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Early Development of the Yellow Perch, *Perca flavescens*[1]

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ABSTRACT

In this study, eggs and larvae of the yellow perch, *Perca flavescens*, were reared in the laboratory from fertilization to postlarval stages. Fish were sampled at intervals and changes in morphology, anatomy, and general characteristics were described and illustrated. Larvae raised in outdoor hatchery ponds were brought into the laboratory for comparison and to complete developmental descriptions up to the young stages.

Eggs of the yellow perch are extruded in adhesive strands, and in the Chesapeake Bay these strands are found in the shallow, upper reaches of many major tributaries in March and April. Within the first few minutes after fertilization, the eggs "water harden" and expand. Eggs fertilized in this study reached a mean diameter of 2.26 mm; the mean diameter of the yolk was 1.28 mm and the oil droplet was 0.64 mm.

Changes in the egg from fertilization through hatching do not deviate widely from known fish embryology. The most distinctive character of the egg is its thick, elastic case containing minute radial striations. Illustrations of important embryological stages allow easy understanding of the progression in development. Hatching occurs in 27 days at temperatures from 8.5–12.0C. This incubation period is long when compared to the hatching time of other common estuarine fish.

In this study prolarvae were 5.5–6.0 mm T.L. at hatching. Early prolarvae have an undifferentiated continuous finfold, pigmented eyes, and a series of 15–20 pigment spots along the ventral surface of the tail. The mouth is fully developed at the end of the prolarval stage and although vestiges of yolk remain, active feeding is initiated.

In postlarvae, pigmentation increases over the body, the head becomes more flattened, and a few teeth protrude from the maxillary. Fin formation starts at approximately 11 mm T.L. with differentiation of the basal portion of the caudal fin. The sequence of fin development is: pectorals (within the egg); caudal; anal, second dorsal, some spines of the first dorsal; pelvics; and, finally, the remaining first dorsal spines.

Yellow perch are transformed from the larval stages at approximately 13 mm T.L. when all fins are formed. However, ray elements within the fins are incomplete until the fish reach 21 to 27 mm T.L. At this size the first soft ray of the anal transforms into a second spine, changing the formula from I, 8–9 to II, 7–8. The formation of distinct body bands begins when the young are about 20 mm T.L. and this pigmentation continues until the vertical bands become a distinct species characteristic. Morphometry, and meristics assume adult proportion near the end of the young stage. Morphometric changes in head length, body depth, and snout-to-vent length are compared. The ossification of a young specimen 17.0 mm T.L., which was cleared and stained with Alizarin red-S, is illustrated.

Habits of cultured fish are briefly mentioned. There was an almost complete lack of feeding success in yellow perch larval stages.

Comparison is made with other work on the yellow perch in the U.S.; excepting hatching size, head contours, and some pigmentation, little difference is noted. Comparison of this study with work from Europe encourages the theory that *Perca flavescens* and *Perca fluviatilis* may be conspecific.

Introduction

This study was begun in 1955 as part of a program to secure vital information on the early stages of some common Chesapeake Bay fishes. The yellow perch, while usually considered a freshwater species, commonly frequents brackish and tidal freshwater areas of the Bay. It concentrates in tidal and non-tidal freshwater areas of the rivers

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and tributaries to spawn in late February and early March (Muncy, 1962), and spawning fish have been found in all the major river systems (Muncy, 1959). Despite the availability of spawn and the commercial importance of the species (14th, according to Anderson and Power, 1957), information on developmental stages is extremely limited.

Ryder (1887:518, 560 and pl. VIII) described a single egg, with emphasis on the structure of the unusual and distinctive egg case or membrane, with its thick, elastic, radiated structure. No details of embryonic development were presented and the accompanying plate showed the yolk without the large oil globule that is always present.

In her study of the early life history of some Lake Erie fishes, Fish (1932:362–4) discussed and illustrated most of the larval stages of yellow perch from recently hatched prolarva of 5.6 mm T. L. to a young of 20.5 mm T. L. However, she presented no information on the eggs, and the discussion of the larvae was somewhat superficial. More recently, Norden (1961) presented more detailed and complete morphometric and meristic data, and discussed development of ossification centers in his work on small yellow perch prolarvae 5.5 mm T. L. to young of 21 mm T. L. He also compared yellow perch larvae with larvae of the pikeperch, *Stizostedion vitreum*, and described characters which separate the species in their early stages.

Acknowledgments

I wish to express gratitude to my late husband, Dr. Romeo J. Mansueti, for his conception of this problem, for his untiring labor in the field collection and laboratory culture of the fish involved, and for his contagious enthusiasm which provided the impetus necessary to bring this work to a successful conclusion. Thanks are also due to Mrs. E. B. Ritchie (formerly on the staff at CBL) for measurements of young; to Mrs. J. Koushnareff for Russian reference translation; to W. L. Dovel (of CBL) for recent collections, and to C. D. Meyers and J. D. Hardy (of CBL) for critical review and constructive comments.

Methods and Materials

Egg Source

All eggs examined and all stages of young hatched in the field, in the laboratory, or in the several ponds mentioned, were initially collected from yellow perch spawning grounds in the upper Severn River, Maryland. The grounds are located near Millersville, Maryland, at the juncture of freshwater Severn Run with the tidal Severn River. Muncy (1959:8) found the greatest quantity of spawn at this point although large amounts have also been observed as far as 2 miles up Severn Run. Accessibility of spawning fish and natural spawn caused the selection of this general site for a production hatchery run by the State of Maryland from 1926 until 1955.

Sources of Developmental Stages

On 4 April 1954 a small sample of eggs in various stages of development were collected and preserved. These were later used for comparison with laboratory-reared eggs. The principal series of developing stages examined in this study was sampled from a group of eggs collected and fertilized in the field on 10 March 1955. According to records for 1955 (Muncy, 1962:148), yellow perch first appeared on the Severn spawning grounds on 22 February (water temperature, 3.9–6.7 C); first spawning was observed on 5 March (water temperature, 6.7 C); and peak spawning was observed on 14–18 March (water temperature, 5.6–7.2 C).

After 5½ hours of closely regulated sampling of fertile eggs for early embryological development, all eggs were taken to the Chesapeake Biological Laboratory facilities at Solomons, Maryland. Sufficient numbers of eggs and larvae were removed from this group in succeeding days to allow preservation, description and illustration but all larvae died by 10 April, just prior to complete yolk absorption.

In order to compare the success and growth of laboratory-developed eggs and larvae with those from a more natural environment, a group of eggs collected on the same date, 10 March 1955, was put in a hatchery box and floated in Shad Pond, about 4 miles north of Solomons, Maryland.

This ¼-acre impoundment had been developed in 1950 for experiments in shad fingerling production and had been highly successful as a clupeoid rearing pond. On 7 April, prolarvae hatched in Shad Pond were taken to the laboratory where culture and daily sampling were conducted. Pond larvae were somewhat larger than laboratory larvae and survived to early postlarval stages.

Since attempts to rear yellow perch through transformation were unsuccessful in 1955, culture was again attempted in Spring 1956 to complete morphometric and meristic data on transforming larvae and to obtain possible data on anal fin ray changes. Approximately 130 prolarvae were taken to the laboratory at Solomons on 27 March and 12 April 1956. These prolarvae (5 to 6 mm T. L.) were obtained from hatching eggs collected on the spawning grounds.

On 6 and 17 May 1956 juveniles were secured from investigators conducting yellow perch growth studies in one-acre impoundments near Elkton, Maryland. Seven juveniles 19 to 38 mm T. L. were collected from the ponds on 6 May but all died in transport to the laboratory. These specimens were preserved for morphometric and meristic study. From 3 to 4 thousand juveniles collected from the same ponds on 17 May were taken to the laboratory at Solomons where observations were made on the survivors until 1 June.

Further samples of young from 13 to 30 mm T. L. were obtained from those preserved by Walker (1956:1–8) during his growth studies at the Elkton ponds.

More recently, specimens from 8.7 to 14.2 mm T. L. were taken from material preserved by CBL staff during a survey of ichthyofauna in the upper Patuxent River, Maryland.

Fertilization of Eggs

Fertilization followed standard hatchery procedures as described by Meehan (1913: 208–10), Titcomb (1910:204–5) and many others. From ripe females, eggs were extruded into shallow glass containers partially filled with river water. Milt from ripe males was then expressed into the containers and the water was gently agitated.

Field Hatching

Hatching boxes, commonly in use by the Maryland Conservation Department for production hatching until 1955, were utilized to produce developmental stages at Shad Pond (previously designated). These buoyant wooden boxes, approximately 2 feet square and 18 inches deep, had fine hardware cloth stretched tightly over the bottom. Fertilized eggs were placed in the bottom of the boxes and the boxes were anchored in the pond. Stirring and examination for dead eggs was conducted but no food was introduced.

Laboratory Culture

Containers:—Size and type of container depended upon sample size and developmental stage of the specimens. Smaller groups and fertilized eggs were held in 350 ml finger bowls; developing larvae were held in 1500 ml culture dishes; and juveniles from Elkton ponds were held in 5 and 50-gallon aquaria.

Temperature and aeration:—No temperature control was attempted. In general, water temperatures varied between 10 and 22 C and it is suspected that this range prevails in the shallow waters of the natural spawning grounds. However, precise measurements of these thermal characteristics are lacking.

Aeration was effected by use of small aquaria compressors and air stones. Bubbled air was made available in all cultures to maintain normal oxygen and to reduce microstratification.

Feeding:—Due to the difficulty of obtaining large quantities of natural food, 1955 larval cultures were fed with brine shrimp (*Artemia salina*) nauplii and eggs. Although stomach examination of live larvae indicated heavy feeding on eggs (40 in one individual), no nauplii or other food was observed in the digestive system. 1956 cultures of prolarvae were fed "green water" from fresh pools near the laboratory. This water contained vast numbers of volvox, rotifers, paramecia and other ciliates, green colonial flagellates, and a few large midge larvae. Stomachs of live, transparent larvae were examined 2 or 3 times daily but no real

estimate of the quantity of food ingested was possible.

Juvenile yellow perch in culture were initially fed commercial hatchery foods, dried shrimp and fish "manna," but plankton gathered from the shores of the Patuxent estuary proved more acceptable. The plankton consisted largely of amphipods, isopods and grass shrimp.

Specimen sampling:—Although gross observations of eggs and larvae were made on living specimens, all detailed examination, illustration and measurement was made with specimens preserved in 4% formalin. All samples were taken at random from containers and cultures. Adhesion of eggs to the container was not a problem as in white perch eggs (Mansueti 1964:105, 108) and samples were easily removed.

Sampling was chronological in order to observe as many developmental stages as possible. This plan had been successfully utilized in 1955 and 1956 on striped bass eggs (Mansueti, 1958), hickory shad eggs (Mansueti, 1962) and white perch eggs (Mansueti, 1964). In the 1954 series of eggs and prolarvae, 20 to 50 specimens were removed from cultures as follows: (1) before fertilization, (2) immediately after fertilization, (3) every 3 to 5 minutes in the half-hour succeeding fertilization, (4) every 10 minutes for the following hour, (5) approximately once each 30 minutes for the next 3 hours, (6) twice each day for 5 days, (7) once each day until all larvae were dead.

Examination and Measurement

Two young yellow perch from the Elkton ponds were stained and cleared using Alizarin red-S and potassium chloride solution in a method modified from Hollister (1934:90–100) and Davis and Gore (1947: 12-15).

All specimens were measured in the preserved state with a stereoscopic microscope and an ocular micrometer and all fish lengths in this paper are cited in mm total length (T. L.). The outer and innermost margins of the egg capsule and the yolk were measured along their midline as they lay, excluding attachment bulges. These measurements proved quite variable due to the conglomerate nature of the egg masses. Oil droplets were measured across their longest axis. Terminology, measurements and meristic counts of the transforming young and larvae follow the rules of Hubbs (1943:260) and Hubbs and Lagler (1958: 19–28) with these modifications:

Snout-to-vent length—distance from the most anterior projection of the snout, to the most posterior aspect of the anal opening.

Preanal myotome count—number of myotomes from a line drawn vertically at the posterior margin of the anus. Myotomes are counted along the mid-lateral line forward from this line.

Postanal myotome count—number of myotomes posterior to line as drawn for preanal count.

Head length in prolarvae--distance from the most anterior projection of the snout to posterior margin of the otolith. In the smallest larvae the operculum is not well-developed and snout-to-operculum length is not truly representative.

Results and Discussion

Description of the Egg Strand

Yellow perch egg strands are distinctive and there is little possibility of confusing them with any other species of fish. In nature, eggs are extruded in long "accordion-folded" strands about 1½ inches thick. These strands are slightly heavier than water and float in the current until they become entangled in debris and fallen branches in the shallow water (two or three feet) in which the parent fish spawn (Muncy, 1962:145 and Harrington, 1947: 199). Although Worth (1892:332) described the character of the egg strands in some detail, he did not describe the embryonic development. He described the eggs as light gray in color. Our specimens showed, however, that they are actually a clear amber color and quite a brilliant mass as extruded from the females. Fig. 1 is a copy of Worth's drawing (1892:Pl. LXI), illustrating the accordion-folds of the strand and the hollow center. Worth also described numerous breaks in the wall of the egg strand and

Fig. 1.– Egg strand of yellow perch, *Perca flavescens*. From Worth, 1892:pl. LXI, Fig. 2.

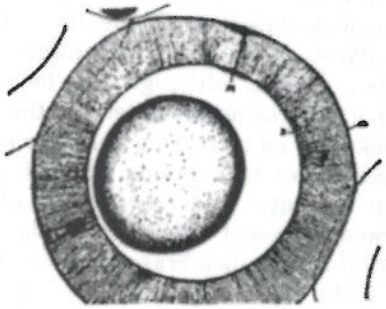


Fig. 2.—Cross-section of egg of yellow perch, *Perca flavescens*. a. adhesive layer; g. the thick elastic middle layer with radial striations; m. micropyle; z. zona radiata. From Ryder, 1887:pl. VIII, Fig. 35.

hypothesized that these facilitate flow of fresh water in and around the eggs. When water-hardened, these strands attain lengths far exceeding that of the parent fish (Worth, 1892:333; Fish, 1932:362).

Description of the Egg

Individual eggs have a thick egg membrane or case consisting of an outer adhesive layer, a wide middle area composed of fine radially arranged fibers or striae and an innermost layer considered the zona radiata by Ryder (1887:518). Ryder described these egg case layers, with an accompanying drawing (Fig. 2), as follows: "The egg membrane is exceedingly complex, and consists apparently of an internal layer, z, which is homologous with the zona radiata of other types. Immediately overlying the zona there is a very thick, highly elastic layer, g, which is traversed radially by fibers or canals which widen perceptibly at the outer surface. A third thin investment, a, overlies this thick elastic layer, and it consists of the hardened mucine-like material which agglutinates the eggs together. At one point on the surface of the egg there is a wider pore canal which leads to the micropyle m." Note that Ryder omitted the single large oil droplet which is always present. There is also some question as to whether his designation of the zona radiata is correct. Fig. 3 indicates the strength and elasticity of this egg membrane which is retained until just before hatching when it becomes weak and loses its elasticity. Before water-hardening, fertilized eggs had a mean diameter of 1.76 mm (range 1.62 to 2.09 mm). Within the first few minutes of fertilization the egg membrane swells and after hardening loses its adhesive qualities. The mean diameter of the egg cases, at fertilization, was 2.26 mm

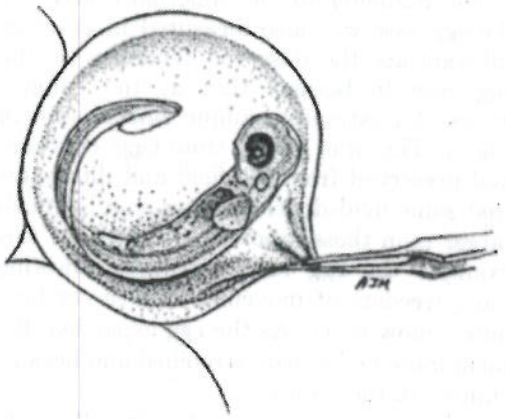


Fig. 3.—Large egg of yellow perch, *Perca flavescens*, taken from a field collection and containing an embryo ready to hatch. The tough, elastic egg case is being stretched with forceps but will return to original shape when released. Diameter of egg is approximately 4.5 mm.

(range 1.87 to 2.81 mm), which deviates from other available data. A sample of eggs from a field collection taken 4 April 1954 averaged approximately 4.5 mm (Fig. 4). Ryder cites the diameter of the yellow perch egg as 3.5 mm and the yolk as 1.75 mm. Other samples taken by Muncy in 1958 averaged 1.7 mm, outside diameter. These discrepancies cannot be resolved with the data available, but a wide variation might be expected where extreme expansion occurs in the process of water-hardening. To strengthen this hypothesis, Mansueti (1948: 7) indicated the water-hardened egg diameter of the striped bass, *Roccus saxatilis*, as 3.40 mm (range 2.40–3.90 mm); however, 1956 CBL collections of positively identified striped bass eggs have been shown to have a diameter as low as 1.8 mm. The membranes of these smaller striped bass eggs had not expanded while yolk and oil droplet diameters were normal size. Similar variations might then be expected in the yellow perch, indicating the unreliability of "average egg diameter" in identification.

Mean diameter of the yolk before the egg was water-hardened was 1.28 mm (range 1.16 to 1.58 mm) and the oil droplet measured .64 mm (range .49 to .92 mm). These measurements were made only during the first few days since they became inaccurate as the embryo developed and was nourished by the yolk.

The diameter of the innermost layer of the egg case was also measured in order to substantiate the observed tendency of the egg case to become thin as the embryo grows. An extreme example can be seen in Fig. 4. This was drawn from eggs collected and preserved from the field and illustrates that some field-developed eggs can be much larger than those laboratory reared. In this example the egg case was thin, allowing more freedom of movement for the embryonic yellow perch. As the egg expanded, the membrane necessarily stretched and became thinner in the process.

Figures 5 and 6 graphically illustrate these changes in membrane, yolk and oil droplet diameters. Fig. 5 shows the diameters of laboratory-reared eggs from fertilization to hatching, a period of 27 days. A

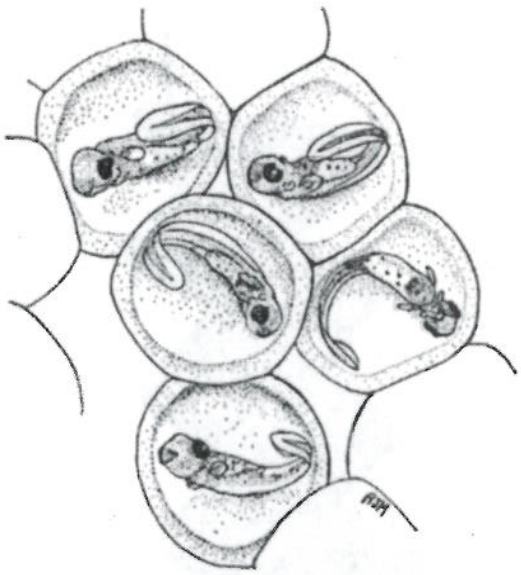
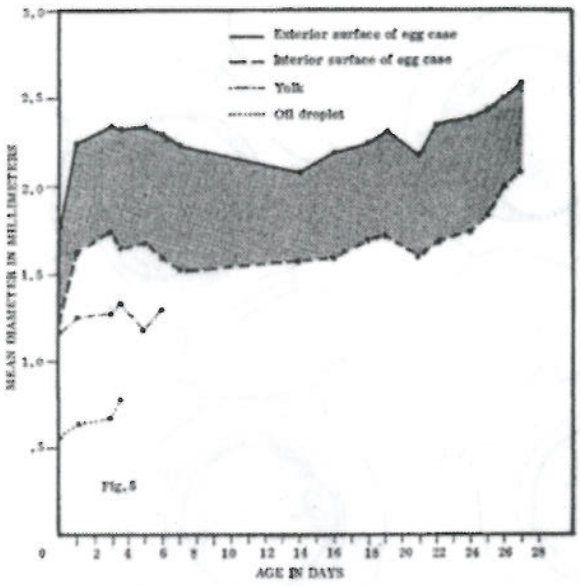


Fig. 4.--Cluster of yellow perch, *Perca flavescens*, eggs containing embryos just prior to hatching. These are from a field collection with egg diameters of approximately 4.5 mm and relatively thin egg cases.

complete series of the yolk and oil droplet measurements are unavailable for reasons stated above. After initial expansion, eggs fluctuated in size, although the tendency was for a decreasing diameter for the first two weeks and an increasing diameter in the two weeks prior to hatching. Shaded areas between the outer and inner layers of the membrane represent thickness of the case showing that the membrane occupies from ⅓ to ¼ the entire egg diameter. Fig. 6 illustrates changes in the egg during water-hardening the first half-hour after fertilization. The greatest amount of expansion occurs in the first three minutes after fertilization; both the yolk and the oil droplet also expand, but to a lesser degree.

Development

A brief description is presented to clarify the series of figures, although these are largely self-explanatory. Stages of cell division between the two-cell stage and late blastula are missing since they occurred when no samples were taken, but all other stages are represented.



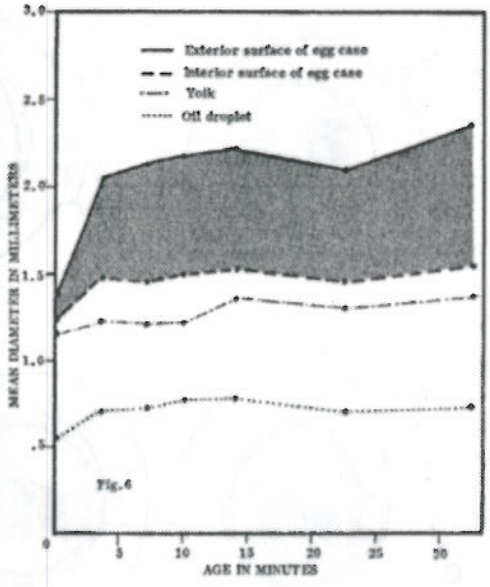


Fig. 5.—Measurements of the mean diameters of the exterior and interior surface of the egg case, the yolk and the oil droplet of the eggs of the yellow perch, *Perca flavescens*, on progressive days from fertilization to hatching at age 27 days. These measurements are from preserved specimens taken at Severn Run, Maryland, on March 10, 1955. The shaded area represents the relative thickness of the egg case in relation to the entire egg.

Fig. 6.—Measurements of the mean diameters of the exterior and interior surface of the egg case, the yolk, and the oil droplet of the eggs of the yellow perch, *Perca flavescens*, during the first half hour after fertilization. Water hardening involving the sudden swelling of the egg membrane occurs during the first few minutes after fertilization. The shaded area represents the relative thickness of the egg case in relation to the entire egg.

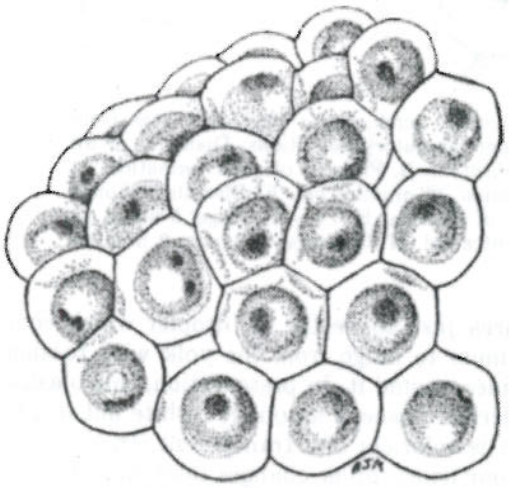


Fig. 7.—Cluster of unfertilized eggs of the yellow perch, *Perca flavescens*, showing a mass typical of both unfertilized and fertilized eggs. Drawn from samples collected in the field, not raised in the laboratory.

Unfertilized egg:—(Fig. 7) These eggs are from samples taken in the field April 1954. Eggs were clustered in typical fashion, but the diameter was small (approx. 1.5 mm) since the hardening process was not complete. The oil droplet is an indistinct, dark-yellow mass and the yolk a pearly-white mass which fills the perivitelline space. Egg membranes or cases of unfertilized eggs had the same elastic qualities as fertile eggs.

Fertilization and blastodisk formation:—(Figs. 8 A through 8 E) At fertilization, the yolk almost completely fills the egg cavity or perivitelline space (this can also be seen in Fig. 5) and the light, amber-colored yolk is firm but unevenly rounded. The deeper amber oil droplet, on the other hand, is smoothly rounded and imbedded within the yolk material. Radial striations within the egg case can be perceived with a monocular microscope at low power, particularly when the angle of light is varied. The

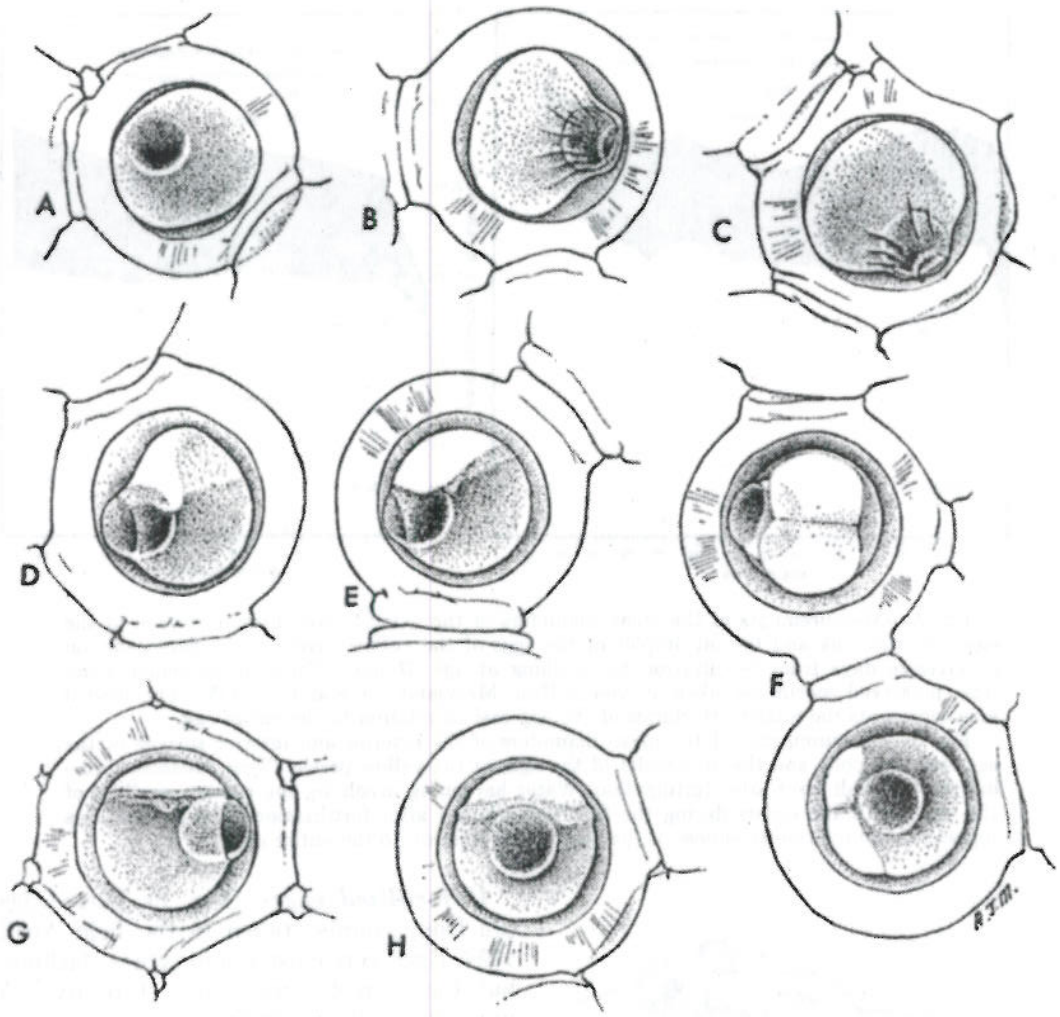


Fig. 8.—Early stages in the development of yellow perch, *Perca flavescens*, eggs from specimens collected 10 May 1955 and raised under laboratory conditions. Diameter of all eggs is approximately 2 mm. A. Egg just at fertilization. B. Prior to blastula formation, 14 minutes old. C. Blastula, 32 minutes old. D. Blastula, 47 minutes old. E. Blastula, 4 hours, 24 minutes old. Blastocoel seen on under surface of blastula. F. Two-cell stage, 5 hours, 14 minutes old. G. Early gastrula, 21 hours, 25 minutes old. H. Gastrula, 29 hours, 9 minutes old.

periphery of the egg capsule has a minutely pebbled texture. There is a shift of the yolk and oil droplet 14 minutes after fertilization (Fig. 8B), although no blastodermal differentiation is apparent. The oil droplet bulges to one side, pulling yolk material along with it so that distinct tension lines appear on the yolk, and there is frequently an indentation of the yolk in the area immediately over the oil droplet. Within half an hour, germinal tissue has thickened in the area just above the oil droplet which continues to bulge from the yolk with tension lines around it. In preservation, this blastodermal tissue is an opaque white but in life it is colorless and transparent. In the next four hours, other changes take place in this germinal tissue, even before the first cleavage occurs. As seen in Figures 8D and 8E, the concentration of blastodermal tissue just above the oil droplet develops into a peak which subsides in time. As the peak

subsides, the yolk becomes more evenly rounded. In Figure 8D the beginnings of a blastocoel on the inner and under surface of the blastodermal tissue can be seen.

Two-cell stage:—(Fig. 8F; age, 5 hours) First cleavage occurs in a little over 5 hours, resulting in a clear-cut two-cell stage.

Blastula:—(Fig. 8G; age, 21 hours) The blastoderm has passed through the multicellular stages beyond the morula and is late blastula, with a peripheral germ ring. The blastocoel can be seen on the under side of the blastula.

Gastrula:—(Fig. 8H; age, 29 hours) The thick germ ring has grown one-third of the way around the yolk, followed by blastodermal tissue. The attachment areas or adhesion discs of the membrane are reduced in their thickness. As the egg develops, reduction in the thickness of these areas continues, so that by hatching time, no disc is present and the eggs adhere to each other. There are suspicions that this disc formation is an artificial condition, resulting from unknown factors in laboratory cultures. Unfertilized eggs and the embryonic samples collected from the field did not have these discs.

Early embryonic stages:—(Fig. 9A to 9D; ages, 3 to 6 days) The embryo develops slightly off center of the yolk, with the head proximal to the oil droplet. The clear amber color of the yolk and the white or creamy opaque germ tissue was a relatively constant character in preserved specimens and at this stage no melanophores were evident. By the sixth day the tip of the tail is freed from the yolk and the yolk has become elongate along an axis perpendicular to the embryo.

Late embryonic stages:—(Fig. 9E and 9G; ages, 11 to 24 days) Between day 6 and 11, development of the embryo continues at a relatively slow rate. Pectoral buds, auditory vesicles, caudal finfolds, a greater number of body melanophores and a sprinkling of small stellate melanophores over the yolk close to the embryo have all appeared.

Pigmentation in the posterior and anterior quadrant of the eyes is apparent on the 14th and 16th day (Fig. 9F). The pectorals are well developed by this time, myotomes are nearly complete, melanophores cover most of the yolk, and the vent is visible at the junction of tail and yolk. At 14 days, internal organ development of the yellow perch embryo is well advanced over that in late prolarvae of other species such as striped bass, white perch and herrings. The mouth is wide and gaping and primitive gill structures have formed; eyes are densely black and show clearly through the egg case; the internal structure of the auditory vesicle and the heart are plainly visible; and the tail is extended in a curve well over the head.

As mentioned, in large eggs, the thin walls and large perivitelline space provide the embryo with greater space to extend itself and the tail is not curled back over the head (see Fig. 4). Embryos in these larger eggs had unusual bubbles near the tip of the caudal finfold which have not been illustrated or described in available literature. A few days before hatching the egg case began to soften and take on a more ragged appearance.

Hatching:—Yellow perch observed during this study hatched from the 25th to the 27th day and ranged 5.5 to 6.0 mm in length. The only observable difference between the earliest and the last hatched was the slightly greater absorption of yolk in later fish. This long incubation period is in direct contrast to that in many common estuarine fishes. The white perch, *Roccus americanus*, for example, hatches in 44 to 50 hours at field temperatures of about 18 C (Mansueti, 1964). Other estuarine fish hatched in the laboratory had similarly short incubation periods including: the striped bass which hatched in 48 hours at temperatures of 16.7 to 17.2 C (Mansueti, 1958), and the hickory shad which hatched in 48 to 67 hours at temperatures of 18.3 to 21.1 C (Mansueti, 1962). Although the yellow perch were developed in the laboratory at a lower temperature range (8.5 to 12 C) this does not account for the discrepancy in hatching time.

The thick elastic egg capsule provides protection not only from abrasion and bumping, but also from predators since it is extremely difficult to pierce the membrane. In nature, the entanglement of egg masses in

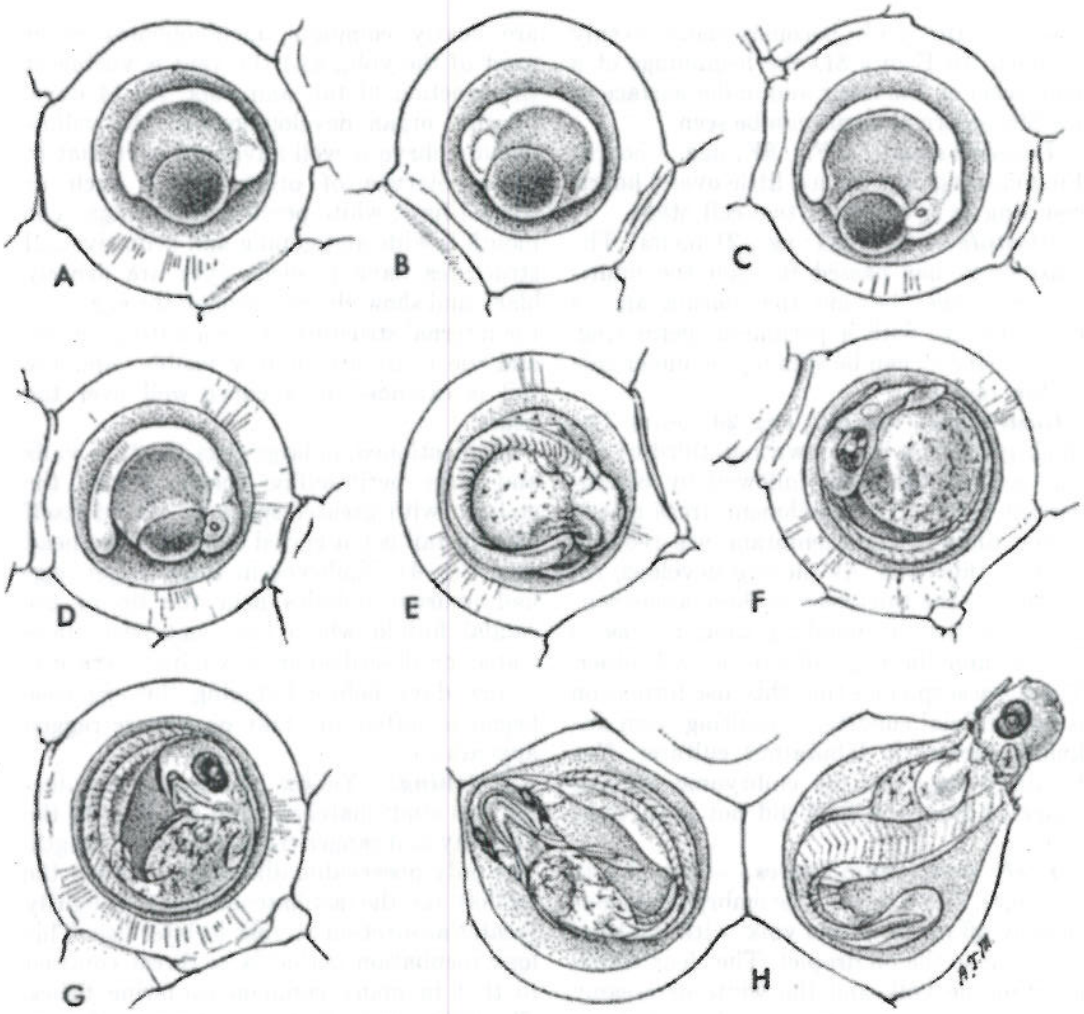


Fig. 9.—Late stages in the development of yellow perch, *Perca flavescens*, eggs from specimens collected 10 May 1955 and raised under laboratory conditions. Diameter of eggs is approximately 2 mm. A–D. Early embryos. A. 69 hours, 54 minutes old. B. 77 hours old. C. 115 hours old, and D. Tail-free, 144 hours old. E. Formation of myotomes and pectoral buds, 11 days old. F. Pigmentation of eye and development of pectoral fins, 16 days old. G. Embryo just prior to hatching, mouth formed and yolk half absorbed, 24 days old. H. Hatching yellow perch, 27 days old.

stream debris also provides some measure of protection. These protective devices probably do not encourage positive natural selection for shorter incubation time as may exist in the more vulnerable striped bass and hickory shad egg.

Length of incubation, total length and stage of development of a hatching prolarva are extremely variable. In discussing the embryology of the closely related European yellow perch, *Perca fluviatilis*, Konstantinov (1957:184) states:

"Descriptions of post-embryonic development in fish usually begin from the time of hatching. Comparison of material from different waters, however, shows that at hatching, yellow perch larvae are far from similar in either length or stage of development. According to our data, yellow perch larvae from the Volga delta in 1949 are somewhat smaller at hatching (4.0–4.95 mm), whereas those from Deep Lake (Emilianov's material for 1937) were slightly more than 6 mm (6.1–6.2 mm) long. Diesler indicates a

length of 6.7 mm for deep-lake yellow perch. Pyersonal'naya (1946), on the basis of data collected from the literature, observes a large variation in size of yellow perch hatchlings—from 4.07 to 6.6 mm. One of the factors responsible for such variability seems to be temperature; in warm water, hatching occurs at a smaller size. For yellow perch, the minimum length of hatching larvae only slightly exceeds 4 mm.

The newly hatched larvae of this size in no way differ from the embryo within its membranes."

Konstantinov divided newly hatched yellow perch prolarvae into the following stages: Stage I (3.7–4.7 mm), Stage II (4.7–6.0 mm), Stage III (6.0–7.0 mm) and Stage IV (7.0–9.0 mm). These specimens were raised under hatchery conditions at temperatures around 20 C. Drawings of a Stage I prolarvae show about the same stage of development as the embryo of *Perca flavescens* (Fig. 9F) of 16 days and Stage II is equivalent to a stage in *Perca flavescens* between 16 and 22 days (Fig. 9F and Fig. 9G). Hatching prolarvae of *Perca flavescens* most closely resemble the length and structure of Stage III *Perca fluviatilis*, 7 to 18 days old. Konstantinov (1957) mentions other studies in which Stage I and Stage II were attained prior to hatching.

Mouth, gills and pectorals of *Perca flavescens* embryos are well developed by the 20th day, and the embryo would probably survive if hatched at this time. If hatched as early as the 16th day, the embryo would be no less advanced than the youngest and smallest of Konstantinov's Stage I, in which the mouth has not yet formed.

Prolarvae:—In newly hatched *Perca flavescens*, the head was separate from the yolk which contained a single large, deep-amber oil droplet anteriorly (Fig. 10A). Occasionally the oil droplet contained a small bubble of unknown purpose or origin. At this stage, the dorsal finfold is continuous with a lunate caudal portion and the pectorals contain some ray elements. The heart is clearly seen in the pericardial sac anterior to the oil droplet and can be observed pulsating in the living animal. There are indications of gill formation. The eye, as within the egg, is darkly pigmented. More black pigmentation is present in the form of large stellate chromatophores scattered over the ventral yolk sac and intestine, and as a series of 15 to 20 spots along the mid-ventral line of the tail. As yolk absorption begins (Fig. 10B), the mouth is more fully developed and seems functional, although no actual ingestion was observed. Three distinct gill arches can be counted, the auditory vesicle bulges prominently behind the eyes, and the urinary duct appears just posterior to the gut. Continued development of the head region and nearly complete absorption of the yolk (along with the oil droplet) occurs at approximately 7.0 mm (Fig. 10C). The operculum can be observed behind the pre-opercular and four gill arches can be distinguished.

Fig. 10D illustrates a prolarvae (7.2 mm, 2 days older than the larvae at 10 C) in which the head has started to elongate and flatten and to take on the characteristic shape of the yellow perch postlarvae. Vestiges of yolk remain. The cleithrum and opercular flap are obvious. Pigmentation has increased, particularly over the head, auditory vesicle, and developing air-bladder; a few melanophores are scattered over the body. Lines of ossification are noticeable along the notocord.

Postlarvae:—In Fig. 10E (2 days older than the larvae of 10D) the yolk has been absorbed and the larvae appear more elongate. Black pigmentation has increased over the head and jaws, most frequently as expanded stellate melanophores. Teeth are evident, and ossification of the notocord continues.

Prolarvae and postlarvae described so far (up to 7 mm) were from two sources: (1) larvae hatched and reared entirely in the laboratory and (2) larvae which were reared in a small outdoor pond and were then transported to the laboratory for further development. Differences were found between these groups which emphasize the importance of environment on the total length attained by the larvae at hatching. Fig. 11 illustrates that the laboratory larvae were significantly shorter than the field-reared larvae. From this, one would expect an over-

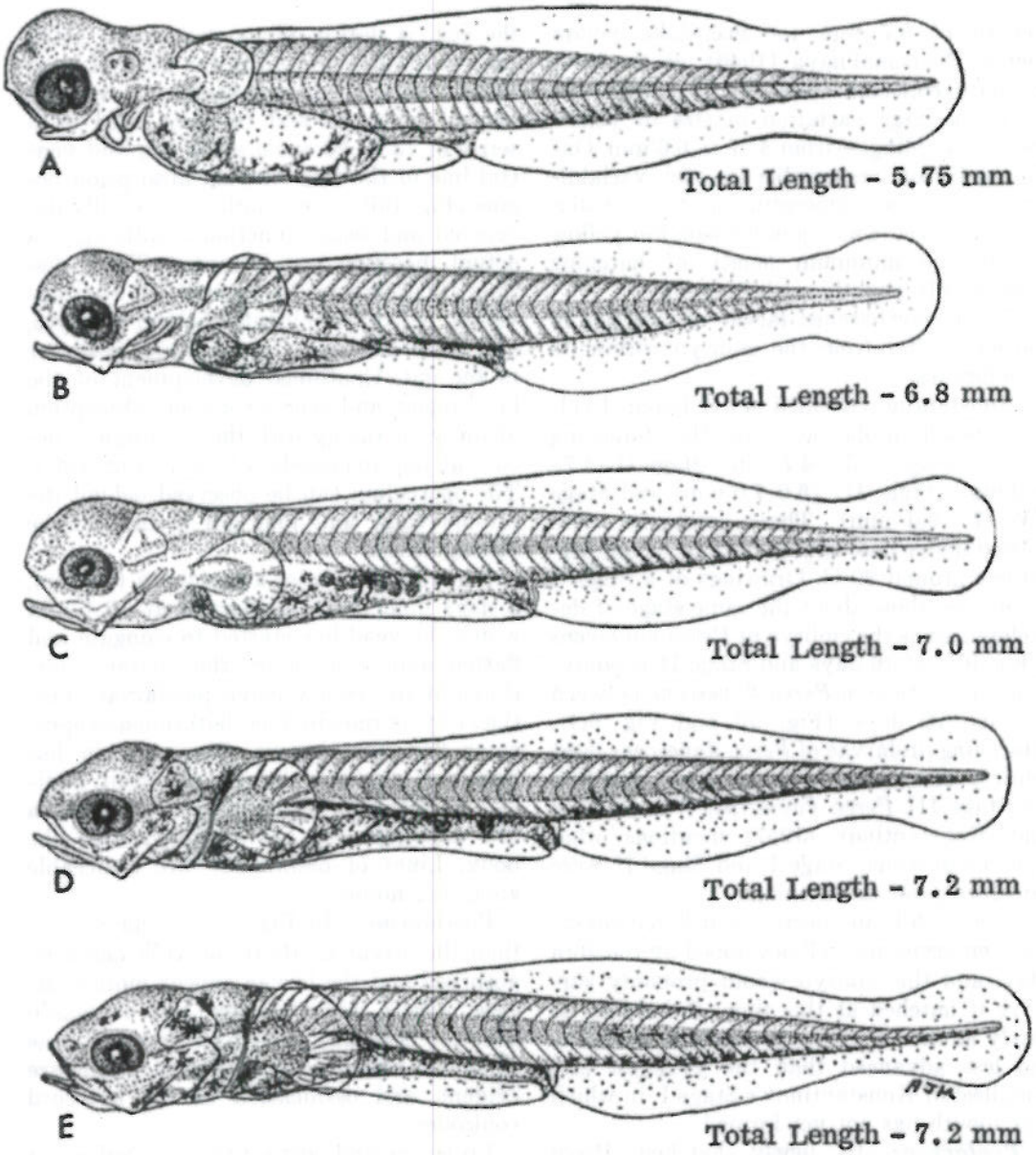


Fig. 10.—Larval stages of the yellow perch, *Perca flavescens*, hatched from eggs taken at Severn Run, Maryland, on 10 May 1955. A. Prolarvae, recently hatched, 5.75 mm T.L. B. Prolarvae, 6.8 mm T.L. C. Prolarvae with only traces of oil droplet and yolk; brine shrimp eggs can be seen within the gut, 7.0 mm T.L. D. Postlarvae, 7.2 mm T.L. E. Postlarvae, 7.2 mm T.L.

all retardation in morphometry, organ maturity, meristics and pigmentation; however, although many structures were at a similar stage of maturity, the laboratory fish were more developed in that the head contours were noticeably flattened and more yolk had been absorbed. There is also some indication that the growth rate levels off when the yolk is absorbed. From these observations, development of the organs and structures may continue even though the fish are growing at a slower rate. Note the differences of the four larvae illustrated (Figs. 10B–10E), between the short interval

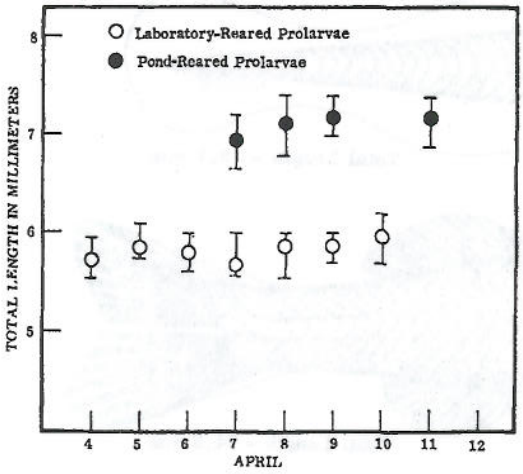


Fig. 11.—Measurements of laboratory and pond-reared prolarvae compared during the period in April when pond-reared larvae were returned to the laboratory. The circles represent the mean total length and the bars, the range of size in each group.

of 6.8 and 7.2 mm. All laboratory-reared larvae died at this stage. Remaining post-larvae and young illustrated are from routine field collections in the Patuxent River by CBL staff.

In the postlarvae illustrated in Fig. 12A, fins are undifferentiated except that development of the basal area of the caudal fin is apparent. The head remains essentially the same shape with a few small teeth protruding from the maxillary. Pigment along the mid-ventral line of the tail is regular; the air bladder is dark; and there are a few stellate spots over the gut, which has just begun to fold back (eventually the gut makes a complete turn). The operculum has not yet covered the gill arches.

Transforming fish between 8.7 mm and 14.2 mm (Fig. 12B) were not available to this study. Norden (1961:284) and Fish (1932:363) have both illustrated transforming postlarvae which show development occurring over this gap.

Young:—At 14 mm larvae may be considered young, although they are not yet fully transformed. Fins are still incomplete; the anal has one spine; rays of the pelvic fin are not clearly differentiated; 7 of the 14 first dorsal spines have emerged from the back, some of which are partly embedded in the flesh; and a small preanal finfold persists. The air bladder is extremely large and the soot-black capping of the air bladder is seen clearly when silhouetted by a light source. The gut has nearly completed its loop. Pre-opercular spines are few in number but proportionately larger than in adult fish. Teeth can now be seen along both jaws. The urostyle has turned dorsally. The internal skeletal structure is evident through the body muscles. At this stage the head has begun to assume the adult contour.

The body is sparsely pigmented until the fish is approximately 20 mm (Fig. 12C) when definite bandings appear along the back of the scaleless body. Pre-opercular spines have increased in number, but decreased in proportion. The young fish is identifiable as a yellow perch, because of its characteristic percoid shape and the presence of six or seven vertical bands along the body. The juvenile yellow perch cannot be confused with white perch or striped bass young even though size, shape, fin conformation and banding are similar because a higher myotome number is obvious. Yellow perch have 36 to 40 myotomes and striped bass and white perch have approximately 25.

As the juvenile yellow perch grows, lateral bandings darken and by the time the fish reaches a length of 28 mm (Fig. 13A), the bands contrast sharply with the lighter body. The dark spot over the brain and a pigment concentration along the edge of the spinous dorsal remain distinct. Scales may now be discerned along the back and over the caudal peduncle. Rays of the caudal, but not the soft dorsal or anal fin, have now become bifurcate. A juvenile of 49 mm (Fig. 13B) achieves complete scalation and fin formation; however, the eye remains proportionately large at this length and pigmentation is sparse. Changes in meristics and pigmentation continue but the configuration is essentially adult.

Morphometric and Meristic Changes

Obvious body changes which take place from prolarvae to juvenile stages can be seen in the series of illustrations. Table 1 contains morphometric and meristic data

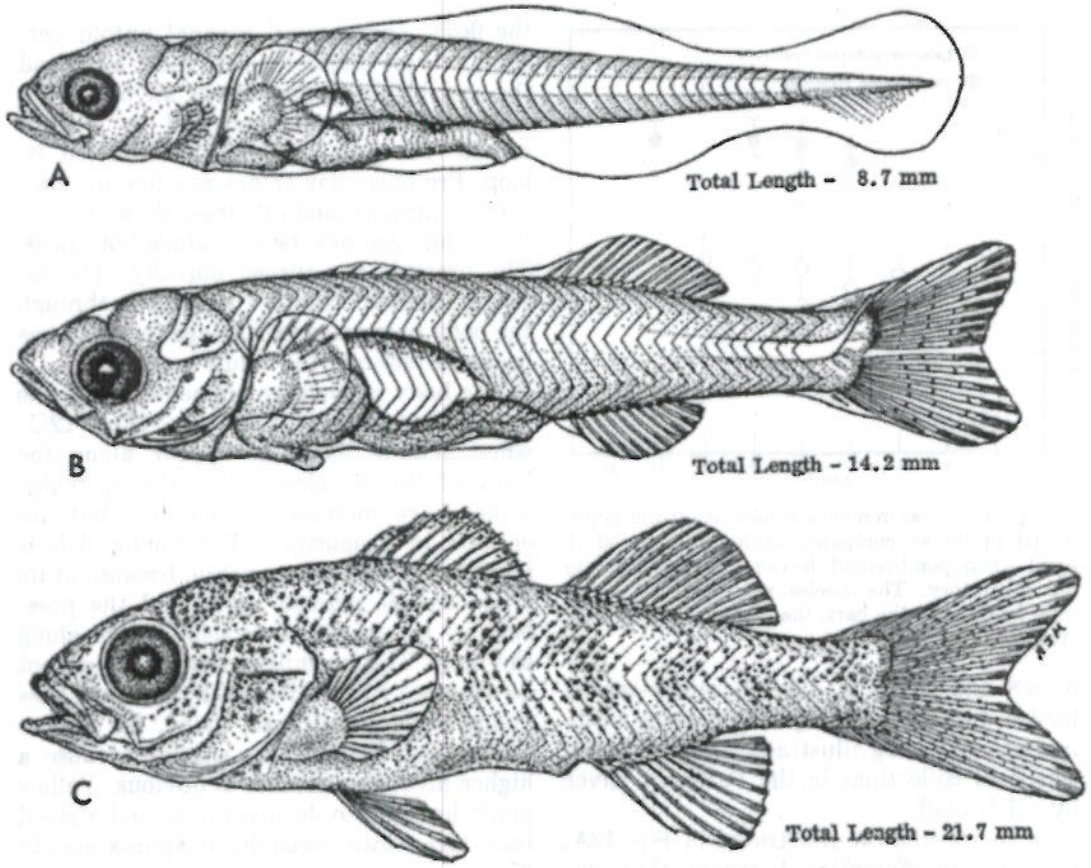


Fig. 12.—A. Late postlarvae of yellow perch, *Perca flavescens*, just before transformation. Caudal fin has started to differentiate. 8.7 mm T.L. B. Young *Perca flavescens* with all fins present but fin counts incomplete. Large air bladder is capped with sooty-colored pigmentation. 14.2 mm T.L. C. Almost fully-transformed young with beginning of pigmented bands along back, 21.7 mm T.L.

on fish from 5.5 mm to 29 mm. Progressive changes in the snout-to-vent measurements, body depth, and length of the head deserve special mention. In Fig. 14 these measurements are plotted against the independent variable of total length.

Snout to vent length:—Rate of increase of snout-to-vent length is relatively constant in relation to total length (Fig. 14A), although there is a slight change when the anus shifts posteriorly. In prolarvae the distance from the tip of the snout to the anus is 52% of the total body length. The proportion of these distances increases to 53 and 54% in postlarvae and young and to 56% in juveniles.

Body depth:—Body depth relates to total body length as a slight sigmoid curve seen in Fig. 14B. This clearly reflects changes that are illustrated and described in larvae during developmental stages. Yolk present in the prolarvae of 5 to 7 mm protrudes ventrally and increases the body-depth proportion; as yolk is absorbed, postlarvae between 7 and 10 mm become slender and the body depth-length proportion decreases. When the fish transform, their bodies become thicker and deeper, again increasing the proportions. Stabilization of this proportion does not occur until the juvenile stage is reached.

Head length:—In very young larvae, when the head and gill are still forming, the head length is approximately 17% of body length. As larvae mature, there is a rapid increase in this percentage until the

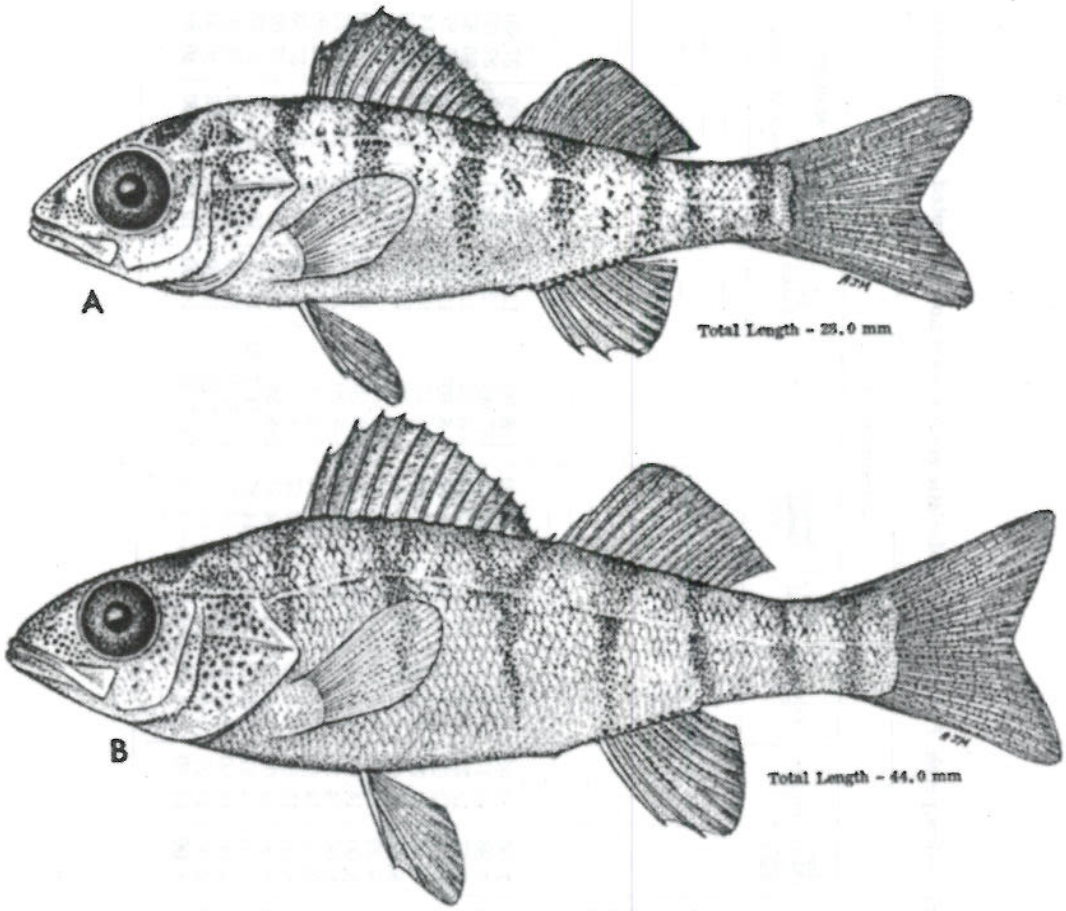


Fig. 13.—Juvenile yellow perch, *Perca flavescens*. A. 28.0 mm T.L. B. 44.0 mm T.L.

larvae have reached 20 mm, when the percentage levels off at approximately 27%. This change can be seen in Fig. 14D. When head length is plotted directly against total length (Fig. 14C), only the barest hint of a curve results; in contrast to the proportional length, rate of growth of the head remains constant throughout all early development stages.

Eyes:—The eyes are large in proportion to the body and remain so throughout the juvenile stages studied. Attainment of the eye proportion characteristic of the adult is beyond the scope of this work.

Meristics:—Myotome number, in the yellow perch, varies between 35 and 40; 36 or 37 were counted most frequently. This is less than the number of vertebrae (39 and 40) counted in the two specimens cleared for structural investigation. Preanal myotome number was most commonly 19 (range 18 to 21), and the postanal, 18 (range 16 to 19). Although there is a slight shift of the vent to the posterior in the young, there seems to be no similar shift in preanal and postanal myotome number.

Branchiostegal rays, gill arches, and fin elements were not counted in smaller larvae due to inherent inaccuracies caused by size.

Development of the fins was usual with the exception of the appearance of the anals. The attainment of a full fin complement and fin development can be seen in the figures and descriptions of individual stages.

Pectoral fins develop while the embryo is still within the egg. The caudal fin appears next with the basal elements evident at 8.0 mm. The soft dorsal and the anal form and then a few first dorsal spines emerge. By 14 mm the last fin, the pelvic, appears. At

TABLE 1.—Measurements and meristic counts of larval and young yellow perch, *Perca flavescens*. Meristic counts were not attempted on the smallest specimens.

Size Intervals (T.L.) in mm	No. of fish	Average Measurements in Millimeters						Meristic Counts									
		Total Length (T.L.)	Standard Length (S.L.)	Head Length	Eye Length	Greatest Depth	Snout to Vent	Branchiostegal Rays	Pectoral Fin	Pelvic Fin	First Dorsal Fin	Second Dorsal Fin	Anal Fin	Gill Rakers	Caudal Fin	Myotomes	
																Pre-anal	Tota
5.5–6.0	46	5.78	5.58	1.04	0.33	0.88	3.00	—	—	—	—	—	—	—	—	—	—
6.0–6.5	7	6.00	5.80	1.09	0.33	0.81	3.16	—	—	—	—	—	—	—	—	—	—
6.5–7.0	17	6.86	6.62	1.19	0.35	1.11	3.58	—	—	—	—	—	—	—	—	—	—
7.0–7.5	67	7.17	6.90	1.28	0.36	1.09	3.77	—	—	—	—	—	—	—	—	—	—
7.5–8.0	1	7.50	7.25	1.25	0.35	1.15	4.00	—	—	—	—	—	—	—	—	—	—
8.0–9.0	1	8.70	8.40	1.70	0.51	1.10	4.15	—	—	—	—	—	—	—	—	—	—
9.0–10.0	2	9.45	9.05	1.80	0.60	1.30	4.88	—	—	—	—	—	—	—	—	—	—
10.0–11.0	1	10.40	10.10	2.10	0.60	1.60	5.70	—	—	—	—	—	—	—	—	—	—
11.0–12.0	1	11.60	10.90	2.70	0.74	1.40	6.40	—	—	—	—	—	—	—	—	—	—
12.0–13.0	1	12.60	11.10	2.80	0.83	2.0	6.80	—	—	—	—	—	—	—	—	—	—
13.0–14.0	1	13.41	10.06	3.32	1.07	2.44	7.27	7.00	12.00	I–4.00	7.00	I–14.00	I–8.00	12.00	18.00	20.00	37.00
14.0–15.0	7	14.73	11.86	3.62	1.14	2.67	7.92	7.86	11.17	I–3.71	8.71	I–13.43	I–7.86	12.33	18.71	19.43	37.00
15.0–16.0	6	15.39	12.11	3.84	1.17	2.79	8.17	7.67	13.33	I–4.67	10.17	I–14.33	I–8.33	12.20	18.83	19.17	36.83
16.0–17.0	8	16.54	13.37	4.14	1.37	2.99	8.63	7.87	13.00	I–4.62	10.50	I–14.50	I–8.50	12.00	19.00	19.75	36.87
17.0–18.0	7	17.29	13.78	4.47	1.42	3.20	8.96	7.86	13.00	I–4.86	11.00	I–14.29	I–8.43	12.80	19.00	20.00	37.14
18.0–19.0	5	18.29	14.45	4.66	1.46	3.47	9.43	8.00	13.40	I–5.00	10.80	I–15.00	I–8.40	12.50	19.00	19.40	37.20
19.0–20.0	4	19.67	15.56	4.93	1.47	3.89	10.22	8.00	14.25	I–5.00	11.50	I–14.75	I–8.75	—	19.00	20.00	37.75
20.0–21.0	1	20.63	16.93	5.71	1.51	4.15	11.80	8.00	14.00	I–5.00	12.00	I–14.00	I–8.00	13.00	19.00	20.00	37.00
21.0–22.0	4	21.43	16.92	5.70	1.63	4.51	11.45	8.00	14.25	I–5.00	11.00	I–14.50	I–8.50	11.33	19.00	19.75	36.75
22.0–23.0	9	22.59	17.93	6.10	1.69	4.66	12.44	8.00	14.00	I–5.00	11.44	I–14.33	I–8.11	12.50	19.00	19.44	36.56
23.0–24.0	3	23.74	18.77	6.37	1.71	4.94	12.95	8.00	13.67	I–5.00	11.67	I–14.67	I–8.33	12.50	19.00	19.67	37.33
24.0–25.0	13	24.55	19.53	6.79	1.76	5.13	13.55	8.00	14.08	I–5.00	11.38	I–14.31	I–8.38	12.33	19.00	19.85	37.07
25.0–26.0	8	25.61	20.39	6.96	1.79	5.29	14.18	8.00	14.37	I–5.00	12.25	I–14.87	I, II–7.62	13.25	18.87	19.75	36.75
26.0–27.0	10	26.52	21.02	7.15	1.82	5.63	14.71	8.00	14.60	I–5.00	12.00	I–14.70	II–7.20	13.43	18.80	19.60	36.50
27.0–28.0	6	27.49	22.01	7.50	1.86	5.83	15.48	8.00	14.67	I–5.00	11.83	I–15.33	II–7.33	13.00	19.00	19.33	36.33
28.0–29.0	5	28.47	22.72	7.73	1.85	5.96	15.84	8.00	14.40	I–5.00	11.80	I–14.60	II–7.20	14.00	19.00	20.00	36.80
29.0–30.0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

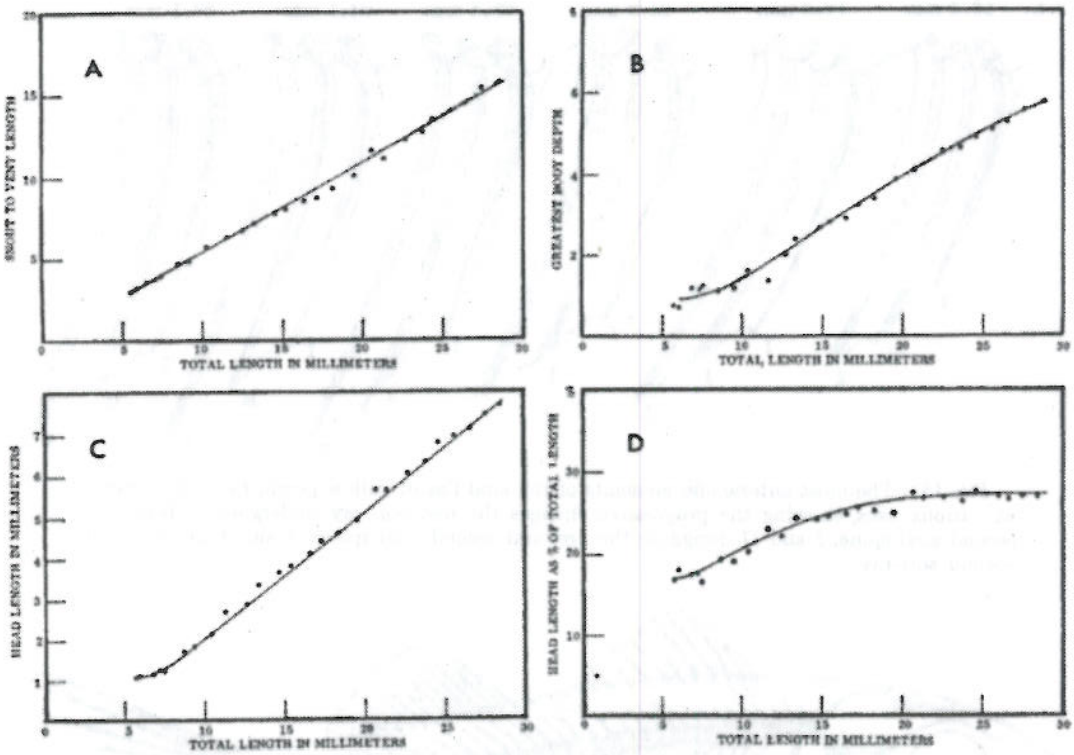


Fig. 14.—Changes in some body structures in relation to total length in the larvae and young of the yellow perch, *Perca flavescens*. A. Snout-to-vent length in relation to total length; B. Greatest body depth in relation to total lengh; C. Head length in relation to total length; and D. Head length as percent of total length. All measurements are in millimeters and the curves are fitted by eye.

this point 7 first dorsal spines have emerged, but the full complement is not attained until the fish are between 25 and 30 mm. The second anal spine also appears when the fish are approximately 25 mm in length and the fish then possess the complete adult number. Changes in the number of anal fin rays are of particular interest as a taxonomic tool.

Anal fin development:—In this group, fish up to 25 mm (Table 1) possessed one spine and an average of 7.86 to 8.75 soft rays. When figures on fish with one spine were examined, 62.1% had 6 soft rays, 31.4% 9 rays, 4% 10 rays, and .8% 5, 6, and 7 rays. During the time the larvae increased in total length from 25 to 26 mm, the first soft ray changed into a spine. Beyond this length, the anal fin formula was consistently II, 7 or 8; a single fish, 26.24 mm, had a count of II, 6. Reduction of the number of soft rays by one and the increase of the spines by one is due to transformation of the first ray element into a spine. The smallest fish observed with two spines was 25.36 mm; however, in a separate group of fish collected for anal fin study, 2 spines were observed in fish 21 mm and a single spine was observed in fish of 27 mm. Thus, the length at which the first ray transforms to the second spine occurs over a size range from 21–27 mm. This phenomenon of transformation has been discussed in great detail in striped bass (Mansueti, 1958B), in white perch (Mansueti, 1964:123), and in the pirate perch (Mansueti, 1963:547–551) and there is no need to recapitulate here. Fig. 15 illustrates progressive changes in the anal fins of fishes measuring 16.5 mm to 27.1 mm. The tip of the future spine can first be seen embedded in the actinotrichia (fringe tip) of the fish measuring 22.8 mm. A fish of 23.1 mm shows an even more distinct spinous tip but actinotrichia and one ray joint are present and it is considered a soft ray. Loss of joints

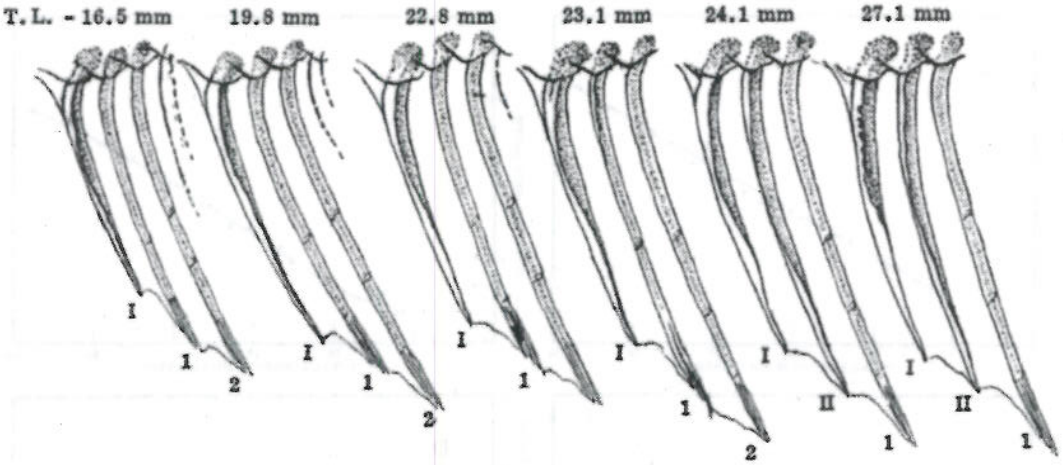


Fig. 15.—The most anterior fin elements of the anal fins of yellow perch, *Perca flavescens*, at various sizes, showing the progressive changes the first soft-ray undergoes to form the second anal spine. I and II designate the first and second anal spines, 1 and 2 the first and second soft-ray.

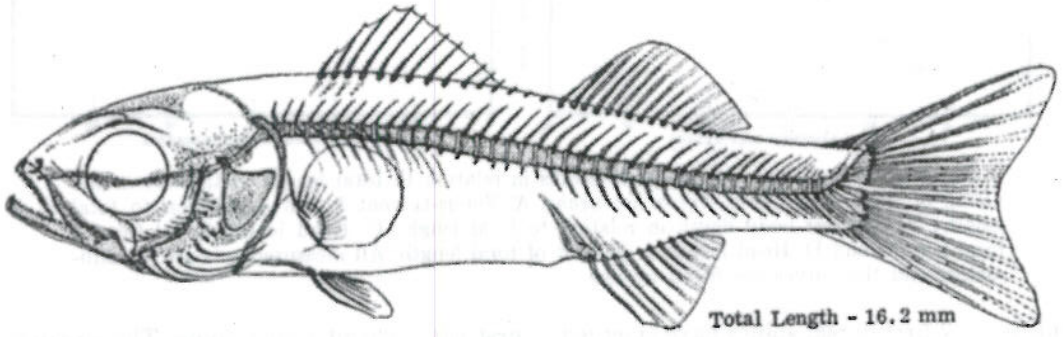


Fig. 16.—Ossification in a yellow perch, *Perca flavescens*, of 16.2 mm T.L. Drawn from a stained and cleared specimen.

and actinotrichia and thickening of the calcified anterior edge change this soft ray into the second spine evident in a fish 24.1 mm. Finally, trabeculations appear in the anterior basal portion of the first spine as seen in the fin of the 27.1 mm fish.

Ossification:—Two specimens 16.2 mm and 23.3 mm were cleared and stained, but only the smaller fish is illustrated (Fig. 16) since little ossification takes place between the two intervals. Several of the most posterior spines of the first dorsal fin are present and ossified on this fish and have taken up the Alizarin red; however, they are still embedded in the flesh and, consequently, they would not be included in counts if the fish were uncleared. Neither the most distal one-third of the rays nor most of the basal pterygials have ossified. The vertebral column is completely bony except for the tip of the urostyle and the most posterior neural spines. The most anterior ribs have taken up the dye, but the majority are still unossified. Extent of ossification of the head, mouth and gill structures is shown shaded in the drawing. The teeth are obvious in both jaws.

Habits of live larvae in aquaria.- -Both 1955 and 1956 efforts to feed postlarvae were unsuccessful except for transformed fish 14 mm and larger. In 1956, young larvae (5 to 6 mm) were fed "green water" which consisted of roughly 20% green colonial flagellates. Since the body wall and intestine of

the larvae are transparent, anything ingested can be seen within the living gut under a microscope. On the seventh day all the yellow perch died, excepting three which were found to contain a small number of these flagellates, and these three lasted two more days. Within a week a second group of prolarvae hatched and for the first four days were dependent on yolk material. They remained active as the yolk was absorbed, although apparently not feeding, and lived for 18 days.

The only apparent feeding success during this study was achieved with young fish (13 and 30 mm in length) from the Elkton Ponds. These fish were fed green water with dried shrimp and baby fish "manna" added and remained in good condition for the 14 days of observation.

Comparisons with other published descriptions:—This contribution seems to agree, with a few minor exceptions, with the descriptions of the larval stages of yellow perch from two other principal references, Fish (1932:362–365) and Norden (1961: 282–287). The extent and density of pigmentation in the yellow perch in postlarval and young stages appear to differ in fish from different areas. Norden states: "Pigment characters are difficult to describe in the postlarvae because those collected from Lake Michigan are much darker than those of equal size collected from Lake Erie. There is little difference in chromatophore development in the prolarvae from these two lakes but a size range from 12.0 to 18.0 mm. The Lake Michigan postlarvae are readily separable from the Lake Erie postlarvae."

The largest yellow perch young studied by Fish, (20.5 mm), had a few scattered chromotophores dorsally with no indication of bandings. In contrast, a young of 21 mm from the Severn River has distinct dark bandings (Fig. 12C).

Norden's prolarvae ranged from 5.5 to 7.0 mm, Fish's ranged from 5.6 to approximately 8.0 mm, and the Maryland samples ranged from 5.75 to 7.2 mm in length. There is also close agreement in hatching size and in the length at which the yolk is completely absorbed. Other points of agreement between all three studies are: (1) initial differentiation of fins occurs in the ventral portion of the caudal fin at 8.00 to 9.00 mm; (2) rays appear in dorsal and anal fins at 12 to 13 mm; and (3) pigmentation over the yolk and along the ventral line of the tail in prolarvae is identical. However, there is a difference in the shape of the heads of the larvae; the head contour of the Maryland fish is more flattened and elongate than that of the Lake Erie fish.

When comparing extent of development of hatching prolarvae of *Perca flavescens* with those of the Eurasiatic *Perca fluviatilis* (Konstantinov, 1957) a taxonomic problem arises; there is some question whether these are the same species, subspecies, or congeneric species. Svetovidov (1963:212) claims, with some justification, that they should be considered subspecies, basing his judgment primarily on zoogeographical data. When the entire series of larval, young and juvenile descriptions and illustrations of *Perca fluviatilis* (Konstantinov, 1957) are compared with those of *Perca flavescens*, the similarity is overwhelming through all stages. Not only do general configuration, pigmentation pattern, and sequence of fin formation follow exactly, but sizes at which these changes occur are virtually identical. Internal organs also appear to be identical not only in structure, but also in the sequence of changes.

Summary

1. Detailed descriptions of the development of yellow perch from fertilization of the egg to fully-transformed juveniles are presented, with accompanying illustrations. Stages up to postlarvae of approximately 7 mm were raised from known parent fish in laboratory aquaria. Information on stages beyond this size are based on fish taken from the field at several localities. Details of development of the embryo within the egg are presented for the first time, and information published previously on the larvae and young is substantiated and elaborated.

2. Eggs of the yellow perch are laid in shallow freshwater in long accordion-folded columns with the bright amber eggs adher-

ing closely to each other. Semi-demersal, they usually become entangled with stream debris rather than sinking to the bottom. Egg diameter varies from 1.7 to 4.5 mm, depending on the extent of water-hardening. Laboratory incubated samples averaged 2.26 mm in diameter. Individual egg membranes are unusually thick, occupying ⅓ to ¼ of the outside diameter of the egg, and contain radiating striations. Cleavage is meroblastic. The eggs have an exceptionally long incubation period of 25 to 27 days at temperatures between 8.5 to 12.0 C. Incubation period and temperature are probably quite variable. The mouth, gills, auditory vesicles, pectoral fins, and dark pigmented eyes all develop within the egg, so that when hatched, the prolarvae is relatively mature.

3. Prolarval yellow perch hatch at a length of 5.5 to 6.0 mm and are immediately active swimmers. There is a single large oil droplet just anterior to the yolk, a continuous dorsal-ventral finfold, gills, and a line of stellate melanophores along the mid-ventral line of the tail. The opercular flap, urinary duct, cleithrum and air bladder all appear before complete absorption of the yolk.

4. The fish are considered postlarvae from the time the yolk has been absorbed at approximately 7 mm length until they are approximately 13 to 14 mm long, when fins have differentiated. It should be noted, however, that the complete number of fin elements is not present until the fish is 25 to 30 mm long. Postlarval fish are slender and active. Teeth appear at 7 mm, pigmentation increases, particularly over the head and jaws, and the head becomes slightly flattened and more elongate. Field-nurtured postlarval fish show faster growth but not necessarily more rapid development than those raised in the laboratory.

5. As postlarvae transform, they become more robust and percoid-shaped. Pectoral fins appear first on the embryo while within the egg case. After hatching, the caudal fin appears and basal elements are evident at 8 mm; next the soft dorsal and anal fins and some of the first dorsal spines appear. By the time the larvae have reached 14 mm, the pelvic fin has appeared, but only seven of the first dorsal spines have developed. A complete fin complement is evident between 25 and 30 mm. In transforming young, the air bladder expands and is capped with black pigment. The intestine begins a slow but complete turn on itself. Six or seven dark pigmented bands gradually appear over the back and sides at 20 mm. These darken as the fish matures and by 28 mm length they are dense and distinct. There is also dense pigmentation on the head. However, as described in the literature, yellow perch from other areas varied greatly in pigmentation. By 30 mm the fish has assumed most aspects of the adult form.

6. Head length, snout-to-vent length, and other measurements develop at a rate proportional to the total length. The relationship of the greatest body depth to the total length varies from a high proportion in the yolked prolarvae to a lower proportion in the long narrow postlarvae. This ratio gradually increases as the fish transforms and becomes more robust. The myotome count is normally 36 or 37, with a range 35 to 40.

7. The first soft ray of the anal fin transforms into the second anal spine when the fish is between 21 and 27 mm long, causing a change in the anal formula from I, 6–10, to II, 6–9.

8. Ossification begins in the spinal column in larva as small as 7.0 mm and the process gradually increases but is still incomplete in fish of 22 mm. Bony parts of all fins and of the vertebral column are complete at 22 mm; however, intermuscular and head bones remain unossified to a large degree.

9. Descriptions presented supplement and reiterate information on the post-hatching stages of the yellow perch previously published. In addition, the American yellow perch, *Perca flavescens*, is shown to coincide during development with the Eurasiatic yellow perch, *Perca fluviatilis*, both in morphometry and size.

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