Hatchery Propagation of the Black Basses

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Historically, hatchery propagation of the black basses in the United States began about 1890. Previously, in 1882 the U.S. Fish Commission provided a stock of smallmouth bass (*Micropterus dolomieu*), to Count von dem Borne of Germany and Lord Exter of England. Since no hatcheries were in operation, these fish were captured from the wild, as were the black bass that Page (1894) mentions as being stocked by private individuals into the Potomac River in 1852.

Early efforts to spread the black basses to new waters appear to have been successful and stimulated the U.S. Fish Commission to try to augment the supply of wild fish with fish from a more controlled source. As a consequence a hatchery at Wythville, Virginia began to propagate bass about 1886 (Anon. 1889). In 1889, a hatchery was built by the U.S. Fish Commission at Neosho, Missouri. Early success at this new hatchery was typical of bass cultural operations for many years; the first crop of fish produced was lost in a flood along with part of the brood stock.

Distribution by the U.S. Fish Commission of fingerling black basses reached significant levels by 1890. For the next decade, however, a fish rescue or salvage station at Quincy, Illinois provided more fingerling bass than did managed production facilities at Wythville, Virginia, Washington, D.C., and Neosho, Missouri. Finally in 1897, Fish Lakes Hatchery in Washington, D.C. exceeded the output of the fish rescue crews. From that time, federal hatchery production gradually increased to a peak of almost 26 million fish distributed in 1960. Hagen and O'Connor (1959) reported that state and federal hatcheries had distributed 35 million centrarchid basses in 1957. Ten years earlier, a production of 31 million bass was recorded (Tunnison et al. 1949).

The initial demand for black bass for stocking purposes centered around introductions into natural waters where the species were absent or in short supply. By the mid-1930s, indiscriminate stocking of these waters fell into disfavor as a management tool (Eschmeyer, 1936). However, discovery of successful stocking methods and management for farm ponds and small manageable lakes (Swingle and Smith 1942) increased the demand for the largemouth bass (*M. salmoides*), which has persisted to the present. During the three decades since the farm pond boom began in the 1940s, federal, state, and private hatchery production of largemouth bass fingerlings totaled millions each year. Although the largemouth bass has consistently dominated the production statistics, smallmouth bass production has also been important though limited by the amount of water that needs stocking with this species. Other basses are seldom propagated in hatcheries, although isolated efforts have provided information on techniques of culture (Howland 1932).

Hatchery propagation of all sizes of black bass appears to be technically possible. Cost of production per fish rises sharply as size increases and becomes prohibitive for the larger sizes, except for special uses such as brood stock or experimental animals. Table 1 shows size, rearing unit, food supply and general use of the commonly cultured sizes of largemouth bass.

Table 1. *Sizes of largemouth bass commonly cultured*

Size (inches)	Rearing facility	Food supply	Use
1.5-2.0	earthen pond	Zooplankton insects	establish sport fish populations
3.0-4.0	earthen ponds	insects	corrective restocking
5.0-8.0	ponds or raceways	artificial food	corrective restocking or test animals
adult	ponds or raceways	forage fish artificial food	brood stock

The greatest need under present stocking programs is for the 1.5-2.0 inch (38-51 mm) fingerlings. Only limited use is currently being made of larger sizes.

General Methods of Culture

Early efforts at culturing the black basses led to use of a natural or seminatural approach in progagation. Although culture at the Neosho hatchery in 1890-1900 involved trough rearing and artificial feeding, the cannibalistic nature of the speices and lack of a suitable ration ultimately led to the use of natural foods and low stocking densities for rearing bass to a distributable size. By 1940, extensive research in conjunction with federal and state efforts to rear the centrarchid basses under hatchery conditions led to the adoption of two basic systems of culture. Both of these systems made use of an earthen pond as the rearing facility (Lydell 1904; Davis and Wiebe 1930; Langlois 1931; Howland 1932; Surber 1935; Meehean 1936, 1939).

The simplest system, diagramed in Figure 1, was the first used to propagate largemouth, smallmouth, spotted (*M. punctulatus*), and redeye (*M. coosae*) basses, and is still occasionally used today, although inherent disadvantages preclude general use. Termed the spawning-rearing pond system, this method is used when the number of fish needed is low, manageable rearing ponds are lacking, brood stock is of poor quality, or a lack of knowledge and skill in the work force limit use of more sophisticated techniques. In the spawning-rearing pond system, adult fish are stocked into clean ponds when rising water temperature in the spring stimulates nesting activity. A light rate of stocking is used, 10 to 40 brood fish per acre (25-100 per hectare) depending on their size. The production pond is fertilized unless abundant zooplankton develop naturally. Fertilizer, such as animal manure, oil seed meals (cottonseed meal, soybean meal), or a green manure crop, has been used. Often superphosphate is combined with the organic material and in some situations half of the nitrogen required is supplied by an inorganic source.

The adult fish produce young that remain in the pond until large enough for distribution. A size of 1-2 inches (25-50 mm) is usually reached. Harvesting is by seining schools of small fingerlings, trapping as the schools break up, or by draining the pond. The brood stock is then returned to the summer holding pond and maintained on forage fish until the next spawning season.

In this system there is no control over stocking density of small fish except by regulating the numbers of spawning fish. Predation by adults on the young often is a major factor in yield of young bass. Because of these and other easons, the practice of collecting schools of small bass, at some stage after they rise from the nest, for transfer to a specially prepared rearing pond was developed in the first third of this century and became popular. Although varying somewhat depending upon the speices and whether or not the schools of fry break up soon after leaving the nest, the fry transfer system follows the concept illustrated in Figure 2.

Under this system, the bass culturist can

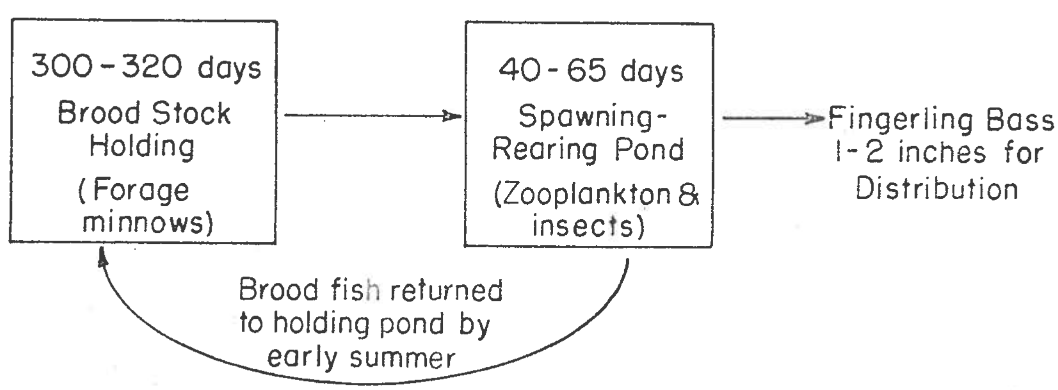


Fig. 1. Spawning-rearing pond system of bass propagation.

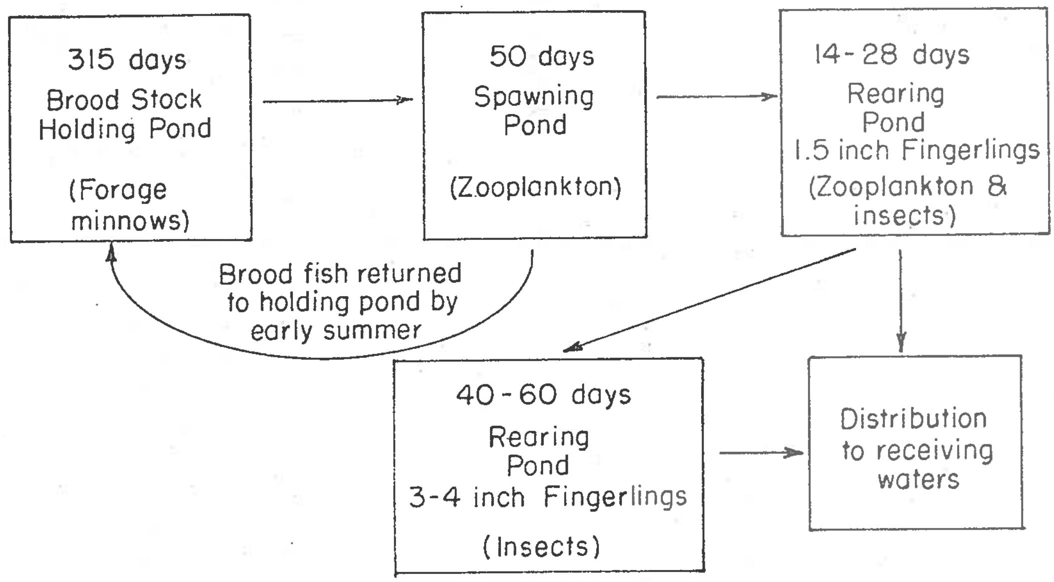


Fig. 2. Fry transfer system of bass propagation.

directly control the density of small fish to be reared by estimating the number stocked per acre. This is done visually by counting a sample into a container. Similar containers receive uncounted fish until the unknown compares in appearance to the counted standard. Weight or volume-based estimates can be obtained by counting the number of small fish in a weighed or volumetrically measured sample. The number-weight or number-volume relationship is then used to calculate the quantity of fry needed for the rearing pond being stocked. If properly applied, any of these techniques should enable the bass culturist to know within ± 10 percent the number of fry stocked. The method of estimating small bass is somewhat a matter of choice, although I believe that visual comparison stresses the fish less than other methods when bass ½-¾ in (10-20 mm) are involved.

In the fry transfer method for largemouth bass culture, one or more spawning ponds are selected and prepared for stocking the spawning fish. As water temperatures rise to the 63°-68°F (17°-20°C) range in the spring a close watch is kept on the brood stock holding pond. When the male fish begin preparing nesting sites it is time to fill the spawning pond. If filamentous algae or submerged rooted weeds are a problem a preflooding treatment with simazine at a rate of 10 pounds of 80 percent active simazine per acre (11.2 kg per ha) minimizes later weed problems (Snow 1967). A period of 7-10 days between treating and stocking offsets any side effects of the weed treatment to the fish crop.

About the time water warms to 65°F (18°C) with some stability, spawning can be expected. When the first eggs are noted, the holding pond can be drained and the brood fish stocked. A rate of 40 to 100 brood fish per acre (99-247 per ha) is generally used with the number stocked being governed by the size of the adult fish, their past history of fecundity, the number of fry needed, the number of brood fish on hand, and other factors. Best use of the brood fish is obtained if more male fish are stocked than females. A ratio of 2 to 1 or 3 to 1 is recommended, based on the work of Bishop (1968). From 5,000 to 25,000 fry per spawn can be expected. A female may spawn from one to five times over the 6-8 week spawning season. Although as many as 500,000 fry per acre (1,235,000 per ha) have been taken from a spawning pond, the average is less than half this number. Factors affecting the production of fry, and the extent that they can be captured for transfer to a rearing pond, include weather conditions, water quality, food supply, condition of the brood stock, weed problems, disease, turbidity of the water, and habits of the species involved, operating singly and in combination.

Fry can be captured for transfer anytime after they are free-swimming. Use of a trapping device (retainer) permits capture of smallmouth or spotted bass fry, which do not remain in a school after rising from the nest. Basically the retainer is a cylinder, about 30 inches (76 cm) in diameter and 36-48 inches (91-122 cm) tall, made with a frame of light metal covered with fine-mesh cloth. This cylinder is placed over the nesting site, usually located on a pile of gravel, after the eggs hatch but before the sac fry become free-swimming. After they swim up, they may be captured with a dip net or fine mesh fry net for stocking in a rearing pond. A retainer can be used to aid in capture of largemouth bass fry, but it is not needed as young of this species remain in a compact school until they reach 0.5-1.0 inch (12-25 mm). Largemouth bass fry are taken with either a one-man net operated from a boat or a longer net fished by a two-man crew wading the shallow spawning pond.

Another effective method of capturing fry is by trapping. Under certain conditions the small bass migrate to the margin of the pond and swim parallel to the shore; when they do this a suitably designed trap is highly effective in taking fish. Another situation suitable for trapping can sometimes be created by admitting fresh or food laden water from an adjacent pond with traps being set to intercept the small bass attracted to the current of inflowing water. Artificial light with and without the fresh water current can also be helpful in trapping.

Preparation of the rearing pond commences about the time the first eggs are deposited in the spawning pond or shortly afterwards. If weeds are likely to be a problem, a preflooding treatment similar to that describscribed for the spawning pond can be applied. Speed of the food chain development is dependent on water temperature. The size of the bass fry being transferred also influences the time required for an adequate food supply to develop.

The rearing pond is filled with water 10 to 20 days before the ½-¾ in (10-18 mm) fry are to be stocked. Fertilization, to develop an abundant zooplankton culture, usually includes one or more applications of organic or organic-inorganic combinations, proved to be effective in a given pond system. For the hatchery at Marion, Alabama, a ryegrass planting in the fall, which is allowed to produce about 2,000-2,500 pounds of green matter per acre (2240-2688 kg per ha) before being flooded, is the most effective technique. One to 3 applications of inorganic 8-8-0 at a rate of 100 pounds per acre (112 kg per ha) per application with applications at weekly intervals may be used to supplement the ryegrass. Inorganic fertilizer is added after the ryegrass has partially decayed following flooding of the rearing pond.

Rearing ponds for production of 1.5-2.0 inch (38-51 mm) bass are stocked at a rate of from 40,000 to 80,000 fry per acre (99,000-198,000 per ha). After stocking, a period of 2 to 4 weeks is needed for the small bass to reach distributable size. During this time, the rearing pond is fertilized once or twice more and weeds are controlled so that they do not interfere with harvesting. With experience in working with a given pond system, the manager can schedule delivery of a lot of fish as soon as the rearing pond is stocked. Recovery of 75-80 percent of the small bass stocked is about average.

Harvesting should begin as soon as the small bass grow to a size of 1.5 inches (38 mm). If growth ceases or a marked difference in length is apparent before this size is reached, overstocking has occurred. If uncorrected, overstocking results in high losses of the stocked fry. Prompt removal of part or all of the fish to a food-rich pond is the corrective measure. No more than 7 days time should elapse between the time a distributable size is reached and the final harvest of a given lot. Further delay generally results in a progressively lower survival percentage of the stocked fry. Survival of 10 percent or less has resulted from a delay of 3-4 weeks. Harvesting can be done by trapping, seining, or draining the pond. An effective technique at some hatcheries is to use traps as long as they are taking fish in quantity, then to complete the harvest by draining the ponds as rapidly as circumstances permit.

Small bass fingerlings are hardy and present no unusual harvesting problems under normal conditions. After being captured they are cleaned of extraneous animal and plant forms, graded, sampled for establishing a number-weight relationship, and treated for disease if necessary. Distribution is usually carried out within 48 hours of harvest to minimize cannibalism during the holding period. While food intake of this size bass fingerling is high, 2-inch bass can withstand starvation for 7-14 days without mortality unless other stresses such as disease organisms are present.

Distribution of fingerlings is customarily by tank truck. Aeration is provided by bottled oxygen, electric agitation, water circulation, or various combinations. Fish at densities up to 1.5-2.0 pounds to each gallon of tank capacity (180-240 grams per liter) can be transported 5-10 hours without harmful stress. Because of the low stocking rate per acre for receiving waters, it is seldom necessary to haul bass fingerlings at maximum densities.

If bass longer than 2 inches are desired, fingerlings from the 1.5-2.0 inch rearing pond are stocked in other rearing ponds at a rate of 10,000-12,000 fingerlings per acre (24,700-29,600 per ha). These rearing ponds are fertilized also, but an effort is made to develop a bloom of phytoplankton which is eaten by immature insects, mainly midges. Growth from a size of 2 inches (51 mm) to 3-4 inches (76-102 mm) is usually done on an insect diet. Research has not indicated that the use of forage minnows as food for larger bass fingerlings is a predictable approach to achieving high returns.

In rearing ponds for the production of 1.5-2.0 (38-51 mm) or 3.0-4.0 inch (76-102 mm) bass, seine sampling and visual observation are frequently used to check on size variation and growth. If a size group develops that can swallow the smaller bass, the pond should be drained and the large fish graded to prevent losses by cannibalism. If ample food is present and uniform size fish used in stocking, size difference should not be a problem.

For rearing largemouth bass to a size of 3-4 inches (76-102 mm) total length, a period of 40 to 60 days is needed at an average water temperature of 25-28°C. Higher temperatures should speed growth; lower ones, especially below (68°F (20°C), will make for slower growth. Since the rearing ponds for 3-4 inch (76-102 mm) bass are in production two to three times longer than for 2-inch bass, more management is needed. Three to 5 applications of fertilizer are applied at 7-10 day intervals. Weeds, which interfere with harvesting and food production, are controlled with appropriate chemical treatment. Sampling by seining every 10-12 days enables the bass culturist to detect size differences which can lead to losses. As in rearing smaller bass, appreciable difference in size between the largest and smallest bass in a pond requires draining, grading, and restocking in fresh ponds with fish of uniform size (Topel 1949).

Harvesting bass 3-4 inches total length usually is done by draining the rearing pond although trapping may be used, particularly if weeds are a problem. During midsummer, harvesting in the early morning hours can offset the effect of high midday and afternoon temperatures. This size bass is hardy and handles well. No particular problems have been experienced in harvesting and distribution. A hauling density of 1.5-2.0 pounds of fish to the gallon (180-240 g per l) of distribution tank capacity has been used for trips of 6-12 hours duration.

The foregoing systems of bass culture have been followed with minor adaptations by hatcheries for many years. Research has enabled improvement in fertilization, weed control, rate of stocking spawning fish and fry, disease control, and management to eliminate cannibalism. Despite improvements, however, limitations of food supply, weather, characteristics of the species, pond variation, and other factors combine to limit the yield which is possible at a given hatchery. These influcences in bass culture inject uncertainties which are lacking in more controlled systems of fish culture.

The "Intensive" System

To overcome the limitations of the spawning-rearing pond and fry transfer systems of bass culture, I have devised and tested a system labeled "intensive" for want of a better term. Under this system bass are fed artificial food in either ponds or raceways to whatever size management of a particular water requires. Work on the system began in

1955 at the National Fish Hatchery at Marion, Alabama and continued for two decades in an effort to advance bass culture toward the goal of controlled culture already achieved by trout and salmon culturists.

Basic to the system, diagramed in Figure 3, is an adequate ration. The most suitable one is Oregon Moist Pellet (OMP) (Hublou 1963). This feed meets the needs of largemouth bass under pond conditions from a size of 2 inches to old age. Brood fish have been maintained on OMP through the seventh spawning season without observed abnormalities. Successful spawning occurred at 7 years of age. OMP has not been successfully used as a starting ration for fry as yet because of inability to prepare a particle small enough for the first feed of this size.

All stages of the intensive culture system have been tested for rearing largemouth bass under conditions at the Marion, Alabama, hatchery except for training the postlarvae to take artificial food. Even with this stage, some success was demonstrated in recent years. In 1973, 3 percent of the fry started were reared to a size of 225 per pound (496 per kg) in an eight-foot rearing trough on a diet of zooplankton and OMP. In 1974, 21 percent of 90,000 fry started in a rearing tank were grown to average size of 24 mm during a 21-day feeding period. First food was zooplankton with ground fish being offered 16 days later. Zooplankton was then discontinued after one week and dry trout feed added. At the termination of the trial, the bass were ready for either a moist or dry diet as they were accepting artificial feed readily. In a similar trial in a trough, 34 percent out of 13,500 started learned to feed. Length of the feeding trial was 28 days. Although little research dealing with artificial feeding of fry has been published, Robertson (1972) reported that both large and smallmouth fingerlings were reared on artificial feed in Michigan, and Beeman (1924) fed wild zooplankton to smallmouth fry in concrete tanks rearing them to an "advanced fry" stage.

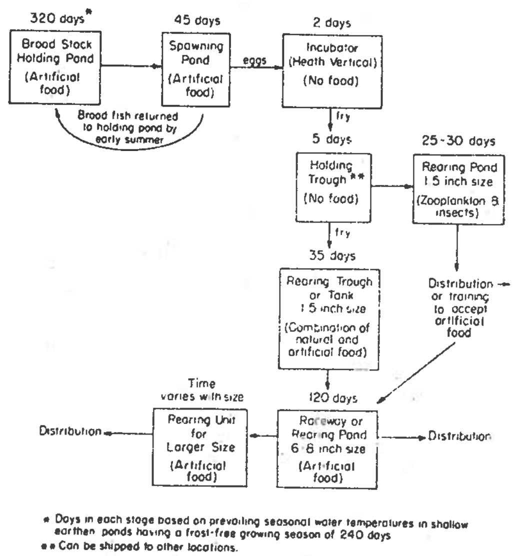


Fig. 3. Intensive system of bass propagation.

In the southern half of the United States, growing 1 to 2 in (25-50 mm) bass fingerlings in ponds on natural food is probably more practical. A period of 3-4 weeks is required and, where suitable rearing ponds are available, use of the fry-transfer system is relatively trouble free. As soon as the young fry reach a cannibalistic size, however, and require large food organisms, high survival, rapid growth, and high fish density dictate a controlled environment and an artificial diet.

The intensive system of culture is described by Snow (1973). The basic system is as follows. Adult fish are maintained between spawning seasons on OMP or other suitable production ration. Ten days before spawning is expected the fish are given a treatment for external parasites (25 ppm formalin as pond treatment) and placed on medicated feed (Snieszko and Bullock 1962). Small earthen ponds 0.1 acre (0.04 ha) in size are equipped with nylon felt spawning mats (Chastain and Snow 1965) and given a preflooding treatment of simazine at a rate of 10 pounds per acre (11.2 kg per ha) (Snow 1967). At spawning time or shortly thereafter, brood fish are placed in freshly filled spawning ponds at a rate of 500 to 2,000 brood fish per acre (1,235-4,940 per ha). A ratio of 1 male to 2 females seems to be about optimum in this system.

Spawning is expected within 72 hours if water temperature is favorable and fish are ripe. Mats bearing eggs are removed daily and replaced with clean ones. Eggs are separated from the mats, cleaned, and placed in a Heath Vertical Incubator for hatching. Collection is scheduled so that the eggs hatch within 24 hours after being placed in the incubator. The second day after hatching the fry are cleaned, their number estimated, and transferred to a holding trough or basket.

Spawning continues for a period of 6-8 weeks. During this time multiple spawning by both males and females is common. An average of 2 spawns per female stocked is considered to be satisfactory. Up to 30,000 eggs per spawn are deposited with an average of 15,000-20,000 being expected (Snow 1971a) from mature brood fish. Best quality eggs are those collected during the first half of the spawning period; the later the spawning, the poorer the hatching percentage. Collections are discontinued when the hatch falls below 30 percent. When the eggs are taken or on enumeration of fry after hatching, disposition of a lot can be scheduled. This involves the preparation of a rearing pond, a rearing tank, or shipment to another hatchery for rearing. At a temperature range of 66-73°F (19-23°C), the yolk-sac absorption stage lasts 5-8 days, which can be lengthened by lowering the water temperature. A holding period of 9-10 days was noted when water temperature was 63-64°F (17-18°C). For largemouth bass it is infeasible to lower the holding temperature below 60°F (15.6°C) as the embryos develop very slowly at this temperature and may die without reaching the feeding stage (Strawn 1961, Hutcheson 1972). Numerical determination can readily be made any time during the yolk-sac absorption stage using a number-volume relationship (McLeod 1972). Also shipment to other locations can be made during this time. When the bass larvae swim up from their resting position they are ready for food and probably should make the transition to outside energy sources within 24 hours (Toetz 1966.

As swimup fry or postlarvae, the young bass can be trained to take artificial food in a rearing tank or can be stocked in earthen rearing ponds for growth to a size of 1.6-2.0 in (40-50 mm) on natural food. If grown on natural food, they can be trained later to accept artificial food but before a cannibalistic size is reached. If the young are reared in a tank-raceway facility, training to accept the artificial ration takes place as soon as the young fish reach a size large enough to swallow the artificial food. This was at the end of the second week of feeding in my 1974 feeding trials.

A period of 7-14 days is needed to change the feeding habits from natural to artificial food. Once the young bass are settled into a feeding routine and are growing rapidly, little trouble is encountered from cannibalism or starvation, the two main causes of loss under conditions of the experimental work carried out at Marion. Water temperatures of 77-86°F (25-30°C) facilitates training to accept artificial food; within this range, digestion is rapid and hunger causes the young fish to accept unnatural food more readily.

Procedures for rearing black basses in ponds on arificial food have been documented in the literature (Langlois 1931; Snow 1969; Snow and Maxwell 1970, Snow 1971b). Although less well studied, raceway culture also appears feasible (Nelson and Bowker 1974).

Although OMP has proved to be the best production ration in the limited study of different rations at Marion, other feeds were used successfully and can be substituted if OMP is unavailable. One of the earliest (Snow 1965) was ground frozen fish. When this diet was fed during the first few days and gradually replaced with pelleted trout feed, 60-70 percent of the fingerlings started were trained to take a mixture of 80 percent dry feed and 20 percent fish. Use of raw fish resulted in thiamine deficiency, which was eliminated by adding ground beef liver at a rate of 10 percent to the diet.

Feed cost can be reduced by using OMP as a training ration and then changing to floating trout feed as soon as the bass are large enough to swallow the smallest available floating pellet. If the fish are fed regularly no trouble is expected from cannibalism. Growth through the seventh year of life has been observed on a diet of OMP with a ½-inch (13 mm) pellet being used for all adult fish. The largest fish in the artificially fed lots were in the 3-4 pound (1.36-1.81 kg) range. Feed intake declined during the second and later years resulting in a slower rate of growth.

The largemouth bass converts artificial

food about as well as other species which have been fed this way. In ponds, we have measured a conversion of 1.3-1.7 rearing 7-inch (17.6 cm) fingerlings on OMP. A change to floating trout feed after growth to 5 inches (12.7 cm) reduced this figure to 1.15-1.25. When the ground frozen fish, liver, and trout feed mixture was used, a conversion of 2.5-3.7 was measured. Beyond a size of 8 inches (21.5 cm) conversion is higher, although small-scale experimentation indicated a figure of 3.1 for OMP and one of 3.5 for dry trout pellets the second growing season (Snow 1969).

Largemouth bass readily made the transition from artificial to natural food in limited experiments reported by Snow (1968). Rapid growth occurred after the transition, indicating that the change took place in a short period of time.

In experiments rearing larger sizes of largemouth bass fingerlings at the Marion, Alabama, National Fish Hatchery, more than 150,000 fish weighing 20,000 pounds (9,070 kg) were reared and distributed for field testing. Handling and hauling bass 6 inches (15.4 cm) and larger poses problems not encountered in distributing smaller fish. To minimize the stress of handling and hauling, we found it desirable to provide terramycin-medicated feed for 7-10 days before harvesting. As our fish were in earthen rearing ponds, provision for a weed-free pond was necessary to permit ready capture of the stock. Feeding was suspended 24 hours before harvest. On the day of removal, 1.5-2.0 feet (45.7-61.0 cm) of water was drained from the pond and a 50-foot (15.2 m) ½-inch (13 mm) mesh nylon drag seine having a 6 x 6-foot (1.83 x 1.83 m) bag was used to reduce the density of fish. The rest of the water was then drained so that the remaining fish could be captured in the pond catch basin. The fish were placed in 100-pound (45.4 kg) burlap feed bags to prevent jumping, 50 fish per bag. A water cushion was maintained when moving the fish from the pond to the holding tank. Sorting was avoided unless necessary. During handling, the fish were kept in water while being counted, sorted, or weighed, and care to avoid skin breaks and abrasions were taken each time the fish were handled.

Conventional distribution equipment was used for the short trips involved in our distribution. The longest trip involved 11 hours and the shortest 5 hours. The heaviest loading was 2 pounds of fish per gallon (240 g per l) of tank capacity. The fish hauled well at this and lower rates although later survival was not determined. During the course of the ten-year investigation of rearing large bass fingerlings, occasional losses of 6-8 inch (15-20 cm) bass were reported after stocking and were attributed to handling injury during harvesting and inventory or to the stress of distribution.

Bass Hatchery Design

The design of a hatchery suitable for culturing bass under extensive conditions is illustrated in Figure 4. The basic production unit is an earthen pond of about 1 acre (0.4 hectare) surface area. A rectangular shape is preferred with a ratio of length to width varying from 2 to 1 to 4 to 1. A minimum depth of 2.5 feet (76 cm) at the shallow end should slope uniformly to one of 5.5-8.0 feet (140-202 cm) at the deep end. Earthen dikes have 12-14 foot (3.67-4.27 m) tops with a slope of 2.5-5.0 to 1 depending on the soil type. An outlet structure (Figure 5), located at the deep end of the pond, is a valuable aid in harvesting the fish crop and dewatering the pond. For use in bass culture, the long axis of the pond should be at right angles to the direction of the prevailing winds. The water supply, from well, spring, or reservoir, is piped into the pond at both the deep and shallow end when possible.

Quality of the water is important. Chemical characteristics desired include an oxygen concentration of 6 ppm or more, carbon dioxide levels of 10 ppm or less, total hardness due to calcium and magnesium 60-180 ppm ad $CaCO_3$, and a pH of 6.5-8.5. Presence of invertebrate life in the water is not undesirable and may even be an asset. Vertebrate life, especially fishes, can pose management problems. The quantity of water should enable a pond to be filled in 72-96 hours. A drainage system should permit emptying the pond of water in 48-72 hours. In bass culture, a shorter draining time will be of value.

Arrangement of the pond units for the

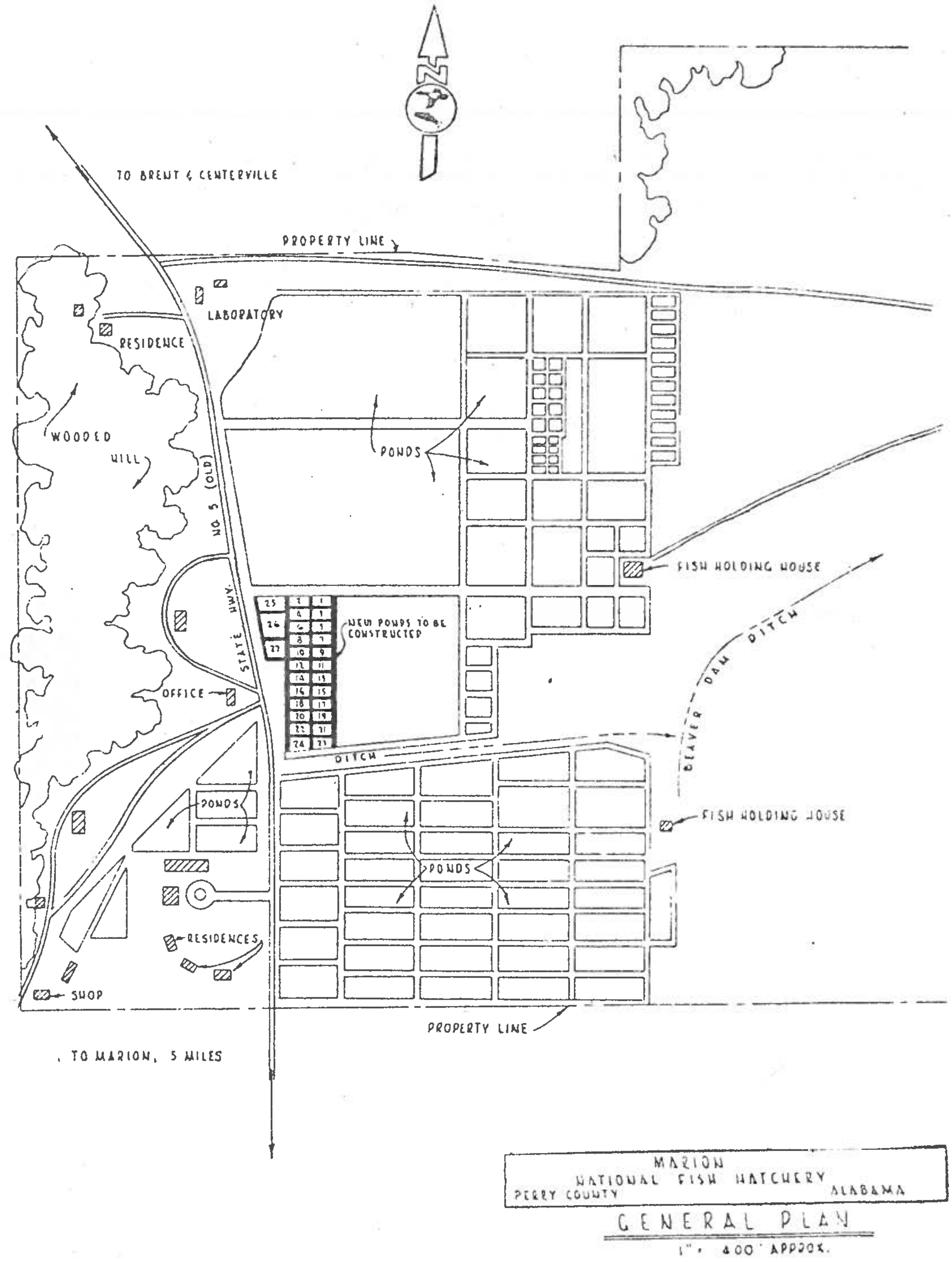


Fig. 4. Diagram of a warm-water hatchery used in the extensive production of largemouth bass fingerlings. Ponds in the lower third of the figure are best adapted to bass propagation.

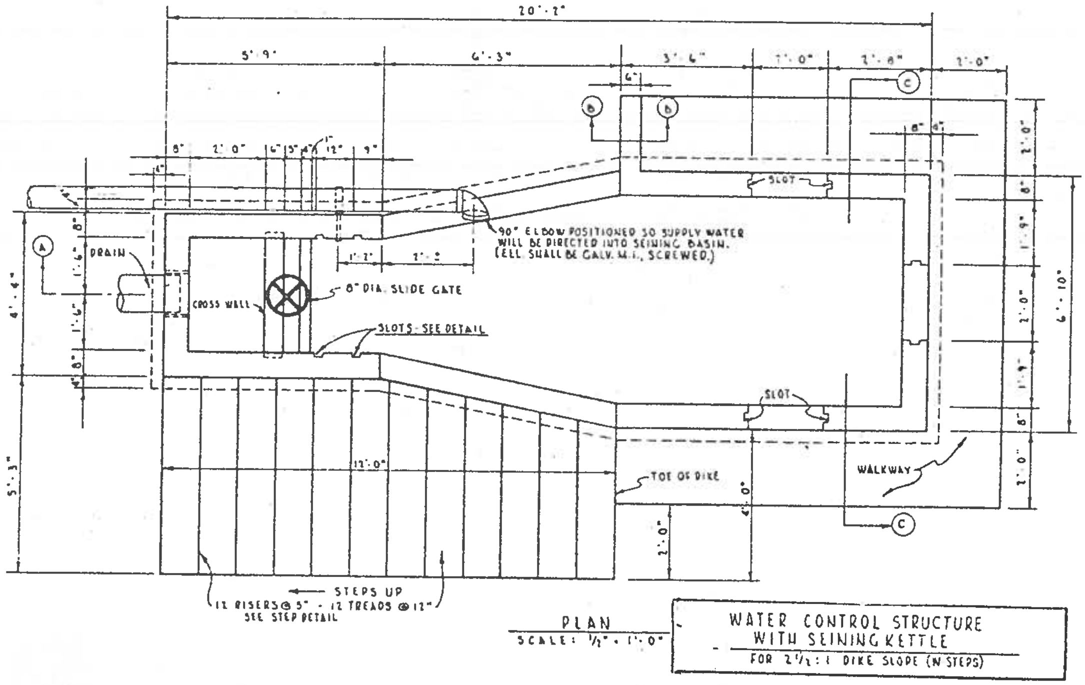


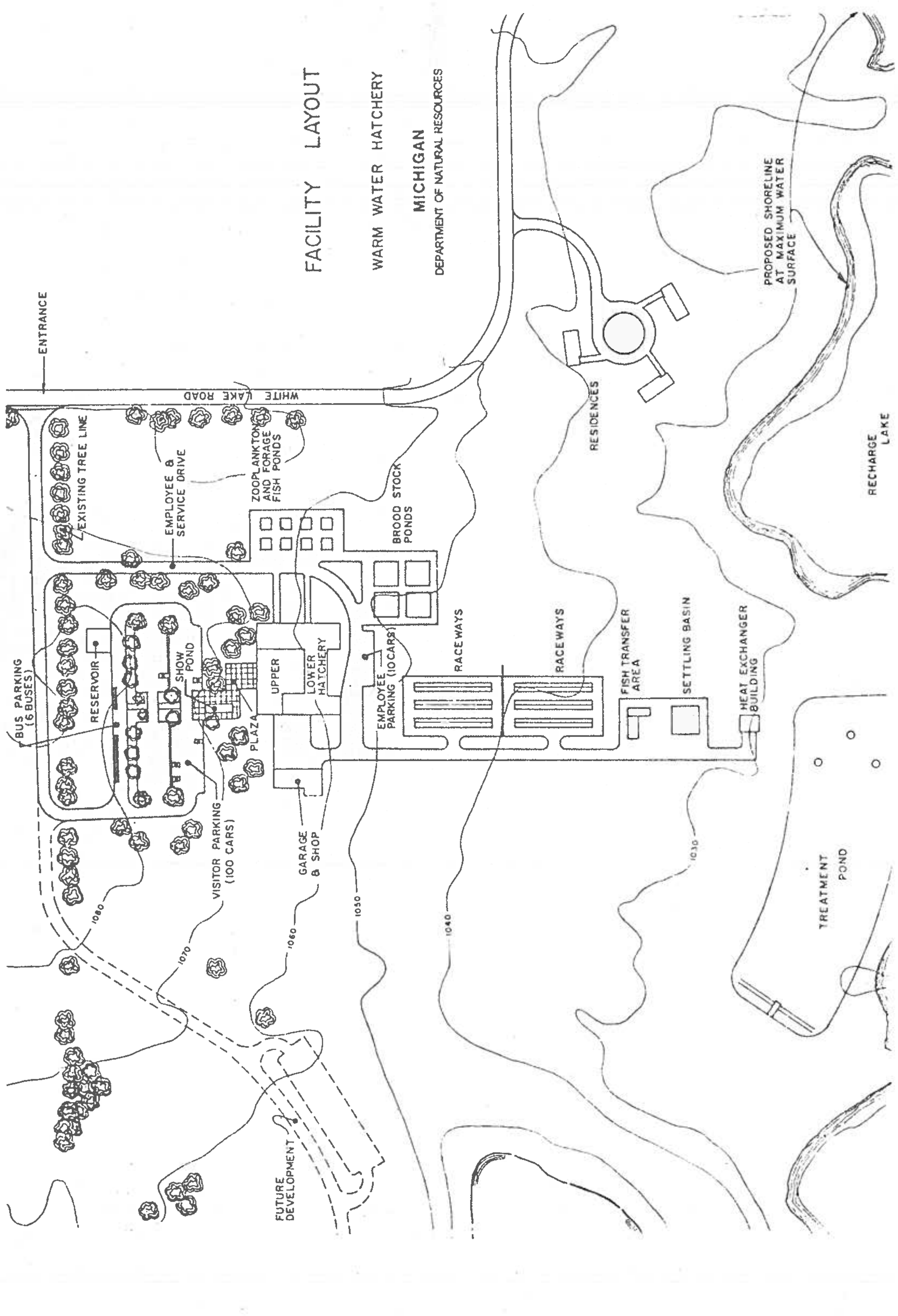
Fig. 5. Construction diagram of a typical water control structure and catch basin (seining kettle). Located in the deep end of the pond, this structure facilitates removal of the small fish with the minimum amount of stress.

most economical construction, considering existing land topography and the later requirements of management, may result in a layout such as Figure 4. The number of units is governed by the size of the production requirement although, as a general rule, production costs per acre decline as the number of production units increase. Production units can be larger or smaller than 1 acre but the larger the unit, the more unmanageable it becomes. As size decreases, the cost of construction and the amount of labor to manage the pond decreases, but not in proportion to the decrease in surface area. Yield per acre is usually higher in small ponds than in larger ones because of the greater ease of applying management techniques, the greater proportion of shoreline to open water area, and other influences.

To facilitate operation of the production units, a service building and a fish holding facility are needed. Up to 100 acres (40.5 ha) can be served by each of these facilities provided that floor space is increased proportionate to production area increase.

A design which appears to have excellent possibilities for the intensive culture of largemouth bass is one presently under consideration for construction in the State of Michigan. Figure 6 illustrates the basic concept of a facility usable for the intensive culture of any warm-water species. Although research has already demostrated that largemouth bass can be intensively cultured through all stages of development, such a hatchery has not yet been built and tested with a production requirement.

Although the systems outlined in this discussion have been specifically developed for culturing the largemouth bass, it is believed that all 6 species of centrarchid basses could be cultured by them with only minor modifications. More is known about the hatchery culture of largemouth and smallmouth species than the others. Fish culturists have demonstrated that either of these species can be successfully produced in the same hatchery at comparable rates of production.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WARM WATER HATCHERY
MICHIGAN
DEPARTMENT OF NATURAL RESOURCES
ENTRANCE
WHITE LAKE ROAD
EXISTING TREE LINE
EMPLOYEE & SERVICE DRIVE
ZOOPLANKTON AND FORAGE FISH PONDS
BROOD STOCK PONDS
RESIDENCES
PROPOSED SHORELINE AT MAXIMUM WATER SURFACE
RECHARGE LAKE
BUS PARKING (6 BUSES)
RESERVOIR
SHOW POND
PLAZA
UPPER
LOWER HATCHERY
EMPLOYEE PARKING (10 CARS)
RACE WAYS
RACEWAYS
FISH TRANSFER AREA
SETTLING BASIN
HEAT EXCHANGER BUILDING
VISITOR PARKING (100 CARS)
GARAGE & SHOP
TREATMENT POND
FUTURE DEVELOPMENT
1080
1070
1060
1050
1040
1030

Fig. 6. (Facing page) Conceptional design of a hatchery being considered by the State of Michigan. It would be used to rear black bass and other warm-water species of game fishes under the intensive system.

Although differences in behavior are readily apparent, modifications in technique can compensate for the differences within the basic concepts illustrated.

As an example, the largemouth bass is attracted to fibrous nylon felt material and by choice will deposit eggs on a site equipped with the material. Smallmouth bass, on the other hand, are attracted to gravel spawning sites. T.H. Inslee (personal communication) designed a spawning box containing gravel which could function in smallmouth bass spawning just as the nylon felt spawning mat does in largemouth spawning. Doubtless, development of mass propagation methods for Suwannee, (*M. notius*) Guadalupe (*M. treculi*), or redeye bass would disclose the need to make a similar modification to the basic systems. In conjunction with a taxonomic study, Ramsey and Smitherman (1972) reared small numbers of smallmouth bass, northern and southern spotted bass, Suwannee bass, and redeye bass with the fry transfer system. Although their work did not require mass production of the young of these species, the system functioned to produce the test animals needed. Such experience suggests that only minor modifications to the outlined systems would enable the bass culturist successfully to mass-produce any of the centrarchid basses.

Application of existing knowledge of black bass culture by competent, well-trained fish culturists, who are provided with an adequately designed hatchery plant, should enable fishery management biologists responsible for maintaining and improving fishing for black basses to have an adequate stocking tool for use where needed. In this way the potential of a most valuable group of sport fishes can be more fully realized.

Summary

Hatchery propagation of the centrarchid basses has been concerned mainly with the largemouth and to a lesser extent with the smallmouth bass. The limited experience reported for the other 5 species suggests that the methods used in largemouth and smallmouth culture are adaptable to these as well.

The most practical method of mass producing bass fingerlings up to a total length of 4 inches (10 cm) is to stock small bass of an appropriate size into prepared rearing ponds at a density governed by the size being reared.

Fry can be produced in a spawning pond under the care of the parent fish or obtained by use of a specialized technique controlled by the fish culturist.

Beyond a size of 4 inches, artificial feeding in either a pond or raceway environment seems more feasible for production of large numbers of fish. Although efficiency of food supplies declines beyond a size of 8 inches (20.3 cm), it is technically possible to rear largemouth bass to adult size if a need exists.

Growth and maintenance of hatchery brood stock is commonly done with a forage fish ration, probably is the best approach for most hatcheries. However, there are advantages to using an artificial feed which could make this procedure worthwhile in many situations.

Additional research appears to be needed in the intensive culture of largemouth bass to increase success in feeding the smallest size fry artificially. Study of methods for rearing adult bass in large numbers on artificial food also is needed. If a need for mass culturing the species of basses other than largemouth and smallmouth develops, it will be necessary to verify the assumption that the present systems are effective in culturing them.

With these exceptions, it appears that existing hatchery technology has the capability to meet any reasonable demand for black bass of any size, provided that facilities, funds, and manpower are made available.

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