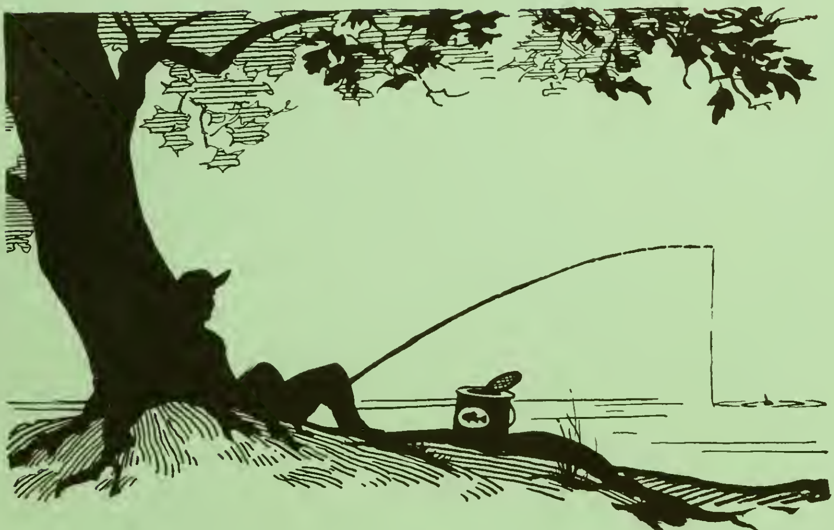
RAISING BAIT FISHES



CIRCULAR 35

FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR

RAISING BAIT FISHES

By John Dobie, O. Lloyd Meehean
S. F. Snieszko, and George N. Washburn

CIRCULAR 35

Fish and Wildlife Service
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FOREWORD

At the second annual meeting of the Tri-State Fisheries Conference (Michigan, Minnesota, and Wisconsin) in 1946, a special committee was appointed to assemble information on bait culture and to assign research to the contributing agencies. In 1948, the results of that cooperative project were published in Circular 12, *Propagation of Minnows and Other Bait Species*. The present publication is a revision of Circular 12 and adds the results of 5 years of pond investigations by research men in the Midwestern States.

The following persons contributed to this revision:

Dr. John Dobie, Minnesota Fisheries Research Unit, revised the sections on production of fish in natural ponds, handling of minnows, and control of predators. Measurements, weights and volumes of minnows, and food habits of some minnows were added to the section on the life histories of important bait fishes. Dr. O. Lloyd Meehean, United States Fish and Wildlife Service, rewrote the sections on pond construction and control of aquatic vegetation. Dr. S. F. Snieszko, United States Fish and Wildlife Service, rewrote the section on control of diseases and parasites and added information on use of the new antibiotics. George N. Washburn, Ozark Fisheries, wrote the sections on methods of fathead-minnow, creek-chub, and golden-shiner propagation used by the large commercial hatcheries of Missouri. John Moyle, Hjalmar Swenson, and Fred Miller, Minnesota Bureau of Fisheries, reviewed the manuscript. Harold Condiff and L. N. Nelson generously provided ponds and field assistance for the Minnesota natural-pond studies. Ruth Aanes, Minnesota Fisheries Research Unit, typed and proofread the manuscript.

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WHY BAIT-FISH PROPAGATION?

With the shortage of minnows in public waters now a reality and strict regulations on minnow seining increasing each year, the bait dealer is faced with the necessity of rearing his supply of bait fishes in ponds or other private waters. Most dealers will find the change from free-lance seining to propagation of minnows in ponds difficult but worth while. This circular presents information on the culture of bait fishes and is intended as a guide for those interested in commercial propagation of minnows.

The growing number of fishermen each year has resulted in a greater fishing load and an increased demand for suitable bait minnows. In an effort to satisfy this demand, commercial minnow dealers have seined lakes and streams over wide areas and have trucked their perishable commodity great distances. Consequently, dealers, fish culturists, sportsmen, and biologists fear that the supply of bait fishes has been greatly depleted in many places, and that the drain on this natural food of game fishes may become a serious problem.

Several factors determine whether seining minnows from natural waters is a wasteful or profitable undertaking. Seasonal fluctuations in the availability of bait fishes are the rule; minnows are not found in the same pools or over the same shoals in our lakes and streams at all times of the year. These changes in the supply of minnows are matched by inverse fluctuations in demand: there are fewer calls for bait during spring and fall when minnows are plentiful, but a great demand exists during the warm summer months when the minnows are difficult to catch. Some dealers have constructed outdoor ponds or indoor tanks large enough to hold over thousands of fish from the time of their greatest availability to that of the greatest demand for them; but the losses are so great that this method is not recommended as being either good business or good conservation.

The natural distribution of commercially important minnow species sometimes does not coincide with the regions where these fish are most in demand, and expensive trips must be made great distances to collect them. Environmental factors may also restrict the supply of minnows in an area where demand for bait is often great. Frequently, the cooler, more-sterile waters in the northern fishing regions do not support the needed quantities or species of bait fishes.

The rearing of bait fishes is by no means easy, but the advantages are many. The cost of raising fish may be less than the cost of seining them in distant waters. Also, the dealer who raises his own fish can have a nearly uniform supply on hand at all times to meet the demands, and is freed from the competition with other dealers for minnows in public waters.

Minnows raised in ponds are usually better fed than fish from public waters and are more hardy. Pond-reared fish also benefit from being seined in smaller numbers and from being in transit a shorter time. So, the fisherman who buys these fish will get better minnows for his money and will be able to keep them alive longer.

Everyone benefits from minnow propagation: the bait dealer is rewarded by a better and more-consistent business, the sportsman is supplied a better bait fish, and the State is aided in conserving its supply of forage fishes.

Even though minnow propagation is desirable, dealers who plan to engage in it should first consider the problems involved. Fish propagation is more than a simple proposition of combining fish and water to produce a profit. Considerable skill and judgment are needed to select or construct good ponds. Most dealers need years of practice before they become proficient at pond stocking, pond fertilizing, and pond harvesting. Each pond is a distinct problem, and conditions in it may change from year to year. The beginner in minnow propagation will do well to start on a small scale and learn as he builds up his business.

ESTABLISHING THE HATCHERY

ECONOMIC CONSIDERATIONS

The bait dealer should consider local economic conditions before he establishes a minnow hatchery. The most important factor is the retail price of the minnows. This price must be high enough to pay production costs plus a fair profit. If artificial ponds have to be constructed, the price received for the minnows must be high enough to pay off the principal and interest on the investment. Topography and land values must be such as to allow the selection or construction of a sufficient number of ponds for a practical business. One small pond is not enough for a sound, full-time business.

The successful dealer considers the following points to avoid producing fish that he cannot sell:

1. Which bait fishes are in greatest demand in the local market?

2. What size minnows do the fishermen want? It is important to know whether the minnows to be raised artificially will reach that size in one or two seasons.

3. In which months do the fishermen need minnows in the greatest number? The dealer must determine whether the pond minnows will be of commercial size in those months. Some species may be too large and others may be too small at the height of the fishing season.

4. Is there a natural supply of the popular species? In Minnesota, for example, fathead minnows are in great demand for crappie fishing, but these fish are so abundant in the natural waters of the State that artificial propagation is not profitable.

5. Do any habits of a popular species of bait fish make its propagation unprofitable?

6. How hardy are the popular species? Those fish needed during hot weather must be able to stand seining and handling when water temperatures are high. In Minnesota, there is a demand for golden shiners in the summer, but the fish are too delicate to stand normal handling in warm water; consequently, the golden shiner is raised only for the use of winter fishermen. While it is possible for the dealers to use special methods of handling the shiners during warm weather, the fisherman is still confronted with a delicate minnow that requires special treatment in the minnow pail.

7. What special handling do the fish require? Bait fishes raised for winter fishing require special holding facilities and suitable food for several months.

TYPES OF PONDS

A practical hatchery can be operated with either natural or artificial ponds—the choice depends to a large extent on the location of the hatchery. Artificial ponds are expensive to build on sand and gravel soils and are rarely profitable because of the added costs of fertilizing and pumping. Fortunately, such areas usually abound in natural ponds that can be leased for a small fee and will be cheap to operate. Even though the yield from natural ponds is less than from artificial ponds, the margin of profit may be higher. On the other hand, in areas of heavy clay soils, pond construction may be fairly cheap. On such soils, natural ponds are usually scarce. While artificial ponds on clay soils may require heavy fertilizing, the production will be high enough to provide a reasonable profit.

ARTIFICIAL PONDS

Artificial ponds for the production of minnows may be divided into two categories: Single ponds, such as those which utilize runoff from the surrounding land, and a series of ponds supplied by a much larger source of water and maintained for large-scale production of bait fishes (fig. 1). There will, of course, be differences in design for each job, depending on local conditions, so that only general recommendations on construction can be made. Wherever possible, the services of an enginer or of someone experienced in the construction of fish ponds should be employed, to make the best possible use of the water supply, particularly if the construction job involves a large investment.

Regardless of size, location, or number of ponds built, there are four essential requirements for success in operating the ponds.

1. The water supply must be dependable at all seasons of the year, and of sufficient amount to exceed all requirements.
2. The pond should be constructed on soil that will hold water.
3. Where a series of ponds is built, construction should, if at all possible, be such that each pond can be handled independently of the others.

FIGURE 1.—Series of ponds used in large-scale production of bait fishes. (Photograph courtesy of the Ohio Department of Conservation and Natural Resources.)

4. Ponds should be constructed in such a way that they can be drained completely, emptied of fish, and refilled when necessary.

Water supply

A suitable and an adequate water supply is of primary importance, and should be considered first in selecting a site for rearing ponds. To be suitable, the water should be only moderately hard and should contain no other species of fish; the temperature of the water should be high enough to promote rapid growth (see p. 69); the pH, or hydrogen-ion content, should be slightly on the alkaline side.

Springs and artesian wells are the most desirable source of supply because such water is dependable, easily controlled, permanently clear, and generally free from pollution. A water supply should be protected from contamination by surface water, which may cause the supply to become turbid or polluted by drainage from stables, yard ponds, and like sources, as well as from contamination by insecticides, fungicides, and herbicides.

Hard water may be undesirable because it generally contains noxious gases, such as carbon dioxide, nitrogen, hydrogen sulfide, and marsh gas. All of these gases are injurious to fish by actually poisoning or asphyxiating them. Other waters may contain excessive quantities of iron. In nearly all of these instances, the water can be purified and made suitable for fish by running it over a series of falls, or baffles, and by storing it in a reservoir with a large surface area to permit thorough aeration.

Spring and artesian water should be tested beforehand by placing fish in it. A temporary pond or trough may be employed for the purpose. If possible, the fish should be held in the pond or trough for a whole season to obtain a good test; however, a shorter period, perhaps a month, may be sufficient. If the fish remain alive, the water can be considered suitable.

Permanent construction should include a reservoir at or below the spring itself. This reservoir may be of concrete, or riprapped with stone or brick for protection. A way must be provided so that excess water from the supply can be diverted around the pond or ponds. A sufficient flow should be provided to compensate for seepage and evaporation from the ponds during the propagation season.

Natural water supplies, such as creeks, lakes, rivers, or ponds, may be utilized as a source of water, but should be considered only when springs or artesian supplies are not available, or where the natural sources have all the necessary attributes of a good water supply. These sources are subject to change in volume, temperature, and turbidity, and may be polluted. In addition, they generally contain undesirable species of fish which prey on minnows and reduce production in the ponds. No hatchery operator has successfully screened undesirable fishes from ponds, except by using expensive and elaborate gravel filters.

In selecting a stream to provide water for rearing ponds, one should take into consideration, primarily, the fluctuations in volume and the amount of turbidity. Turbidity is particularly important because excessive silt may gradually fill the ponds to which the water is supplied. Turbid water also reduces productivity by restricting light penetration and, as a consequence, the development of food organisms. Where turbidity is periodic and of short duration, the water should be bypassed downstream.

The volume of water must be kept within certain limits throughout the year, depending on the number of ponds operated. Fortunately, by building proper structures, a suitable volume of water can be obtained. If the stream flow is constant or if the fluctuation in volume is within narrow limits, sufficient water may be obtained by the building of a low dam (fig. 2).

This dam should be located so that water can be obtained for the ponds by gravity flow. The water control structure should be of concrete and equipped at one side with an intake box from which the desired amount of water may be obtained for the pond system. Dams of low head provide no obstacle to flood waters and allow debris to pass over readily without obstructing flow. Where the flow is intermittent or becomes considerably reduced during the dry season, it may be necessary to make a larger impoundment by constructing a higher dam.

The dam should be anchored in both banks of the stream with bulkheads as high as the banks—to protect the banks. The spillway should be built somewhat lower than the bulkheads. A concrete apron should be provided to keep the water flowing over the spillway from undercutting the dam. The intake box should be provided with a coarse grating to obstruct large masses of debris. It should have a slot in which a fine screen is inserted to keep out leaves and materials that might obstruct the flow of water through the pipe to the pond and to keep out other fishes. So that the screen may be kept clear of debris without too much diffi-

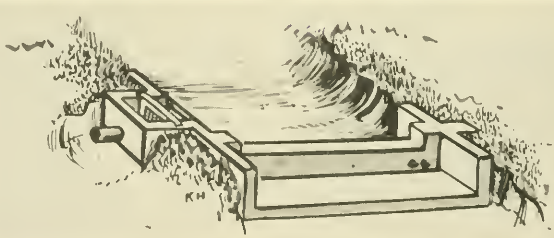


Figure 2.—A low dam with outlet for supplying water to ponds.

culty, the screening surface should be large in proportion to the amount of water used.

Where there is considerable debris in the water, the operator may have difficulty in keeping the screens clean. In this situation, another type of construction is often used. This involves building a concrete box in the bottom of the stream; the box is slightly raised from the bottom so that it does not become covered with gravel, and so that the current continually washes over the surface and carries away leaves and other debris. Information concerning a structure designed along these lines is obtainable from a qualified civil engineer.

Where water cannot be obtained by gravity, pumping is sometimes justified. The pumping cost is a continuing and constant one, and operations must be on a scale large enough to justify it. It is essential to have a cheap source of power. To make operations as thrifty as possible, the ponds must be tight enough to prevent too great a loss from seepage. Some operators arrange construction in such a way that when one pond is being drained a portion of the water can be directed into an empty pond and used again. This saves pumping costs and fertilizer.

Where a series of ponds is operated, the most satisfactory results are obtained by storing the water in a reservoir from which it may be taken as required. Generally, such a reservoir is constructed by building an earthen dike just below the source of water. This has the advantages of providing an adequate source of water as needed and of removing noxious gases or minerals by aeration and storage.

Water may be forced to a higher level by means of a ram if conditions are satisfactory for its operation. When the source of water is a spring, it must have a large capacity to justify the use of a ram, which is wasteful of water. A maximum of about one-seventh of the water can be forced upgrade. A 1-foot fall from the spring to the ram is required for every 10 feet that the water must be forced vertically to the pond, and the flow is further reduced in proportion to the horizontal distance the water must be pushed. A large reservoir that permits the use of water in the pond system, as necessary, is preferable to having a ram supply the ponds. Usually, obtaining water by use of a ram is inadequate and unsatisfactory.

A windmill can be used to supply water to small ponds of ¼ to ½ acre. Local conditions, such as the amount of rainfall and evaporation, help to determine the size of pond that can be filled and maintained by this method. The size of the pumping equipment and other elements involved in windmill operation will assist in deciding whether a windmill should be used.

Choosing the pond site

Too much emphasis cannot be placed on the proper location of ponds. The selection of a good site results in economical construction and satisfactory operation. Time spent in surveying possible sites before a final selection has been made will pay dividends. Many failures are traceable to a compromise in design features because of the cost difficulties involved. Selection of a site on which favorable conditions can be utilized will avoid excessive costs and impractical installations.

After a suitable water supply has been located, other details of site selection may be considered. The area must be relatively flat and large enough to include the ponds, buildings, and other structures required for a modern hatchery. The ground should slope gently from the upper end of the site, which is below the source of water, to the lower end, where water is drained from the individual ponds into a convenient watercourse. The main objective is to select a site of suitable size for anticipated need and of such topography that ponds can be constructed without moving or hauling an excessive amount of dirt too far. Any good engineer can make a topographic survey to determine the feasibility of constructing a pond system on a piece of land.

The most satisfactory ponds are constructed on impervious soil. Clay soils or soils with a high clay content are most desirable. The best material consists of approximately two-thirds sand and one-third clay, but generally some compromise in quality has to be made. It is good practice to have the soil tested. If there is any doubt as to the porosity of the soil structure, borings should be made to determine the depth of the impervious layer. Care should be taken that there are no rock strata reaching the surface or beds of gravel anywhere in the pond bottom, as water follows these formations readily with considerable loss to the pond.

Where an extensive pond system is not desired, small impoundments for the propagation of minnows may be located in an area much more restricted than a hatchery-pond system would require. These ponds may be located in a natural gully where the land slopes from three directions into the pond area and where the dam will be neither so long nor so high that the cost of construction will be excessive (fig. 3). The shape of such a pond depends entirely on the topography.

It is not desirable under any circumstances to dam a stream to make a pond, or to locate the pond where it is subject to regular floods. The best impoundments are supplied by just-sufficient spring water to maintain the pond level, or are located high enough on the drainage basin that the water level is maintained by runoff from surrounding land.

In sections of the country where rainfall is relatively high, as in the Gulf States as far west as Louisiana, the drainage area should be about 5 acres for each acre-foot of water in the pond. In those sections where rainfall is lower—as in southeastern Wisconsin and southern, central, and western Minnesota—the proportion of drainage

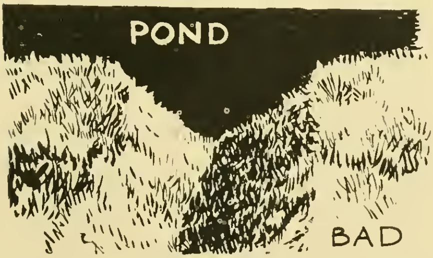
FIGURE 3.—Pond located in a natural gully, using runoff as a source of water. (Photograph courtesy of the U. S. Department of Agriculture.)

area should be greater. It is particularly desirable that drainage be from good pastureland, a stable forest area, or other well-covered land. Eroded or improperly tilled soils allow rapid runoff, which results in silty waters and gradual filling of the pond. Some operators who must take waters from tilled land construct a small settling pond or silt basin above the regular pond. The lower end of the pond site should be of sufficient width to provide an adequate auxiliary spillway to carry off occasional floodwaters (fig. 4).

Pond construction

The dam.—Small impoundments are generally made by building a dam across a narrow gully where the banks are of sufficient height to provide water deep enough for fish during winter. The depth at the dam should be from 5 to 15 feet, depending on the severity of winter weather and the topography of the pond bottom. In northern Illinois, the depth should be at least 10 feet; the farther north the pond, the more this figure should be increased.

First consideration is given to



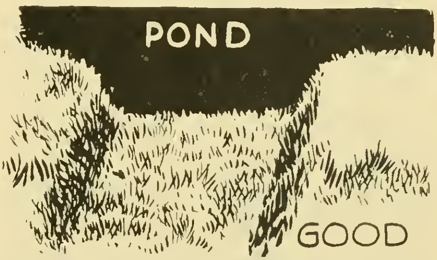


FIGURE 4.—A spillway with a flat design, as on the right, is less likely to wash out when heavy rains come than is the badly designed, V-shaped spillway on the left.

laying out the dam and outlining the confines of the water level in the pond. Because of the acreages of water impounded, earthen dams are used almost exclusively. Determining the desirable top width is the first step in the design of the dam. Generally, the top of the dam is 8 feet wide, but if it is to be used as a road for automobile travel, it should be at least 11 feet wide. The equipment to be used in constructing the dam also influences the width of the top. If teams are used, the top of the dam should be 5 feet wide; if tractors, a width of at least 10 feet is required. When the height of the dam and width of the top are determined, the base can be laid out.

Ordinarily, the upstream, or pond, side of the dam is sloped at the rate of 3 feet for each 1 foot of height. On the downstream side, the slope is generally 2 to 1. If the soil contains more than the recommended amount of sand or gravel, however, the slope should be increased to as much as 5 to 1, depending on the nature of the construction materials used. This simply means that if the top of the dam is 8 feet wide and the height is 10 feet, the base will be 78 feet wide.

The site of the crest of the dam should be laid out first, then stakes set along the inside and outside toes, or limits, of the dam. Stakes should also indicate the limits of the water level in the pond. The dam should be high enough to allow 2 to 3 feet of freeboard; that is, the top should be 2 or 3 feet above the normal water level of the pond (fig. 5).

All trees and bushes should then be removed from the dam site or stacked and burned. All stumps should be removed from the pond site, particularly if the pond is to be drained for the removal of minnows, in which case it is also desirable to grade the bottom so that no low spots or water pockets will be left after the pond has been drained. Every piece of root or stump should be removed from the site where the dam is to be located. If this is not done, the decaying wood may cause trouble.

The next step in construction of the dam is to form a tight bond between the dam and the base on which the dam rests. If the surface is covered with a layer of organic matter, it should be removed and stored for later use in covering sections of the dam which will be seeded with vegetation. The area covered by the base of the dam should then be plowed.

No structure is better than its foundation. To assure a good pond, a section of earth should be removed, parallel to and directly under what will be the highest part of the dam, down to solid, mineral soil. If clay soils are underlaid with sand or gravel, do not dig through the clay into the sand, or the pond will leak. Excavation for the clay core may be accomplished with equipment commonly used, but under certain conditions may be done more rapidly with dynamite. Dynamite is particularly effective

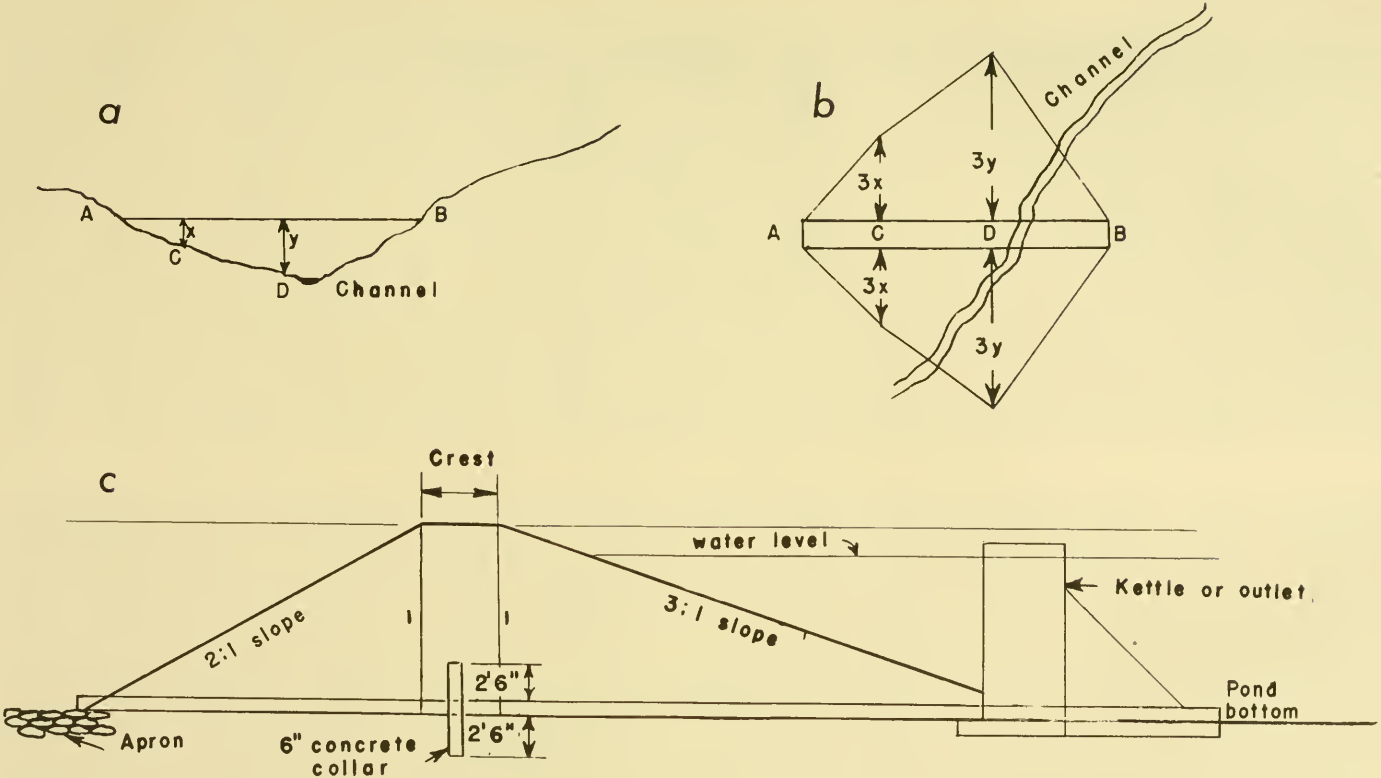


FIGURE 5.—Details of dam construction showing outlet structures. *a*. Channel to be dammed. *b*. Top view of base of dam indicating width of the fill (x and y) to compensate for depth of the channel at C and D. *c*. Cross section of dam and outlet showing outlet pipe.

where the earth is saturated with water—the wetter, the better—and where it would be impossible to use other methods. Holes, 12 to 20 inches apart, should be driven down to solid earth (rarely more than 16 inches below the surface). These holes should be charged with dynamite made of 50-percent nitroglycerine, and set off with an electric battery to obtain the greatest possible lifting power. The "propagation" method may be used where the soil is very wet. By this method, one cap is used to set off the first stick of dynamite, and the other sticks are exploded by the shock of the first charge. If the soil is not wet, a cap should be used for each charge. Less time is needed to construct a ditch in this way than is required for other methods.

By now the soil types should be known with some degree of accuracy. Only pure clay or clay soils should be used to fill the trench that has been excavated. This cutoff wall, or core, should be built up several feet through the center of the dam. The better, more impervious soils that are available for construction should be used directly under the center of the dam and on the upstream side. Less desirable or lower quality earths, such as sand, stone, or gravel may be used in the fill, but they should be incorporated only on the downstream side of the highest point in the dam and extend to the toe. So placed, these poorer earths provide weight to prevent slipping and are at the maximum distance from the saturation point of the water.

With small dams or pure clay soil, it is unnecessary to construct a core through the dam. The same result may be effected, after the whole area of the base is plowed, by removing the topsoil down to solid earth on the upstream half of the dam and properly placing it on the lower half. The solid earth should then be plowed so it will bind with new earth moved in. Thereafter, the builder should follow the same construction procedure recommended for a dam in which a core is made.

After the base has been properly prepared, the drain line should be laid. A shallow excavation to solid earth should be dug from the proposed pond outlet to a point below the dam. Earth, the best clay available, should be firmly packed around the pipe, particularly on the underside. Addition of water to the soil to form a stiff mud will facilitate a firmer pack in the tamping process. At some central point in the dam, a concrete collar should be poured around the pipe. This prevents water from following the pipe and developing leaks; it also prevents burrowing animals, such as crayfish, from following the pipe. After the pipeline has been set up, construction of the dam may go forward.

Earth from somewhere within the pond area can be used to provide dirt for the dam. Most of the soil should be obtained in the vicinity to save labor. The whole bottom area of the pond should be deepened and graded to drain properly, and soil removed from all the pond edges so that the water has a minimum depth of approximately 2 feet. Earth taken from the edges and not used in the dam may be used for sloping the bottom of the pond so it will drain properly.

Earth can be properly placed on the fill by keeping the fill higher on the edges than in the middle. If this is done, there will be no tendency for equipment to spill over and earth can be dumped the proper distance from the edge. Dirt should first be dumped about 2 feet from the upstream, or inside toe, stakes and about 18 inches from the lower, or downstream, stakes. This procedure will save labor by making a natural slope. Conversely, all cuts with the scraper should be made deeper at the edges than at the center. This prevents the equipment from sliding away from the banks, a possibility which might result in a ragged slope.

Fill placed on the dam should be properly compacted. Maximum compaction is effected by putting earth in place in thin layers and traveling the full length of the fill each time. On high dams, special compacting equipment, such as a sheepsfoot roller, is needed, and the required density is obtained by the control of moisture content. Although the compacting reduces the amount of settling, allowance should always be made for it.

The actual process of constructing a series of hatchery ponds is somewhat different from building a dam, but the method of placing and compacting the material is the same. The slopes on the dikes between the ponds should be uniformly 2 to 1. Where there is a series of ponds, it will be necessary to make only the dams or levee on the outside of the series water-tight by using a clay core. All levee bases should be properly prepared by clearing off organic debris and plowing the entire area.

The design of a hatchery is dependent on the size, shape, and topography of the land on which it is located. If the plot of land is properly sloped, ponds may be planned in such a way that sufficient earth can be removed from the pond site for the embankments. Ideally, the ponds should be from ¼ to 1 acre in area, but the topography of the land will dictate, to some extent, the size of pond that can be constructed most economically. Under no circumstances should there be any large number of ponds of an acre or more in size. Small ponds are handled more easily and are generally more productive (fig. 1).

Plans for excavation and for the placement of drains and waterlines should be made by a competent engineer. All elevation stakes for drain and waterlines and for the dikes should be placed before excavation starts. The drainage lines are generally placed in or through the levees so that it is essential to have these lines in place before pond construction starts. The drainage

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lines always lead from the deepest part of the pond to a convenient watercourse that will carry off the drainage water.

Ponds should be so constructed that the minimum depth at the shallow end is about 2 feet. Ponds to be used for propagation purposes should be sloped so that they are at least 5 to 6 feet deep at the outlet. Ponds used for holding fish through the winter must be at least 10 to 12 feet deep in the Northern States; however, the size of the pond will, to some extent, determine the depth at the outlet.

The pond bottom should be sloped from the sides and ends toward the center and the center sloped from the shallow end to the outlet. The grade through the centerline of the pond should be not less than 1 foot for each 100 feet of pond length. Where a series of hatchery ponds is being constructed, the ponds are partly above and partly below natural ground level.

The type of equipment most economical to use for excavating a series of ponds depends on the size of the job and the distance that earth must be moved. Horse-drawn equipment is economical only for small jobs and short hauls, but may be used for larger jobs if it is the only equipment available. With horses, a slip scraper may be used economically for moving earth as much as 50 feet, but for distances of more than 150 feet the cost is so great that some other type of equipment should be considered. If horses are used for longer distances, a four-horse-loaded, two-horse-transport wheeler should be used.

Maximum efficiency may be obtained with a 35-dhp (D–4) tractor bulldozer at distances from 100 to 150 feet and where the grade is not more than 5 percent. As the grade increases, the efficiency of a bulldozer decreases rapidly. A self-loading, carrying-type scraper should be used at distances greater than 150 feet. On larger jobs, or where hauls are more than 500 feet, a 113-dhp tracktype tractor is more economical. Of course, availability of equipment may be the decisive factor in most cases.

Structures.—The types of structures to be used in conjunction with hatchery layouts are largely a matter of preference, but experience has shown that adequate construction is highly advantageous. Likewise, experience has demonstrated that adequate construction is more economical than skimping on sizes and materials. Thus, pipelines of sufficient size are more economical than pipelines that are too small. In the past, tile drainlines, caulked with cement, have been used extensively because the original construction cost is lower. Unfortunately, there have been many failures with these lines on account of loose caulking, entrance of tree roots, pressure from the fill, and for other reasons.

Great advances have been made in the last few years in pipeline fabrication. Among the types recently developed, the most suitable for use as outlets and the most easily installed are spiral-welded steel pipe and asbestos-cement cast pipe. Spiral-welded pipe is lightweight, long lasting if properly installed, and comes in long lengths. Asbestos–cement pipe comes in shorter lengths but can be cut with a saw, and the joints have considerable flexibility. Not subject to corrosion, its period of utility is indefinite. Standard fittings can be used with both kinds of pipe, and they can be utilized for both drainage and waterlines.

In ponds ¼ acre or less in area, the drainline should be not less than 6 inches in diameter; and in ponds of ¼ to 1½ acres, the line should be not less than 8 inches. Use of large drainlines has a number of advantages, including savings in time and labor and frequently a saving in fish (which may be lost otherwise because of high temperature, suffocation, muddy water, or other causes, in the draining process).

Every pond should be equipped with an outlet structure of some type. This outlet, or kettle, serves a number of purposes. It acts as an overflow when rain or other inflow of water raises the pond level above normal. In the process of draining the pond, the outlet holds back the fish so that they can be removed when the water level has fallen to a depth that the operator can wade.

In small impoundments which are to be drained infrequently, one of a number of outlets may be used. The Canfield outlet is the type most commonly used (fig. 6). It consists merely of a pipe cut to the proper length so that it will act as an overflow and control the pond level. This pipe is inserted in a 90° ell attached to the drain-

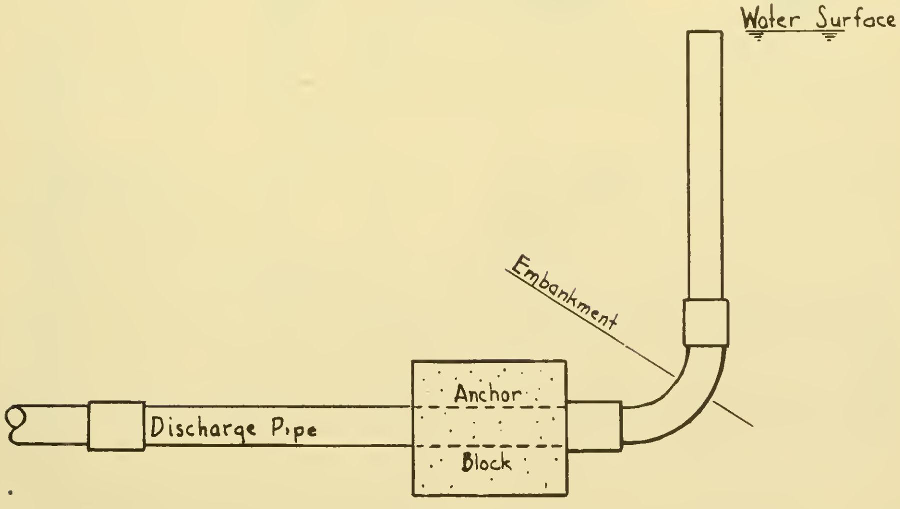


FIGURE 6.—Canfield pond outlet. Commonly used in small impoundments that are drained infrequently.

line and can be tipped to the desired level to drain the pond.

Another outlet is merely a cement block laid around the outlet pipe, attached to which is one of a number of gates (fig. 7). The most commonly used gate is the usual irrigation gate, the cost of which will vary according to size and type used. A homemade gate can be made by bolting a channel iron to the block on either side of the opening and inserting a piece of boiler plate that fits over the opening and has a handle welded on it (fig. 8). It can be made by a blacksmith.

Research workers at Alabama Polytechnic Institute, Auburn, Ala., have designed an inexpensive gate which is attached to the bell of a piece of soil pipe. They recommend an adaptation which is attached to a 30° ell so that the gate can be opened by pulling a wire on shore. This arrangement eliminates the need for a platform to the outlet, which must be located in the pond beyond the toe of the levee and at the lowest point in the bottom. If the pond is to be drained frequently, however, one of the standard outlets for hatchery ponds should be used.

Hatchery ponds should be equipped with an outlet to permit ready drainage and removal of the fish that have been propagated. There are two general types of outlets which may be adapted to conditions. One type has the outlet and water-control structure inside the pond and the catch basin for

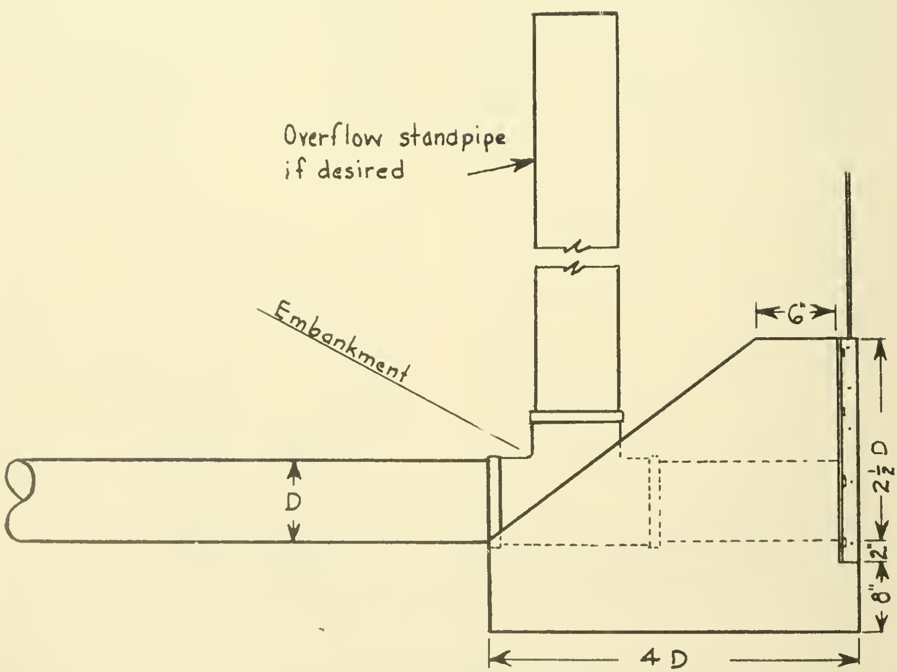


FIGURE 7.—Cement-block pond outlet.

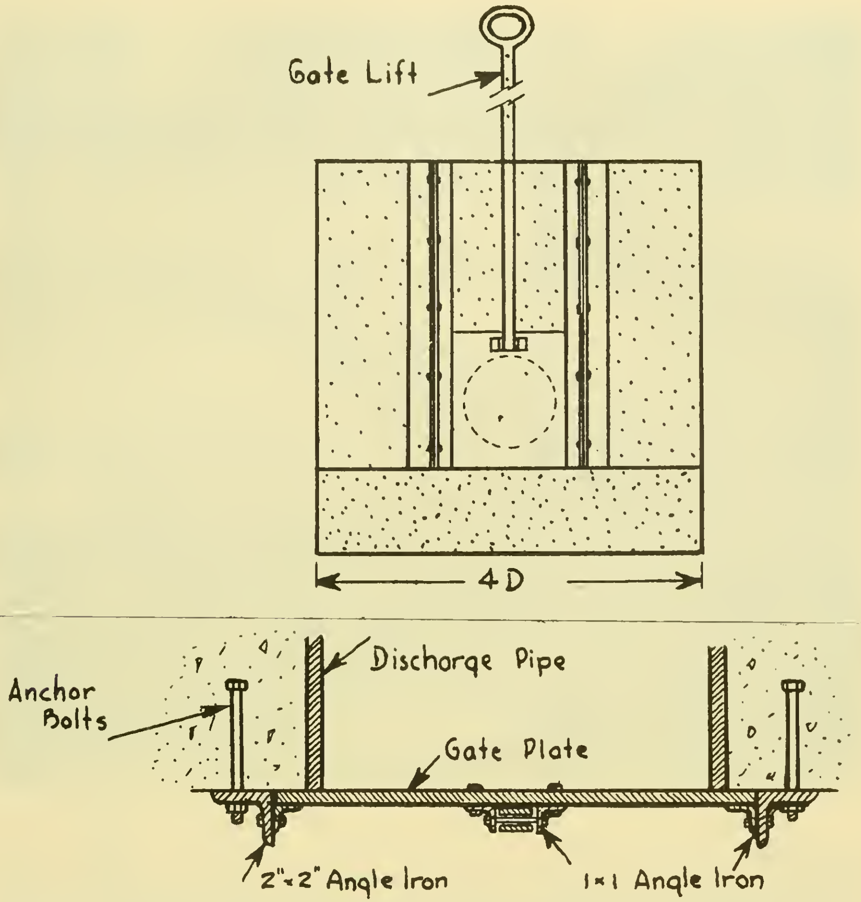


FIGURE 8.—An inexpensive pond outlet gate that can be made from materials on hand.

collecting fish outside (fig. 9). The other has the outlet kettle and catch basin inside the pond.

The plan of a conventional type of catch basin and outlet is shown in figure 10. Built of concrete, this structure makes it possible to control the water level and to drain the pond. The outlet is at the low point in the bottom of the pond, usually midway of one side. The catch basin should extend 6 to 10 inches above the bottom of the pond.

The chimney usually has two sets of slots. The outer slots are provided for a screen (*A*), which prevents fish from leaving the pond and debris from entering the pipeline. The screen is made of hardware cloth on a wooden frame which fits into the slots. The screen may be as fine as 8 meshes to the inch or as coarse as 4, depending on the use to which it will be put.

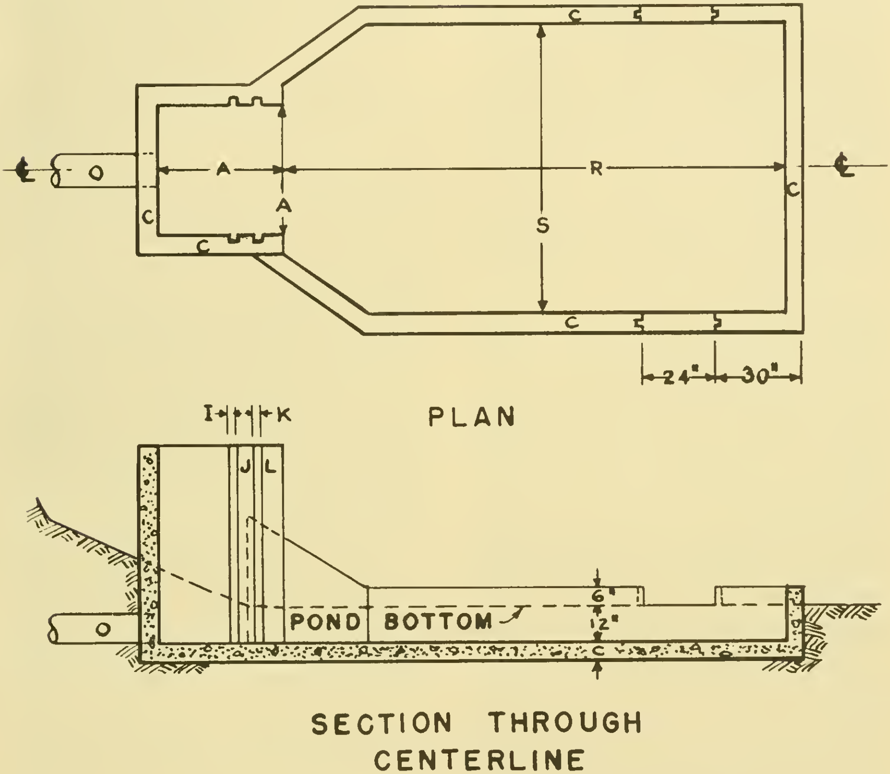
The second set of slots is for dam boards, or stoplogs, which are

FIGURE 9.—Catch basin constructed outside the pond.

usually made of 2-inch by 8- or 10-inch treated, finished lumber, and beveled on either end to fit. The boards are placed one over the other up to the desired water level in the pond, and they serve as an overflow where rainfall or other water may raise the pond above the desired level. These boards may be kept tight by small wedges inserted at either end of the upper board.

The type of construction used is a matter of preference. The solid wall provides a tight outlet with an easily manipulated outlet gate. On the other hand, the dam boards, or stoplogs, can be removed at will and the water level kept at any desired point in the pond. Also, if an irrigation or other gate is used, the total pressure of the water is against the screen when the pond is being drained, and should the gate become blocked with debris (as is generally the case), the screen may be broken. If dam boards are used, they are removed one at a time and the pressure is only the depth of the flow over the board; consequently, the screens seldom become entirely blocked and are never broken by pressure; also, there is no loss of fish from their being forced against the screen.

The kettle, or catch basin, which is attached to every outlet box, should be about 10 to 18 inches deep, and should extend above the bottom of the pond. Experience has shown that most of the fish can be removed with a seine as the water is being drained, but some receptacle should be provided to capture the last few fish. The catch basin



MEASUREMENTS									
POND ACREAGE	A	C	I	J	K	L	O	R	S
¼ OR LESS	30"	6"	1½"	6"	1½"	6"	6"	10'	6'
½ - 1½	36"	6"	1½"	6"	1½"	6"	8"	12'	6'
2 – 3	42"	6"	2"	6"	2"	6"	10"	14'	8'
4 – 8	48"	8"	2½"	6"	2½"	6"	12"	16'	8'
10 – 15	54"	8"	3"	6"	3"	6"	15"	18'	10'

FIGURE 10.—Plan of catch basin with suggested measurements for the catch basin according to size of the pond.

and outlet combination should be set at the toe of the levee and halfway down one side of the pond at the deepest end.

An alternative type of construction involves the use of an outlet box and the catch basin at some point outside the pond (fig. 9). The outlet box is similar to that designed for a natural pond and does not require the use of a screen. All the water is drained through the outlet to a catch basin outside the pond.

The outside seining, or catch, basin is a concrete tank constructed in such a way that water from the pond outlet flows into it. Grooves are provided for a screen and dam boards. Where the outlet from the pond comes into the seining basin, it is provided with an irrigation gate or valve which may be shut when desired.

Most of the water from the pond is drawn through the seining basin until a considerable number of minnows come into it from the pond. The outlet valve to the pond is closed and the water in the basin lowered until the majority of the minnows can be removed to suitable receptacles. This operation is repeated until all the water has been drained from the pond and all the minnows have been removed from the seining basin and placed in holding facilities.

The type of construction with ponds in a series along a watercourse or grouped in such a way that a number of pond outlets can be brought into the seining basin is most economical, because more than one pond can be drained into the basin. If there is a large group of ponds, the situation may not lend itself to this type of construction, because only one pond can be drained at a time. Where there is a basin in each pond, more than one pond can be drained at a time—often a very desirable procedure.

Waterlines supplying the ponds should be of sufficient size to fill the ponds rapidly and to maintain water levels. At least 4-inch, and preferably 6-inch, pipes should be run to each 1-acre pond. The main supply lines from which these pipes lead off should be designed in accordance with the number of ponds supplied, the amount of water pressure, and other factors. Cement–asbestos pipe is ideal for the main supply lines. These lines should be laid in the dikes at the proper stage of construction.

There is some difference of opinion regarding the proper location of the water-supply lines to the individual ponds. Where the seining, or catch, basin is located in the pond, the supply line should be located at the basin. This permits the use of fresh water when the pond is being drained and when the pond water is muddy from frequent agitation. It also provides a source of fresh water to fill receptacles used to transport fish from the pond. Except in those ponds used for the propagation of stream-breeding species such as the creek chub, there seems little in favor of having the water supply at the end opposite the outlet.

NATURAL PONDS

In some localities, the bait dealer will have to use natural ponds for the production of minnows because of the lack of suitable locations for artificial ponds. While natural ponds often do not produce as many minnows to the acre as do artificial ponds, there are some points in their favor. Natural ponds do not require expensive dams and control structures, rentals are usually low, and little or no fertilizer is needed. As these factors add up to low production costs, the margin of profit is usually high.

Natural ponds available for the production of minnows vary greatly in size and shape, but medium-sized ponds are most practical to operate. Large ponds are too difficult to seine and small ponds cost more per acre to seine than do medium-sized ponds. Deep ponds produce better in hot, dry years when shallow ponds become too warm and may even dry up, but in cold, wet years, the shallow ponds come into their own. As it is difficult to predict a full season of weather, the dealer should try to operate both shallow and deep ponds each year. While the type of pond most practical for production varies with the species of minnow to be raised, Minnesota dealers have found that natural ponds 3 to 5 acres in size and 5 to 8 feet deep are most profitable.

Natural ponds vary greatly in fertility. Ponds located in rich farmland are usually very fertile, and ponds on poor, rocky soils are infertile unless the runoff includes such sources of fertility as barnyard drainage. The type of soil on the pond bottom has a definite effect on pond fertility. Fine-textured soils that cloud the water easily and give up their fertility readily are usually found in fertile ponds. Soils that have most of their fertility tied up in vegetation or organic matter give up that fertility very slowly and ponds with such soils tend to be moderately fertile. The relative fertility of a pond can be judged by how green it becomes during hot weather: the greener the water, the richer the pond.

A rich pond will contain a large amount of nutrients in the water and will produce good crops of water fleas for fish food at various times during the season. Such a condition is desirable for the production of large fish crops, but rich ponds also may produce great amounts of algae. Even though algae enter into the food chain, these microscopic plants are not readily eaten by most minnows, and when they decompose the dissolved oxygen in the water is used up and large amounts of ammonia are produced. The fish need a fairly high concentration of oxygen for respiration, and ammonia in large concentrations is toxic to them. Consequently, the decomposition of a heavy algal growth may kill a large number of fish. Algal blooms are likely to be more harmful in shallow ponds than in deep ponds. Some species of minnows tolerate lower oxygen and higher ammonia concentrations than others and are, therefore, more successful in fertile ponds. Each species has its limits of tolerance that cannot be exceeded if the production of a pond is to be profitable.

The productivity of a pond is also related to the hardness of the water. Medium-hard to very-hard water will usually produce more fish than soft water. Sometimes it is possible to increase the hardness of the water by the addition of lime, but fish production will not increase unless the water contains sufficient nutrients, or a sufficient amount of these elements is added with the lime.

Seining conditions in natural ponds must be considered before the pond is selected. While it is possible to trap minnows, they often do not move into the traps when needed, and seines must be used to get them out in time for the market. A pond with boggy shores, steep banks, soft bottoms, or brushy edges should be avoided unless it has an open, firm-bottomed beach for good seine landings.

Fertile ponds covered with ice and snow will often run out of oxygen before spring, and the fish will smother unless the pond is at least 15 feet deep. During winters of no snow, the ice will transmit enough light to keep the plants in the pond actively supplying oxygen and the fish may survive in quite shallow ponds. During winters of early and heavy snows, fish will survive if the ice is kept clear of snow. Because of the difficulties encountered in holding minnows over winter in natural ponds, most dealers plan their production so that all minnows can be sold the first year. When this is not possible, holding ponds with running water are used and the fish are fed artificially through the winter.

CHOOSING THE FISH

Many factors must be considered in choosing a bait species to be raised. Several species should be reared if the dealer expects a sustained income from his operations. If properly selected, they will provide suitable sizes through most of the year. As a general rule, a beginner should raise only one species in each pond.

The following characteristics should be considered in selecting a bait species for propagation:

a. The fish should be reasonably tolerant to seining, handling, and transporting.

b. The fish should have a rapid rate of growth. Even then, some species must be held more than one winter in northern latitudes.

c. The adults must be large enough to be suitable bait for the predominant game fish of the region.

d. The species should have an extended spawning season.

e. The fish should be prolific.

f. The fish should not be excessively cannibalistic.

g. The fish should be resistant to the more virulent fish diseases.

h. Those species lacking spines and hard parts are most suitable.

i. The minnow should be one that thrives under cultivation.

j. The fish should be suited to the ponds available.

k. Holding qualities are of the utmost importance.

l. Species that are hardy on the hook sell the best.

None of the bait species will meet all of these conditions, but all the points should be considered when choosing a species of fish to raise. Often popular demand will dictate the kinds that can be sold. Among the most popular bait fishes for propagation are the sucker, golden shiner, creek chub, fathead minnow, and goldfish; and specific information relative to their production is given in the section on Some Important Bait Fishes, pp. 68–102.

OPERATING THE HATCHERY

FERTILIZING THE POND

The object of fertilizing a pond is to produce foods in large quantities at the time they are needed most by the fish. Several methods of supplying fish foods are in use at the present time. In the Northern States, organic fertilizers are added to the pond to produce a growth of bacteria and protozoa (fig. 11). These small forms are food for the waterfleas and rotifers, which in turn are the main source of food of the important bait fishes. In most Southern States, the ponds are fertilized with inorganic fertilizers, which release nitrogen and phosphorus into the water. Minute plants (algae) which often give a greenish color, or bloom, to pond waters utilize this nitrogen and phosphorus. When they die and decay the food stored in them becomes available to minute animals (protozoa) in the water. These animals are food for the waterfleas and rotifers. The food cycle with algae in the primary stage is dangerous to use in northern ponds because of the danger of an excessive algal growth, which uses such a large amount of oxygen from the water when it decomposes that the fish suffocate.

A third method of providing crustacean (waterfleas) fish foods, that is little used but offers great possibilities, is dry fallowing. Each pond is drained and dried up periodically. When the pond bottom is dry enough to support farm machinery, it is disked, fertilized with 10-10-10 fertilizer, and planted to rye. The rye is allowed to grow to a height of 6 to 8 inches before the pond is refilled. As the rye decomposes a growth of bacteria and protozoans develops. In 7 to 10 days the pond contains a crop of waterfleas 8 to 10 times greater than that obtained by fertilizing. Natural ponds maintain their fertility by a similar process. When the pond level is low, the exposed bottom becomes covered with a growth of hay. When the pond level is high, the hay is flooded and decomposition starts a new food cycle.

For maximum growth of the fish and maximum fish production, the food chain should be started early and should be maintained throughout the growing season. In northern ponds, barnyard manure is generally used in the spring because it decomposes rapidly and gets the food chain off to an early start. Manure should be applied at the rate of 400 to 1,000 pounds to an acre of water, depending on the fertility of the pond. Dried sheep

FIGURE 11.—Ponds often need to be fertilized to increase their productivity.

manure can be used at half the rate of fresh manure. The proper time of application is 2 weeks before the pond is to be stocked so that a heavy food crop is ready for the fish.

During the growing season, the food supply is maintained by periodic applications of dried sheep manure. The applications should be made at 2- to 3-week intervals all summer. Ponds should be fertilized at the optimum rate rather than the maximum because an excess is a waste of fertilizer and the decomposition of a large quantity of fertilizer may reduce the oxygen content of the water enough to cause suffocation of the fish.

When soft-water ponds are fertilized, it will be necessary to add agricultural limestone to the water to maintain proper alkalinity. A rule-of-thumb for liming ponds is to add half as much limestone as fertilizer.

In the Southern States, fertilizing should be started during the first warm weather of spring, and should be continued through the summer and early fall. In the far South it may be advisable to fertilize monthly during the winter.

In fertilizing a pond, supply enough nutrients to the water to induce the growth of microscopic plants, which give the water a green or brown tinge. It is necessary to apply the fertilizer frequently enough to build up a surplus of minerals. Applications should be made at weekly or 10-day intervals and should be continued until the water becomes so turbid (as a result of these microscopic organisms) that the bottom cannot be seen at a depth of more than 12 to 15 inches. Fertilizing should then be stopped until the water begins to clear, when it should be resumed. The objective is to maintain a constant amount of turbidity in the water. One should not overfertilize, as the production of too many of certain microscopic organisms will be detrimental to the fish by removing too much oxygen from the water at night and on cloudy days.

Each application of fertilizer should consist of 100 pounds of fertilizer of approximately an 8–8–4 formula for each acre of water surface. This means that each 100 pounds of fertilizer contains 8 pounds of water-soluble nitrogen, 8 pounds of phosphate, and 4 pounds of potash. If fertilizer of this formula cannot be purchased, regular garden or farm fertilizer may be supplemented with nitrate of soda, ammonium nitrate, superphosphate, or other chemicals. Any fertilizer dealer can give information for modifying regular fertilizers to obtain the proper formula. The 8–8–4 formula was first worked out by Swingle and Smith at Alabama Polytechnic Institute and is generally applicable.

There is some variation in fertilizer requirements, however, according to the chemical content of the water. For instance, in very hard water at the Leetown, W. Va., station and surrounding territory, it was found that a 12–5–5 mixture gave best results. In general, hard waters require more nitrogen and less phosphorus and soft waters less nitrogen and more phosphorus. Under acid conditions it may be advisable to use lime. At the present time, there is insufficient knowledge to make specific recommendations for all conditions. One can obtain the desired results simply by increasing the amount of fertilizer per application, where a "water bloom" is not obtained within a reasonable time. Generally, 6 to 12 treatments are required through the summer, depending on the fertility of the water, length of the season, amount of runoff, and other conditions.

STOCKING THE POND WITH ADULT FISH

A very important step in operating the pond is to stock it with the correct number of brood fish. Adult fish seined from streams or lakes in the spring before they have had time to spawn are commonly used as brood stock. Because of the uncertainty of the natural supply, it is desirable for the dealer to hold the brood stock from year to year.

When selecting fish for brood stock, the dealer should attempt to get an assortment of sizes. For example, the male fathead and bluntnose minnows are larger than the females, while the male golden shiner is smaller than the female. If only the largest specimens are selected, the pond will have an unbalanced sex ratio. In certain of the Lake States, the following rates of stocking of adult fish have been found satisfactory:

Species stocked	Fish stocked per acre	State	Reference[1]
Fathead minnow	1,500	Minnesota	Bureau of Fish Propagation.
Do	5,000	Ohio	Wascko (1946).
Do	1,000	Wisconsin	Hasler et al. (1946).
Golden shiner	500 to 1,000	Louisiana	Viosca (1937).
Do	1,800	Ohio	Wascko (1946).
Silvery minnow	714	New York	Raney (1941).

[1] See Bibliography, p. 118, for publications indicated by year in parentheses.

ARTIFICIAL FEEDING

Food preferences of fish usually vary with age. The young can swallow only small organisms and, therefore, feed mostly on plankton. Adults require larger and more substantial food. For maximum production in ponds, minnows should be provided with the foods most suited to their needs and their ages. Choice of ponds and fertilizer can greatly affect the type and availability of food.

The alternative to fertilizing is artificial feeding. The usual procedure is to feed the fish all the ground food they will eat in 2 hours. Ponds operated under artificial feeding have such large populations of fish that food cannot be allowed to remain longer than 2 hours without danger to the oxygen supply in the water. One food formula used successfully contains 15 percent of cottonseed meal and meat scraps mixed with 85 percent of middlings. Another formula contains 100 pounds of beef melts, 50 pounds of dry dog food, 50 pounds of whitefish meal, 6 pounds of salt, and water enough to make a good feeding consistency. Fifty pounds of ground, raw carp can be substituted for 25 pounds of fish meal. A formula that produced large numbers of minnows in Michigan is composed of the following ingredients:

	Pounds
Cooked cornmeal and oatmeal	275
Bone meal	200
Clam meal	400

Maggots can be provided by putting fresh-meat scraps in a screen-bottomed box, which is placed over the pond so that the maggots fall into the water.

Many minnow ponds produce large numbers of crayfish from natural stock that either migrate into the pond or hibernate in the pond bottom. In many localities, crayfish can be sold for bait, but where there is no demand, ground crayfish makes excellent minnow food. Such food is usually available only in the fall when the ponds are drained to harvest the fish. Crayfish, ground or whole, can be fed to the fish in winter holding ponds, or used for fertilizer on the pond bottom.

At least twice as many fish can

be raised per acre of water by artificial feeding; consequently, only half as many ponds are needed to produce a good supply of minnows. Though the cost of production is higher when the fish are fed artificially, this may be offset by a reduction in the original cost of the pond and in the annual maintenance. The artificial feeding of heavy fish populations (more than 2,000 pounds of fish per water acre) requires a constant flow of water through the pond for aeration and cleanliness. Only a small part of the natural pond fertility and very little of the fertility available from the decomposition of food wastes are used. Such concentrated populations must be treated for disease at frequent intervals. (See page 50). The Michigan Institute for Fisheries Research has developed a combination method whereby creek chubs are artificially fed and suckers are raised on the bloom produced by the decomposition of the feeding wastes. The costs of production were reduced under this method.

It should be remembered that water temperatures have a direct effect on the amount of food eaten by fish. In cold-water ponds, the consumption of food is low and growth is slow. Also, when the water becomes excessively hot, food consumption declines and growth becomes slow.

HANDLING BAIT FISH

While many species of fish can be found in the tanks of the bait dealers, certain species are more popular and are handled in greater quantities. These fish require different methods of propagation, but the handling techniques will be similar for all. The following table lists the kinds of bait fishes in greatest demand in the Lake States:

Species	Michigan	Minnesota	Wisconsin
Sucker	x	x	x
Creek chub	x	x	x
Pearl dace	--------	x	--------
Finescale dace	--------	x	--------
Northern redbelly dace	x	x	x
River chub	x	--------	--------
Golden shiner	x	x	x
Emerald shiner	x	--------	x
Common shiner	x	x	x
Fathead minnow	--------	x	x
Bluntnose minnow	x	x	x
Western mud minnow	--------	x	x

HARVESTING FISH

Seining

Whether seining in public water or in his own minnow pond, the bait dealer should seine with the objective of catching the maximum number of fish with a minimum of loss. The following suggestions are presented to help the beginner avoid undue loss.

Types of seines.—Minnow seines, generally speaking, can be classified into three types depending on the kind of weave used in their construction. The most common minnow net is made of woven threads, and with prolonged or severe use it will develop "runs" caused by thread breakage and separation. This type of netting can be obtained in mesh sizes of 1/8 to 3/8 inches (bar measurement). The second type of seining fabric is constructed with a nonslip knot tie. Each mesh is individually knotted, and it will not develop runs or thread separation under the most severe operating conditions. In this type of netting, mesh sizes ranging from 1/4 inch upward can be obtained. The third type of netting material used by fish culturists and bait dealers is called "bird's-eye," or bobbinet cloth. It is a fine-woven fabric and is excellent for use in collecting small fish (fry). The new nylon bobbinet is much better material for short seines than is the old cotton "bird's-eye."

The net should be picked according to the job to be done. A 1-acre circular pond can be seined very effectively with two hauls of a 200-foot net, at depths of 6 to 12 feet. A pond that can be drained to a seining pool can be seined much more easily with a 30-foot net (fig. 12). A net that is too long for the job is cumbersome to use and increases the chance of injury to the fish. For seining in public waters, the net should be at least of 1/4-inch mesh so that the minnows too small for use can escape for further growth. In a small production pond a bobbinet seine can be used to transfer the small fish to a wintering pond (fig. 13).

Good seining methods.—When possible the seine should be landed on a firm, sandy bottom. The silt stirred up on a soft bottom adds to the discomfort of the fish and may cause suffocation. When there is danger of suffocation, smaller hauls should be made and the fish should be bagged and moved to deeper water as fast as possible (fig. 14).

When landed, the seine should never be pulled onto the shore. As soon as the fish are in the net, it should be bagged loosely and floated to deeper water. The fish should then be dipped with a small hand net, or scap net, into a floating live box (wooden box with a hardware-cloth bottom) for sorting (fig. 15).

Once in a while the bait dealer will find it necessary to seine minnows in large bodies of water with a small net during a season when the fish are too far from shore to be taken by the usual method. In such a case, two or three seiners put

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FIGURE 12.—Seining minnows from an artificial pond. Drawdown has exposed the inside seining well. (Photograph courtesy of the Michigan Department of Conservation.)

on waders and wade out as far as possible. Two men take the seine brailles and a third keeps the floating live box in tow. The three men stand with their backs together and roil the water with their feet. When the water has been thoroughly roiled for a few minutes, two seiners back off in opposite directions pulling the seine in a circle. By going backward, they can travel faster than if they went forward. The third man turns and backs out of the way splashing the water as he goes to drive the minnows into the net. When the seiners have completed the circle, they take up the slack in the net, bag it, and hoist it out of the water. Though the take by this method is not large, the roiling process increases the harvest as much as 8 to 10 times. (See figure 16.)

Trapping bait fish

Wire and glass traps.—Wire and glass traps are commonly used by minnow dealers to collect bait. Similar in design and differing only in construction materials, both consist of a pot and an entrance funnel or funnels. The wire trap (fig. 17) is more variable in design, being round, rectangular, or square, and having from one to four funnels.

Figure 13.—A bobbinet seine is used to catch the fry in a small production pond. Good seining methods help to prevent fungused fish. (Photograph courtesy of the Minnesota Department of Conservation.)

Glass traps usually are round and have only one funnel entrance.

Glass traps are used mainly in streams. This type of collecting gear has proved highly efficient; not only can a large number of minnows be taken in a relatively short time, but the fish can be collected with little or no injury. Operation of a glass trap is simple. The first step is to follow along the banks of a stream until a school of minnows is located. The next step is to seek an area upstream from the school of minnows where the current is weak and the water depth does not exceed 1 foot. (These locations are usually found near the banks of the stream.) At this point a small depression about the size of the glass trap is gouged out of the bottom, and the trap, baited with finely-ground cracker crumbs, is placed in the depression with the funnel opening facing downstream. Within a few minutes, by current action, some of the food particles originally within the trap will be drifting downstream, attracting the fish below. Immediately, the minnows will move upstream toward the source of the food supply; within a half hour, the food supply in the trap will be exhausted and a num-

FIGURE 14.—Removing the fish from a seine in such a way as to avoid the roily water close to the shore of a shallow pond. (Photograph courtesy of the Minnesota Department of Conservation.)

ber of minnows will have been captured.

The minnows should be removed from the trap as soon as the food is gone, as experience has proved that the minnows will soon escape. On one stream in Michigan, four glass traps took a total of 600 minnows, 2½ to 5½ inches long, in 1 hour. The number of minnows captured per trap per set ranged from 10 to 70. The average duration of a set (established by food depletion) was about 20 minutes.

Wire traps.—Wire traps are most efficient when set in quiet waters and attended daily. They are baited with bread or cracker crumbs and placed on the bottom of a stream or pond or suspended above the bottom at a desired depth by a stake. The traps should be attended daily and all fish removed on each visit. If the minnows are allowed to remain in the trap for any extended period, many become injured by continued contact with the sides of the screen. In a pond or lake where a good population of minnows is known to exist, one wire trap, 2 feet long by 16 inches square and containing a funnel at each end, will take as many as 500 minnows in 1 day's operation.

FIGURE 15.—Transferring the fish from seine to floating live box. (Photograph courtesy of the Minnesota Department of Conservation.)

FIGURE 16.—Seining in deep water after the fish have been attracted to an area of roily water. (Photograph courtesy of the Minnesota Department of Conservation.)

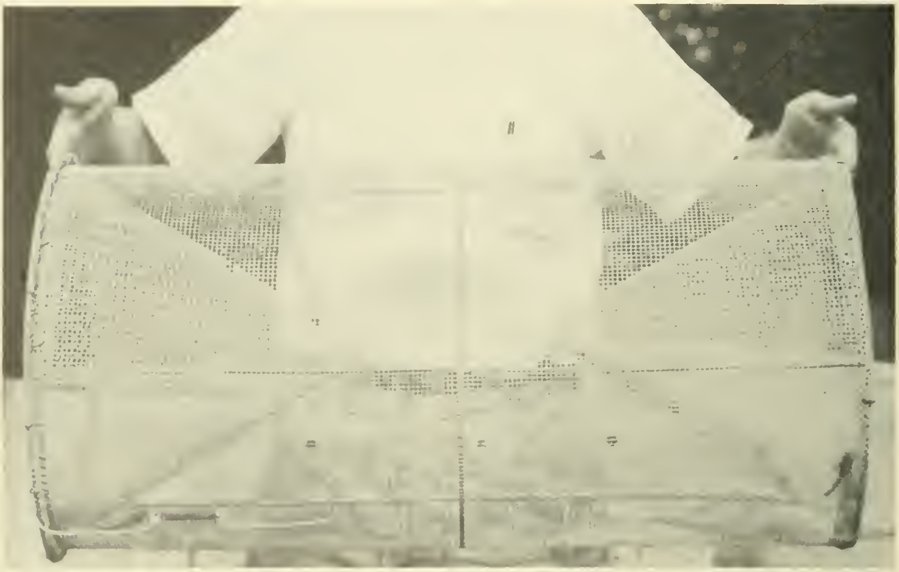

FIGURE 17.—Wire trap commonly used by bait dealers. (Photograph courtesy of the Minnesota Department of Conservation.)

Artificial ponds that are difficult to seine because of weeds or soft bottoms can be equipped with a wire trap at the inlet (fig. 18). By running a current of water through the trap, the dealer can catch the entire population of a pond in 2 or 3 days.

Netting fish

Drop nets.—One of the nets frequently used in harvesting minnows from lakes and ponds is the lift, or drop, net. This net is usually square in design, and it forms a pocket when lifted directly upwards. Sometimes the netting is supported by a rigid framework which prevents collapse when lowering or lifting the net. Guy ropes are attached to each corner to enable the operator to lift the net upward on an even keel. On occasion, instead of a rigid framework support, the netting is suspended from flexible steel bands running diagonally across the net. When the net is lowered, the bands tend to flatten out, and when lifted they bend inward, creating a pocket (fig. 19).

Whether the drop net is small (3 feet square) or large (8 to 10 feet square), the principle of operation is the same. The net is lowered to the desired depth by hand in the case of the small net, and by rope from a tripod and pulley or on the end of a pole in the large net. Bread and cracker crumbs or oatmeal are wetted and thrown into the water immediately above the net to attract the fish. Usually, as soon as the bait has dropped to a depth equal to or nearly equal to that of the set, the net can be lifted. When the small net is used, the fish can be

FIGURE 18.—A wire trap built into the inlet of an artificial pond. When the trap is not in use the ends are left open, as in the photograph. (Photograph courtesy of the Minnesota Department of Conservation.)

FIGURE 19.—A drop net used to remove fish from the pond. Feeding is done on the submerged net and from 2,000 to 3,000 minnows are raised at a time. (Photograph courtesy of the Ohio Department of Conservation and Natural Resources.)

lifted in the net from the water and poured into the holding cans. Where larger nets are employed, the "lift" should not clear the water, but rise to a point where sufficient water will be present for ample movement of the captured fish. The fish in the net can then be transferred to the holding cans with a long-handled dip net.

Drop nets are operated successfully in quiet waters on certain species, such as the golden shiner, fathead minnow, and creek chub. Minnows can be collected efficiently with little or no injury by this method under the guidance of a good operator. There are many advantages in using a drop net, where practicable, instead of a seine. In capture, the fish are not rolled, crowded, or crushed; the bed of the pond is not broken, nor is the bottom debris roiled to any extent. Furthermore, minnows under salable size can be returned to the waters, uninjured.

In clear waters, the drop net will work more efficiently for certain species if the netting, ropes, and frame support are dyed a neutral color that harmonizes with the surrounding water. In highly turbid waters, dyeing would probably be of no material value. Where fragile minnows are being collected with a drop net, the netting material should be a soft fabric, such as cheesecloth. When this material is used, some minnows which scale easily, such as the golden shiner, can be harvested successfully during the hottest weather.

Dip nets.—The so-called dip net is frequently used in taking shiners in the Great Lakes. This net is usually of conical design, 1 to 2 feet in diameter at the opening, and 2 to 3 feet deep. The rigid hoop that forms the opening is fastened to a handle. The mesh size of the netting material used in construction varies, depending on the size of the minnows to be collected (fig. 20).

Scap nets.—A scap, or hand, net is very useful in the handling, sorting, and transfer of fish. Generally, the scap net is small, from 6 inches to 1 foot across, if square, and not more than 8 to 10 inches in diameter, if round. The netting material is supported by a rigid framework attached to a wooden handle. These nets usually have shallow pockets. The netting material is of small mesh and soft in

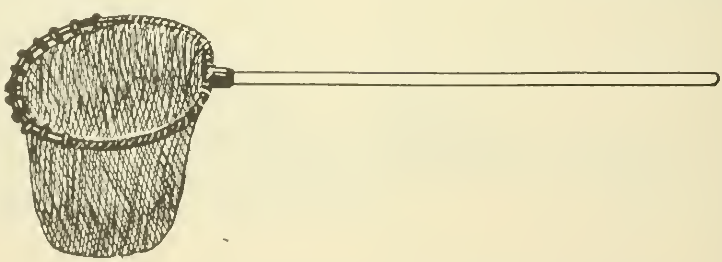

FIGURE 20.—The dip net is used to handle bait fish in quantity.

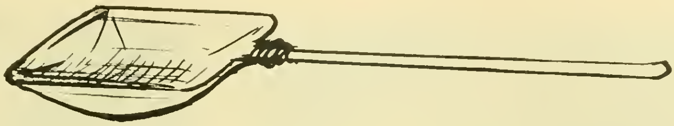

FIGURE 21.—The scap net has many uses about the hatchery.

texture so as to prevent injury to the fish being handled (fig. 21).

Care of collecting gear

Nets should be carefully inspected for holes, repaired when holes appear, and thoroughly dried after each use. Nets should be stored in a cool, dry place with a good circulation of air. If they are frequently used in waters rich in organic matter, it is well to have the nets treated occasionally with a preservative, such as tannin or copper oleate. It is not desirable to use tar as a preservative for minnow nets because this substance has a tendency to harden the fibers, and thus introduces conditions which may be injurious to the fish being handled. Nylon nets do not require a preservative.

Small hand nets, such as dip nets and scap nets, used daily in and about a bait dealer's establishment, when not in use, should be kept in a sterilization bath consisting of a weak chlorine solution. In this way, disease organisms will not be carried from one tank to another by the nets. One formula used in Michigan hatcheries consists of 26 fluid ounces of cleanser (3-percent available chlorine) to 30 gallons of water. As chlorinated solutions deteriorate rapidly in the presence of organic materials or when exposed to air, the bath must be strengthened about once a week by adding 13 ounces of cleanser. Once a month the entire solution should be discarded and a new bath prepared. A word of caution: chlorine is toxic to fish, and discretion should be used when disposing of old sterilizing solutions.

ESTIMATING PRODUCTION

As soon as a tankload of fish has been seined and transferred to the live box, the fish should be weighed (fig. 22), and carried in a pail of water to the tank. The usual procedure is to hang the scale from a tripod set in several feet of water. A half-bushel metal basket is partly filled with clean water. Ten pounds of fish are weighed and carried to the truck. By weighing 10 pounds of fish at a time it is easy to keep account of the fish taken, or the production of a pond. Fish handled in these amounts will not be too crowded or easily injured. If the operator is interested in knowing the number collected, he can weigh and count the fish in 1 pound.

Another method of measuring minnows that is not destructive of the fish is the wet gallon measure. A 5-gallon pail is marked off from the 1½-gallon level to the top in

FIGURE 22.—Production should be determined by weighing rather than by volume. (Photograph courtesy of the Minnesota Department of Conservation.)

½-gallon units. When the fish are to be measured, the pail is filled with water to the 1½-gallon level and minnows from a dip net are added until the level reaches the 2-gallon mark for half a gallon of fish and to the 2½-gallon mark for a full gallon. One gallon of minnows is counted when a large number of minnows are to be sold by the dozen.

GRADING FISH

The most practical method of sorting, or grading, fish—with the least amount of damage to the fish involved—is by using a mechanical grader. Similar to those used in trout culture, the bait-fish grader consists of a wooden box having a bottom of tubular grating (fig. 23). The tubes, of lightweight metal of about a ¼-inch diameter, extend across the bottom of the grader, producing a sievelike structure. By regulating the spacing between the tubes, fish of a desired size can be retained in the box or permitted to pass through. If the fish are to be graded in several sizes, several grading boxes will be necessary, one for each size group desired.

Periodic sorting of the fish throughout the growing season will reduce the number of small fish that have to be held through the winter, and will result in greater production of fish of a desirable bait size.

FIGURE 23.—Two sizes of slat sorting boxes used in grading minnows. (Photograph courtesy of the Minnesota Department of Conservation.)

TRANSPORTING AND HOLDING BAIT FISH

Aeration and temperature control are important factors in the successful operation of both carrying and holding tanks. A series of experiments was run in Minnesota to determine the effect of these factors on the mortality of fish. It was shown that fathead minnows exposed over a period of hours to nonaerated waters die with increasing rapidity at the higher temperatures. The most rapid loss occurs at temperatures above 65° F. Fathead minnows can be kept in well-aerated water for several hours at relatively high temperatures without loss, and greater numbers of minnows can be carried at all temperatures in aerated water than in nonaerated water.

These experiments showed that safe operation of minnow tanks requires close adherence to the following limits:

1. When tanks are aerated by circulating water, a continuous flow of not less than 1 gallon per minute for each 25 gallons of water in the tank should be maintained. The water should reach the tank from pressure jets placed so the water is sprayed toward the opposite side of the tank. Each tank should have a minimum of two pressure jets and at least one jet for every 25 gallons of water in the tank.

2. When oxygen or other forms of aeration are used, the equipment should be operated so as to maintain a minimum of 3 p. p. m. of dissolved oxygen. When oxygen is used for aeration, it should be dispersed into the water through carborundum tips or a perforated oxygen-release tube.

3. Water in nonaerated tanks should be kept at 65° F. or lower.

A popular practice when handling minnows is to fill the truck tank at the bait store with cold water (often around 50° F.). While this water is being hauled to the pond, it does not have time to warm up very much. The minnows are seined from a warm-water pond and placed in the cold water of the tank with only a few minutes of tempering. The shock is not great enough to kill the fish at once, but within a few hours a large percentage will be dead. Those that survive this period usually develop fungus and die within a few days. A minnow should not be subjected to more than a 10° F. change. A pocket thermometer should be used to determine temperature differences.

Likewise, bait fish that are to be used locally should not be held in very cold water unless the fisherman travels far enough for the water to warm up. Minnows that are taken from a cold minnow pail and put into warm lake water will turn belly up in a few minutes.

Transporting minnows

The hauling of minnows over long distances during very hot weather presents a difficult problem. Success depends on close observance of the following important requirements:

1. Harden the fish before they are transported. Conditions such as crowding, excessive handling, and changing water temperatures, encountered when transporting minnows for long distances,

often prove fatal to many of the fish. As a means of reducing this loss, a 24-hour "hardening" process is employed. The fish to be transported are collected and placed in a tank where the water temperature can gradually be reduced until it is between 50° and 60° F. The fish are left in this bath for about 24 hours for conditioning. At the end of this period, they are transferred to transporting tanks that contain water of the same temperature and are ready for moving. People who use this technique claim that the fish will not only stand the trip better but will tolerate more handling and crowding than before hardening.

2. To prevent injury to the fish, the wooden sides of the tank should be smooth. Several types of tanks have proved satisfactory. One popular type is a single-compartment tank, 4 feet square and 3 feet deep, aerated with oxygen dispersed through a perforated release tube. This tank will carry 125 pounds of minnows for 300 or 400 miles with little or no loss. Another successful tank is 6 feet long, 3 feet wide, and 2½ feet deep. This tank is divided into two compartments, each of which will hold 100 pounds of minnows. It has the advantage of permitting the dealer to sort his fish either by species or by size (fig. 24).

3. Carrying tanks must be well aerated either by injecting oxygen into the water or by pumping the water through pressure jets. Under full load, any system used should maintain a minimum of 3 p. p. m. of dissolved oxygen for the duration of the trip.

All carrying tanks used on long hauls should have two aerating devices that can be operated independently of each other, in case one breaks down. An oxygen tank can be substituted for one pump in most cases.

Aeration is sometimes obtained from wind scoops and water pumps driven by the truck motor. Both of these methods depend for their success on the ability of the truck to maintain motion. When the truck breaks down the fish are out of oxy-

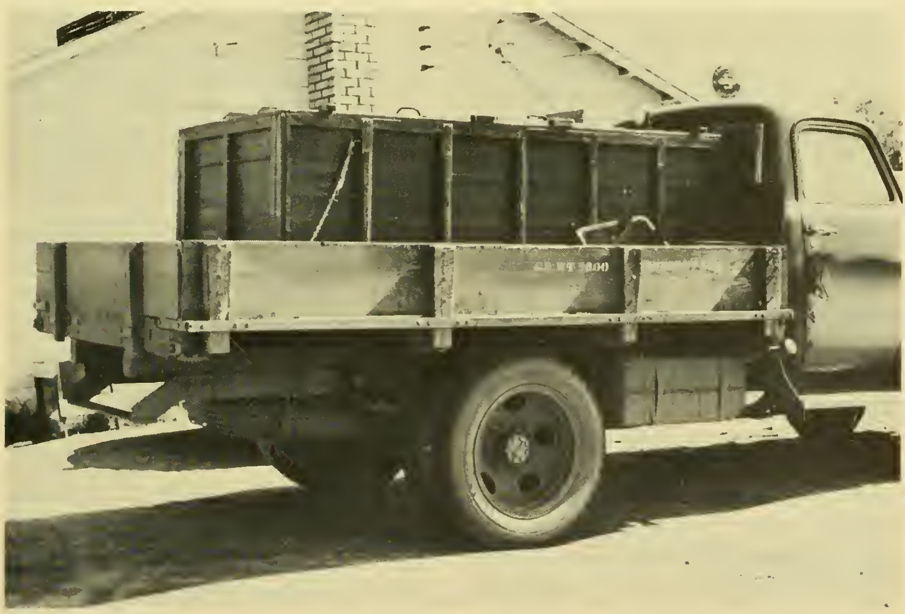

FIGURE 24.—An inexpensive fish-distribution tank truck. (Photograph courtesy of the Minnesota Department of Conservation.)

gen in a short time. Such devices should only be used as auxiliary equipment or as primary oxygen sources when supplemented by other sources that are independent of the truck motor.

4. When the trip is unusually long and the weather extremely hot, the temperature should be maintained between 65° and 70° F. by periodic icing. When possible, long hauls should be made on cool days. Tanks that are constantly used for long hauls should be insulated with a 4-inch layer of cork.

Occasionally the dealer will find it necessary to temper minnows as they are being transported from the lake or stream where they were seined. For this purpose the truck must be equipped with a small box of ice. The minnow tank is filled with lake or stream water and the aeration pump is adjusted so the aerated water passes over the ice before it returns to the tank. Periodically the operator will have to stop the truck and take the temperature of the water in the tank. When the water is of suitable temperature, the water line to the ice box should be shut off. If the water in the tank is cooled too much or too rapidly, the minnows will develop fatal "frost bites." The water line to the ice box must be equipped with a valve so the rate of cooling can be adjusted.

Some dealers cool the tank water by using the live box as an ice tray. After the truck tank is loaded with water and minnows the live box full of ice is placed over the top of the tank. The tank water is cooled as the ice melts and drips into the tank. The cooling rate cannot be controlled by this method and more fish suffer from "frost bite" from it than from the ice box.

5. Salt is a tonic for fish and can be used to help them over the rigors of transportation. A salt bath should be given after the trip. When the aeration equipment consists of a pump and water jets, salt should not be used in the tank because sodium chloride rusts the equipment.

6. Truck tanks should never be overloaded, especially during hot weather or on long trips. A load of 9 gallons of minnows per 100 gallons of water, or 5.6 pounds of minnows per cubic foot of water, has been found safe under severe conditions.

Operating the holding tank

The bait dealer encounters his greatest loss from handling and holding minnows in the holding tank. Though much of the loss is attributed to fungus disease, the largest part is the direct result of rough handling and careless operation. There is no magic formula for preventing minnow losses. Disease-control treatments will not prevent losses due to careless handling, but following the suggestions given here will help to keep losses in bait fishes to a minimum.

1. Minnows should be handled carefully during seining operations. Dealers who buy their minnows should refuse to accept fish that have been handled roughly.

2. The minnows should be carefully tempered when they are transferred to the truck tank and again when put in the holding tank (see p. 41 for "hardening" process).

3. The minnows should not be crowded.

4. Holding tanks should be constructed of wood or smooth concrete, and painted heavily with asphaltum paint. Smooth sides in the tank help prevent disease and injury to the fish. The tank should be deep enough so that the fish are not injured by the jets of water used for aeration. The bottom should slope slightly toward the outlet to facilitate cleaning and draining.

5. Each tank should be supplied with plenty of filtered water—spring water is filtered—and each tank should drain directly to the sewer without passing through other tanks. The water should enter the tank through pressure jets

placed well above the surface of the water. One overflow outlet should be at or near the bottom to remove stagnant water and waste material.

6. Well water containing more than 1 p.p.m. of iron will cause heavy minnow mortality. Iron can be removed from the water with the right kind of filter. Some water-softening filters will remove iron if the water is aerated before it is filtered.

Copper well points and copper water pipes often give off enough copper to kill minnows in holding tanks. This is especially true in soft water or where the pH is high. In such cases, the offending pipes must be replaced with iron pipes.

7. Each tank should be small enough that the complete contents can be sold in a few days. No more fish should be added until these are sold, and the tank should never be overloaded. The transfer of fish from one tank to another will greatly aid the spread of disease.

8. When the fish from one tank have been sold, the tank should be drained and carefully cleaned. The sides and bottom should be thoroughly scrubbed with a 1 : 10,000 solution of sodium hypochlorite. This solution is mixed by adding 1 quart of sodium hypochlorite or 3 to 5 quarts of any commercial bleach to 250 gallons of water. The tank should be thoroughly sterilized at least once a week. After an ample rinse the tank can be filled with water and stocked with fish.

9. All dead fish in the tanks should be removed immediately and destroyed.

10. There may be considerable loss from the common practice of selling minnows wholesale by the gallon. This procedure necessitates the measuring of minnows in a nearly dry state. Such measuring cannot be done without injury to the fish.

11. Very large dip nets should not be used for minnows. Lifting a half bushel of minnows in a dip net is likely to injure those on the bottom. Overloading smaller nets will also produce injury and consequent loss of fish.

12. Feed minnows that are held for more than a few days. A series of feeding experiments conducted by the Wisconsin Fish Management Division to determine the effect of food on the loss of minnows in holding tanks, showed that brassy minnows could be held for 63 days at 46° F. with very little loss of weight when fed all the canned carp they could clean up. Fish that received half as much carp survived nearly as well and showed only slightly more loss of weight. Fish that received no food succumbed to heavy infestations of fungus, but those receiving food had very little fungus.

Minnows will eat a variety of foods, but the most practical foods are those that are easy to handle and convenient to store. The food should appeal to the fish so that it is consumed fast enough to prevent undue contamination of the tank water. Oatmeal and cottonseed meal are satisfactory foods. Meal worms, flour-weevil larvae, and similar worms are very attractive to minnows and form a substantial food ; but all must be raised for the purpose, As this takes quite a bit of time and space, most bait dealers do not use these organisms. Dry dog foods or commercial fish foods can be used as a balanced diet that is easy to handle and is reasonable in cost.

13. Early treatment of diseased fish is important. Epidemics of fungus disease will produce a large loss of fish in holding tanks. While careful seining, transportation, and holding of the minnows will greatly reduce the chances of an epidemic starting, it may happen even in the best-regulated establishments.

At the start of the epidemic all dead fish should be removed and destroyed at once. The remaining fish should be dipped in malachite green 1 : 15,000 solution (⅛ ounce in 15 gallons of water) for 10 seconds. The tank must be drained and sterilized with sodium hypochlorite 1 : 10,000 solution. All tools and dippers must be sterilized in the same solution and must be resterilized daily until the epidemic is over.

Addition of some disinfectants and drugs to water in tanks holding fish is recommended by numerous investigators for the control of various fish infections. Since a number of these methods are of recent origin they have not been tried under various conditions and with different species of fish. Therefore, it is possible that drugs listed in the section on diseases (p. 57) may be found toxic to some species of minnows or aquarium fishes and entirely harmless to other. All of these drugs are used in highly diluted forms and the fish should be able to remain in such medicated water for 2 to 3 days, or even longer, without any apparent injury. If treatment should last more than a week, water in the tanks should be changed frequently, preferably every 3 to 6 days. After each change of water, the required quantity of fresh drug should be added. Treatments should not be carried on for more than 2 weeks at a time to reduce the possibility of devlopment of drug-resistant strains (varieties) of the disease-producing organisms.

Since some of these chemicals may be found to be toxic to some fishes under all conditions or under special conditions like high temperature of water or oxygen deficiency, all treatments should be made with great caution and tried first with a small number of fish. The medicated water should be replaced with fresh water whenever fish show any signs of distress.

Infected minnows should not be purchased or seined, as the danger from loss and spread of disease to healthy fish is too great. During times of scarcity when only infected minnows are available, the fish should be dipped for 10 seconds in a 1 : 15,000 solution of malachite green before being placed in the holding or tempering tanks. The malachite green should be discarded after 100 pounds of minnows have been treated or at the end of the day.

14. Minnows that have not spawned should be placed in warm-water ponds until they spawn. Then they can be put in cold-water tanks or ponds and held for long periods without heavy losses.

When men of the Wisconsin Fish Management Division were conducting feeding experiments with brassy minnows, they noticed an increased mortality during May and June. Post-mortem examinations revealed that the majority were gravid, egg-bound females. That they were ready to lay eggs but could not because of the cold water was interpreted as the cause of their deaths. This may account for part of the heavy loss of minnows in cold-water holding tanks during the warm summer months.

Holding minnows in ponds

In some States, holding ponds are a much debated subject. The bait dealers insist that they must have holding ponds to stay in business, and the conservationists maintain that holding ponds are one of the chief causes of minnow losses. The opponents to holding ponds point out that most ponds are used to hold lake shiners from early spring when they are abundant until summer when they are needed for bait, that the shiners do not thrive in holding ponds because most of the ponds are too cold, and the fish become egg bound, and furthermore, that fish held in ponds are not able to spawn that year and both the adults and their reproduction are lost from the lake. The problem is usually solved on a compromise basis that limits the number and size of the ponds that each dealer can use.

On the other hand, all parties agree that holding ponds are indispensable to the hatchery operator who wishes to produce a year-round bait supply from his production ponds. Minnows for the early fishing season must be over-wintered in ponds that will maintain an ample supply of oxygen through the longest winter.

The most satisfactory ponds are those supplied with an ample amount of oxygen-bearing, running water from rivers, creeks, springs, or flowing wells. There are advantages and disadvantages to all of these sources. Water from unpolluted rivers and creeks is usually high in oxygen and contains some natural minnow foods, but it may not always be of the right temperature. Water from springs and flowing wells is usually cool and of uniform temperature, but it is often low in oxygen and is always low in natural minnow foods. Springwater must usually be run over a riffle before it enters the pond. This means that fish held in ponds supplied with stream water will not need as much artificial food, but they must be moved to growing ponds before the water warms up in the summer. Minnows held in spring-water ponds can be left in the ponds all year round, but they will require large amounts of artificial food.

Holding ponds should be small enough and shallow enough so that the fish can be readily removed whenever they are needed. An acre pond that is 4 or 5 feet deep is very practical, and a number of small ponds is preferable to one large pond because different species and different sizes of minnows can be held separately in the small ponds. This usually reduces losses and minimizes the sorting operations in the spring.

In areas where holding-pond construction is not practical, minnows can be overwintered in production ponds, if the ice is kept free of snow all winter. There are several ways to remove snow from the ponds, but the use of soot spread thinly over the snow seems the most practical. The soot absorbs enough heat from the sun to melt 6 to 9 inches of snow and ice. In areas of light snow, plowing may be practical, but in regions of 3- to 6-foot snowfalls plowing is very expensive. Some operators use a centrifugal pump to spray water over the snow; the resulting slushy condition usually freezes to clear ice that transmits enough light to keep the plants producing oxygen.

WEED CONTROL IN PONDS

With good pond management, weed control is generally not a problem. Ponds that are farmed intensively are heavily fertilized, either directly by the use of fertilizers or indirectly by food that is not picked up by the fish and by the heavy concentration of excretory products that results from large populations. Under these conditions, submerged vegetation will be controlled by the waterbloom produced, and emergent vegetation such as cattails or

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pickerelweed, will invade the pond rather slowly, and can be controlled by hand or by the use of chemicals.

Water quality and temperature are controlling factors in the effectiveness of treatments to kill vegetation and in the toxicity of the chemicals to fish. Each hatchery presents a different situation with a new set of conditions, so that it is necessary at first to experiment on a small scale with control measures, and modify them to fit the local situation. We can only give general recommendations, which must be adjusted to meet the specific conditions in an area.

Many things can be done in pond management that will make the control of pond and emergent vegetation simpler. Among these are the following:

1. A bloom heavy enough to shade out the rooted plants should be maintained throughout the season. A bloom that hides the pond bottom at a depth of 1 foot is heavy enough for this purpose. The pond will have to be watched closely, as there is danger that the bloom may become heavy enough to cause an oxygen depletion during warm nights. This method has the advantage of producing fish food while controlling the weeds.

2. Deep shorelines (at least 18 to 24 inches) at the edge of the bank combined with a waterbloom will discourage emergent vegetation, as bulrush, arrowhead, and cattails.

3. Pond banks that can be mowed, with a good cover of hardy grasses, will discourage invader plants from the shore, such as wildmillet and parrotfeather.

4. If a bloom is kept on the pond, the repeated cutting of emergents below the surface is an effective means of controlling undesirable vegetation in the pond. In shallow ponds a scythe will be the most satisfactory tool, but in deep ponds one of the mechanical weed cutters is necessary. When possible, the vegetation should be raked up on the banks to prevent an oxygen depletion when it decomposes.

CHEMICAL AGENTS

Subject to local conditions, the following table lists chemical agents which may be used to control the various weed plants. Plants should be treated while they are young and actively growing. Do not wait until they become a nuisance, because controls then may be only partly effective and a great deal of time and money will be lost. Always kill the vegetation before the seed forms. The data in the three following tables are taken from the Fish-cultural Manual, Region 2, Albuquerque, N. Mex., U. S. Fish and Wildlife Service.

Plant	Chemical agent	Application [1]
Floating plants:		
Duckweed	2,4-D	1% solution in oil.[2]
Filamentous algae	Copper sulfate	3 lbs. of crystals per 1,000 sq. ft.
Water hyacinth	2,4-D	0.5% solution in oil.[2]
Emergent plants:		
Alligatorweed	do	1% solution.
Burreed	do	Do.
Cattail	do [3]	0.5% solution in oil.[2]
Cow lily (yellow pond lily).	do	1% solution in oil.[2]
Duckpotato	do	1% solution.
Giant cutgrass	do	1% solution in oil.[2]
Grass (most kinds)	Sodium TCA	7 oz. per 5 gal. of water (1% solution).
Johnson grass	2,4-D	1% solution in oil.[2]
Lotus	do	0.5% solution in oil.[2]
Maidencane	Sodium TCA	1 lb. dry powder per gal. of water.[4]
Parrotfeather	2,4-D	0.5% solution in oil.[2]
Reed's canary-grass	Sodium TCA	1 lb. dry powder per gal. of water.[4]
Smartweed	2,4-D	1% solution.
Softstem bulrush	do	1% solution in oil.[2]
Squarestem bulrush	do	0.5% solution in oil.[2]
Water chestnut	Sodium arsenite	1 lb. powdered sodium arsenite plus 1 lb. sodium chlorate in 1 gal. of water to 150 sq. ft.
Watercress	2,4-D	1% solution.
Weakrush	do	Do.
White waterlily	do	2% solution in oil.[2]
Submerged plants:		
Bladderwort	Sodium arsenite	2.5 p. p. m.[5]
Chara (muskgrass)	Copper sulfate	3 lb. of crystals per 1,000 sq. ft.
Coontail	Sodium arsenite	2 p. p. m.[5]
Curlyleaf pondweed	do	2.5 p. p. m.[5]
Fineleaf pondweed	do	2 p. p. m.[5]
Leafy pondweed	do	Do.[5]
Naiads	do	2.5 p. p. m.[5]
Parrotfeather	do	3 to 4 p. p. m.[5]
Water crowfoot	do	3 p. p. m.[5]
Water milfoil	do	3 to 4 p. p. m.[5]
Water purslane	do	Do.[5]
Water stargrass	do	2.5 p. p. m.[5]
Waterweed (Anacharis)	do	2 to 4 p. p. m.[5]
Woody plants: All species	2,4,5-T	2.3 qt. of 44% esters per 100 gal. of water.[6]

[1] In water solution, unless otherwise specified.

[2] Refer to dilution table, p. 48.

[3] 3 oz. Esteron 44 in 1 gal. of kerosene or fuel oil, plus a detergent, is very effective on cattails and rushes. Highly volatile and should not be used if damage to adajacent croplands probable, in which case use instead Estericide D–4.

[4] Effective if sprayed twice when pond is dry.

[5] Liquid form is most convenient; for example, 5½ pt. of Atlas "A" (contains 4 lb./gal. AS_2O_3, the active ingredient) per acre-foot equals 1 p. p. m. Do not treat more than one-third of pond area at a time because of danger of oxygen depletion. See table, p. 48, for concentrations.

[6] Spray during active growing season and thoroughly wet the plants. Include a detergent in the solution.

The amounts of commercial solutions of 2,4-D that are required to spray an acre of water are shown in the following dilution table:

Acid content of 2,4-D (percent)	Amount of 2,4-D needed for 100 gal. of spray with a strength of—	
	10,000 p. p. m. (1 percent solution)	5,000 p. p. m. (0.5 percent solution)
90	8 lb. 12 oz	4 lb. 6 oz.
85	9 lb. 6 oz	4 lb. 11 oz.
80	10 lb	5 lb.
70	11 lb. 14 oz	5 lb. 15 oz.
60	13 lb. 12 oz	6 lb. 14 oz.
40 (liquid)	2.5 gal	5 qt.
20 (liquid)	5 gal	2.5 gal.
10 (liquid)	10 gal	5 gal.

Under average conditions, 2.5 p. p. m. sodium arsenite will provide adequate control of rooted vegetation as well as pond scum. In some waters of high mineral content, particularly in the Southwest, 8 p. p. m. or more may be required. This can only be determined by trial.

The amount of liquid sodium arsenite (containing 4 pounds of arsenious oxide per gallon) that should be used in a section of pond where the average depth and surface area in square feet are known and where a concentration of 8 p. p. m. is desired is as follows:

Average depth (feet)	Amount of sodium arsenite needed to spray—			
	1,000 sq. ft.	1,500 sq. ft.	2,500 sq. ft.	3,500 sq. ft.
0.1	50 cc	75 cc	125 cc	175 cc.
0.25	150 cc	225 cc	375 cc	525 cc.
0.5	250 cc	375 cc	1.5 pt	1 qt.
0.75	375 cc	1 pt	1 qt	3 pt.
1	1 pt	1.5 pt	2.5 pt	3.5 pt.
1.5	1.5 pt	2.25 pt	3.75 pt	5.25 pt.
2	1 qt	3 pt	2.5 qt	3.5 qt.
2.5	2.5 pt	1 qt	6.25 pt	8.75 pt.
3.5	3.5 pt	5.25 pt	8.75 pt	6 qt.
4	2 qt	3 qt	5 qt	7 qt.
4.5	4.5 pt	6.75 pt	11.25 pt	2 gal.
5	5 pt	7.5 pt	12.5 pt	9 qt.
5.5	5.5 pt	1 gal	7 qt	10 qt.
6	3 qt	4.5 qt	7.5 qt	10.5 qt.

For 1 acre-foot (an acre of water 1 foot deep) use 5.3 gallons of sodium arsenite spray; for ½ acre-foot, or for 4 p. p. m. on 1 acre-foot, use 2.65 gallons.

If you are in doubt concerning the type of vegetation in your pond, you should send samples of the questionable species with either the blossoms or fruit to the nearest State University for identification. Submerged vegetation should be thoroughly dried before mailing it. Preparation of the specimen is best accomplished by spreading the plant flat on a piece of paper or between the folds of a newspaper, and placing a weight on it until dried. Attach a label to each sample giving such information as you can about the location and depth of water where the plant was found.

APPLYING CHEMICAL AGENTS

The best way to apply a weed killer is in liquid form. It is necessary that sprays be applied directly on the plants (in controlling emergent vegetation), or to areas where the plants cover the bottom of the pond (in submerged vegetation).

Sodium arsenite

Sodium arsenite is heavy and sinks rapidly to the bottom. Consequently, the areas to be treated can be restricted by spraying only those places where it is intended to kill submerged vegetation. Some time will elapse before the effect of the chemical can be noticed. Since the vegetation that is killed will begin to decay and remove oxygen from the water, it is advisable to treat not more than one-third of the pond at one time. The remainder can be sprayed a few days later. This gives the fish an opportunity to move into waters where oxygen is available.

To hasten the effect of sodium arsenite, it is helpful to fertilize the areas where the weeds are beginning to die. This will produce a waterbloom and oftentimes will result in a complete kill of all vegetation in the pond, thus eliminating the need for the use of chemicals on the untreated areas.

Sodium arsenite is very poisonous, and care should be taken when applying it that the spray is not inhaled and does not come in contact with the skin. Livestock should be kept away from sprayed ponds for at least 2 days. Containers in which the chemical has been mixed should be thoroughly cleaned and removed from places where livestock may have access to them. The water itself is not poisonous, since the amount of chemical used is not sufficient to provide a lethal dosage.

Copper sulfate

Copper sulfate should be obtained in small crystals so that it can be spread evenly over the area to be treated. As in the case of sodium arsenite, only part of the pond should be treated at one time, and copper-sulfate crystals should never be in excess of 0.5 p. p. m. for the pond as a whole. Also, fertilization of the treated area will assist in producing a waterbloom, particularly if the vegetation is heavy.

2,4-D

In the use of 2,4–D, it is essential that a uniform application be made on the treated area and that all plants be thoroughly wet. Under these conditions, usually about an 80- to 90-percent kill results, and a second application must be made wherever new shoots appear. This may be followed by an occasional shoot appearing that can be pulled by hand.

SPRAYING EQUIPMENT

Many sprayers are on the market that can be used to spread these chemicals. If considerable use is to be made of such equipment, it probably would be advisable to have a sprayer that can be mounted in the back of a truck. There are many pieces of equipment on the market designed for specific jobs. Large dealers handling farm equipment or garden supplies can recommend the proper piece of equipment for your specific needs.

CONTROLLING DISEASES AND PARASITES

When raised in ponds, minnows can be expected to suffer from many of the diseases of hatchery fishes. For this reason, it seems wise to mention some of these diseases and parasites, and to outline briefly a program for their prevention and cure. Moreover, diseased and ailing fish are often collected by unsuspecting dealers, or the fish may become fungused from improper handling in the nets or tanks.

The best method of disease control in a hatchery is prevention. Fish that are handled properly and that are adequately "tempered" before handling will usually be free from disease.

Bait fishes are infested by several kinds of parasites, and the following numbers of species have been reported from them:

	Number of parasites
White sucker	20
Golden shiner	14
Bluntnose minnow	9
Western mud minnow	4
Common shiner	3
Fathead minnow	2
Silvery minnow	2

Most of these parasites will not cause loss, and only a few are characteristic enough for the hatcheryman to recognize. Most likely to cause considerable loss in bait fishes are fungus diseases, fin or tail rot, black grub, and certain other diseases that are discussed in succeeding pages.

WHEN TO TREAT

In any method of treatment, time is of vital importance. Disease rapidly lowers the vitality of small fish, and although today they can withstand the rigors of treatment, tomorrow may find them too weak. The fish culturist must maintain strict watch on his stock. Early warning of the presence of many external parasites is evidenced in the fish refusing to eat, scratching themselves, or assuming a characteristic bluish-gray sheen. Fungus is an excellent indicator of trouble, but it usually does not appear until after the telltale rise in the daily losses—which is the surest proof that trouble is present.

Immediately upon any suspicion of trouble and always in the event of increasing losses, the fish should be carefully examined for gross lesions, and all possible extraordinary factors, such as bad food, silt, and sudden fluctuations in water temperature, should be checked. If none of these is involved, the fish should be examined for parasites and microscopic lesions. There are many diseases of fishes which are difficult to diagnose or treat, or both.

When in doubt as to the cause of losses, the fish culturist should seek the advice of a State fishery biologist. Whenever it is necessary to send the diseased fish to a diagnostic laboratory, the specimens selected should be fish with the most typical symptoms or signs of the disease, but still living. It is very difficult and often impossible to diagnose a disease from a dead fish. If living fish cannot be brought to the laboratory, live fish with typical symptoms should be placed in a jar containing 1 part of commercial formalin diluted with 3 to 4 parts of water. A letter should accompany the specimen, giving as detailed information as possible regarding the progress of the disease, percentage and rate of losses, and a detailed description of the conditions existing in the pond or tank, such as turbidity, presence of vegetation, waterbloom, water temperature, and any treatment of the pond or fishes. The more accurate the description of the symptoms and conditions that is given the more likely it is that the biologist will be able to determine the cause of trouble and recommend treatment.

METHODS OF TREATMENT

Regardless of the concentration of the disinfectant used, the technique of application influences the success of any treatment to no small degree. It might, therefore, be advantageous to briefly outline the various methods of treatment in common use and the recommended techniques.

Salting

Salting is good trough treatment, but it will not cure everything. In troughs, it is extremely simple to apply, is reasonably effective against external protozoan parasites, is an excellent tonic for the fish, and its application demands the least accuracy of any known form of treatment.

There are many ways to treat fish by salting, and some methods are better than others. In the method recommended here, fish are treated with a known concentration of common salt. Salt should be dissolved in water in a quantity to give a 3-percent concentration when added to the water in which the fish will be treated. This can be done by determining the volume of water contained in a trough or tank at an arbitrarily predetermined depth, say 2 inches (5 cm.). By multiplying the inside length of the trough by the inside width and the product of these two numbers by the predetermined depth, all expressed in inches or centimeters, one can calculate how much salt to use. A 3-percent concentration can be obtained by using 1 ounce of salt to each 60 cubic inches of water, 30 grams to the liter, 4 ounces to the gallon, or 30 ounces to the cubic foot of water. To give fish a salting, shut off the inflowing water, drain the trought to the predetermined depth, remove some of the water in a bucket and add the required quantity of salt, dissolve the salt, and mix this strong solution with the water in the trough.

Fingerling trout will withstand a 3-percent concentration for 6 to 10 minutes. Most minnows will probably stand this treatment for only 2 or 3 minutes. When several of the weaker fish have turned over, the inflow is resumed at the maximum rate which the fish will withstand and the drain is partially opened to permit a rapid replacement of the salt water. This method may be applied to fish as often as desired without apparent injury and, indeed, with a definitely tonic effect. When repeated three times at 24-hour intervals, salting is quite effective in curbing epidemics caused by external protozoans, and it is the only treatment which should ever be applied in the absence of definite knowledge regarding the cause of any mortality. Salting, however, becomes progressively more expensive, less effective, and more difficult to apply as the size of the body of water to be treated increases.

Flushing

Control of fish pathogens or parasites by flushing does not have wide use, but in certain instances it is quite effective. Flushing consists in routinely adding a stock solution of a disinfectant or drug of known strength to the upper end of a trough and allowing it to flow down the trough and out. Most frequently it is used with malachite green to control fungus infection of fish eggs during hatching. Preliminary experiments also indicate that such treatment with malachite green may be of use in control of the external infection of fish by fungi belonging to the genus *Saprolegnia.* The most-frequently used procedure is to make a stock solution containing 0.5 gram of pure malachite green per liter of water (2 grams to the gallon, 1 ounce to 14 gallons) and after the dye is completely dissolved, 100 milliliters (3.5 fluid ounces) of the solution should be poured in at the head of the trough and half of that amount in the middle of the trough. Burrows (1949) described a treatment of eggs by a constant flow of malachite-green solution.

Malachite green also can be added in powdered form to a fish tank or concrete pond, and dissolved by mixing. In such cases it should be added at a rate of 1 p. p. m. Water containing malachite green should be gradually replaced with fresh water. If the flow of water is such that the concentration of the dye will be reduced in the pond by about 50 percent during the first hour, no toxic effect on fish should be noticeable. The use of malachite green requires further investigation.

Dipping

The third basic method of controlling diseases and parasites in bait fishes, hand dipping, could be the subject of several volumes. Suffice it to say that it is a dangerous treatment, for the solutions used are powerful and relatively concentrated. Hence, the difference between an effective dose and a killing one is exceedingly narrow in view of our present lack of knowledge concerning this very common method of treatment. When applied with extreme care, dipping undoubtedly may be of great value in controlling infestations of external parasites and infections caused by certain types of bacterial diseases, such as fin rot and the eastern type of gill disease. Certainly, hand dipping should never be applied to any large number of fish unless there is valid reason to believe that some external parasite is causing the losses. In the absence of such reason, a dip should be applied to a small number of fish as an experiment. If the percentage loss in this experimental group does not fall significantly below that of the rest of the affected fish within 2 days after the experimental treatment was given, hand dipping should not be used.

Hand dipping, in the opinion of the authors, is best done in a dipping box. This apparatus consists of a solidly constructed, watertight, wooden box—in cross section about 2 inches narrower than the hatchery troughs, about half again as deep, and approximately 3 feet long. The height reached by a known volume of water is legibly marked on the box. In the dipping box is slung an inner compartment, with four ears which are sufficiently wide to rest on the top of the dipping box, yet sufficiently narrow to permit the compartment to slip into the hatchery troughs. This inner compartment has two wooden sides which round vertically at the ends, and the bottom is covered with a galvanized, coarse wire mesh. If a dip bath is used that contains copper sulfate or acetic acid, the galvanized screen should be painted with asphalt, since even traces of dissolved zinc may be toxic to the treated fish. The galvanized mesh, in turn, is covered on the inside with bobbinet, that is caught to the wire mesh at a sufficient number of points to keep it from floating off.

The desired quantity of disinfectant is weighed out and dissolved in the dipping box which has previously been filled with water to the calibration mark. The inner compartment is then placed in the trough which contains the fish to be treated, and a convenient number of fish from the trough are placed in it by means of a scap net. The compartment is then removed to the dipping box and the fish immersed in the disinfectant. After the required time for the dip has elapsed, the inner compartment is carefully lifted from the dipping box and immersed in the trough to which the treated fish are being transferred. By slowly lifting the "upstream" end of the inner compartment, the fish slip out into the trough. The solution in the dipping box should be aerated constantly and renewed frequently. Differences in water temperature between the infected trough, the dipping box, and the treated trough should at no time exceed 5° F.

For treatment by dipping as used most frequently, the formula for external parasites is glacial acetic acid, 1 part dissolved in 500 parts of water; for gill disease, it is 1 part of copper sulfate (blue stone) in 2,000 parts water; and for various external infections with animal parasites and fungi, it is a 3-percent solution of salt. Fish are usually dipped for 1 minute in acetic acid and copper sulfate, and in salt for several minutes until the weakest fish begin to turn over.

Prolonged treatment

Prolonged treatments are based on the theory that long exposure to a dilute solution of disinfectant is more effective and less toxic than is the shorter, more-concentrated hand dip. Furthermore, prolonged treatment may be applied without handling the fish, a factor which is not serious if the fish are carefully treated from troughs, but may become very serious when the fish are in ponds or pools where a seine must be used and a large number of fish is involved.

Prolonged treatment originally consisted of adding to the inflowing water a sufficient amount of dissolved disinfectant at a uniform rate to maintain a constant concentration of disinfectant over a definite period of time, usually 1 hour. This method of treating the inflowing water is subject to an inherent inaccuracy due to the diluting influence of the residual water in the pond at the time treatment is started. Although not serious in the case of troughs or small raceways which may be drained practically to dryness and which fill rapidly, the inaccuracy becomes progressively greater as the size of the body of water to be treated is increased.

For treatment of fish in larger water areas, such as circular pools, raceways, or ponds, the prolonged treatments are identical in principle to salting, page 51. The volume of water in the pool (capacity of the pool) to be treated must be known; then the required quantity of the disinfectant is weighed, or measured by volume if it is a liquid, and dissolved in a small quantity of water. This stock solution is mixed thoroughly and quickly with the water in the pond. To ensure an even distribution of the disinfectant and to aerate the water during treatment, the water should be recirculated in a closed system from the lower end of the pond to the upper end by means of a centrifugal pump.

Prolonged treatments can be carried out easier if fish are not fed for 24 hours before treatment. This reduces the fishes' metabolism rate and oxygen requirement. According to Fish (1947), for safe treatment, fish should not be too crowded; there should be no more than that 1 part of fish by weight to 100 parts of water (1 pound of fish per 12 gallons of water). If such a ratio is maintained, the flow of water or aeration can be cut off for 1 hour.

Gammexane has been described as an effective treatment for infestation with *Argulus*, a copepod. It should be added at a rate of 1 part to 10 million parts of water to the pond or tank holding the infested fish. In tanks, the medicated water should be replaced with fresh water after 2 to 3 days of treatment. How effective gammexane is for the treatment of infestations caused by *Lernea* (another copepod) is not known at this time.

The most-frequently used prolonged treatments are with formalin and pyridylmercuric acetate, technical (P.M.A.). Formalin is added to water at a rate of 1 part of formalin (containing about 40 percent formaldehyde) to 4,000 parts of water by volume. Pyridylmercuric acetate (P.M.A.) is used at a rate of 2 parts per million. Treatment with formalin is effective against many of the external parasites, like *Gyrodactylus*, *Dactylogyrus*, *Chilodon*, *Costia*, *Trichodina*, fin rot, and others. A 10-percent stock solution of P.M.A. can be easily prepared and kept on hand when needed. P.M.A. is used mainly for the treatment of gill diseases, but some of the external parasites listed here are also affected by it. P.M.A. is toxic to some fish, like rainbow trout. It is not known how toxic it may be to minnows and other bait fishes.

Antibiotics, such as chloramphenicol and terramycin, have been found to be effective in the control of ulcer disease and furunculosis in trout and red-leg disease in frogs. Since the bacterium *Pseudomonas* (*Aeromonas*) *hydrophila*, which causes red-leg disease is identical with that which causes infections in many warm-water fishes, chloramphenicol may be the choice in treatment of infections of aquarium fishes. It should be added to water in which fish are kept at the rate of 50 milligrams per liter (190 milligrams per gallon of water). Water should be changed once a week and fresh chloramphenicol added. Chloramphenicol is also available in capsules, each containing 250 milligrams of the drug (1 capsule per 5 liters or 1.3 gallons of water). If fish are kept in flowing water, flow should be stopped for 1 hour (or for as long as possible). Treatments should be repeated at intervals of several days, if needed. Use of antibiotics in treatment of external or internal diseases of fishes is very recent, and the available information on this subject is scant. Caution, therefore, is advised when using antibiotics. They should not be used for prolonged periods of time, (i. e. several weeks) because drug-resistant varieties of pathogens may appear, and in such cases antibiotics will become useless against them.

Internal treatment

In internal treatment, drugs are given the fish by mouth with their food, or in certain instances they have to be introduced in capsules directly to the stomach. Whenever drugs are given with the food, it is important to select a food of good cohesion (or use medicated pellets) which is readily taken by fish. This is important, because if food is permitted to remain in the water even for a short time the drugs may leach out. Drugs must be mixed well with the food so that each fish will get the quantity of drug proportional to the amount of food taken. Food should be fed judiciously in quantities exactly required by the fish. If too much food is given, both food and drug will be wasted. If there is not enough food given, the weakest fish, which may need the drug the most, will be deprived of it. Among the drugs given orally are sulfonamides, antibiotics, calomel, carbarsone, and kamala.

Sulfonamides are most effective in treatment of furunculosis, which is a disease predominantly affecting the salmonid fishes. Sometimes, however, this disease may cause losses among warm-water fishes. Of the great variety of sulfonamide drugs, those most frequently used are sulfamerazine and sulfamethazine, with the possible addition of sulfaguanidine. The effective dosage rate is 8 to 12 grams of sulfamerazine daily per 100 pounds of fish. Some workers have found that replacement of one-third of either of the first two sulfonamides, with sulfaguanidine is somewhat more effective. For best results, treatment should start as early as possible and be continued for about 2 weeks. In a recurrence of the disease, treatment should be repeated. During the period of treatment, only medicated food should be fed to the treated fish.

Calomel and carbarsone are effective in the treatment of intestinal infections caused by one-celled animal parasites, like *Octomitus*. Either one of these drugs should be added at the rate of 1 gram to the pound of food. Feeding of the medicated food should be continued for 3 days, and repeated when needed. Kamala is used for treatment of intestinal tapeworms in fishes. It can be added to food at a rate of 1 to 1.5 percent, or given in capsules to large brood fishes, the dosage being 0.1 gram for each 3 pounds of fish. Treatment with kamala should be continued for 3 days.

Here is a list of the chemicals and drugs that are recommended for use in the treatment of bait fishes:

Drug	Concentration	Disease
Acriflavine	1 part per 50,000 to 100,000 parts of water.	External parasites.
Calomel	1 gram per pound of food	Intestinal infections, as *Octomitus*.
Carbarsone	do	Do.
Chloramphenicol	50 mg. per liter of water, or 190 mg. per gal.	Bacterial infections.
Copper sulfate	1 part to 2,000 parts of water, or 1 oz. in 15 gal.	Fungus.
Formalin	1 part of 40 percent formalin to 4,000 parts of water.	External parasites.
Gammexane	1 part per 10,000,000 parts of water.	Infestations with copepods (*Argulus*, possibly also *Lernea*).
Glacial acetic acid	1 part in 500 parts of water	External parasites.
Kamala	0.1 gram to each 3 lbs. of fish	Intestinal tapeworms.
Malachite green	1 part in 15,000 parts of water, or ⅛ oz. in 15 gal. of water.	Fungus.
Pyridylmercuric acetate technical (PMA).	2 parts per 1,000,000 parts of water.	Bacterial infections.
Quinine hydrochloride	1 part per 50,000 to 100,000 parts of water.	External parasites.
Salt	3 percent solution, or 1 oz. per 60 cubic inches of water, or 4 oz. per gal.	External protozoan parasites and fungi.
Sodium sulfamerazine	1 part per 1,000 parts of water	Bacterial infections.
Sodium sulfathiazole	do	Do.
Terramycin	50 mg. per liter of water, or 190 mg. per gal.	Do.

CONTROL OF SPECIFIC DISEASES

Fungus diseases

Fungus disease of fish is usually attributed to an organism called *Saprolegnia parasitica*. At the point of infection, the fungus appears as a grayish-white fuzz. This growth spreads rapidly over the body surface, and the fish is sometimes almost completely enveloped before death occurs. It is a common disease of fish, especially in warm waters, or in tanks and aquaria. The focus of infection is usually traceable to some injury which permits entrance of the spores. This disease is controlled in nature by certain bacteria which are found in the mud and ooze of lake and pond bottoms. Infected fish from tanks should be dipped for 5 minutes in a concentrated salt solution (see Dipping, p. 53). In stubborn cases, the treatment can be repeated several days in succession. A 10-second dip in malachite green 1:

15,000 solution (1/8 ounce in 15 gallons of water) is very effective (see also Flushing, p. 52).

Bacterial diseases

Fin rot.—This disease may be caused by several different bacteria. The disease is characterized by a progressive degeneration of a fin or the tail of a fish until the entire appendage is destroyed. The infection starts at the free end of the fin. The diseased tissue is separated from the uninvaded tissue by a white line. Control of this disease is accomplished by dipping in a 1 : 2,000 solution of copper sulfate for 1 or 2 minutes. If the water is hard, 10 milliliters of glacial acetic acid should be added to 10 gallons of water (1 fluid ounce to 30 gallons). Fish on which the disease has progressed to a marked degree should be destroyed, as the dip can do little for them. Bacterial fin rot has also been controlled with a 1 : 4,000 (8 ounces to 100 gallons of water) solution of formalin (see Prolonged Treatment, p. 54).

Columnaris. — During recent years, many outbreaks of infections of warm-water pond fishes with a bacterium called *Chondrococcus* (*Cytophaga*) *columnaris* have been reported. This bacterium attacks fish mostly at higher water temperatures, like 25° to 30° C. (77° to 88° F.). The infection is characterized by the appearance of grayish-white spots on the head, gills, fins, or some part of the body, which is usually surrounded by a zone with a distinct reddish tinge. Superficially, the spots resemble lesions produced by *Saprolegnia*, but a close inspection shows that they lack the fuzzy appearance so characteristic of a fungus infection. *C. columnaris* can easily be identified under the microscope by an experienced person. Disease breaks out most frequently as a result of handling, and this can be prevented by dipping the fish right after handling for 1 minute in a solution of copper sulfate. This chemical added to pond water at a rate of 1 p. p. m. may arrest the progress of the disease.

Infectious dropsy.—*Pseudomonas* (*Aeromonas*) *hydrophila*, a bacterium commonly present in water, causes this disease. Occasionally more infective races (mutants) of this bacterium appear, which are more destructive to fishes. The resistance of fishes is lessened by handling, crowding, or other unfavorable conditions. Outbreaks of infectious dropsy occur most frequently in spring when the temperature of water rapidly increases and fish are still weakened by winter. Sometimes up to 80 percent of the fish may die within several days. It is one of the most destructive bacterial diseases of warm-water fishes.

The symptoms of this disease are variable. Sometimes the diseased fish may have deep boils or shallow ulcers on their bodies. Frequently the body is swollen and the abdomen filled with a watery fluid (dropsy). Occasionally the skin on the abdomen may become pink or red with some small hemorrhages. The intestine also may show congestion. Scales may stand out on the swollen fishes. *Ps. hydrophila* can be isolated from the abdominal fluid, blood, and lesions, and identified by a bacteriologist. Frogs also sometimes become infected with this bacterium, and the resulting disease is called "red leg," stressing the most characteristic symptom of this disease in frogs.

There is no known treatment for this disease. If fish are in an aquarium or a tank, addition of chloramphenicol may be used. Also feeding food that contains chloramphenicol or terramycin may be effective (see Prolonged and Internal Treatments, pp. 54 and 56).

Furunculosis.—Produced in fish by *Bacterium salmonicida*, this is a disease of salmonid fishes (salmon and trout), but whenever minnows or other warm-water fishes are kept in water which flows from tanks or ponds holding infected trout, it may cause severe mortality among them. Furunculosis has variable symptoms. In minnows, the most typical signs are boils or bloodshot fins. Diagnosis can only be made with certainty by bacteriological examination of the diseased fishes. Furunculosis, if correctly diagnosed, can be effectively treated by feeding the infected fish with food containing sulfamerazine, or sulfamethazine. Some authors recommend replacement of one-third of either of these two sulfonamides with sulfaguanidine, which belongs to the same group of drugs. Recommended dosage is 8 to 10 grams of sulfonamides daily per 100 pounds of fish (see Internal Treatment, p. 56).

Parasitic worms

Black grub.—Black grub, or black spot, is caused by the larval form of the flatworm, *Neascus* sp. The parasite occurs on fishes as a small black spot about 1/25 of an inch in diameter. This black cyst encloses a small worm which is usually limited to the scales and integument, but which may occasionally be found in the flesh just below the skin. The life history of the black grub is complicated, but is typical of many of the parasitic flatworms. The adult worm occurs in the kingfisher. Eggs of the worm are discharged into the water, where they hatch into small, free-swimming organisms. These larval forms swim about until they come in contact with a particular species of snail. Then they bore into the snail and reproduce themselves many times. Finally, numbers of free-swimming forms break out in the water and move about until contact with a fish is made. They then burrow in and encyst in the scales or in the flesh. When the fish is eaten by a kingfisher, the encysted worm develops into an adult and the life cycle is completed. It usually causes little damage to the fish, but may, at times, be present in numbers large enough to cause death.

Klak (1940) reports a heavy

Neascus infection of fathead minnows in a pond at Leetown (W. Va.). The encysted worms were found in the abdominal cavity in such numbers that the abdomen was greatly distended. Mortality was so high that a change to golden shiners, a more resistant species, was recommended.

The only control for this parasite is draining the pond long enough to kill the snails and controlling the kingfisher population. Snails in ponds can be killed rapidly by disinfection of the pond with chlorine (see Disinfecting Ponds and Equipment, p. 61).

Tapeworm.—*Ligula intestinalis* is a tapeworm whose last larval stage is commonly found in the body cavity of suckers and minnows, and rarely in perch, darters, and bass. Infested fish are easily recognized by their swollen bellies. Worms 6 inches long have been taken from minnows, and worms as long as 12 inches have been taken from suckers. The adult stage lives in the intestines of water birds.

Minnows and suckers reared in ponds or taken from shallow waters along lake shores may be infested. The parasite is known to be of wide occurrence in the Great Lakes and adjoining areas. Because the parasite's eggs are spread by water birds, and early larval forms live in the natural food organisms of fish, there is little chance for permanent control, although drying and freezing of pond bottoms may reduce infestation.

Other tapeworms can frequently be found in the intestinal tract of warm- or cold-water fishes. Heavily infested fish become sterile, therefore, the removal of tapeworms is important in the case of brood stock. Several drugs given orally may be effective. McKernan (1940) found that the addition of 1 to 1.5 percent of kamala to their food rids fish effectively of tapeworm. One contributor to this publication (Snieszko and Powell, unpublished) successfully cured adult largemouth black bass by treating the fish for 3 days with kamala in capsules. Each adult bass received daily one capsule containing 0.1 to 0.2 grams of kamala, dosage being about 0.1 gram for each 3 pounds of fish. The treated fish eliminated great masses of tapeworms with the feces.

External animal parasites

Here are included such protozoans as *Costia*, *Chilodon*, *Trichodina*, *Scyphidia*, *Epistylis*, *Ichthyophthirius*, and external trematodes such as *Dactylogyrus* and *Gyrodactylus*. All of these parasites except *Ichthyophthirius* live on the surface of the fish's body and gills and are readily removed by salting, dipping in glacial acetic acid, or by using prolonged treatments with formalin. *Ichthyophthirius* differs from the other external parasites listed here, since in its adult stage it buries in the epidermis of the fish; therefore, these treatments are not effective against it unless they are repeated daily until the desired results are attained. Where water flows through the pond, increasing the rate of flow is considered the most effective means of controlling this parasite. If fish are held in tanks or aquariums, the addition of hydrochloride or sulfate of quinine to the water at the rate of 1:50,000 to 1:100,000 is recommended. Water containing quinine should be replaced by fresh water when the fish are cured. Recently Schäperclaus (1954) recommended using acriflavine in the same way as quinine. Acriflavine is believed to be even more effective than quinine in the treatment of *Ichthyophthirius* and other external protozoans.

Copepods.—Suckers and minnows held in sluggish or warm waters may develop raw circular wounds with what appears to be a slender bonelike splint projecting from the center of each lesion. The white splint actually is a copepod parasite, *Lernea* sp., which has burrowed head first into the flesh, usually beneath the dorsal fin. This parasite is common in southern portions of the Lake States and is more abundant southward.

The projecting portion of the parasite contains reproductive organs which scatter eggs into the water as the host fish swims about. These eggs hatch into tiny free-swimming larvae. The larvae, in time, attach themselves to another fish, transform their body shape to a great degree, and burrow in. Meehean was able to cure the infection on fancy goldfish by reducing the pond level to a point where water flowing in and out of the pond produced a mild current. The young that hatched did not reinfect the fish, and the adult parasites dropped off after they reproduced. Infected goldfish could be healed in about 10 days.

Recently a chemical, gammexane, has been recommended for treatment of fish infected with the copepod *Argulus* sp. It may also be effective against other copepods. It should be added to water containing infected fish at a rate of 0.1 p. p. m. and mixed well. It is recommended that after 2 to 3 days of treatment, the water containing gammexane should be replaced with fresh water. Since this is a new and little-known treatment, it should be carried out with great caution.

DISINFECTING PONDS AND EQUIPMENT

The incidence of disease can be greatly diminished or even entirely avoided by observation of certain sanitary measures. Some of them will be listed here. For more detail, see publications by Davis (1947 and 1953) and O'Donnell (1947).

If disease recurs frequently, the hatchery must be carefully examined to determine the source of infection. Most frequently the source of infection can be found in not-completely cured fish or in older fish (brood stock), which may serve as a reservoir of infection without any visible symptoms of a disease. Since frequent treatments are costly and time consuming, it is often bet-

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ter to kill the diseased fish, disinfect the ponds, and start over with healthy stock.

In case of an outbreak of a disease in one part of a hatchery, the infected part should be isolated and quarantined. All of the equipment used in this part of the hatchery should be disinfected. Ponds, also, should be disinfected as soon as the fish are removed.

Disinfecting equipment

For disinfection of tools and utensils, any good disinfectant can be used. Chlorine in the form of hypochlorite is generally available, inexpensive, and easy to use. The concentration used in hatcheries is 200 p. p. m. of free chlorine. The quantity of hypochlorite that has to be used to obtain this concentration can be calculated from the contents of available free chlorine as indicated on the product's label. Hypochlorite in open containers and exposed to moisture and light loses its strength rapidly.

Roccal, another widely used disinfectant, is recommended for disinfection of hands, boots, nets, and other equipment. It is sold as a 10-percent solution. The disinfecting solution can be obtained by diluting 1 part of commercial roccal with 100 parts of water. Roccal is colorless, odorless, and harmless, if not taken internally.

Disinfecting ponds

Ponds can be disinfected by the addition of hypochlorite, or liquid gaseous chlorine, to water. The concentration of free chlorine should not fall below 100 p. p. m. during disinfection, which should last at least for 1 hour. Water containing chlorine is very toxic to fish and other life. If water with chlorine is kept in ponds for 2 or 3 days, all chlorine will disappear. If, however, water with chlorine must be released sooner to a stream with fish, the free chlorine should be neutralized with photographer's hypo (sodium thiosulfate). Chlorine will also kill fish parasites present in water, as well as snails which often act as intermediary hosts to some fish parasites.

Drying and liming of ponds are also good practices; however, ponds so treated must remain completely dry for several months to make this practice entirely effective.

CONTROLLING PREDATORS AND PESTS

INSECTS

Minnow ponds may become overpopulated with aquatic insects that prey on fish fry. Of these, the beetle larva called the water tiger and the adult insect known as the backswimmer (*Notonecta*) are the most destructive. As both come to the surface of the water for air, they can be controlled by covering the ponds with a film of oil. Kerosene, fish oil, No. 2 fuel oil, and cod-liver oil can be used for this purpose, as they are not injurious to fish. The cod-liver oil must be mixed with gasoline before use. Meehean (1937) recommended using 10 to 12 gallons of kerosene to an acre of water surface. The same result can be obtained with 4 or 5 gallons of commercial fish oil. The fish oil is sprayed on the surface to control the thickness of the film. Kerosene becomes too thin to be effective when sprayed, so it is best poured along the windward side of the pond.

BIRDS

Herons and kingfishers may cause a heavy loss of fish from ponds. Occasionally, the entire production of a pond has been taken by birds. The private hatcheryman is not allowed to shoot or trap these birds; so he must depend on scares, wires, and fences to keep them from the ponds.

Herons do not usually alight in the water, and a low chicken-wire fence close to the edge of the pond, or very steep banks around the pond, will keep them out. Sometimes, several wires around the pond will work as well.

Kingfishers are attracted to posts that overlook the water. Removing all posts and dead trees near the ponds should help to discourage these birds.

The hatchery operator should try to keep predatory birds from his pond, as the heron spreads the yellow grub, and the kingfisher is host to the black grub.

SNAKES

A large percentage of the food of the common water snake and some garter snakes consists of fish. The water snake has a preference for streams but frequents fish ponds.

Snakes can be controlled by killing all that are seen around the ponds. The grass and weeds at the edge of the pond should be cut short at all times so as to deprive the snake of much-needed cover. Logs, tree roots, and boulders should be removed for the same reason. Ponds that are fenced to keep out herons should be provided with pits at intervals along the outside of the fence to catch snakes and turtles. Water-snake traps are now advertised for sale in some communities.

TURTLES

Some species of turtles are known to be fish eaters and, consequently, are predators if given access to a minnow pond. As a safeguard, all turtles frequenting a pond of minnows should be considered predators and controlled. Turtles can be captured with baited hooks or turtle traps (fig. 25).

PREDATORY FISH

Predatory fish and the adults of cannibalistic minnows must be controlled in minnow ponds. As mentioned before, lake and river water should be filtered to keep predatory fish fry from entering a pond. When possible, the minnow pond should be drained dry during the winter to kill any predatory fish that may have escaped notice. Ponds that cannot be drained

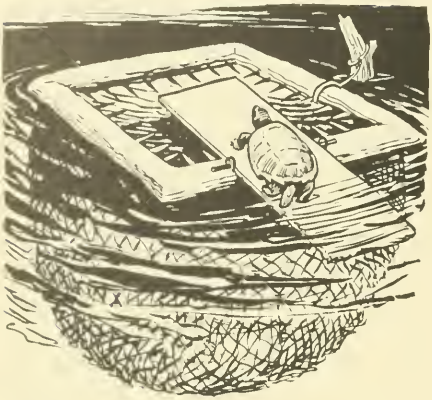

Figure 25.—Floating turtle trap. Turtles seeking a sunning spot are tipped into the net or wire bag.

should be treated with rotenone before minnows are introduced and whenever there is an indication that predatory fish have become established.

The best procedure is to apply 1.5 to 3 pounds of 5-percent rotenone powder to an acre-foot of water, depending on the hardness of the water. Ponds with hard water, very cold water, or containing bullheads require a heavier dosage. Emulsifiable rotenone can be used at the rate of 1 gallon for each 3 acre-feet of water. The emulsifiable rotenone can be applied as it comes from the can but the powder must be mixed with water to form a thin batter. The poison is usually spread evenly over the pond with a boat and outboard motor. The rotenone is poured over the edge of the boat into the propeller wash at a steady rate. The pond should be crisscrossed in a good pattern with lines about 50 feet apart for good distribution of the poison.

SALAMANDERS

The tiger salamander (fig. 26) is abundant in many minnow ponds and is often considered an important predator of minnows. Salamanders grow fast enough to keep ahead of most minnows and could be fish predators during the entire period of pond life. Studies on Minnesota sucker ponds show that the salamander is more important as a competitor of the sucker, than as a predator. The stomach contents of 133 salamanders of all sizes from 8 sucker ponds was only 2.3 percent minnows. Copepods and cladocera which are important sucker foods made up 29.6 percent of the total food of the salamander. Corixid water bugs which are little used by suckers made up 28.9 percent of the salamander diet.

Figure 26.—The tiger salamander is abundant in many streams and is considered an important predator of bait fishes. (Photograph courtesy of the Minnesota Department of Conservation.)

Salamanders can be controlled in artificial ponds by keeping the pond dry until after they have deposited their eggs. Because the salamander returns to the pond to lay its eggs shortly after the ice melts, the pond can be safely filled in late spring. In natural ponds the salamanders can be controlled by removing the large gelatinous egg masses before they hatch. The egg masses are usually formed on sticks or weeds in shallow water, so they are easy to find.

Salamanders do so little harm in sucker ponds that control is usually not necessary. At seining time, the dealer should sort out the salamanders as soon as possible because they will gulp down large numbers of minnows when held in such crowded conditions.

MUSKRATS

The only appreciable damage done by these animals results from their burrowing in the dikes of ponds. At times they can be serious pests, causing abnormal bank leakage and slipping that result in expensive maintenance costs. If a minnow producer has difficulty with these animals, he should consult his State conservation department as to methods of control. Most States have specific laws protecting the muskrat because of its value as a fur-bearing animal.

CRAYFISH

In many places the crayfish (fig. 27) is considered a predator or a nuisance in ponds, but in regions where crayfish are used extensively for bait, they may be an important byproduct of minnow production, or may rate separate ponds.

In areas where crayfish are a nuisance in ponds, they can best be controlled at harvest time when they can be removed at no extra cost. Every haul of the seine will bring in large numbers of crayfish that should be separated from the minnows as soon as possible to prevent damage to the minnows from their claws. If crayfish removal is to be effective, the crayfish must be carried away from the pond or buried, as those thrown up on shore will crawl back to the pond in a short time.

FIGURE 27.—The crayfish is considered an important predator in some areas. (Photograph courtesy of the Minnesota Department of Conservation.)

SOME IMPORTANT BAIT FISHES

Knowledge of the life history and behavior of the bait fishes he is raising helps the operator achieve maximum production in his ponds. This knowledge aids him in selecting the species for each type of pond, in choosing the spawning facilities to be supplied, and in determining the amount and kind of fertilizer to use.

The name "minnow" is commonly but erroneously applied to small fishes of all species. The true minnows are members of a family of fresh-water fishes, the Cyprinidae, and have definite characteristics that separate them from other families. Most bait fishes are true minnows, but some important species like the mud minnow and the sucker belong to other families. Most bait fishes are small, but some, like the carp, an introduced "minnow," and the Colorado River white salmon, attain weights of 40 to 80 pounds. Young game and food fishes, such as perch and pike, and which should be called fry or fingerlings, are often improperly called minnows.

Of the fishes used for bait, the true minnows are most important. They can be distinguished from other fishes by the following characters: No teeth in the jaws; no scales on the head but over remainder of body; no spiny rays in any of the fins; one dorsal fin; less than 10 rays in the dorsal fin; pelvic fins abdominal in position; size usually small, under 6 inches (fig. 28).

Fish have definite food preferences. Many species feed entirely on the tiny, drifting plants of the plankton, others on animals, and some on both; some prefer insects, and others take whatever comes along (figs. 29–32).

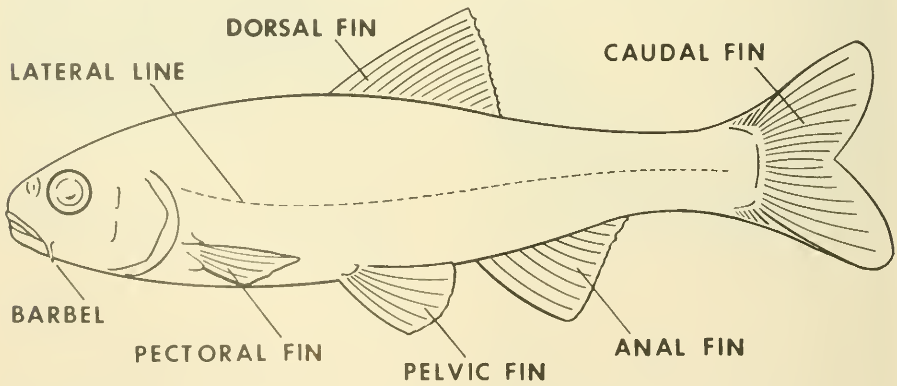

FIGURE 28.—A typical minnow, showing the parts used in identification.

FIGURE 29.—*Daphnia*, a pond organism used by bait fish as food; greatly magnified. (Photograph courtesy of the Minnesota Department of Conservation.)

Spawning requirements, like feeding habits, differ for different species. Some bait fish require flowing waters; others do not. Some lay their eggs on vegetation; some lay their eggs on open gravel shoals or under debris. Some have extended spawning seasons and others have short ones. Adequate facilities for spawning are a necessity in good pond management.

FIGURE 30.—*Cyclops*, another minute crustacean used by bait fish; greatly magnified. (Photograph courtesy of the Minnesota Department of Conservation.)

To comply with natural habitat requirements is important. Those normally living in bog streams or swift currents might not readily adapt to life in ponds or holding tanks. In general, however, most stream or lake minnows can be reared in ponds, and with proper food may grow faster than in their natural environment.

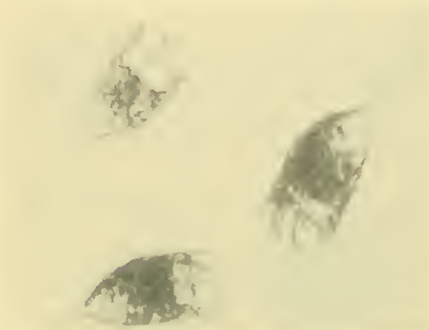

FIGURE 31.—The rotifier, *Karatella;* greatly magnified. (Photograph courtesy of the Minnesota Department of Conservation.)

There are many species of bait fishes, but the following pages include some of the more important species. The culture of several "minnow" species that are of wide

FIGURE 32.—Some common aquatic insects and worms and their relation to bait fish. Top row: Stonefly (food), mayfly (food), dragonfly (predator). Middle row: Water tiger (predator), whirl-a-gig beetle (predator), canefly (food), chironomid-fly larvae (food). Bottom row: Leech (competitor), annelid worm (food).

distribution and that have been successfully introduced in various parts of the country is treated in detail.

WHITE SUCKER *Catostomus commersonnii*

Also called Common Sucker.

LIFE HISTORY

Description.—Sucking mouth with thick fleshy lips on underside of head; fine scales near head and coarse ones on tail; small specimens have three large dark blotches on each side of body; more than 10 rays in dorsal fin (true minnows have less than 10); no spiny rays in any of the fins.

Range.—This fish is widely distributed in the United States, occurring east of the Great Plains from northern Canada, Hudson Bay drainage, to Labrador, and south to Georgia, Arkansas, and Oklahoma. It thrives under a variety of conditions, but prefers clear-water lakes and streams.

Breeding habits.—The sucker runs upstream to spawn early in the spring. It prefers swift water and gravel bottoms, scattering its eggs freely in the current. It will spawn to some extent in lakes if there are no outlets and inlets. Work done in New York indicates that temperatures from 57° to 68° F. are best for hatching eggs. In this temperature range, the incubation period was 5 to 7 days. At 70° F., mortality was high and the incubation period was about 4 days. At 40° F., none hatched in more than 14 days. As many as 47,800 eggs were taken from one female.

Food.—The sucker has diversified feeding habits. It seems to feed on any food that may appear in the water. A study of 1,080 suckers from Minnesota natural ponds shows the average food content to be cladocera, 30.6 percent; copepods, 17 percent; ostracods, 2.4 percent; chironomid larvae, 26.4 percent; miscellaneous insects, 1.5 percent; rotifers, 10 percent; protozoans, 0.8 percent; nematodes, 0.6 percent; and miscellaneous organisms, 10.7 percent. This list suggests that the planktonic crustaceans are the preferred food of the sucker, but a closer study reveals that chironomid larvae are eaten whenever they are available irrespective of crustacean abundance. Very small suckers prefer small organisms but can exist on larger forms when necessary.

Importance.—The common, or white, sucker is a popular minnow for propagation because it is easy to raise in large numbers, grows rapidly, is very hardy in the minnow pail, and is preferred by fishermen as a bait for walleyed pike. Suckers are raised more cheaply in natural ponds than in artificial because the sucker needs a large amount of growing space that can be provided more cheaply in natural ponds.

PRODUCTION

The white sucker is naturally a fish of clear waters, so ponds[1] for

[1] Many Minnesota dealers have had no returns from sucker fry planted in natural ponds. There are four pobable reasons for this: 1. There may not have been ample food for the fry at the time of planting. A questionable pond should be fertilized with barnyard manure about 2 weeks before the fry are planted. 2. There may have been a large population of aquatic insects in the pond at planting time. The back-swimmer and the water tiger prey heavily on fish fry and should be killed off 2 days before the fish are planted in the pond (p. 62). 3. The natural pond may have had a population of predatory fish or minnows at planting time. 4. The ponds may not have been stocked with free-swimming fry.

its production must be selected more carefully than those used for other bait species (fig. 33). Experience has shown that the following points are important in choosing sucker ponds:

1. Ponds of moderate fertility usually produce the most suckers. Sterile ponds do not produce enough food for the fish and very fertile ones often produce enough algae to cause summer kill. Any pond that becomes pea-soup green should not be stocked with suckers because production will be very small. If the pond is over 10 feet deep and the algal bloom is moderately heavy, the byproducts of algal decomposition will be dispersed widely enough to make a fair sucker production possible.

2. Ponds with large populations of chironomid-fly larvae, or blood worms, in the bottom muds will produce good sucker crops more consistently year after year than ponds that do not have an ample supply of these larvae.

3. The texture of the pond soil is very important. Ponds with loam and sandy-loam soils produce best, peat and peat-loam ponds are average producers, and silt and clay loam ponds are poor. The pond soil is important in its effect on water fertility and the production of chironomid-fly larvae.

4. Ponds with heavy, mosslike growths of filamentous algae over the bottom do not produce good crops of suckers. One Minnesota pond always produced large sucker crops until the filamentous algae got started and covered the entire bottom. Since then production has been almost zero. This is possibly because filamentous algae decompose readily and

FIGURE 33.—A profitable sucker pond in Minnesota. (Photograph courtesy of the Minnesota Department of Conservation.)

produce toxic ammonia just as the waterbloom does, and because the algal mat on the bottom may interfere with the feeding activities of the sucker.

Collecting the eggs

Suckers and minnows that spawn in running water are usually stripped and the eggs are hatched in jars. Taking eggs from the sucker and fertilizing them is not difficult, but considerable strength is required. The sucker not only is large, but it is one of the most active and powerful fish for its size native to our waters. On the upper Mississippi and its tributaries, suckers literally swarm during May and June over the shallow, rocky stream bottoms in swift water, as well as along the rocky, wind-driven shores of many of the northern lakes.

The fish in these spawning runs are caught with seines or traps and are sorted. The ripe males and females are carefully put in separate tubs of water and the unripe fish are released for another day. If those selected for stripping do not give their eggs and milt freely under light pressure, with the thumb and forefinger moved downward over the abdomen toward the vent, they should also be released. Eggs forced from the fish by heavy pressure will not prove fertile. The males mature somewhat earlier in the season than the females, and the bulk of them may have moved higher up stream than the point at which the bulk of the females are taken, resulting in a local scarcity of males. Both sexes would be available, however, if the fish are caught as they run up the stream and are put into a suitable holding pond until needed for stripping operations. In any event, eggs should not be taken unless a ripe male is immediately available for fertilizing them.

The female is held over a dampened pan into which the eggs are expressed (fig. 34). Immediately after the eggs are taken, a male is stripped of his sperm; the milt and eggs are thoroughly mixed by gently swirling the pan. Four or five pairs of fish may be stripped into one pan providing each batch of eggs and milt are thoroughly mixed immediately after stripping. After a lapse of 2 or 3 minutes, water may be slowly added to the pan and the stirring continued at intervals by rocking the pan gently to and fro, swirling the water.

The milt can now be washed out by frequent changes of water (fig. 35). If the eggs have a tendency to stick together in clumps, a cup of muck or corn starch of the consistency of bean soup should be added as the eggs are stirred (fig. 36). The muck or cornstarch is then washed out with the milt.

After being washed, the green fertilized sucker eggs are transferred to a tub to harden (fig. 37). The tub is placed in cold creek water and is shaded from the sun. Periodically the eggs are stirred gently and the water is changed. After 2 hours the eggs are hard enough to withstand the rigors of transportation to the hatchery.

FIGURE 34.—A female sucker is stripped of its eggs. (Photograph courtesy of the Minnesota Department of Conservation.)

Artificial hatching

At the hatchery, the eggs are transferred to Meehan hatching jars (fig. 38). Usually 2 or 3 quarts of eggs are placed in each jar, and the water is adjusted so the eggs are in constant but gentle movement throughout the lower portion of the jar. For best results, the water should contain sufficient dissolved oxygen for the eggs, but should be free of air bubbles because the bubbles adhere to the eggs and carry them up and out of the jar. Length of hatching time depends on temperature of the water. Eggs will hatch in 4 to 6 days in water warmer than 65° F., in 10 to 15 days in water of 50° to 60°, and not at all in water colder than 50°. Minnesota hatchery operators prefer to start the eggs at 50° to prevent clumping, and then increase the temperature to 55° or 60° for hatching, if possible. In some States, the water from lakes and streams reaches optimum temperature in time to be used in the hatching battery.

Fortunately, sucker fry stay in the jars after hatching, and do not swim out with the water until they are about 5 to 10 days old. Conse-

FIGURE 35.—The milt is washed away with frequent changes of water. (Photograph courtesy of the Minnesota Department of Conservation.)

FIGURE 36.—A cup of muck is added to keep the eggs from clumping. (Photograph courtesy of the Minnesota Department of Conservation.)

FIGURE 37.—The fertilized eggs are transferred to a tub to harden. (Photograph courtesy of the Minnesota Department of Conservation.)

quently, the fry can be held in the jars until they are free swimming, and are not put in the pond until they are strong enough to search for food. Because the suckers stay in the jar and settle to the bottom when the water is turned off, it is very easy to determine the number

FIGURE 38.—Hatching sucker eggs. (Photograph courtesy of the Minnesota Department of Conservation.)

on hand and the number to be used in each pond. The fry can be poured into a glass measure graduated in ounces and measured after they settle. Counts made in Minnesota indicate that there are 2,720 5-day-old sucker fry per ounce. Suckers grow rapidly in ponds. In 60 days they average 2.8 inches and may reach a length of 3.5 inches in that time. The following table shows the rate of growth of young suckers in ponds:

Number of days	Length of fish (inches)	Number of days	Length of fish (inches)
10	0. 7	40	2. 0
20	1. 1	50	2. 4
30	1. 5	60	2. 8

Sucker pond production is usually expressed in pounds and wholesale sales are usually in gallons. The following table presents the number of suckers of various sizes per pound and per gallon:

Length of fish (inches)	Number of fish per pound	Number of fish per gallon [1]
1	4, 250	34, 000
1.5	1, 120	8, 960
2	440	3, 520
2.5	220	1, 760
3	118	944
3.5	70	560
4	46	368
4.5	31	248
5	22	176
5.5	16	128
6	12	96
6.5	10	80
7	8	64

[1] 1 gallon equals 8 pounds.

Stocking the ponds with fry

While it is important for the operator to know how many fry per acre to stock in each pond, there is little exact information on the subject. Some years ago the Minnesota Bureau of Fisheries set an arbitrary figure of 40,000 fry per acre, because that was a fair division of the fry available for distribution. Experience has since shown that this stocking rate is satisfactory. Recent studies indicate that certain ponds tend to produce only so many fish no matter how many are stocked. Of course, understocking produces fewer fish, but overstocking wastes fry. If the supply of fry is limited, the dealer should experiment until he knows the optimum stocking rate for each of his ponds. For example, when a Minnesota pond was stocked with 69,000 fry to the acre of water, the survival was 17 percent; when 51,000 fry were stocked the survival rate increased to 27 percent; and when 37,000 fry were stocked the survival reached a peak of 40 percent. The number of fish produced per acre during the 3 years was 12,000, 14,000, and 15,000 fish of pike-bait size. The survival rate for suckers in all Minnesota ponds under observation during these 3 years averaged 22 percent and reached a high of 50 percent.

Dealers who are confronted with seasonal markets which require fish of acceptable size may find that it is not advisable to produce the maximum number of suckers in a pond. Studies of natural sucker ponds in Minnesota have shown a very definite relation between the number of fish produced in a pond and the size the fish will be in 60 days. As the number produced in the pond is dependent on the number of fry stocked, the dealer must decide before stocking time the size of fish he wishes to raise and stock accordingly. The following table shows the relation between the number of fish produced in some Minnesota sucker ponds and the size of the fish at 60 days:

Number of fish produced per acre	Average length at 60 days
	Inches
19, 000	2
8, 000	2. 5
4, 000	3

These values may not hold true in other areas, so each dealer will have to study his ponds and determine the prevailing relationship. Of course, the stocking rates necessary to produce certain numbers of fish will vary with each pond according to the survival rate that exists in that pond.

The dealer who knows these relationships for his ponds will be able to stock some ponds lightly to produce bait for midsummer. Ponds stocked moderately will produce the same size bait for late summer, and those stocked heavily will produce small fish that can be held over winter for the early summer season in the following year.

Operators that do not know the stocking requirements of their ponds well enough to build a graduated series of populations that will produce pike-bait sized suckers during the entire fishing season can adjust the pond populations by moving fish from one pond to another. By a system of periodic test nettings, the dealer can determine the growth rate of the fish in each pond. By moving fish from one pond to another, he can release some populations for faster growth and can crowd others for slower growth.

In actual practice, the operator tries to obtain the desired minnow population in each pond by regulating the stocking rate, and then compensates for errors in judgment and seasonal variations in the survival rate by moving fish from one pond to another. When this program is used in conjunction with an overwintering pond, a year-round supply of pike-bait sized suckers can be produced.

Fertilizing sucker ponds

As most natural ponds produce enough water fleas to feed all the suckers the pond will hold, fertilization is usually not necessary and should be avoided whenever possible. A number of Minnesota ponds have been operated for 6 or 7 years without fertilization and are still producing good crops of suckers. Suckers seem to grow faster and more consistently when feeding on chironomid-fly larvae than when feeding on water fleas. If the fish in a pond are growing very slowly, the pond should be fertilized with barnyard manure or dried sheep manure to increase the number of chironomids in the bottom muds (see Fertilizing the Pond, p. 24).

Commercial inorganic fertilizer should be used sparingly on northern natural ponds because the phosphorus tends to produce heavy algal blooms that may result in fish kills. In very fertile ponds, the control of algae with copper sulfate may be more important than fertilization (see table, p. 47, for amount to use).

Harvesting the fish

Natural ponds can be harvested most efficiently with a large seine that is set out in a semicircle from a boat and pulled in slowly to a good landing beach. When the net reaches the shore, it is bagged and moved quickly to deeper water so the minnows will not smother or choke on silt. The minnows are transferred to a floating live box as soon as possible, and all turtles, salamanders, and crayfish are thrown out. If the minnows are uniform in size and are large enough for pike bait, they are loaded into a tank of fresh water and hauled to the bait shop. If the haul produces large numbers of undersized minnows, the fish are put in a slat grader (fig. 23) and the small ones returned to the pond for further growth. The pond is then reseined at periodic intervals until further hauls are not practical. The minnows that have been missed can be trapped under the ice during the early part of the winter.

The time of harvest for each pond will depend on the seasonal market and the size of the fish being raised. In Minnesota, the sucker harvest starts during the last week of July and continues until September. The only ponds that have not been harvested by that time are those producing fish to be held over winter. In areas where winter spearing is allowed, the cash return from a poor pond can be improved by holding the fish until October or November, when they can be sold as decoys for spearing. Higher prices can be obtained for them at that time than if they were sold as pike-bait-sized minnows in the summer.

While the production of sucker ponds varies with pond conditions and pond-management methods, the average production of sucker ponds in Minnesota was 10,000 fish per acre for 26 pond-seasons, with a high of 25,000 and a low of 1,500. The average was 165 pounds to the acre, with a high of 490 pounds and a low of 6 pounds. These production figures are far below the yield goals set in some publications on minnow propagation, but the ponds still are considered very practical. The cost of operation was low and the margin of profit was high.

In most sucker ponds, the poundage of fish produced can be greatly increased by cropping and grading the fish periodically. On the average, the production of Minnesota sucker ponds was increased 75 percent by cropping. When the ponds were cropped twice in a season, the poundage increase was only 5 or 6 percent, but when the ponds were cropped 6 to 8 times, the poundage increase was as high as 140 percent. This means that if the dealer harvests all of the minnows from a pond the first day he seines, large numbers of the suckers will be small and will have to be sold as crappie bait. If the dealer removes only the pike-bait size each time and allows the small fish to stay in the pond and grow, he will be able to sell the entire production as pike bait. The number of times a pond can be cropped will depend on the cost of seining and the value of pike bait versus crappie bait.

Holding suckers over winter

In the Northern States, where 3 feet of snow and 20°-below-zero weather are common, propagation ponds are not practical for overwintering suckers. The fish must be seined or trapped and moved to holding ponds supplied with running water (fig. 39). River-water ponds are preferable to those fed with spring water, because the river water supplies some natural food and the minnows are in better condition in the spring. In either type of pond, the fish must be fed artificial food, but less food is needed in river-water ponds than in spring-fed ponds. Suckers feed readily on moist meat scrap or fish-meal mash thickened with middlings and formed into fair-sized balls. The balls are dropped to the bottom of

FIGURE 39.—A winter holding pond supplied with river water. (Photograph courtesy of the Minnesota Department of Conservation.)

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the pond and left until consumed. Additional food should not be added until the first has been cleaned up.

Even with good artificial feeding, suckers held over winter in holding ponds will be thin the following spring. The best way to fatten them is to place the fish in shallow natural ponds that have a good supply of natural foods. Fish that are about 2.5 inches long will soon grow to pike-bait size and those that are 3.5 inches will increase to bass-bait size by June or July.

FATHEAD MINNOW *Pimephales promelas*

Also called Tuffy Minnow.

LIFE HISTORY

Description.—First obvious ray of the dorsal fin thickened so that it stands out; mouth small, terminal, and upturned; scales small and crowded behind the head; back rounded and arched; lateral line only on anterior half of body. Breeding male with black head; soft swollen pad on top of neck region; breeding tubercles on snout and under the chin. Lining of body cavity black; intestine two to three times body length.

The males are larger than the females and reach a maximum length of 3½ inches.

Range.—The fathead is generally distributed throughout southern Canada and in the United States from Lake Champlain west to the Dakotas and south to Kentucky and the Rio Grande River. In northern Wisconsin and Michigan, it frequents boggy lakes, ponds, and streams. In southern Wisconsin, it is found commonly in small ponds and silty streams.

Breeding habits.—The males bear pearl organs on their black heads and soft, swollen pads on their backs during the spawning season. The spawning season extends in some localities from May until the latter part of August. A temperature of about 64° F. seems necessary before spawning begins. The females may reach maturity and begin spawning the following spring at an age of 1 year. The eggs are deposited on the underside of many objects in a pond. Several females may deposit their eggs in a nesting site which is zealously guarded by one male. From 36 to 12,000 eggs have been deposited at one site in a circular or oval spot. A single female has yielded 4,144 offspring in 11 weeks, and spawned 12 times. The eggs hatch in 4½ to 6 days. The older fish in a pond should be used for bait when they have spawned, as they die soon after.

The rate of growth of the young fathead under normal conditions is as follows:

Number of days	Length of fish	Number of days	Length of fish
	Inches		*Inches*
10	0. 20	70	1. 35
20	. 40	80	1. 53
30	. 58	90	1. 75
40	. 76	100	1. 95
50	. 98	110	2. 15
60	1. 15	120	2. 32

Fathead production is usually expressed in pounds and wholesale minnow sales are usually in gallons. The following table presents the number of fatheads of various sizes to the pound and the gallon:

Length of fish (inches)	Number of fish per pound	Number of fish per gallon [1]
1	2, 600	20, 800
1.5	740	5, 920
2	300	2, 400
2.5	150	1, 200
3	84	672
3.5	52	416
4	34	272

[1] 1 gallon equals 8 pounds.

Food.—The fathead minnow feeds mainly on zooplankton and insects.

Importance.—This minnow is a popular bait for panfish in Minnesota. It has been used for pike fishing when larger species are not available. After the early spring seining of "shiner" minnows, the fathead minnow is probably the most easily obtained bait fish in the State. It grows well in small ponds and is easily managed anywhere in the United States. More than 200,000 fish (328 pounds) have been raised to the acre of water.

PRODUCTION

The fathead minnow is the most widely and abundantly propagated bait minnow in Missouri and other Southern States, but in the Lake States public waters supply enough of these minnows to satisfy local demands. The mature fathead minnow ranges in length from 1½ to 4 inches, the male being consistently larger than the female. The life span of the hatchery-reared fathead minnow is from 12 to 15 months, depending on the size of the fish at maturity. It is quite certain that during the early spawning season a large majority of the males die within 30 days after the onset of spawning activities, and that a large percentage of the gravid females die within 60 days. Immature fatheads, ranging in length from 1 to 2 inches, even though a year old will die shortly after they become gravid at the age of about 15 months. It has been noted that a small percentage of the adult hatchery-reared fatheads are sterile, and also, that these fish live longer and grow larger than the fertile fish.

In Missouri, the fathead is commercially produced by two types of culture: intensive and extensive. Intensive culture refers to the operation of hatcheries where large populations of fish are fed artificially. Extensive culture refers to hatchery operations where smaller fish populations are fed natural foods produced by fertilization. Both methods have merit, depending on the type of water available at the hatchery site. Intensive fathead culture requires much more labor and initial capital expenditure than does extensive; however, fish may often be produced in greater numbers and at lower cost by the intensive type of fish farming.

Intensive culture of fatheads

To practice intensive fish culture, it is necessary to have a source of flowing, cool water from a spring or well. The ponds should not be larger than 1 acre or smaller than ¼ acre. The depth of water should range from 2 feet at the shallow end to 6 feet at the drain, and average about 3 feet deep. The pond should be equipped with a controllable inlet and similar bottom drain. To raise fatheads profitably, it is necessary to have at least 6 ponds available for propagation, and it is much more economical, as far as production costs are concerned, to have 12 to 15 ponds. In every unit of 6 ponds, it is desirable to use only 2 for reproductive purposes, leaving the remaining 4 for growing ponds. The ponds to be used for reproductive purposes should be ballasted along two banks with rocks ranging in size from 6 to 12 inches in diameter, or with tile (fig. 40). This construction should extend from about 6 inches above the planned normal water level to a depth where the rocks will be covered by about 2 feet of water. The purpose of this installation is to provide adequate spawning facilities for the fatheads; at the same time, it offers considerable protection to the levees against pond erosion.

The brood ponds should be stocked in the early part of April, and the breeders should consist of both mature and immature fatheads in ratio of about 60 percent

FIGURE 40.—Four-inch tile used for spawning devices. (Photograph courtesy of the Ohio Department of Conservation and Natural Resources.)

adult to 40 percent immature fish. Both adults and juveniles are used as breeders because of the short life span of the fathead. Since the larger fish will die shortly after the onset of spawning, it is necessary to provide immature, developing fish to have spawners later. In this way, one can be sure of a continuous, uninterrupted supply of newly hatched fry. The brood ponds should be stocked at the rate of 15,000 to 25,000 fish to the acre of water.

Spawning.—In Missouri, fatheads normally start spawning activities during the latter part of April or at a time when the pond-water temperature reaches 65° F. They spawn intermittently throughout the summer, providing the water temperature does not rise above 85°. When this temperature is reached, spawning ceases, and is not resumed until the temperature is lowered by prevailing weather conditions or by an increase in the flow of spring water into the pond.

Sometimes, during the warm summer months when the surface water temperatures rise above the 80° to 85° F. range, the breeding fatheads will conduct their spawning activities at lower depths than normally to attain a cooler stratum of water. The water at this level (2 to 3 feet below the surface) frequently is low in the concentration of dissolved oxygen. Even though the breeder fatheads can tolerate the low oxygen content, the developing eggs cannot; and subsequently, they all will die before the incubation period is completed. To counteract this condition, the fathead minnow grower must keep his brood ponds free from rich organic deposits, either by reducing the amount of artificial food supplied to the breeders, by reducing the amount of fertilizer, by increasing the incoming spring-water supply, or by using a combination of all three. Fathead brood ponds averaging an acre in size should have a minimum incoming flow of 25 gallons of water a minute during the warm summer months.

During the latter part of April when the water temperature approaches 65° F., spawning activity can be observed. Within a few days, small fry will be seen swimming near the surface, a few feet out from shore. As soon as these small fish become numerous, they can be captured by a small bobbinet seine and transferred to the growing ponds. The stocking rate in a growing pond should range between 300,000 and 600,000 fry for each acre of water. At this rate of stocking, the successful operator will harvest a minimum of about 150,000 salable fathead minnows annually for each acre of water.

Growing-pond operation.—During the first few weeks of life after the fry is transferred to the growing pond, its rate of growth is very rapid, and sometimes individual fish attain a length of 1½ inches. Within 8 to 12 weeks, many of these first-generation fish will mature and begin to spawn. When this occurs, and it frequently does, the propagator is confronted with a major problem: If he allows this reproductive activity to progress unattended, he will soon find that the growing pond is overstocked and that all of the fish are stunted. When this situation arises, there are two corrective measures available. One is to remove the excess fry by seining or by draining the pond, and transfer the fry to another pond or destroy them. The other solution is to introduce predacious species, such as the creek chub or the golden shiner, to forage on the small fatheads. This method should not be used unless a minnow propagator has had a number of years of experience in fish-cultural work, because he may find that his introduced predators are too efficient at control, resulting in nearly a total loss of fathead production for the pond. If it becomes necessary to resort to this method of population control, a successful stocking rate is 50,000 feeder (1- to 2-inch) creek chubs or golden shiners for each acre of water.

Intensive culture of fatheads requires many daily tasks. The water level should be checked each day in the ponds assuring the operator that both the inlet and outlet valves are in operation. It is necessary to feed the fish each day and to fertilize the pond when food alone will not maintain a desirable plankton bloom. A productive pond should have a plankton turbidity in the water sufficient to blank out a white surface at 12 inches. A feeding ratio demonstrated as successful for fatheads consists of 6 parts gray shorts, 1 part low-grade flour, and 1 part cottonseed meal. This diet is fed at the rate of 1 pound of food for every 20 pounds of fish in the pond. By feeding only a few pounds of feed at first to a pond containing fatheads, an observing fish culturist can easily determine each day how much food is to be applied to each pond. If the plankton bloom remains about the same in the water from day to day and the fish are growing, then the amount of food is sufficient. If the plankton bloom becomes too intense and the fish continue to grow, then he is feeding too much; or if the fish are not growing, the amount of food is too small. At the end of the growing season, a successful propagator should not have used more than 1 pound of food for each 20 pounds of fish in any 1 day during the peak of growth. Also, if his operations were successful, he should not have used more than 6 pounds of food to produce 1 pound of salable fatheads.

When about 50 percent of the fatheads (by weight) in a growing pond attain salable size (1½ inches or more in total length), it is desirable to remove as many as possible by trapping, seining, or by draining the pond, and to place the fish in a pond by themselves. To drain a fathead pond during the hot summer months, it is necessary to pull the water level down to about ⅕ of its original volume and to triple the incoming flow of cool water, or, at least, to increase the flow until all of the water remaining in the pond has a temperature below 80° F. If the water temperature in a pond cannot be lowered to this extent, it is better to seine or trap out as many of the salable fish as possible and to leave the others in the pond, rather than to run the risk of losing most of the fish by trying to get them all out.

Extensive culture of fatheads

The extensive culture of fathead minnows employs the use of much larger ponds than are used in intensive culture. Locating the site for a hatchery of this type is relatively easy, since the water supply is not too important; however, it is necessary to locate the hatchery on soil that is composed of a tight clay loam capable of holding water. The source of water is provided by rainfall, and the ponds are strategically located to pick up surface runoff. The design of the hatchery usually follows a characteristic pattern. It consists of one or more large (20 to 30 acres in surface area) reservoir ponds having a maximum depth of 15 to 20 feet, surrounded on the lower-gravity side by several small (¼- to 1-acre) ponds.

The smaller ponds, in turn, are filled with water acquired by gravity flow from the larger pond above. In instances when the annual rainfall is not sufficient to fill the reservoir ponds, some operators resort to the use of a pumping system, obtaining their water from a nearby stream. The large reservoir ponds usually have a bottom drain and an emergency high-water overflow. The small ponds are supplied with water from the large ponds by means of a series of contour ditches. Very few of the smaller ponds have bottom drains, and the operator must cut a hole in the levee to drain the pond, siphon the water out, or resort to a mechanical pump. About the only advantage of this type of hatchery construction is its relatively low initial cost and the ease with which the site can be obtained. The disadvantages are that during the warm summer months the operator must supply the ponds with cold water from a deep well or provide a holding station where cold water is available to store his salable minnows.

In the actual operation of an extensive type of minnow hatchery for fathead production, it is not necessary nor is it desirable to ballast the banks of the pond with rocks for the breeding fish. Usually the large reservoir pond is used for this purpose, and the water level may fluctuate as much as 10 feet during a season. Also, these large ponds usually contain enough rocks, roots, and other debris to provide sufficient spawning structures for the number of breeders introduced. In stocking a pond with breeders, about 4,000 fish per acre are used, consisting of about 60 percent adults and 40 percent juveniles.

When the water temperatures in the reservoir pond reach 65° F. spawning occurs, and within a week or 10 days fry appear on the surface. Within 3 to 4 weeks, the fry should be sufficiently large and abundant enough to warrant transfer, by trap net or bobbinet seine, to the smaller growing ponds. Since there is no assurance of an incoming supply of fresh water, the artificial feeding of both the breeders and the fish in the growing pond has to be quite restricted. The same rule applies to fertilizing the ponds. During the midsummer period in Missouri, the water temperatures of reservoir-type ponds usually are too high for continued fathead reproduction. At this season, it is desirable to fertilize both the brood ponds and the growing ponds with a combination of superphosphate and cottonseed meal in equal proportions at the rate of 25 pounds an acre every 10 days, or until a plankton turbidity colors the water sufficiently that a white object cannot be distinguished at 1½ feet. If the pond becomes too rich in organic matter, it is quite possible that all of the fatheads will die from oxygen depletion. At best, it is more practical to fertilize sparingly, and allow the natural fertility of the soil to determine the productivity of the pond.

Harvesting and storing the fish

If some of the fathead minnows attain a salable size during the summer months, they can be removed by trapping or seining. In the fall or at any time during the cooler seasons of the year, the pond can be drained and the entire population removed. These fish in turn can be graded as to size and stored for future sales, or they can be placed in different ponds for additional growth. The drained ponds can again catch the surface runoff, thus storing the next year's water supply.

A minnow producer, using intensive techniques, should be able to harvest from 200 to 300 pounds of salable minnows from each acre of water in production. This poundage converted into numbers of fish would represent from 40,000 to 70,000 fish.

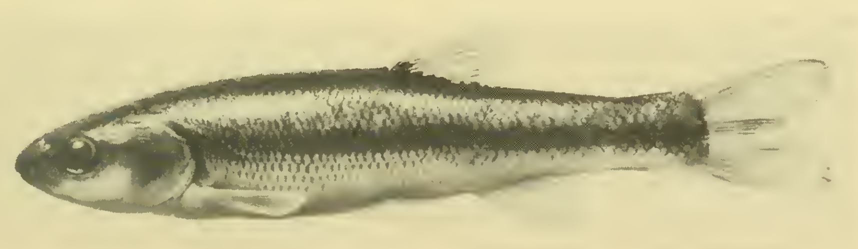
When removed from ponds, fathead minnows should be placed in cool water for hardening before they are sold. The water temperature in the storage vats should not be allowed to rise above 70° F. during the summer months, and the fish should not be confined at this temperature for more than a week. If the operator needs to store the fatheads for a longer period, it is desirable to reduce the water temperature to 65° F. Fathead minnows can tolerate a 20° temperature change within a few minutes without any harmful effects. Also, these fish can stand excessive icing during transit in warm weather.

Grading

In grading the fathead minnow for sale in Missouri, a box constructed of 3/16-inch aluminum bars has proved satisfactory. The mechanical graders are made in two sizes: One, constructed to allow the small unsalable fatheads to pass through the openings, has a clearance between the aluminum bars of 13/64 inch; the other, to separate the larger size from the smallest salable size, has a spacing of 15/64 inch between the bars (see fig. 23). In using these graders, two size groups of salable fish are obtained. The first group ranges in length from 1½ to 2 inches and averages about 325 fish to the pound. Fish of the second size group are from 2 to 3½ inches in length and average about 225 to the pound.

CREEK CHUB *Semotilus atromaculatus*

Also called Horned Dace.



LIFE HISTORY

Description.—Black spot at base of dorsal fin; mouth large, extending back to below eye; small barbel hidden just above corners of mouth in groove behind underjaw; scales smaller and more crowded at front end of body; color, olive green on top, steel blue on sides, white on belly; size of females to 5 inches, males to 11 inches.

Range and breeding habits.—This minnow is found most often in creeks and rivers from Montana and New Mexico east to the Atlantic coast and south to Florida. The creek chub, sometimes called the horned dace because of the tubercles the males develop during the breeding season, spawns during April, May, and June in small creeks, on gravel beds at the base of pools, or at the head of riffles. The male prepares and guards the nest during the breeding season. The young fish make an excellent growth in the first year, reaching a length of 3½ inches by September. Those maturing late in the fall spawn the following season.

Food.—The creek chub seems to eat anything that comes its way. It has been known to feed on algae, vegetable matter, aquatic insects, terrestrial insects, crayfish, small fish, fish eggs, chub eggs, snails, and small mollusks, and it often rises to a trout lure. Sometimes a chub stomach will contain only surface drift. A study of 37 stomachs taken from fish collected in the eastern and midwestern United States showed the average percentage of the various food items to be as follows: Insects, 51.3; mollusks, 3; crustaceans, 0.8; fishes, 5.4; crayfish, 3; annelids, 2.1; surface drift, 26; algae, 2.8; plants, 4.6; vegetable debris and plant seeds, 1.

Importance.—The creek chub is excellent bait for pike and panfish. Though it spawns in moving waters, it grows very well in ponds and slow-moving streams. The adults strip easily and the number of eggs is relatively large. This fish is exceptionally suited to production in large numbers in artificial ponds.

PRODUCTION

The tenacity of life of the creek chub makes it a good minnow for handling, holding, and transporting. It can tolerate, to a considerable degree, exposure to sudden changes in water temperature, but the culture of this species is not an easy task. A suitable spawning area (running water in a gravel-bottomed stream) must be provided where natural spawning can occur, or the breeders must be stripped and the fertilized eggs incubated in a hatchery.

Preparing the spawning raceway

When selecting a location for a creek-chub hatchery, it is most important to formulate plans for the number of minnows to be raised, so as to determine whether a sufficient volume of water is available at the location to operate the needed number of raceways and rearing ponds.

The general layout of an area for the culture of creek chubs consists of a stream emptying into a pool. The stream provides the spawning space, and the pool acts as a refuge area for the breeders during the spawning season and later as a collecting basin or a rearing pond for the newly hatched fry. In Ohio, a successful raceway prepared for the propagation of creek chubs consisted simply of a gravel-bottomed stream and a base pool confined within the basin of a pond covering an area 143 feet long, 13 feet wide, and from 1 to 3 feet deep. Starting at the inlet, the upper 24 feet of the pond was filled with fine soil to create a steeper slope on which a meandering channel (27 feet long, 27 inches wide, and 2 to 10 inches deep) was prepared. At places in the dirt fill where there was likely to be some washing by current action, heavy reinforcing material was used. The banks and bottom of the channel were covered with a heavy layer of gravel. Water supplied by an 8-inch inlet passed down the stream channel and into the base pool below that was formed by impounding the water in the remaining portion of the original pond basin.

In Michigan, a successfully used creek-chub spawning raceway was built within the basin of a pond, and likewise consisted of a stream and base pool; however, the design of the stream was radically different from that used in Ohio. The sequence of the Michigan construction was as follows: (1) Excavating the main channel; (2) installing refuge zones at 25-foot intervals along the stream; (3) surfacing the entire raceway with gravel; (4) installing splash boards (check dams) at 25-foot intervals; (5) regulating the stream flow, height of the splash boards, and the water level of the base pool; (6) placing covers over the refuge pits; and (7) erecting netting over the stream bed for control of predatory birds.

The main channel (6 feet wide, 1 foot deep, and 300 feet long) was dug within the basin of a 1.8-acre pond. Starting at the inlet—following along the base of one of the dikes—the excavation gradually descended (an 8-inch fall per 100 lineal feet) into the basin of the pond. The materials removed from this ditch were placed on both sides of the channel, forming 1.5-foot banks. At intervals of 25 feet along the course, rectangular pits, 2 feet deep, 3 feet wide, and 8 feet long, were prepared. These pools, referred to as refuge zones, crossed the streambed and extended into one of the banks for a distance of about 4 feet (fig. 41, upper). That portion of the refuge zone extending into the bank was curbed to prevent its filling by erosion.

At this point of construction the entire stream, including those portions of the refuge zones lying within the channel and both banks, was surfaced with a 6-inch layer of washed gravel (¼- and ¾-inch screened stones in equal proportion). About 38 cubic yards of gravel were used to surface the 300-foot raceway. Immediately after the spreading of the gravel, splash boards (fig. 41, lower) were installed across the channel at each refuge zone. These boards were driven into the bottom soil to a depth of 1.5 feet and were exposed about 3 inches above the gravel. The purpose of the splash boards was twofold: (1) To act as a break

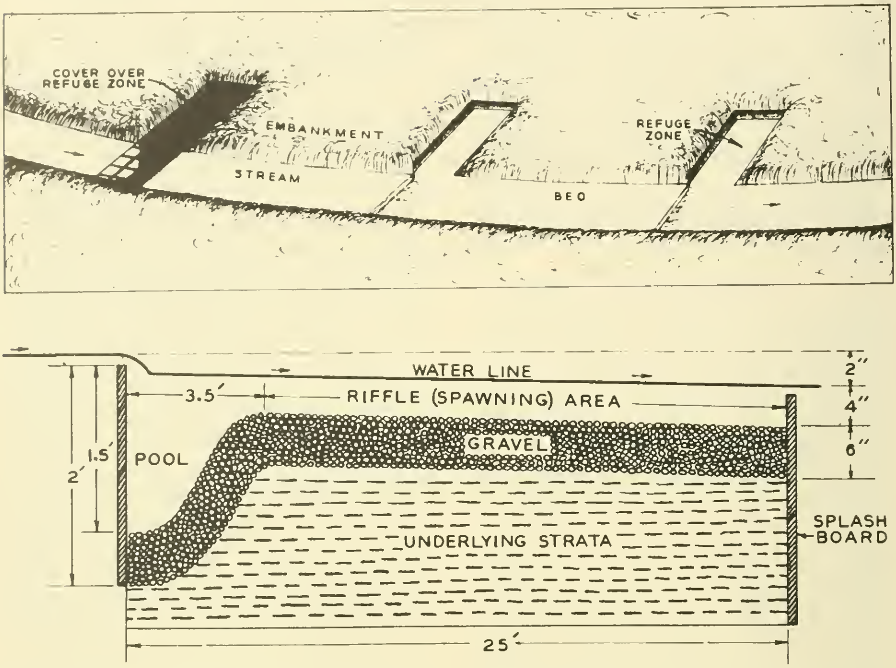


Figure 41.—Typical raceway construction for spawning creek chubs. Upper: Diagrammatic view of streambed and shelters. Lower: Cross section of spawning area. (Diagrams courtesy of the Michigan Department of Conservation.)

against the continuous current—resulting in the formation of areas of slow and fast-moving water and thus simulating conditions in spawning areas in natural waters; and (2) to prevent the refuge pools from being filled by washing gravel. To determine to what degree these splash boards were accomplishing their purpose, the inlet valve of the pond was opened to allow 1.5 cubic feet of water per second to flow down the stream channel as a test. Some splash boards projecting too high above the streambed (forming barriers) were lowered; others, too low to be effective in checking the current and preventing wash, were raised to the desired height. The outlet valve was then closed and the water allowed to accumulate within the basin of the pond until it reached a level even with the lower end of the stream (fig. 41, lower).

After the sluice boards had been installed in the outlet to maintain this height, the outlet valve was opened and the overflow water allowed to pass through. Finally, the refuge zones were covered with lids made of tarred paper and strips of lath and netting was stretched over the stream.

Anyone contemplating the propagation of creek chubs need not construct a raceway exactly duplicating either of the two just described. When constructing a spawning stream, it is important to take into account the ecological conditions affecting the breeding habits of the creek chub, such as currents, pools, hiding places, and types of bottom soil. As life-history studies show that the creek chub prefers a certain type of habitat (p. 86), it is desirable to provide these conditions as completely as possible. Raceway streams can be made any length desired; the width does not necessarily have to be confined to 4 or 5 feet, provided that a sufficient volume of water is available to operate effectively a wider channel. Most important is the water supply. The water should be clear in color, have a temperature range of 55° to 60° F. during the spawning season, and be free of other species of fish.

Stocking the raceway

Selecting the brood stock.—An operator selecting brood stock must bear in mind that the male chub grows larger than the female; that the mature male is distinguishable from the female by the presence of bony protuberances (horns) on the head immediately before and during the spawning season; and that the male is usually highly colored during the spring, having tinges of red on the paired fins and abdomen. In contrast, the adult female is generally smaller and more drab in color and has a swollen abdomen during the spawning season.

Results of Michigan studies in the selection of brood stock indicate that it is advisable to use 6- to 8-inch males and 5- to 6-inch females for breeders. If larger males (7 to 10 inches in length) are available and the total stock of breeding males could be represented by fish of this size, results should prove satisfactory. Likewise, if larger females (6 to 8 inches in length) are available, they could also be used.

It is not advisable to mix small (5-inch) mature males with larger (10-inch) males in the same raceway, because mortality occurs as a result of fighting. Where small (3-inch) females are mixed with larger (8-inch) females in the same raceway, a prolonged spawning season occurs, resulting in a loss of fry. The larger females mature about 2 weeks earlier than the smaller ones, and by the time the smaller females are through spawning, many fry have hatched and emerged from the earlier-formed nests. The presence of fry in the raceway and base pond before the brood stock is removed naturally complicates removal of the fry.

One more suggestion concerns the age of adult fish. Normally, only a few pond-reared creek chubs can be expected to mature in their first year and be used as breeders. In the second year, possibly 50 percent will mature (depending on the rate of growth, the larger fish being the more favored); as a result, most of the brood stock will have to be selected from older fish. In natural waters, female creek chubs normally do not mature until their fourth year and males their fifth. Creek chubs are not long-lived fish, rarely exceeding 6 or 7 years.

Stocking rates.—Recommended stocking rates calculated on a theoretical basis derived from observations and studies conducted in Michigan may not be entirely satisfactory for all types of raceways. It is believed, however, that a brood stock should contain more females than males (approaching a ratio of 2 to 1 or 3 to 2). Furthermore, each female in stock composed of 3.5- to 7-inch fish should be provided with 1.5 square feet of spawning area for egg deposition, and each female from a group composed of 4- to 8-inch chubs, 2 square feet of area. In calculating the square feet of available spawning area in a raceway, the margins along the banks (about 3 inches on each side of the stream) and any areas used for refuge zones or current deflecting structures should be omitted. Generally, about one-fourth of the total area will be taken up by these structures.

To illustrate, let us suppose that an operator had a raceway 200 feet by 4 feet, and wished to determine the number of breeders it would accommodate. Assuming that one-fourth of the total area would be occupied by the banks, refuge zones, and other structures, he would have to make his calculations on the remaining 600 square feet of streambed. If 3- to 7-inch females were used, about 400 of these and 200 males would be required if a sex ratio of 2 to 1 were established, or about 266 males if a 3 to 2 ratio were followed. If 4- to 8-inch females were used, 300 would be needed with the corresponding ratio of males. The mortality rate of adult creek chubs during the spawning season has been exceptionally high, sometimes amounting to as much as 75 percent. To be assured that an adequate supply of adult fish will be available each spring, provision should be made whereby a new group of fish will be maturing each year.

Results from creek-chub studies in Michigan indicate that with a fair amount of success in fish culture, about 800 fry may be expected for every female creek chub introduced in a spawning raceway. In Ohio, each female introduced into a spawning raceway in 1941 gave a return of about 400 salable fish, and in 1942 about 450. Since we have some idea as to the spawning needs of the female chub and can roughly calculate the number of females which will satisfactorily stock a specified raceway, a crude estimate can be made as to the number of females and the size of the raceway necessary to realize a predetermined production.

There was considerable difference in the size range of the fish produced in individual ponds. Ponds that had a high production contained smaller fish than those of low production. In ponds where the average length of the chubs was about 2 inches, the number of fish per pound was 300. In other ponds where the fish averaged about 3½ inches in length, the number per pound was reduced to 100 fish. In some ponds where overstocking had occurred, the minnows at the end of the growing season had an average length of 1½ inches. It was learned that when these unsalable fish were returned to growing ponds the next year, it took several weeks before growth was resumed. It seems that these fish had been stunted the previous year by the crowded condition. From this experience it is suggested that an operator should be careful and not stock his ponds at the maximum rate.

The following table presents the number of creek chubs of various lengths to the pound and gallon.

Length of fish (inches)	Number of fish per pound	Number of fish per gallon [1]
1	1, 360	10, 880
1.5	915	7, 320
2	360	2, 880
2.5	170	1, 360
3	92	736
3.5	57	456
4	36	288
4.5	24	192
5	17	136
5.5	12	96
6	10	80

[1] 1 gallon equals 8 pounds.

Spawning

Creek-chub breeders should be introduced into the raceway when the species is known to be spawning in nearby natural waters. If a check cannot be kept on natural spawning, or if no natural spawning occurs in the area, it is advisable to introduce the fish when the water temperature in the raceway has reached 55° F. for a 2- or 3-day period. Creek chubs usually start to spawn during the latter part of April in waters north of an imaginary line drawn east and west from the Michigan-Ohio border. Spawning is terminated late in May or early in June in the Lake Superior area, but continues into July in northern Minnesota. The nesting season for any one locality usually lasts about 3 weeks.

At one commercial hatchery, it was noted that the breeder chubs used the spawning raceway for about a 3-week period. During the first few days, the population of breeders steadily increased until a maximum number was present on about the seventh day. At this time about 4,000 breeders were occupying the raceways. Following this peak, the number of breeders decreased daily until only about 100 were left at the end of the 3-week period. During the early part of the spawning period, the male chubs select areas in the raceways well isolated from one another. Later, however, there is considerable pirating among the redds—the increased population of breeders bringing on additional competition for space. It is estimated that at least 50 percent of the redds are destroyed in this manner during the spawning season. Many dead chubs of both sexes collect on the surface of the brood pond within a week after the onset of spawning activity. By keeping a careful record of the number of breeders removed from the pond each fall for the 4-year period, it was calculated that at least 30 percent of the males and 15 percent of the females die each year.

Stripping creek chubs

In regions where natural ponds are used for minnow culture, creek-chub raceways are not practical because of the lack of running water. Fry for these ponds can be obtained more easily by stripping the adults of their eggs, fertilizing the eggs, and hatching them in jars. Until recently, ripe creek chubs were difficult to obtain and the green fish would not ripen in the ponds that were available.

Michigan workers (Ball and Bacon, 1954) have been successful in injecting creek chubs with carp pituitary to ripen them. The fish then are stripped of their eggs, which are hatched in Meehan jars.

The pituitary was obtained from 6- to 8-pound carp by the following procedure:

The head of the carp was removed, and the brain was exposed by removal of the dorsal surface of the brain case. The broad white ophthalmic nerve, attached to the fore of the brain, was picked up with a pair of tweezers and the entire brain lifted up and laid back. The pituitary gland, a small organ resembling an acorn, is located underneath the largest, rounded portion of the brain. Occasionally the gland will remain on the floor of the brain case.

The glands were either immediately frozen or dehydrated and defatted in cold acetone for 36 hours. The acetone-treated glands were dried on filter paper and stored under refrigeration until needed.

Whole glands were used in all experiments, no attempt to separate the lobes being made. Just before use, dried glands were pulverized in a mortar and mixed with distilled water; frozen glands were macerated to form a thick suspension in distilled water. No difference between the effects of frozen and dried pituitaries on fish was noted in any experiments.

Each ripe female received one-fourth of a pituitary from a 2-milliliter glass hypodermic syringe supplied with a No. 19 needle. The tip of the needle was placed under a scale, pushed through the belly wall into the body cavity, and directed parallel to the ventral surface. Two men were required for the job: one to hold the fish and the other to handle the needle. After injection, the chubs were held in tanks in which water varied from 46° to 64° F. At the end of 48 hours, the fish were stripped and nearly all gave up their eggs. Fertilization of the eggs by the usual hatchery method produced nearly a 100-percent hatch.

Growing-pond operation

As soon as the fry concentrating in the base pool become conspicuous and are grouped in schools along the shore, they can be collected with a bobbinet seine and transferred to rearing ponds. The removal of the fry from the brood pond is a simple task. The creek-chub fry tend to school in large numbers near the surface along the shore of the brood pond. By using a small nylon hand seine, one operator can collect up to 500,000 fry in a day. In collecting the fry, the operator carries a floating container tied to his wader strap. In this manner, the small fish are transferred from the hand net to the container without injury.

As soon as a sufficient number of fry is collected, the fish are transferred in cans to the growing ponds. It is almost impossible to make an accurate count of the number of fry collected other than by hand counting, which would be an endless job. About the only method for estimating numbers of fish would be to concentrate the fry in a container, such as a tub, and remove them with a quart dipper in which the estimated number per dipper had already been determined. Naturally, there would be considerable error involved.

Stocking the growing ponds.—The stocking rate of chub fry in growing ponds can be varied considerably. In ponds where an operator can supply an incoming flow of about 150 gallons of spring water a minute for each acre of water, he can stock at the rate of 600,000 fry to an acre and obtain a very satisfactory return. If the incoming water supply is limited to about 25 gallons a minute for each acre of water, then it is desirable to reduce the stocking rate to about 300,000 fry to an acre of water. In ponds that do not have an incoming supply of water, the operator should not stock heavier than 50,000 fry to an acre of water.

The records show that in the transfer of fry from the brood ponds to the growing ponds a high survival can be expected. It also seems, according to the information available, that the rate of survival is in direct proportion to the stocking rate. Ponds stocked at the rate of 50,000 to 200,000 fry per acre of water had about a 90-percent survival; those stocked at the rate of 250,000 to 400,000 gave a return of about 80 percent survival; and those ponds in which a maximum transfer was made gave a return of about 60 percent.

Artificial feeding.—During the first 6 weeks of life, development of the chub fry is rapid in ponds having a prevailing water temperature of between 70° and 75° F. In this period the fry readily eat fine-grained artificial food. By the end of the 6 weeks, most of these small fish will have reached a length of about 1½ inches, and there is a marked change in their diet demands: they are no longer interested in the fine food, but seek larger food particles. The operator must now provide a pellet type of food ranging in diameter from $\frac{1}{16}$ to ⅛ inch, or introduce a small forage minnow, such as fathead fry.

A considerable amount of study has been conducted on diets for the creek chub at commercial hatcheries, and at present the most satisfactory diet mixture consists of 4 parts of gray shorts or ground whole wheat, 3 parts of meat scraps or some comparable

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animal protein, 1 part of cotton seed meal or soya-bean meal, 1 percent of brewers yeast or wood yeast, and 1 percent of a mineral supplement, such as that used in livestock feeds. The small fish are given this formula in a dry, powdered form, and the larger fish are provided with the same food prepared in pellet form.

In feeding creek chubs, care must be taken not to overfeed. The operator should watch the plankton turbidity of the water and be sure that the bloom will not mask a white disk at a depth of 24 inches. The food can be fed to the fish once each day or, in reduced amounts, several times a day. Usually, an acre pond with a good flow of spring water and a large population of growing chubs will require about 50 pounds of food daily during the minnows' maximum growing season. At the end of a growing season, a successful operator should be able to realize a food conversion whereby 2 pounds of food has produced 1 pound of salable minnows. In heavily stocked ponds where the average length of the minnows will be smaller than those in lighter stocked ponds, the conversion ratio will be about 4 to 1.

Harvesting and storing the fish

The production of creek chubs in pounds or in numbers of salable fish per acre of water has considerable variation. The records from one commercial hatchery, covering a 4-year period starting in 1949, show that the annual production of salable creek chubs per acre of water varied from a low of 500 pounds to a high of 3,000 pounds. It was found that when only a portion of the fish are to be removed and these are to be removed by trap or seine, then it is not too important whether the water is cool or warm; but if the pond is to be drained, it is very desirable to lower the water temperature to about 70° F. before any fish removal attempts are made.

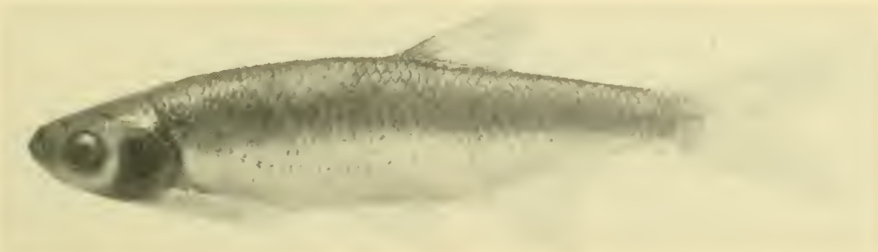
When chubs are removed from the growing pond to be placed in storage vats for sale, they should be held in water having a temperature of 60° to 65° F. By using cool water in the storage tanks, the chubs can be kept for a 2- or 3-week period without any ill effect. Also, when chubs are in storage for any extended period of time, they should be fed the same type of food daily that they received in the growing pond.

GOLDEN SHINER *Notemigonus crysoleucas*

Also called Roach.

LIFE HISTORY

Description.—Body thin and flat from side to side, deep from top to bottom; adult golden in color, scales loose and easily visible; mouth small and upturned, with no barbels; base of anal fin long, containing many more than the cus-



tomary 7 or 8 rays; dorsal fin far behind the pelvic fins; dorsal and anal fins sharply pointed; sharp ridge or keel on belly between pelvic and anal fins; lateral line curves downward and follows ventral body contour.

The female grows faster and larger than the male. This species may mature in 1 year in warm regions at a length of 2½ inches, but in most of the Lake States it probably does not mature before the second year. Members of this species are known to have lived for 8 years. A maximum length of 10 inches has been reported.

The following tables present data on the rate of growth of golden shiners in natural ponds, and the number of fish of various sizes to the pound and gallon.

Number of days	Length of fish (inches)	Number of days	Length of fish (inches)
10	0. 3	50	1. 5
20	. 6	60	1. 8
30	. 9	70	2. 1
40	1. 2		

Length of fish (inches)	Number of fish per pound	Number of fish per gallon [1]
1	4, 250	34, 000
1.5	1, 120	8, 960
2	430	3, 440
2.5	215	1, 720
3	118	944
3.5	71	568
4	47	376
4.5	32	256
5	23	184
5.5	16	128
6	12	96

[1] 1 gallon equals 8 pounds.

Range.—The golden shiner is widely distributed throughout the eastern United States from Canada to Florida, and westward to the Dakotas and Texas. The western form, *auratus*, is most common west of the Allegheny Mountains and north of Arkansas and is the only subspecies occurring in the Lake States. This species prefers lakes, but is also common in the quiet sections of some of the larger rivers, frequenting weedy bays and shoals.

Breeding habits.—The golden shiner has a long spawning season, extending from the time the water reaches 68° F. through the rest of the summer. The eggs, which are adhesive and stick to plants, are commonly scattered over filamentous algae and less frequently over rooted aquatic plants.

Food.—The golden shiner is omnivorous. The young feed on algae and entomostracans. The adults have been known to eat young fishes, insects, plankton, crustaceans, protozoans, algae, diatoms, and mollusks. Some stomachs contain nothing but insects; some, nothing but plankton; others, 95 percent algae; a few had more than 75 percent amphipods; and three contained 5 percent arachnids. The food percentages in golden-shiner stomachs examined by a number of workers are as follows: Insects, 35; plankton, 28.5; algae, 13.8; plants, 5.3; amphipods, 0.4; mollusks, 1.9; arachnids, 1.4; bryozoans, 1.4; rotifers and protozoans, 0.2; and crustaceans, 12.

Importance.—In Minnesota, this shiner reaches a size for pike bait in the fall of its first year. In Michigan and Iowa, it has been produced at a rate of more than 200,000 a water acre in fertilized ponds.

The golden shiner is a popular minnow with fishermen everywhere. The light color and general activity make it a good minnow to use for walleyes. The greatest demand for this minnow comes in the winter time when the water is cold. In warm weather, the golden shiner is very delicate and is hard to keep alive in the bait pail so the fisherman uses suckers for summer pike fishing.

PRODUCTION

The propagation of the golden shiner is conducted in extensive and intensive artificial ponds and extensive natural ponds. Intensive ponds are operated on the principle that greater production can be obtained if the brood fish are maintained in a pond with ideal spawning conditions and the fry are transferred to growing ponds as soon as they are free swimming. In an extensive hatchery, the fry remain in the same pond with the brood fish until harvest time.

An intensive golden-shiner hatchery should be made up of units that contain one large pond for spawning and three smaller growing ponds. When the ponds are supplied with spring water, the growing ponds do not have to be adjacent to the brood pond. If the ponds are maintained by surface runoff, the growing ponds should be located so the water from the brood pond can be used in the growing ponds.

The brood pond used in intensive operations should be free of vegetation so that the fry can be removed without difficulty. An extensive production pond should contain enough vegetation to protect the fry from the cannibalistic adults.

In the Northern States where pond construction is expensive, golden shiners are raised in natural ponds (fig. 42). Usually they are raised in ponds that are too fertile for suckers, because the golden shiner can stand more adverse conditions. It is also desirable because most of the fertile ponds contain masses of filamentous algae which provide plenty of places where the shiners can deposit their eggs. The best natural pond for the propagation of golden shiners is 2 to 3 acres in size and 4 to 5 feet deep. The pond must be free of fatheads or the spawning success of the shiners will be poor.

Stocking the ponds

Golden-shiner breeders should be at least 1-year-old fish, ranging in size from 3½ to 8 inches in length. About 50 percent of the brood stock should be less than 5½ inches in length; or otherwise, the total stock will be predominantly females, since the males are consistently the smaller. The stocking rate in large ponds, where the fry will remain with the adults (extensive culture) should range from 2,000 to 3,000 fish

FIGURE 42.—A productive golden-shiner pond in Minnesota.

for each surface acre of water. In ponds where fry removal is planned (intensive culture), the stocking rate of breeders should be 4,000 to 8,000 adults per surface acre of water. In Minnesota natural ponds, the stocking of 500 adults to the acre has proved satisfactory.

Spawning

In Missouri, the golden shiner starts spawning activity when the temperature of the pond water rises above 70° F. If the temperature exceeds 80° F., spawning ceases. In this State, the spawning activity of the golden shiner starts during the latter part of April or the forepart of May, and usually terminates in early June. During this period, at least 4 or 5 distinct spawning cycles have been observed. The cycles are separated by periods of about 4 or 5 days. During the summer months when the water temperature in the brood ponds exceeds 80° F., there is no spawning activity unless a cool rain reduces the water temperature sufficiently to shock the fish into further spawning activity.

The spawning act usually starts early in the morning and terminates before noon. The females deposit their eggs on any type of submerged debris. With a water temperature ranging between 75° and 80° F., the fertilized eggs will hatch within 4 days after deposit.

A few days after the eggs are fertilized very small fry can be observed swimming in schools near the surface along the shore margin of the pond. At this stage of development, an operator can collect these small fish with a fine-mesh net and transfer them to the growing ponds. By transferring the fry to other ponds, he can realize about twice the production of those ponds where the adults and fry are left together. The reason for this increased production is due to the fact that the adults prey on the smaller fish throughout the season, thus reducing the total population. If the minnow producer decides to transfer the golden-shiner fry to growing ponds, the recommended rate is from 200,000 to 300,000 for each acre of water. Under this program, a successful propagator can realize a production of 75,000 to 150,000 salable fish per acre of water. In ponds where the fry remain with the adults, 60,000 salable minnows for each acre of water is considered good production.

Artificial feeding

Golden-shiner production ponds that contain only small fish introduced at the prescribed stocking rate (see above) can be fed daily a diet of 8 parts of gray shorts, 1 part of cottonseed meal, and 1 part of tankage or meat scraps. In ponds where there is no incoming fresh water, the daily feeding, regardless of the number of fish within the pond, should not exceed 10 pounds of food for each acre of water. At this rate, the operator should not feed more than 4 days each week. In ponds supplied with an incoming flow of fresh water, a daily food quota of up to 25 pounds to an acre of water can be supplied. In all instances, regardless of the feeding, the plankton turbidity of the water should not be allowed to become dense enough to obscure a white object at a depth of less than 12 inches.

Harvesting and storing the fish

The harvesting of the golden shiner in Missouri and surrounding States is an exacting task, otherwise severe injury will result in a high mortality. When golden shiners are to be seined from a pond during warm weather, the seine should be made of either a cotton netting or bobbinet material. The fish trapped in the seine should not be rolled or crowded while bringing them in near shore. When the golden shiner is removed from the seine by a hand net made of a soft fabric, the fish should be transferred with a considerable amount of water.

When the entire population is to be removed by draining the pond, it is necessary to lower the temperature of the pond water to about 75° F. before undertaking the task. If the pond is such that the water cannot be cooled to this degree, the operator should wait until weather conditions are favorable for the removal. In the reservoir type of culture, many operators have to wait until fall.

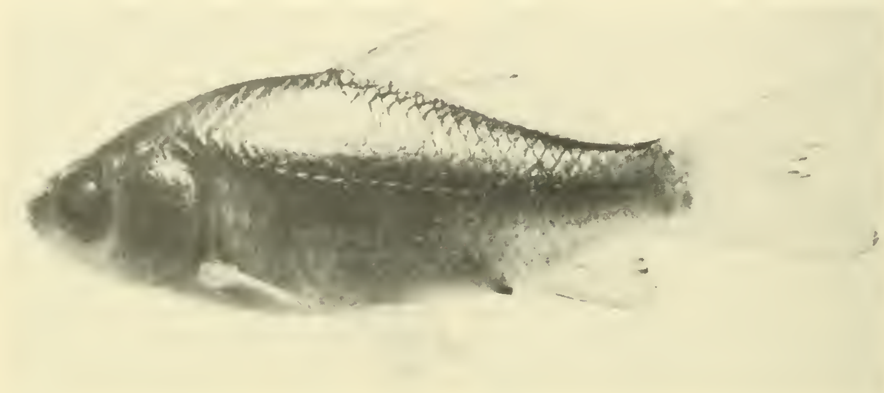
In Minnesota, natural shiner ponds should be harvested in the fall when the weather is cool. The fish will be of pike-bait size then and hardy enough to stand handling. While it is possible to handle golden shiners in summer with special nets, the fish are too delicate for the fisherman to carry in the minnow pail. Most of the fish seined in the fall will have to be held in large tanks or holding ponds supplied with running water until they are needed for winter fishing.

Production in golden-shiner ponds varies more than that in sucker ponds because shiner production not only is dependent on the rate of stocking and the amount of food available, but is primarily determined by spawning conditions and spawning success. A pond with poor spawning conditions will produce a small crop of fish, while a pond with good spawning conditions will produce a large crop. Of course, the fish from the last two or three spawnings will not grow large enough to be used the first year, but most of the others will be suitable for winter fishing the first winter. Optimum production in natural ponds probably can be obtained by removing the adults from the pond after the fourth or fifth spawning. The production of eight Minnesota golden-shiner ponds averaged 145 pounds an acre, and the maximum was 390 pounds an acre. When the production was over 300 pounds to the acre, about 5 percent of the fish were pike-bait size minnows. When the production was around 150 pounds, 70 percent of the fish were pike-bait size.

When golden shiners are removed from the ponds to the storage vats, the storage water should not exceed 70° F. During the first 24 hours of storage, the fish are highly excitable and react violently to any sudden jar or fast-moving object. It is well for the operator to take these factors into consideration and to approach the storage tanks quietly when attempting to handle the fish. If he plans to confine the salable golden shiners for a 2- or 3-week period in holding tanks, it is desirable to maintain a water temperature of about 60° F.

GOLDFISH *Carassius auratus*

Also called Indiana, Baltimore, and Missouri Minnow.



LIFE HISTORY

Description.—Mouth small but not sucker shaped; no teeth in the jaws; dorsal fin with more than 10 rays; a smooth spine at the leading edge of the dorsal and anal fins; scales large; no scales on the head, cheeks, or gill covers. The male develops tiny tubercles on the sides of the head and front edges of the pectoral fins during the mating season. In natural waters, goldfish grow to a weight of 3 to 5 pounds.

Range and breeding habits.—The goldfish was originally imported from Eurasia as an ornamental aquarium fish, but has since been introduced into natural waters by well-meaning persons who tired of their care.

Goldfish normally start spawning when the water reaches 60° F., and continue to spawn throughout the summer if the temperature remains above 60° and the fish are not overcrowded. The favorite spawning time is right after sunrise on sunny days. The female lays the eggs on grass, roots, leaves, or similar objects. The eggs are adhesive and stick to any object they touch. The male fertilizes the eggs immediately. The eggs are clear when laid and turn brown as they develop. Dead eggs are cloudy and opaque. The eggs hatch in 6 to 7 days in water of 60° F. A female goldfish may lay 2,000 to 4,000 eggs at one time and may spawn several times during the season.

Food.—Goldfish feed largely on plankton, but will take insects and very small fish.

Importance.—Many States prohibit the use of goldfish for bait because of the danger of introducing them into valuable game-fish waters. Experience in some of these States has shown the goldfish to be as vigorous as carp in destroying game-fish habitats.

The goldfish is a good bait fish to raise in the States where it is legal. It is hardy and lives well in crowded pails even during hot weather. It reproduces in large numbers and grows rapidly. Goldfish of various sizes can be used as bait for most of the fish-eating game fish.

PRODUCTION

In the southeastern United States, where the goldfish is legal bait, it is perhaps the best bait fish to raise. Even in the South, a hatchery operator who plans to propagate goldfish for bait should check the State laws that regulate minnow use and transportation.

The best type of pond for goldfish is less than ½ acre in size and 4 or 5 feet deep. Small ponds can be harvested before the water becomes too warm and the oxygen supply becomes too low for the fish. Production ponds should be filled early in March and fertilized at the rate of 200 pounds of 8-8-6 fertilizer per acre. Similar applications should be repeated at 2- or 3-week intervals until the pond is drained.

Stocking the pond

Medium-sized, uncolored goldfish should be used for brood stock, because fish of that size reproduce well and fish of that color are preferred for bait. Brood stock that is overwintered in crowded ponds will not spawn in the holding ponds. Maximum egg production is obtained by keeping the brood fish in the overwintering pond until after the last spring frost. Then the fish can be put in the production ponds without danger of frost damage to eggs or fry.

The production ponds should be stocked with 200 to 300 adults per water acre. As the males can be recognized by their tubercles, it is possible to stock equal numbers of males and females.

Spawning

Spawning is encouraged by placing a row of spawning mats near the shore of the pond. Spawning mats are wire-bottom frames filled with moss, excelsior, or grass, that float on the surface of the pond. The fish lay their eggs on the bottom side. When the mats are moved to clean ponds to hatch the eggs, the sides of the spawning pond should be covered with boards so the fish cannot spawn on the grass. If the eggs are allowed to hatch in the ponds where they are laid, the adults will stop spawning when the pond becomes crowded with young fish. When the eggs are moved to clean ponds to hatch, the uncrowded adults will spawn all summer.

Artificial feeding

Goldfish production can be increased in most ponds by supplementing the natural food produced by fertilizing with artificial food. Soybean meal, peanut meal, poultry mash, and cottonseed meal are good supplementary foods for goldfish. The food should be fed at the same time each day and should be thrown into shallow water in the same place each day so the fish become familiar with the routine. The fish should be fed all of the food they can consume in 2 hours.

Harvesting the fish

Goldfish production will vary according to the size and condition of the brood stock, number of disease organisms affecting the adults and the young, amount and kind of fertilization, and the quantity and kind of supplementary feeding. In general, ponds containing both young and adults will produce up to 100,000 fingerlings to the acre. Intensive hatcheries where a heavily stocked brood pond provides fry for 8 or 10 growing ponds, the production will reach 200,000 to 300,000 bait fish to the acre.

PEARL DACE *Margariscus margarita*

Also called Leatherback Minnow.

LIFE HISTORY

Description.—Robust minnow; snout blunt and head rounded; small but visible scales; mouth not extended behind eye; color a dusky silver mottled by darker scales; no large nuptial tubercles, no black pigment spots on fins. The pearl dace grows to a length of at least 3½ inches in 1 year, and reaches a maximum of 7 inches.

Range.—The pearl dace prefers cool lakes, bogs, and creeks. Its range is through all Canada east of the Rockies and the northern United States to New York.

Breeding habits.—Dr. T. H. Langlois (1929) reports that—

> the Northern Dace were seen spawning in a clear water stream of 1½ to 2 feet depth and 15 feet width, in or out of the current, on sand or gravel bottom, with the water temperature from

63° to 65° F. * * * Each adult male maintains a small area of the stream bottom as his private spawning ground, guarding it against intrusion by other males, and apparently restricting his own spawning to it the major share of the time. * * * his brief periods at home are spent nosing over the bottom as if seeking eggs to eat. The moment another dace reaches his vision he is off in pursuit, but seldom ranges farther than 4 feet from his home. If the stranger proves to be a male he is promptly escorted away * * * *

If the stranger should be a female, and if she permits the male to drive her into his holding instead of fleeing, and if, once there, she stays and permits the male to pair with her, the process occurs in this manner. The two fish come to a position side by side, close to bottom, and, if there is a current, heading upstream. The oversized tubercle-roughened pectoral fin of the male is slipped beneath the anterior part of the body of the female, and his tail is crossed over her back, just behind her dorsal fin. * * * When this position has been reached both fishes vibrate the posterior parts of their bodies rapidly * * * and * * * the eggs and milt are * * * extruded * * * since each female repeats the act many times during the breeding season she must extrude but a few eggs each time.

Food.—The food habits of the pearl dace have received little attention. From the studies available, it seems probable that insects are preferred, but the fish has been known to feed on phytoplankton, mollusks, surface drift, and water mites.

Importance.—It is possible that the pearl dace can be reared successfully in artificial ponds, and that bait sufficiently large for catching panfish could be raised in one season. Because it makes a fine growth in northern boggy waters, this fish could be raised in northern areas in places where land is cheap. For dealers with little working capital, this species seems to offer excellent opportunities.

HORNYHEAD CHUB *Nocomis biguttatus*

Also called Redtail Chub.

LIFE HISTORY

Description.—Heavy, robust minnow; blunt nose; large scales clearly outlined; large diffuse black spot at base of tail, tail fin red in young (accounting for some calling it the redtail chub); small barbels at corners of mouth; body color usually olivaceous; large tubercles on top of head and orange-red spot behind eye of breeding males.

Range.—The hornyhead chub is a minnow of large creeks and small rivers, preferring swift waters and gravel bottoms. It is found in the United States from North Dakota and Colorado east to the Great Lakes and the Hudson River, and south to Oklahoma and the Ohio River valley.

Breeding habits.—This chub spawns late in May and early in June on gravelly riffles in 1 to 2 feet of water at 65° F. or warmer. The nest is either a natural cavity in the stream bottom or one fanned out by the fish. Mating activities and stone carrying into the nest by males are alternated so that the pebbles and eggs are mixed in the nest. The nest pile is large, often covering several square feet of bottom, and 2 to 6 inches deep. Each nest is occupied by a single male who probably spawns with several females. These nest piles are often used by common shiners at the same time, the males of both species guarding the nest. The male attains a maximum length of about 10 inches and the females are smaller. This minnow requires several years to reach maturity.

Food.—The food of the hornyhead chub is mostly insect larvae and crustaceans. A summary of several food studies made in New York showed an average percentage of the following food items: Crayfish, 5.6; mayflies, 11.1; caddisflies, 2.8; chironomid larvae and pupae, 29.4; miscellaneous insects, 7.8; small beetles, 23.9; algae, 13.9; and silt, 5.6.

Importance.—The hornyhead is an excellent bait fish for pike, hardy on the hook or in storage tanks, and attains large size.

RIVER CHUB *Hybopis (Nocomis) micropogon*

LIFE HISTORY

Description.—Body robust, nose blunt, scales large and easily seen, similar to hornyhead chub, p. 103; black spot at base of tail indistinct and of no definite shape; tail fin of young sometimes amber but not red; no red spot behind eye; several large tubercles on swollen forehead of breeding males. It differs from the hornyhead chub in having an indistinct black spot of no definite shape at the base of the tail, no red on the caudal fin, and in its preference for larger rivers.

Range.—The river chub is found in the eastern United States from New York to Virginia and in the Tennessee River drainage in Georgia and Alabama, and northward to southern Michigan.

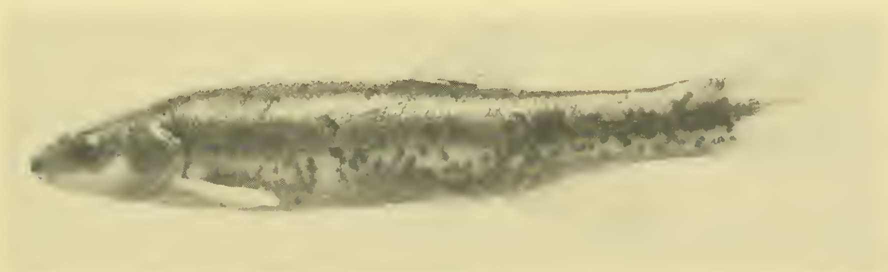
Breeding habits.—The life history of the river chub is similar to that of the hornyhead chub. Excellent descriptions of the breeding habits of this chub have been written by Michigan investigators. According to their observations, the male first digs a pit 12 to 15 inches in diameter and 3 to 6 inches deep in the streambed in water less than 2 feet deep. Stones are removed by being carried away in the mouth. The male then fills the pit again with other stones until a heap of large pebbles, 30 inches across and 3 inches high, is accumulated—all in 2 to 5 days. Small spawning troughs are then made by the male in the surface of this stone pile to receive eggs and milt as they drop from the spawning fish above. The troughs are filled again with pebbles immediately after spawning. Common shiners, hornyhead chubs, and stonerollers may use the stone pile for a spawning place at the same time.

Food.—The feeding habits of the river chub are probably very similar to those of the hornyhead chub. The two species were thought to be the same for many years and very little work has been done on them separately.

Importance.—The river chub is probably as important a bait fish as the hornyhead chub, and most dealers do not distinguish between them.

BLACKNOSE DACE *Rhinichthys atratulus*

Also called Slicker.



LIFE HISTORY

Description.—Active, streamlined minnow, usually under 3 inches in length; color dusky or black above with pronounced freckles or dark spots over top and sides of body; black streak on side of body, extending forward through eye and snout; scales small but easily seen; small barbel clearly visible at each corner of mouth especially when the mouth is opened;

fins short and rounded; dorsal set behind pelvics.

Range.—This dace is found in clear, rocky streams from Virginia northward to the St. Lawrence River, westward through the Ohio River system and Great Lakes' basin, to Nebraska, Iowa, and North Dakota. It is most abundant in small, cool streams, and is rarely taken from lakes or ponds.

Breeding habits.—The blacknose dace spawns in April and May when the water temperature of the creek reaches about 75° F. The spawning site is located at the head of riffles. It frequently occupies the same riffles used by creek chubs—when the chubs are absent. Langlois (1941a) comments on the spawning activities:

> Each male occupies a "holding" though shifting around considerably. When a female enters a "holding," the male goes to her and sometimes passes several times around her before coming to a lateral parallel position for spawning. When side by side, the female vibrates her tail, sometimes nearly burying it while doing so, and at the same time the male's tail starts vibrating and curling up over the female's tail to her dorsal fin, when vibrations cease. Occasionally the pair remains in place and spawns again immediately, but usually they separate, the male darting forward while the female relaxes limply onto one side, remaining there sometimes for several seconds.

The milt and eggs may be stripped from ripe males and females, and artificial fertilization is practical. The eggs are about $\frac{1}{16}$ inch in diameter when spawned, but quickly swell to about $\frac{1}{8}$ of an inch.

Food.—The food of the blacknose dace varies according to what is available. Some workers have found the diet to be 100 percent insects while others have found it to be at least 24 percent filamentous algae. Crustaceans, diatoms, and water mites are eaten when available in large enough numbers.

Importance.—The blacknose dace is a fairly important bait fish in Minnesota where it is sold along with the longnose dace under the name of slicker. It is a hardy minnow that can be used in pike, bass, and catfish fishing.

LONGNOSE DACE *Rhinichthys cataractae*

LIFE HISTORY

Description.—The longnose dace has an elongate and cylindrical body. The color is olive green to brown above, with dark blotches on the sides, an indistinct lateral band, and pale beneath. The upper jaw extends considerably beyond the lower one. In this fish, the air bladder is rudimentary or not fully developed.

While the longnose dace reaches 5 inches, the growth is very slow. Studies in Minnesota indicate the longnose is 1.9 inches at the end of the first year, 2.4 at the end of the second, 2.9 at the end of the third, 3.4 at the end of the fourth, and 3.9 inches at the end of the fifth year. The fish for this study were collected in southern Minnesota trout streams.

Range and breeding habits.—This species ranges from coast to coast in northern North America, and southward in the interior to Iowa, and along the mountains to North Carolina, and also to northern Mexico. It is found in small to moderate-sized streams, and is scarce or lacking in lakes. Usually found with the blacknose dace, its habitat preferences may be considered similar to that species.

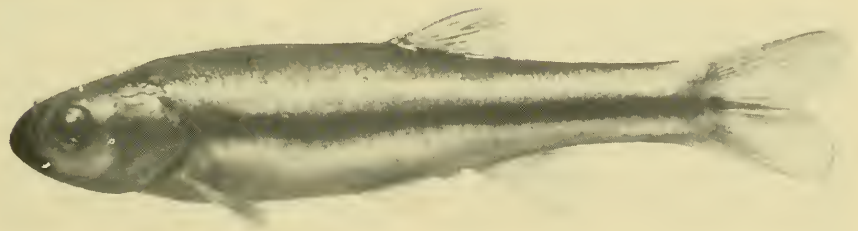
The longnose dace breeds in April and May over sand or gravel bottom in clean, swift streams. During this period the males have considerable red on head, sides, and fins.

Food.—The food of 186 longnose dace from Minnesota trout streams was chironomid fly larvae and pupae, 43 percent; simuliid larvae and pupae, 23.2 percent; ephemerid nymphs, miscellaneous insects. 0.2 percent; annelid worms, 1 percent; algae, 0.8 percent; and debris, 5.8 percent.

Importance.—Like the blacknose dace, the longnose dace is used by anglers for bass and catfish bait. This minnow has been propagated at least once in Minnesota and seems to do well in long, narrow ponds supplied with a very small amount of running water.

FINESCALE DACE *Pfrille neogaea*

Also called Rainbow Chub.



LIFE HISTORY

Description.—Robust minnow growing to 5 inches in length; nose blunt, fins short and rounded; large terminal mouth, no barbels; very fine scales; color dark; one indistinct, black lateral band on side of body; inner lining of body cavity black; intestine less than twice as long as body. It reaches a size of 6 inches. Like the pearl dace, its bright-red sides retain their brilliance most of the year but are most beautiful in late winter.

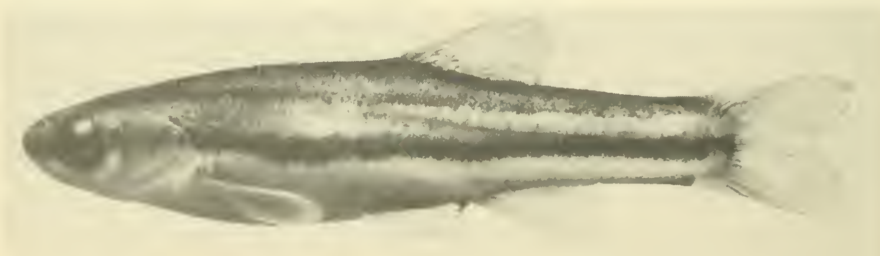
Range.—This species is most often found in cool, boggy creeks and ponds. Its range includes eastern Canada, the upper Mississippi Valley, and northern parts of northeastern United States.

Food.—The limited food studies conducted indicate that both phytoplankton and higher plants are preferred. In some stomachs, however, nearly half of the food has been insects, and the minnow is known to eat zooplankton and crustaceans to a limited extent.

Importance.—The finescale dace is tenacious of life and survives well in crowded containers. It is satisfactory pike bait. Though little is known of its spawning habits or requirements, it is possible that this species could be grown successfully in small boggy ponds.

NORTHERN REDBELLY DACE *Chrosomus eos*

Also called Yellowbelly Dace and Leatherback.



LIFE HISTORY

Description.—Small minnows averaging 3 inches in length; two dusky lateral bands from head to tail; dark bronze color except for silvery belly of females, scarlet in males; mouth small and pointing upward at end of snout; lining of body cavity black, intestine more than twice as long as body. The scales are minute, and this species has been called "leatherback" by sportsmen and minnow dealers.

Range.—Though their ranges slightly overlap, the bait dealer can best distinguish the northern and southern forms of the redbelly dace by the location of their capture. The northern form is found commonly in bog ponds and sluggish creeks from British Columbia east to Nova Scotia, southward to southern Michigan, southern Wisconsin, southern Minnesota, the Dakotas, Montana, and Colorado; and in portions of northeastern United States to Potomac River drainages of Maryland. In Minnesota, it seems to prefer acid bog lakes; in Michigan, in addition to its occurrence in bog lakes, it has been found in small ponds showing a heavy growth of chara and a rapid deposition of marl.

Breeding habits.—In the spawning season, the males are brilliantly colored. The abdomen is a beautiful red, and the fins are highly colored with red and yellow.

The spawning habits, rate of growth, and age at maturity have been carefully studied in Michigan. The eggs are deposited entirely upon filamentous algae. One female lays from 5 to 30 nonadhesive eggs scattered through and entangled among the filaments. The female darts from one algal mass to another, laying eggs in each new mass. The eggs hatch in 8 to 10 days at water temperatures of 70° to 80° F. Spawning takes place from the latter part of May into August in southern Michigan.

Adult females, when dissected, revealed the simultaneous maturation of several hundred eggs and the presence of at least two size groups of maturing eggs. This suggests that one female has no fewer than two distinct spawning periods during a season. The young, hatching early in the summer, attain nearly adult size by the end of the first growing season and spawn early the next summer. Those hatching late in the season pass the first winter as small fish and require most of the next summer to reach maturity, often not spawning until their third summer.

Food.—Studies made in the St. Lawrence watershed of New York indicate that the northern redbelly dace is mainly herbivorous, that it feeds almost entirely on diatoms and other algae, the remains of seed plants, and only to a limited degree on insects and animal plankton.

Importance.—Experimental propagation of this species in Michigan has shown that 128,000 fish can be raised per acre of water surface. The redbelly dace is best suited to cool waters. This species does not reach a length of more than 2½ inches and is valuable only as bait for panfish.

SOUTHERN REDBELLY DACE *Chrosomus erythrogaster*

LIFE HISTORY

Description.—The southern redbelly dace differs from the northern form in its more horizontal mouth, longer snout, and narrower caudal peduncle.

Range and breeding habits.—The southern redbelly dace is more southern in range than its northern relative, and has a decided preference for cool, gravelly creeks from Iowa, southern Minnesota through southeastern Michigan eastward to Ohio River drainages of Pennsylvania and West Virginia, and south-

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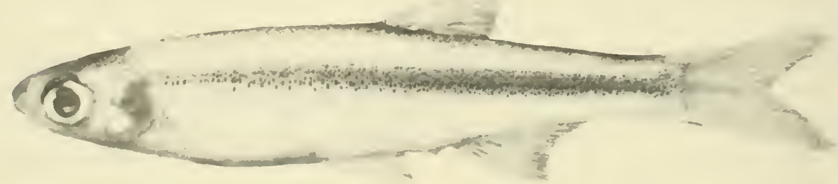
ward in the Mississippi River valley to the Tennessee River system in Tennessee and northern Alabama, the northern Ozarks in Arkansas and Oklahoma, and the Missouri River drainage in Kansas.

The feeding and spawning habits of this form are believed similar to those of the northern species. The major differences seem to be a preference by this species for spawning on gravelly bottoms and selection of a more insectivorous diet.

Importance.—In Minnesota, this dace is not as hardy as the northern species, but is frequently used as bait for crappies in the southern part of the State.

EMERALD SHINER *Notropis atherinoides*



LIFE HISTORY

Description.—Body thin and streamlined, snout blunt; scales silvery colored, with no black pigment, loose and easily removed; mouth large with thin black lips running to tip of nose; dorsal fin behind point of pelvic-fin attachment; anal fin pointed (as is dorsal) and containing about 9 rays.

Range and breeding habits.—The lake emerald shiner is found in large lakes and rivers, usually in large schools in open waters. Its range includes the larger glacial lakes in Hudson Bay, the Great Lakes drainages, and the larger tributaries of the Mississippi River.

The emerald shiner spawns over gravel shoals from the middle of May to early June. The fish average 1¾ inches at the end of the first year and 3 inches at the end of the second.

Food.—The food of the emerald shiner consists largely of insects, most of which are terrestrial. This shiner has been known to feed on entomostracans, algae, small fish, fish eggs, terrestrial insects, aquatic insects, and oligochaete worms. The studies of several workers with the lake emerald shiner show that, in general, the food percentages are as follows: Water fleas, 26.8; algae, 7.9; water boatmen, 1.0; mayflies, 1.3; caddisflies, 2.1; chironomids, 9.7; terrestrial insects, 7.9; miscellaneous insects, 26.3; fish eggs, 2.9; crustacean debris, 10.7; and miscellaneous, 3.2.

Importance.—The emerald shiner is often used for bait despite the fact that it dies quickly and its scales come off easily. It is a good bait for bass, perch, and walleye pike. Hardy in cold weather, this fish is a favorite for winter fishing.

COMMON SHINER *Notropis cornutus*

Also called Skipjack.

LIFE HISTORY

Description.—Color silvery on sides, white on belly when alive; scales large, high, and narrow on side of the body; no barbel; dorsal fin inserted directly over pelvics; a size of 8 inches, or more, attained by males.

Range.—This minnow is common in nearly all cool creeks and lakes of northeastern United States. It occurs from southern Canada along the Atlantic coast to Virginia; centrally, southward to northern Alabama, and westward from Ozark region of Missouri to Arkansas River system in Arkansas and Oklahoma.

Breeding habits.—Breeding males have large tubercles over the top of the head, and body and fins are brightly colored orange and pink. It spawns on stream riffles over gravelly bottoms, but its abundance in some inland lakes may mean that it is successful in spawning on gravel shoals in quiet waters. The spawning season is short in Michigan, extending from the latter part of May into June; it begins somewhat earlier in Minnesota's western waters. Studies in Michigan have shown that the common shiner grows about 2 inches the first year and requires 2 or 3 years to reach maturity.

Little or no success has been obtained in stripping the eggs from this fish. To raise this species, rearing ponds should be arranged to allow adult fish to swim upstream from the ponds to lay their eggs. The young will then drift downstream and grow in the ponds, as do other species.

Food.—Only in the most recent food studies have the subspecies of this minnow been considered separately. Here, the food habits of the northern (*frontalis*) and the southern (*chrysocephalus*) are considered together.

The common shiner is omnivorous in its feeding habits. It has been known to eat algae, insects, fish, plants, entomostracans, hydrachnids, protozoans, and desmids. Stomachs of this species have contained in some instances 100 percent insects; in other, 100 percent algae and other plants. The studies of several workers show that, in general, the food percentages are as follows: Insects, 37.2; algae and other plants, 39.9; plankton, 11.8; fish, 7.1; sand and silt, 1.1; and miscellaneous foods, 2.9.

Importance.—It is used widely as bait for bass and pike, but is one of the less-hardy bait fishes.

SPOTFIN SHINER *Notropis spilopterus*

Also called Blue Minnow.

LIFE HISTORY

Description. — Body thin from side to side, deep from top to bottom; dorsal fin with black pigment on one or two membranes between posterior rays; breeding males often steel blue with orange fins and small, pointed tubercles on snout; females and young fish silvery blue in color.

Range.—The spotfin shiner prefers rapid-running streams, but is sometimes found in clear, weedy lakes. It occurs from the eastern part of the Dakotas to New England, except in Lake Superior and its tributaries, and south in the central Mississippi basin to the Tennessee River drainage of Alabama, and to central Missouri.

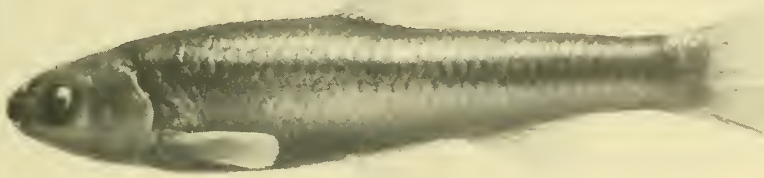
Breeding habits.—The spotfin shiner spawns from May to August on gravelly riffles or over sandy shoals. The adhesive eggs are often laid on logs and dock pilings, in crevices of submerged tree trunks, and even in old pails.

Food.—The food of this shiner consists mostly of insects. It has been known to eat both aquatic and terrestrial insects, small fishes, vegetable matter, small crustaceans, plankton, and carp eggs. Food studies by several workers show that in general, the food percentages are as follows: Midge larvae, 17.5; mayfly nymphs, 6.2; insects, 64.7; and miscellaneous, 11.5.

Importance.—The spotfin is a good bait species for crappies and pike; it is active, and is hardy on the hook and in the live box.

BRASSY MINNOW *Hybognathus hankinsoni*

Also called Grass Minnow.



LIFE HISTORY

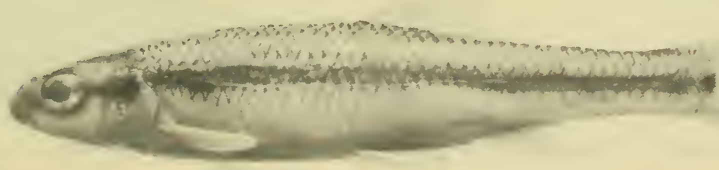
Description. — Small minnow with large, easily removed scales; scales not small and crowded behind head; brassy sheen on sides of body; snout blunt and rounded, mouth small; fins short, rounded on tip and free edges; lining of body cavity black, intestine (coiled like a watch spring) more than twice as long as body.

Range.—One of the most common and widespread bait fishes of the Great Lakes region, except Lake Erie in Ohio; ranges from Montana to southern Ontario, and the Lake Champlain region, southward to Missouri, Nebraska, and Colorado in the West. This minnow is often found in small creeks, commonly in bog streams, and sometimes in lakes.

Breeding.—Little is known of its spawning habits, but adhesive eggs probably are scattered over bottom sand, mud, or debris early in the spring when water temperatures reach 50° to 55° F. Growth is slow and maturity probably is reached at the age of 2 years with a length of 2½ to 3 inches. Larger specimens may be raised in fertilized ponds.

Food.—The food of the brassy minnow is varied. A summary of food studies made by two investigators indicates the following percentages: Zooplankton, 25.9; phytoplankton, 31.6; aquatic insects, 21.3; plants, 3.4; surface drift, 16.1; and silt, 1.7.

BLUNTNOSE MINNOW *Hyborhynchus notatus*



LIFE HISTORY

Description.—First obvious ray of the dorsal fin thickened, standing out from following rays; scales small and crowded behind the head; mouth small, horizontal, and under the snout; back flat and straight; lateral line complete from head to tail; breeding male with a tiny blisterlike swelling of skin at each corner of mouth, tubercles on snout only; spot at base of tail dark but diffuse; body cavity lined with black; intestine less than twice body length. The males grow larger than the females, attaining a maximum length of 4 inches.

Range and breeding habits.—This minnow resembles the fathead minnow (p. 78) in appearance, breeding habits, and distribution. It is more abundant than the fathead in the large, clearer lakes and firm-bottomed streams. In Michigan, the bluntnose has been called the most common minnow in inland waters. Spawning begins the latter part of May and continues through August in Michigan, but may begin 1 month earlier in western Minnesota. Water temperatures of 70° F. or higher are necessary before spawning takes place. A female may spawn at least twice in one season, and eggs are laid under any flat object on the bottom in water as deep as 8 feet (fig. 43). A depth of 6 inches to 3 feet is preferred. A count of eggs in 10 females averaged 2,005 eggs per fish. The eggs hatch in 7 to 15 days. The young reach marketable size by fall and spawn the following spring. The maximum age is about 4 years.

FIGURE 43.—Spawning boards strung in pond for bluntnose minnow.

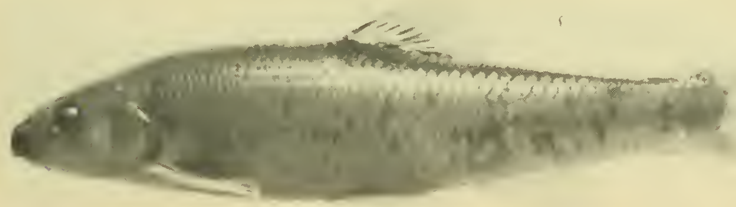
Food.—Because good keys for the separation of minnow species were not available until recent years, much of the literature and the records of stomach contents for the bluntnose minnow has probably been confused with those of the fathead minnow. More recent studies indicate that the feeding habits of these two species are similar; so the records, general as they are, could apply to either species.

The bluntnose minnow is known to eat diatoms, algae, aquatic insects, entomostracans, fish eggs, fish fry, and oligochaete worms. Occasionally this minnow will eat its young. Some stomachs of the blunt-nosed minnow contain only phytoplankton; others, only surface drift; and others large percentages of insects, higher plants, zooplankton, debris, or silt. A summary of food studies by several workers shows that, in general, the food percentages are as follows: Insects, 15.9; crustaceans, 3.5; entomostracans, 2; surface drift, 10.7; annelids, 0.5; zooplankton, 6.9; phytoplankton, 35; plants, 8.7; algae and diatoms, 4.9; and silt and debris, 11.8.

Importance.—This minnow is easily propagated and has been widely introduced. It has been propagated in Michigan at the rate of 104,800 fish (250 pounds) an acre. In general, this species seems less prolific than the fathead minnow, but in Ohio, 473,350 to an acre of water have been raised. This species will not withstand crowding in minnow containers so well as the fathead minnow. It is important as a food for game fish, because of its preference for large lakes where game fish are abundant.

STONEROLLER *Campostoma anomalum*

Also called Racehorse Chub.



LIFE HISTORY

Description.—Plump, sturdy minnow, underslung suckerlike mouth with horny ridge forming the lower lip; scales large, sometimes flecked with black pigment; black crescent on dorsal fin of adults; large tubercles on top of head of breeding males; lining of abdominal cavity black, intestine very long and wound spirally around air bladder.

Range.—The stoneroller is a minnow of creeks and small rivers, and prefers rocky, shady streams with swift water. Of very wide distribution, it is common in southern Michigan, Minnesota, and Wisconsin, and is found from the St. Lawrence southward to northern Alabama excluding the extreme southeastern United States, and westward from Wyoming to Texas.

Breeding habits.—This fish spawns from May to June 15. Great numbers ascend streams, where the bright-colored males excavate funnel-shaped cavities several inches deep and guard these and the eggs for a short time. The stoneroller minnow reaches maturity during its second or third summer. Males attain a size of 6 inches and females less than 5.

Food.—The stoneroller is chiefly a bottom feeder. It has been known to eat algae, diatoms, small amounts of zooplankton, a few aquatic insects, and plant tissue. Sand and clay are often found in the intestinal tract, but are probably taken along with the various foods. A study of 20 specimens from the Oswego River system (New York) showed food percentages as follows: Midge larvae, 10; diatoms, 50; algae, 10; and sand and silt, 30.

Importance.—The stoneroller is tenacious of life, and is regarded as one of the best baits for bass. In Minnesota, it is widely sold under the name of racehorse chub. One dealer has experimented with propagation of this minnow in shallow ponds supplied with a slow-moving current. The first attempts were moderately successful, but were not on a large enough scale to be practical.

WESTERN MUD MINNOW *Umbra limi*

LIFE HISTORY

Description.—Tail fin rounded; dorsal fin far back on body with about 12 rays; dark vertical bar at base of tail; scales on head (no other fish described in this section possesses scales there). This fish is not a true minnow, but is related to the northern pike. It grows to a length of 5 inches.

Range and breeding habits.—This species is distributed from Manitoba through the Great Lakes region to Quebec and Lake Champlain, southward in the central basin to the Upper Ohio River system, and in northwestern Tennessee, northeastern Arkansas, and Kansas. It prefers spring-fed, soft-bottomed pools, and weedy streams and ponds. It is common in boggy or stagnant places. Spawning takes place in early spring, usually upstream in small brooks.

The mud minnow hibernates in the mud and will go down 4 to 9 inches. It may be found in the mud in a horizontal position or in a vertical position with the head upward. When alarmed, it usually buries itself in the mud.

Food.—The food of the mud minnow is mostly of an animal nature. It has been known to eat insects, spiders, mites, amphipods, entomostracans, snails, leeches, oligochaete worms, nematodes, earthworms, rotifers, protozoans, and algae and other plants. A summary of the records indicates that mud minnows will take as much as 80 percent of their food from insect fauna, some have taken 90 percent amphipods, others have taken 50 percent entomostracans. More than 20 percent of the stomach contents of others has been plant food. More than 50 percent of the food of some stomachs has been mollusks, and in one collection 40 percent of the stomach contents was surface drift.

Stomach analyses by various workers showed that the digestive tracts of mud minnows contained the following average percentages: Insects, 45.6; amphipods, 11.1; entomostracans, 16.3; mollusks, 12.3; arachnids, 0.16; plants, 7.1; surface drift, 4.6; algae, 1.4; miscellaneous, 1.24; and silt, 0.2.

Importance.—The mud minnow is very hardy, but is not a popular bait species, except in Wisconsin, as it is not very active.

Evermann (1901) had the following to say regarding this fish:

> So persistently do they cling to life that it is really difficult to kill them. * * * Its unexcelled tenacity of life is, however, about the only thing it has to recommend it as a bait minnow. Its somber, unattractive color prevents it being readily seen by game fishes, and its tendency to pull down or get to the bottom also militates against it. But bass and pickerel and pike do sometimes take it and, in spite of its deficiencies, the Mudfish is a good thing to have in one's minnow pail.

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TABLE OF EQUIVALENTS

1 liter	=1,000 milliliters or 1,000 grams.
1,000 liters	=1,000,000 grams.
1 : 1,000	=0.1 percent.
1 : 10,000	=100 parts per million.
1 : 100,000	=10 parts per million.
1 part per million (p. p. m.)	=1 gram in 1,000 liters of water.
	=1 gram in 264 gallons.
	=1 gram in 35.5 cubic feet.
	=1 ounce (avoir.) in 28,350 liters.
	=1 ounce (avoir.) in 7,480 gallons.
	=1 ounce (avoir.) in 1,000 cubic feet.
	=8.34 lbs. per million gallons.
1 part per thousand (p. p. th.)	=1 gram per liter.
	=1 ounce (avoir.) per cubic foot.
1 part per 100 (1%)	=1 gram in 100 grams of water.
	=10 grams in 1,000 grams (1 liter).
	=37.8 grams in 1 gallon.
	=283 grams in 1 cubic foot.
	=1 ounce in 100 ounces (avoir.) or 0.75 gallon.
	=10 ounces in 1 cubic foot.
0.5% solution	=0.7 ounce per gallon.
1% solution	=1.3 ounces per gallon of water.
2.5% solution	=3.3 ounces per gallon.

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NOTES

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