928, pp. 433–37.

Creaser, Charles W., and Hubbs, Carl L.
1922. A Revision of the Holarctic Lampreys. Occ. Papers Mus. Zool. Univ. Mich., No. 120, pp. 1–14.

Davis, H. S.
1937. Care and Diseases of Trout. U.S. Bur. Fish Invest. Rept. No. 35, pp. 1–76.
1938. Instructions for Conducting Stream and Lake Surveys. U.S. Bur. Fish., Fish. Circ. No. 26, pp. 1–55.

Eddy, Samuel
1940. Minnesota Lake Surveys and Fish Management. Proc. Minn. Acad. Sci., Vol. 8, pp. 9–14.
1943. Limnological Notes on Lake Superior. Proc. Minn. Acad. Sci., Vol. 11, pp. 34–39.
1945. Little-known Fishes of Minnesota. Minn. Dept. Cons., Cons. Bull. No. 9, pp. 4–40.

Eddy, Samuel, and Carlander, Kenneth
1939. The Growth Rate of Walleyed Pike, *Stizostedion vitreum* (Mitchill), in Various Lakes of Minnesota. Proc. Minn. Acad. Sci., Vol. 7, pp. 44–48.
1940. The Effect of Environmental Factors upon the Growth Rates of Minnesota Fishes. Proc. Minn. Acad. Sci., Vol. 8, pp. 14–19.
1942. Growth Rate Studies of Minnesota Fishes. Minn. Dept. Cons., Bur. Fish. Research Invest. Rept. No. 28, pp. 1–64.

Eddy, Samuel, and Simer, Parke H.
1929. Notes on the Food of the Paddlefish and the Plankton of Its Habitat. Trans. Ill. State Acad. Sci., Vol. 21, pp. 59–63.

Evermann, Barton Warren, and Cox, Ulysses O.
1896. A Report Upon the Fishes of the Missouri River Basin. Rept. U.S. Fish Comm., 1894, pp. 325–429.

Evermann, Barton Warren, and Latimer, Homer Barker
1910. The Fishes of the Lake of the Woods and Connecting Waters. Proc. U.S. Nat. Mus., Vol. 39, pp. 121–36.

Evermann, Barton Warren, and Smith, Hugh M.
1896. The Whitefishes of North America. Rept. U.S. Fish Comm., 1894, pp. 283–324.

Forbes, Stephen A., and Richardson, Robert Earl
1908. The Fishes of Illinois. Nat. Hist. Surv. Ill., pp. i–cxxi, 1–357.
1920. The Fishes of Illinois. (2d edit.) Nat. Hist. Surv. Ill., pp. i–cxxi, 1–357.

Friedrich, George W.
1933. A Catalog of the Fishes of Central Minnesota. Copeia, No. 1, pp. 27–30.

Gage, Simon H.
1893. The Lake and Brook Lampreys of New York, Especially Those of Cayuga and Seneca Lakes. In: Wilder Quarter-Century Book, Ithaca, pp. 421–93.
1928. The Lampreys of New York State—Life History and Economics. In: A Biological Survey of the Oswego River System. Suppl. 17th Ann. Rept. N.Y. State Cons. Dept., 1927, pp. 158–91.

Greene, C. Willard
1930. The Smelts of Lake Champlain. In: A Biological Survey of the Champlain Watershed. Suppl. 19th Ann. Rept., N.Y. State Cons. Dept., pp. 105–29.
1935. The Distribution of Wisconsin Fishes. Wis. Cons. Comm., Madison, pp. 1–235.

Greenbank, John T.
1945. Limnological Conditions in Ice-Covered Lakes, Especially as Related to Winter-Kill of Fish. Ecol. Monogr., Vol. 15, pp. 343–92.

Hankinson, Thomas L.
1929. Fishes of North Dakota. Papers Mich. Acad. Sci., Arts, and Letters, Vol. 10, 1928, pp. 439–60.

Harris, W. C.
See in: Sage, Townsend. Smith, and Harris, 1902.

Henshall, James A.
1881. Book of the Black Bass. Comprising Its Complete Scientific and Life History Together with a Practical Treatise on Angling and Fly Fishing and a Full Description of Tools, Tackle. and Implements. Belford Clark and Co., Cincinnati, pp. i–vii, 1–463.

Hile, Ralph
1937. The Increase in the Abundance of the Yellow Pike-perch, *Stizostedion vitreum* (Mitchill), in Lakes Huron and Michigan, in Relation to the Artificial Propagation of the Species. Trans. Am. Fish. Soc., 1936, Vol. 66, pp. 143–59.

Hinks, David
1943. The Fishes of Manitoba. Dept. Mines and Nat. Res., Prov. Manitoba. pp. 1–102.

Hubbs, Carl L.
1921. An Ecological Study of the Life-history of the Fresh-water Atherine Fish *Labidesthes sicculus*. Ecol., Vol. 2, pp. 262–76.
1926. A Check-List of the Fishes of the Great Lakes and Tributary Waters with Nomenclatorial Notes and Analytical Keys. Misc. Publ. Mus. Zool. Univ. Mich., No. 15, pp. 1–77.
1930. Further Additions and Corrections to the List of Fishes of the Great Lakes and Tributary Waters. Papers Mich. Acad. Sci., Arts, and Letters, Vol. 11, 1929, pp. 425–36.
1930. Materials for a Revision of the Catostomid Fishes of Eastern North America. Misc. Publ. Mus. Zool. Univ. Mich., No. 20, pp. 1–47.
1945. Corrected Distributional Records for Minnesota Fishes. Copeia, 1945, No. 1, pp. 13–22.

Hubbs, Carl L., and Bailey, Reeve M.
1938. The Small-Mouthed Bass. Bull. Cranbrook Inst. Sci., No. 10. pp. 1–92.
1940. A Revision of the Black Basses (*Micropterus* and *Huro*) with Descriptions of Four New Forms. Misc. Publ. Mus. Zool. Univ. Mich., No. 48, pp. 1–52.

Hubbs, Carl L., and Cooper, Gerald P.
1936. Minnows of Michigan. Bull. Cranbrook Inst. Sci., No. 8, pp. 1–95.

Hubbs, Carl L., and Eschmeyer, R. W.
1938. The Improvement of Lakes for Fishing. Mich. Dept. of Cons., Bull. Inst. Fish. Research, No. 2, pp. 1–233.

Hubbs, Carl L., Greeley, John R., and Trazwell, C. M.
1932. Methods for the Improvement of Michigan Trout Streams. Mich. Dept. of Cons., Bull. Inst. Fish. Research. No. 1, pp. 1–54.

Hubbs, Carl L., and Greene, C. Willard
1928. Further Notes on the Fishes of the Great Lakes and Tributary Waters. Papers Mich. Acad. Sci., Arts, and Letters, Vol. 8, 1927, pp. 371–92.
1935. Two New Subspecies of Fishes from Wisconsin. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. 29, pp. 89–101.

Hubbs, Carl L., and Lagler, Karl F.
1941. Guide to the Fishes of the Great Lakes and Tributary Waters. Bull. Cranbrook Inst. Sci., No. 18, pp. 1–100.

Hubbs, Carl L., and Raney, Edward C.
1944. Systematic Notes on North American Siluroid Fishes of the Genus *Schilbeodes*. Occ. Papers Mus. Zool. Univ. Mich., No. 487, pp. 1–36.

Hubbs, Carl L., and Schultz, Leonard P.
1941. Contribution to the Ichthyology of Alaska, with Descriptions of Two New Species. Occ. Papers Mus. Zool. Univ. Mich., No. 431, pp. 1–31.

Hubbs, Carl L., and Trautman, Milton B.
1937. A Revision of the Lamprey Genus *Ichthyomyzon*. Misc. Publ. Mus. Zool. Univ. Mich., No. 35, pp. 1–109.

Hubbs, Carl L., and White, A. McLaren
1923. A List of Fishes from Cass Lake, Northern Minnesota. Copeia, No. 123, pp. 103–4.

Jordan, David Starr
1888. Science Sketches. A. C. McClurg and Co., Chicago, 276 pp.
1904. Manual of the Vertebrate Animals of the Northern United States. (9th edit.) A. C. McClurg and Co., Chicago, pp. i–vi, 1–397.
1905. A Guide to the Study of Fishes. Henry Holt and Co., New York, Vol. 1, pp. i–xxvi, 1–624; Vol. 2, pp. i–xxii, 1–599.
1923. A Classification of Fishes. Stanford Univ. Publ., Biol. Sci., Vol. 3, No. 2, pp. i–x, 79–243.
1929. Manual of the Vertebrate Animals of the Northeastern United States. Inclusive of Marine Species. (13th edit.) World Book Co., Yonkers-on-Hudson, New York, pp. i–xxxi, 1–446.

Jordan, David Starr, and Evermann, Barton Warren
1896–1900. The Fishes of North and Middle America. Bull. U.S. Nat. Mus., No. 47, Pt. 1; pp. i–lx, 1–1240; Pt. 2, pp. i–xxx, 1241–2183; Pt. 3, pp. i–xxiv, 2183a–3136; Pt. 4, pp. i–ci, 3137–3313.
1902. American Food and Game Fishes, a Popular Account of All the Species Found in America North of the Equator, with Keys for Ready Identification, Life Histories, and Methods of Capture. Doubleday, Page and Co., New York, pp. 1–573.
1911. A Review of the Salmonoid Fishes of the Great Lakes, with Notes on the Whitefishes of Other Regions. Bull. U.S. Bur. Fish., Vol. 39, 1909, pp. 1–41.

Jordan, David Starr, Evermann, Barton Warren, and Clark, Howard Walton
1930. Check List of the Fishes and Fishlike Vertebrates of North and Middle America North of the Northern Boundary of Venezuela and Colombia. Rept. U.S. Comm. Fish., 1928, Pt. 2, pp. i–iv, 1–670.

Kawajiri, Minoru
1928. On the Studies of the Population-density of Cultured Fishes. I. On the Influence of the Population-density of Fishes upon the Survival-rate and the Rate of Growth. Jour. Imp. Fish. Inst. (Tokyo), Vol. 24 (1), pp. 8–11.

Kendall, William C.
1917. The Pikes. Appendix 5, Rept. U.S. Comm. Fish., 1917, pp. 1–45.

Kidd, Patience Ellis
1927. The Food of Minnesota Fishes with Special Reference to the Algae. Trans. Am. Fish. Soc., Vol. 57, pp. 85–91.

Koelz, Walter
1929. Coregonid Fishes of the Great Lakes. Bull. U.S. Bur. Fish., Vol. 43, 1927, Pt. 2, pp. 297–643.
1931. The Coregonid Fishes of Northeastern North America. Papers Mich. Acad. Sci., Arts, and Letters, Vol. 13, 1930, pp. 303–432.

Koster, William H.
1937. The Food of Sculpins *(Cottidae)* in Central New York. Trans. Am. Fish. Soc., Vol. 66, pp. 374–82.

Kuhne, E. R.
1939. A Guide to the Fishes of Tennessee and the Mid-South, Div. Game and Fish, Nashville, pp. 1–124.

Lagler, Karl F., and Hubbs, Francis V.
1940. Food of the Long-nosed Gar (*Lepisosteus osseus oxyurus*) and the Bowfin (*Amia calva*) in Southern Michigan. Copeia, No. 4, pp. 239–41.

Meek, Seth Eugene
1889. The Native Fishes of Iowa. Bull. Lab. Nat. Hist. State Univ. Iowa, No. 1, 1888–90, pp. 161–71.
1891. Report of Explorations Made in Missouri and Arkansas during 1889, with an Account of the Fishes Observed in Each of the River Basins Examined. Bull. U.S. Fish Comm., Vol. 9, 1889, pp. 113–41.
1892. Report upon the Fishes of Iowa, Based upon Observations and Collections Made during 1889, 1890, and 1891. Bull. U.S. Fish Comm., Vol. 10, 1890, pp. 217–48.

Moore, H. P.
1917. The Burbot, a Fresh-Water Cousin to the Cod. U.S. Bur. Fish. Ec. Circ. No. 25, pp. 1–4.

Morris, A. G.
1939. Propagation of Channel Catfish. Progressive Fish Culturist, No. 44, p. 23.

Needham, Paul R.
1938. Trout Streams. Comstock Publishing Company, Ithaca, N. Y., pp. 1–233.

Okkelberg, Peter
1922. Notes on the Life-History of the Brook Lamprey, *Ichthyomyzon unicolor.* Occ. Papers Mus. Zool. Univ. Mich., No. 125, pp. 1–14.

Olson, Sig
1946. Spawning of the Eelpout. Minn. Cons. Volunteer, Vol. 9, pp. 43–44.

Olson, T. A.
1932. Some Observations on the Interrelationships of Sunlight to Aquatic Plant Life and Fishes. Trans. Am. Fish. Soc., Vol. 62, pp. 278–89.

Olson, Theodore A., and Slagle, E. C.
1932. Investigations of Fish Life in Certain Streams Tributary to the Red River of the North. June 10–16, 1932. (Mimeographed Rept.) Minn. State Board Health, Div. Sanitation.

Parker, Nathan H.
1857. The Minnesota Handbook for 1856–57. John P. Jewett Co., Boston, 159 pp.

Pratt, H. S.
1929. Parasites of Fresh-water Fishes. U.S. Bur. Fish. Ec. Cir. No. 42, pp. 1–10.
1935. A Manual of Land and Fresh-Water Vertebrate Animals of the United States. (2nd edit.) P. Blakiston's Son and Co., Philadelphia, pp. i–xviii, 1–416.

Reighard, Jacob
1900. Breeding Habits of the Dog-fish, *Amia calva*. Abstract. Rep. Mich. Acad. Sci., Vol. 1, 1894–99, pp. 133–57.
1906. The Breeding Habits, Development, and Propagation of the Black Bass (*Micropterus dolomieu* Lacépède and *Micropterus salmoides* Lacépède). Bull. Mich. Fish. Comm., No. 7, pp. 1–73.

Sage, Dean, Townsend, C. H., Smith, H. M., and Harris, W. C.
1902. Salmon and Trout. The Macmillan Co., New York, pp. i–x, 1–417.

Smith, Hugh M.
1907. The Fishes of North Carolina. N.C. Geol. and Econ. Survey, Vol. 2, pp. i–xi, 1–453.

Smith, Lloyd L., Jr., and Moyle, John B.
1944. A Biological Survey and Fishery Management Plan for the Streams of the Lake Superior North Shore Watershed. Techn. Bull. Minn. Dept. Cons., No. 1, pp. 1–228.

Stoudt, J. H., and Eddy, Samuel
1937. Walleye Pike Tagging Study, 1937–1938, Chippewa National Forest. Trans. 4th N. Am. Wildlife Conf., 1939, pp. 305–10.

Surber, Thaddeus
1913. Notes on the Natural Hosts of Fresh-Water Mussels. Bull. U.S. Bur. Fish., Vol. 32, pp. 101–16.
1920. A Preliminary Catalogue of the Fishes and Fish-Like Vertebrates of Minnesota. Appendix Bienn. Rept. State Game and Fish Comm., 1920, pp. 1–92.
1940. Propagation of Minnows. Spec. Bull., Minn. Div. Game and Fish, pp. 1–22.
1942. Common Minnesota Game Fish. Minn. Cons. Volunteer, Vol. 4, pp. 1–6.

Surber, Thaddeus, and Olson, Theodore A.
1937. Some Observations on Minnesota Fish Ponds. Trans. Am. Fish. Soc., Vol. 66, pp. 104–27.

Swingle, H. S., and Smith, E. V.
1940. Increasing Fish Production in Ponds. Penn. Angler, Vol. 9, No. 1, pp. 18–29.
1942. Management of Farm Fish Ponds. Agric. Expt. Sta. Ala. Poly. Inst., Bull. 254, pp. 1–23.

Thompson, David H.
1933. The Finding of Very Young *Polyodon*. Copeia, No. 1, pp. 31–33.

Trautman, Milton B., and Hubbs, Carl L.
1935. When do Pike Shed Their Teeth. Trans. Am. Fish. Soc., Vol. 65, pp. 261–66.

Van Oosten, John
1937. Artificial Propagation of Commercial Fish of the Great Lakes. Trans. 2nd N. Am. Wildlife Conf., pp. 605–12.
1941. Relationship between the Plantings of Fry and Production of Whitefish in Lake Erie. Trans. Am. Fish. Soc., 1941, Vol. 71, pp. 118-21.

Wagner, George
1908. Notes on the Fish Fauna of Lake Pepin. Trans. Wis. Acad. of Science, Arts, and Letters, Vol. 16, No. 1, pp. 23–37.
1910. The Whitefish of Silver Island Lake, Minnesota. Bull. Wis. Nat. Hist. Soc., Vol. 8, No. 3, pp. 132–34.

Weed, Alfred C.
1927. Pike, Pickerel, and Muskellunge. Field Mus. Nat. Hist., Zool. Leaflet No. 9, pp. 1–52.

Wiebe, A. H.
1930. Investigations on Plankton Production in Fish Ponds. Bull. U.S. Bur. Fish., Vol. 46, pp. 137–76.

Woolman, Albert J.
1895. A Report upon Ichthyological Investigations in Western Minnesota and Eastern North Dakota. Rept. U.S. Fish Comm. for 1893 (1895), pp. 343–73.

Index