Redirect - Rebuttal Testimony of

Dr. C. P. Goodyear

Factors which Influence the Rate of Growth of Larval Striped Bass

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During these proceedings, the length of time for which striped bass may be susceptible to withdrawal by the Indian Point Plant has not been precisely evaluated. It is the Staff's position that this period of time is in the range of six to eight or more weeks, and, as a consequence, the entrainment problem is significant. This concept is based upon data which is available concerning the factors which influence development of larvae, and the rate of growth of striped bass in the Hudson River. This particular aspect of the entrainment analysis is of special concern because it involves the determination of the duration of the passive or semi-passive stages of striped bass. In effect, the longer the duration of the passive stage, the more important is the entrainment aspect of the impact which may occur as a result of operation of Indian Point Units 1 and 2. Fortunately, there are a great deal of data which have been obtained concerning the development of striped bass larvae in conjunction with the successful attempts to artificially propagate striped bass and to introduce this fish into reservoirs to upgrade the sport fishing in those reservoirs.

Because of the many problems which have been encountered in relation to artificial propagation of striped bass, the recent interest in developing fresh water fisheries through stocking programs has resulted in a simultaneous expansion of research to determine the factors that control the survival and growth of larval stripers. These efforts have not been restricted to U.S. investigations, and it is noted that Soviet researchers in collaboration with U.S. fisheries experts have contributed considerable information by establishing the nature of feeding and the preferred food organisms in the early stages of larval development (Bogdanov, Doroshev and Karpevich, 1967, Stevens, 1966).

The following discussion is taken from a recent comprehensive description of the morphological and behavioral development of larvae which was done as part of an examination of the potential for development of a striped bass fishery in Russia.*/ This data is summarized in Table 1 and described in more detail as follows:

Two days after hatching, the larvae are elongated (length 4.5 - 5.2 mm), such that the head projects over the oil droplet, the formation of the mouth, and the divisions of the brain, auditory capsule, intestinal tube and rudiments of the pectoral fin are clearly discernible at this stage. The pigmentation of the eyes develops rapidly, but in this stage they appear gray. Melanophores are located along the intestinal tube, and on the oil droplet and the yolk sac. Blood circulation in the circulatory system can be clearly traced; the erythrocytes are either colorless or stained a light orange. In the two days after hatching, the length of the larva increases on average by 12%, the diameter of the yolk sac decreases by 20%, and that of the oil droplet by 11%. The larvae become active by this time and spend the greater part of the time swimming pelagically even in the absence of a current.

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* Doroshev, S. I., "Biological Features of the Eggs, Larvae and Young of the Striped Bass [Roccus saxatilis (Walbaum)] in Connection with the Problem of its Acclimatization in the USSR," J. of Ichthology, 235-278, (1971).

Five days after hatching the larvae are 5.5 - 5.8 mm long. There is formation of the mouth (teeth are absent from the jaws), the gill apparatus (the gill cover does not cover the gills), the pectoral fin and the gas bladder (single-chambered, not filled with air). The diameter of the yolk sac is practically halved by this time and equals the diameter of the oil droplet; the intestinal tube widens and increases sharply in volume, squeezing the yolk sac to one side of the body. The intestinal folds and peristalsis of the intestine at intervals of a few minutes are clearly apparent. The liver and a large gall bladder light yellow in color can also be seen. The erythrocytes are light orange in color; blood circulation is clearly apparent in the peripheral vessels; the heart beats at a rate of 90 - 110 beats a minute.

At this period the larvae are very mobile, have sharply expressed positive phototaxis and remain continually suspended in the water, not sinking to the bottom at all. They do not react to food.

Eight days after hatching, the larvae are between 5.8 and 6.5 mm long. Approximately a quarter of the initial volume of the yolk sac remains and the oil droplet varies in size from practically total resorption to a volume sharply exceeding the remains of the yolk. The gill cover almost completely covers the gills, and the eyes become mobile and rotate in the socket.

At this period, on the 8th - 9th day after hatching, the larvae begin to transfer to active feeding. The larvae feed only pelagically and only on mobile plankton food. Feeding larvae may be distinguished very easily both by their behavior (characteristic passes, aiming and then rushes at comparatively large prey), and by their appearance (the food is clearly apparent in the intestine to the naked eye).

In a small proportion of the larvae (5-10%) the gas bladder fills with air simultaneously with the commencement of active feeding, but in the bulk of the larvae the gas bladder fills 1-3 days after transition to active feeding.

At an age of 15 days after hatching, the larvae are 9-12.5 mm long, the gas bladder is filled with air and is single-chambered. The fin fold is clearly divided into three divisions and the lepidotrichia of the caudal fin are clearly apparent. The gill cover completely covers the gills, there are 25 myotomes. At this development stage, known as the postlarva (Mansuetti, 1958), the larva becomes considerably less transparent.

At an age of 30 days after hatching and a length of between 12 and 16 mm, the second dorsal, anal and caudal fins are differentiated; the caudal fin is homocercal in shape; the first dorsal and pectoral fins are wanting. The larvae become translucent and continue to feed on plankton.

At an age of 40-50 days the fingerlings are between 22 and 33 mm long. All the fins, including the first dorsal and the pectoral fins, are formed. Pigment is uniformly distributed over the body with small concentrations along the backbone, on the head and at the base of the fins. The color is light gray. The fingerlings feed readily not only on plankton, but also on nectobenthos - on mysids, chironomid larvae, etc.

Age	Length mm	Most important diagnostic characters
?0-40 min after fertilization	2.3	Commencement of cleavage
? hours	3.4	End of swelling
? hours	3.4	Commencement of overgrowth
.2 hours	3.4	Half overgrown
.6 hours	3.4	Formation of embryo
0 hours	3.4	Formation of eyes
6 hours	3.4	Separation of caudal division from yolk sac
8 hours	2.9-3.7	Hatching
nd day after hatching	4.5-5.2	Pigmentation of eyes; differentiation of jaws and intestine; 21-23 myotomes. Partly lying on bottom, partly floating
th day after hatching	5.5-5.8	Resorption of yolk by one-third; commencement of intestinal peristalsis; 23-24 myotomes. Swimming pelagically
h day after hatching	5.8-6.5	Teeth on jaws, orange pigment in caudal division; differentiation of stomach; resorption of three-quarters of yolk; 25 myotomes. Transition to active pelagic feeding
th day after hatching	10-12.5	Division of fin fold into 3 divisions; complete resorption of oil droplet; single-chamber gas bladder filled with air. Feeding on plankton
th-30th day after hatching	12-16	Differentiation of rays in caudal, anal and dorsal fins. Feeding on plankton and nectobenthos, cannibalism
th-50th day after hatching	22-35	Differentiation of rays in first dorsal and pectoral fins. Feeding on nectobenthos. Possibility of habituation in nonliving food
h-70th day after hatching	35-45	Scales
h-90th day afterhatching	50-80	Appearance of longitudinal stripes. Feeding on nectobenthos, fish fry and nonliving food

At an age of 50-60 days the fingerlings are covered with scales and become light silvery in color. At this period they become very timid and are easily injured in collisions with the wall of the raceway. They take any food, including dry floating food from the surface of the water.

At an age of 80-90 days the young reach a size of 50-80 mm, in addition to the eroded vertical stripes on the sides of the body there now appear 5-6 well-discernible longitudinal stripes above and below the lateral line, from which the striped bass takes its name. At this period the appearance of the young corresponds to the appearance of the adult fish. The fingerlings are very mobile, readily leap out of the water and keep together in a school. These studies represent near optimum growth rate for striped bass since food was supplied at a rate which was the maximum rate that could be physiologically incorporated by the fish and at a temperature that was very near optimum. The importance of this factor can be examined by comparison to the results obtained by Mansueti, summarized as follows:

(1) At hatching - the prolarvae were about 36-48 hours old after fertilization, and ranged from 2.0-3.7 mm total length. See Figure 17.

(2) At about 5 mm. they were about 2-5 days old, were more slender, with the yolk sac fully absorbed and with no oil globule visible. No fins were visible except the pectorals. See Figures 22 and 23.

(4) At about 10 mm. they were 20 to 30 days old. The dorsal and anal fin-rays were somewhat differentiated, although the first dorsal elements and pelvic fins were absent. See Figures 24 and 25.

(5) At about 15 mm. they were 30 to 40 days old.

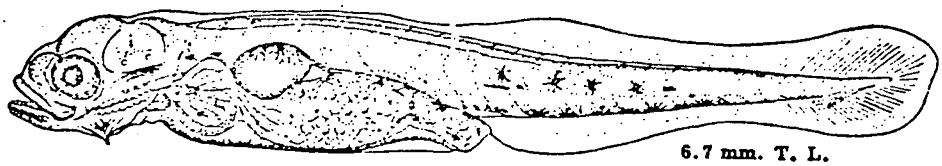
(6) At about 20 mm. they were 50 to 70 days old. See Figure 27.

(7) At about 25 mm. they were 60 to 80 days old.

(8) At about 30 mm. they were 70 to 100 days old. See Figure 28.

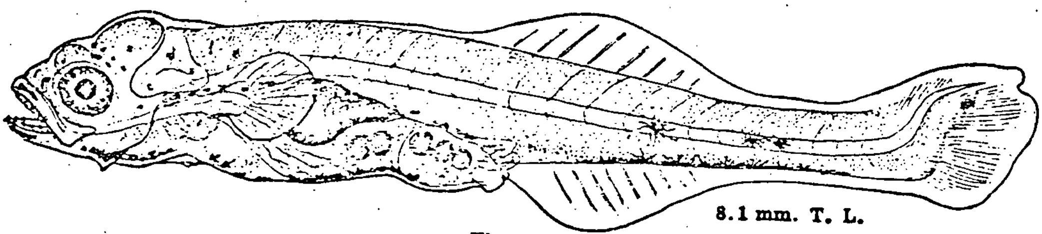
It is important to note at this point that Mansueti believed his fish to be stunted. The rearing techniques and food habits had not been worked out at the time Mansueti undertook the study. This hypothesis is fairly consistent with the information he derived. As a consequence, the rate of growth which his fish exhibited should be considered to be a lower bound of the growth rate exhibited by larval striped bass.

However, an interesting comparison can be made between the apparent growth rate of Mansueti's fish and that of the fish taken from the Hudson River during the Carlson and McCann study as reported in Fig. V-5 of the FES. When maximum size was utilized to interpret the rate of growth of striped bass from the Hudson River, the length of time between the initiation of spawning and the time that the first fish which were collected reached a length of one inch was some ten weeks. In contrast, Mansueti's fish did not reach the same length until their twelfth week of existence. Thus the growth rate of fish in the Hudson lies between the minimum growth rate exhibited by Mansueti's data and the maximum rate of growth which has been determined in laboratory studies. As a consequence, it is believed by the Staff that a period of six to eight weeks is not an unreasonable estimate



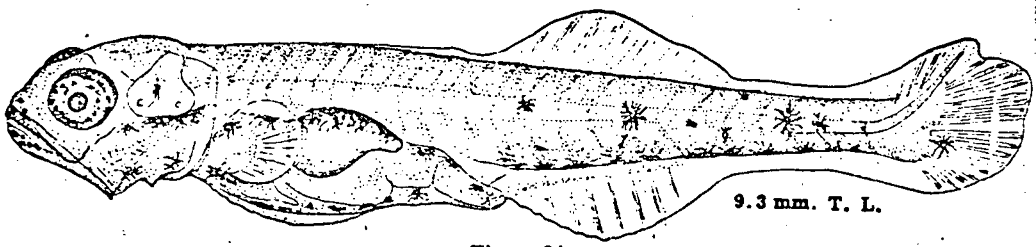
6.7 mm. T. L.

Figure 22



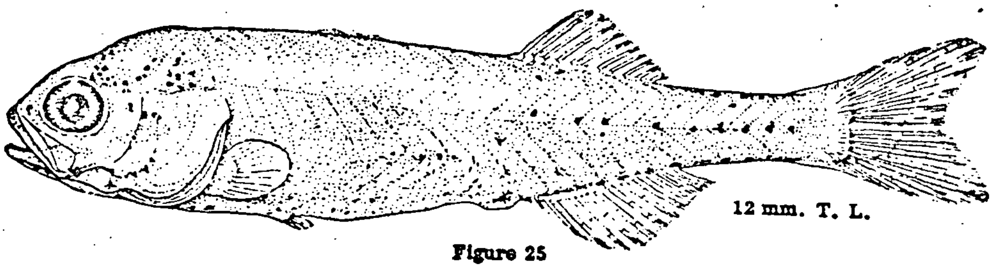
8.1 mm. T. L.

Figure 23



9.3 mm. T. L.

Figure 24



12 mm. T. L.

Figure 25

STRIPED BASS POSTLARVAE

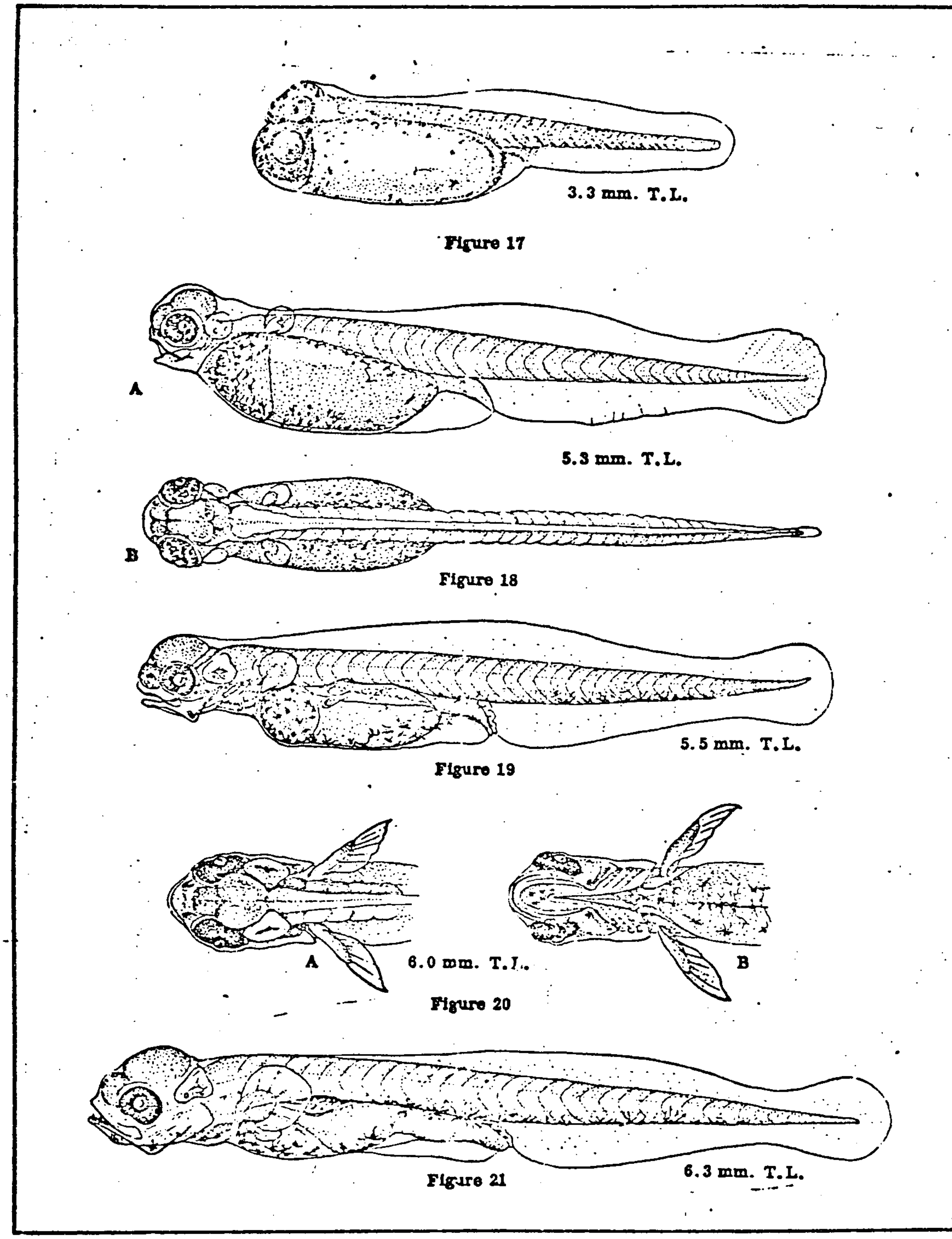
FIGURE 22. Postlarva, 6.7 mm. long (early stage).

FIGURE 23. Postlarva, 8.1 mm. long (early metamorphosis). Brine shrimp eggs can be observed in the intestine.

FIGURE 24. Postlarva, 9.3 mm. long (metamorphosing).

FIGURE 25. Young, 12 mm. long (largely metamorphosed).

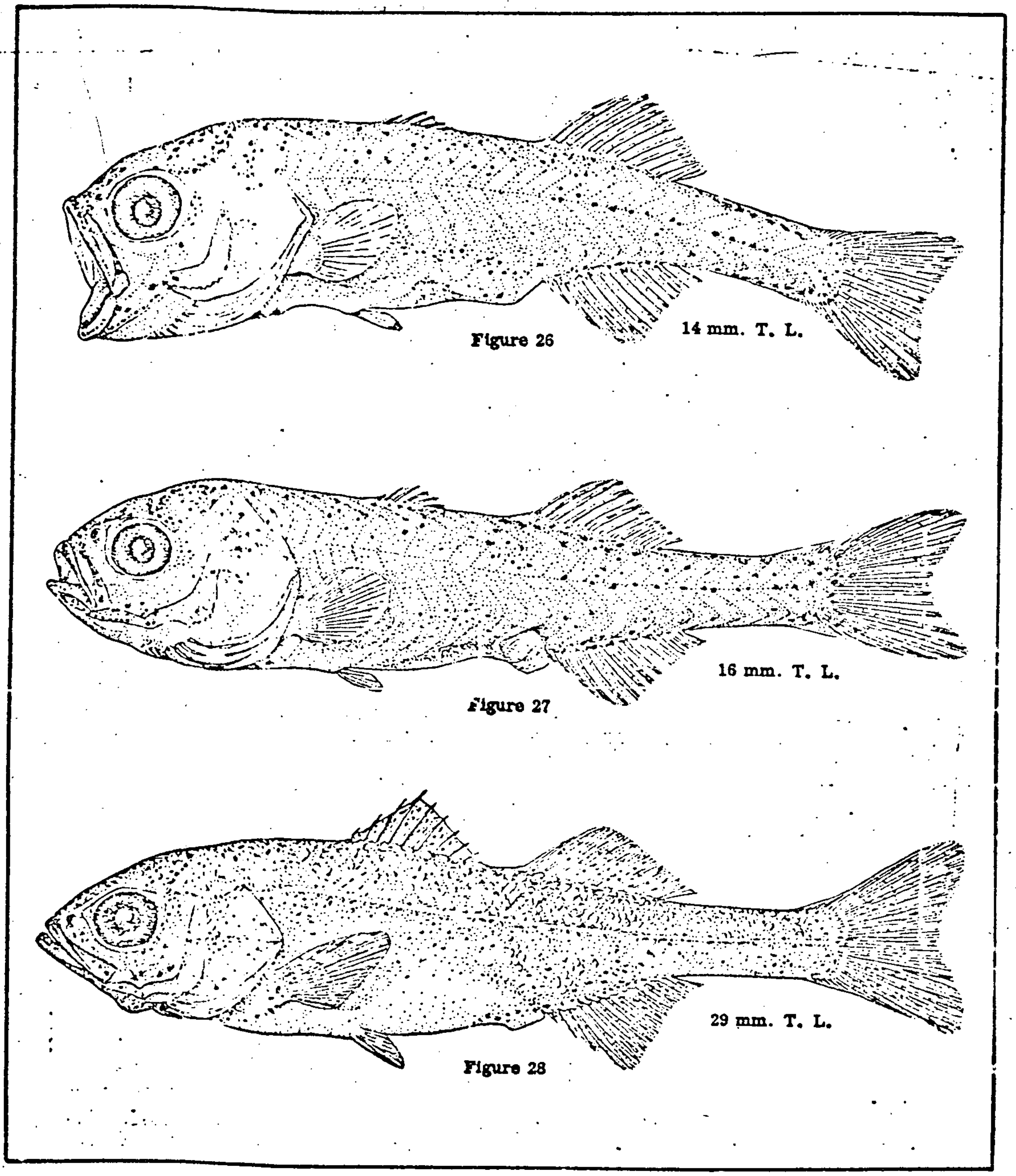
From Mansueti 1958



STRIPED BASS PROLARVAE

FIGURE 17. Prolarva, soon after hatching, 3.3 mm. long.
FIGURE 18. Prolarva, 5.3 mm. long. A. Lateral view. B. Dorsal view.
FIGURE 19. Prolarva, 5.5 mm. long.
FIGURE 20. Prolarva, 6.0 mm. long. A Dorsal view. B. Ventral view.
FIGURE 21. Prolarva, 6.3 mm. T. L., almost indistinguishable from early postlarva.

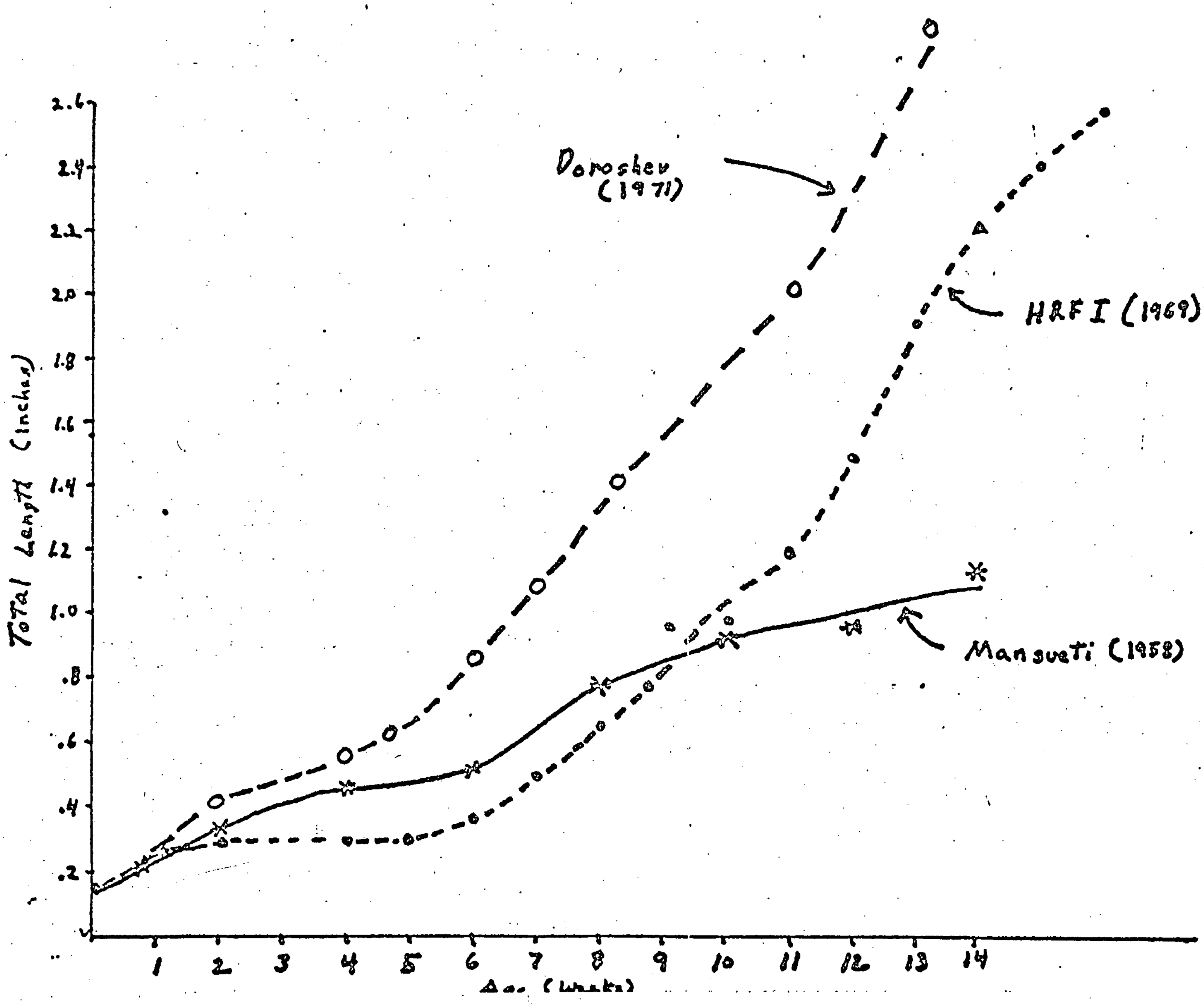
From Mansueti 1958



STRIPED BASS YOUNG

FIGURE 26. Young, 14 mm. long.
FIGURE 27. Young, 16 mm. long.
FIGURE 28. Young, 29 mm. long.

From Mansueti 1958



Doroshev (1971)
HRFI (1969)
Mansueti (1958)
Total Length (Inches)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5
6
7
8
9
10
11
12
13
14

for the length of time that larval striped bass will be susceptible to withdrawal at the Indian Point facility (see Figure 1).

This growth rate is partly a function of the food habits of the organism which in turn is a function of their size. Thus very small fishes must feed upon very small organisms, such as microcrustaceans. These organisms have comparatively low food value when contrasted to the more piscivorous diet of the older striped bass. Thus it is not surprising that the general trend for larval striped bass is a relatively slow growth rate for the first several weeks of its life which subsequently is followed by a period of very rapid growth that continues throughout the first several years of its existence. The larval food habits are briefly described in the following section.

3. Larval Food Habits

Until recently the food of striped bass larvae has remained little studied. It has been assumed that the larvae fed on zooplankton under natural conditions (Mansuetti, 1958). Many investigators have attempted to rear larvae on various types of foods including young Daphnia and Artemia, but in all experiments high larval mortality was observed (Pearson, 1938; Mansuetti, 1958; Anderson, 1966; Stevens, 1967). However, Sandoz and Johnston (1966) found that larvae, which begin to actively feed on the 8th day after hatching, first consume the early stages of copepods.

Mansueti, R., "Eggs, Larvae and Young of the Year Striped Bass," Maryland Department of Resources and Education, Contribution No. 112, 1958

Pearson, J.S., "The Life History of the Striped Bass, or Rockfish, Roccus Saxatilis (Walbaum), U.S. Bur. of Fish. Bull. No. 28, 49: 825-851 (1938)

Anderson, J.C., "Production of Striped Bass Fingerlings", Progressive Fish Culturist, 28:3, 1966

Sandoz, O.R., and Johnston, K.H., "Culture of Striped Bass", Proceedings of the 19th Annual Conference of the Southeastern Association of Game and Fish Commissioners, 1966

In experiments in 1965 Russian investigators used various types of food (young Daphnia, Paramecium, Chlorella, egg yolk, emulsified fish flesh, etc.), beginning from the 5th day after hatching, but they found that the larvae did not consume any of the foods. On the 8th day, after natural zooplankton from ponds in the Moscow area had been added to the aquaria, the larvae began to feed actively, selecting the nauplii and early stages of Cyclops and to a lesser extent Brachionus and rejecting Daphnia, Bosmina, Keratella and other rotifers. At a concentration of Cyclops nauplii approximately equal to 15,000 per liter of water in the aquarium each larva consumed 6-8 crustaceans in 15 min and digested them in no more than 1 hour (Bogdanov et al., 1967). Cyclops nauplii were needed only for the first 3-4 days of larval feeding.

At an age of 11-12 days the larvae transfer fully to feeding on young Cyclops of stages II, III and IV. At this period the concentration of food may be lowered to 2-5000 crustaceans in 1 liter, since the gas bladder of most larvae is filled with air and energy expenditure on feeding is sharply reduced, the effectiveness of the search for food is increased. Therefore, the size of the food organisms utilized by the larvae varies during the first week after transition to active feeding between 150 and 300 μ. During this period each larvae consumes between 120 and 360 nauplii and copepodid stages of Cyclops and rotifers in the course of a day.

From an age of 16-18 days after hatching (second week of feeding) the larvae begin to feed on larger Cyclops (stages IV, V) and on young cladocerans having a soft carapace (Moina sp., Alona sp., Ceriodaphnia sp.), but reject Daphnia magna. When the food concentration in the aquarium was 1000-1500 crustaceans per liter, up to 35 crustaceans were found in the intestines of larvae, 60-80% of which were Cyclops.

In the absence of other foods the larvae begin to feed on young Daphnia magna measuring 1000-1200 μ. A considerable quantity of the larvae perish since the crustacean, which has a hard carapace and is round, obstructs the pharynx and the esophagus. During this period the optimum size of the food organisms ranged from 400 to 1000 μ.

In the 3rd-4th week of feeding the preferred food (from the standpoint of larval growth) becomes nectobenthic organisms such as small insect larvae and small Mysids. The most important aspect of this period is that cannibalism begins to occur. When the larvae reach a size of about one inch, they will consume other larvae of 1/2 inch or less. On most instances both the predator and the prey perished.

Beginning with the second month after transition to active feeding, striped bass fingerlings can be adapted comparatively easily to non-living foods (Anderson, 1966; Stevens, 1967). At an age of 2 months, a length of 2-2.5" and a weight of 2 g, the young will readily feed on Gammarus other fishes with a long thin body, but do not consume forms with a deep body.

The data obtained by the Russian investigators are in agreement with the results of American research in ponds which contain zooplankton consisting of Ceriodaphnia sp., Daphnia magna and Cyclops. For instance,

Table 2. FEEDING OF YOUNG STRIPED BASS IN THE EARLY DEVELOPMENT STAGES

Age, days	Length of fishes mm	Weight of fishes mg	Preferred Food Items	Diameter or length (mm)
9 (Transition to active feeding)	6-7	1-5	Cyclops, nauplia I, II, Brachionus Artemia, nauplia	0.15-0.3
15	9-15	8-14	Cyclops, III-V, Molna sp.	0.3-0.6
22	18-22	15-80	Cyclops, Moina, Chaoborus	0.8-1.5
32	20-30	40-220	Mysis, Chironomidae	4-7
45	30-50	220-1000	Mysis, Chironomidae, Gammaridae	10-15
65	50-70	1000-3500	Mysis, Gammaridae, fish fingerlings	15-20
100	80-120	5000-20000	Mainly fish fingerlings	Up to 30

Source: Doroshev, S. I., "Biological Features of the Eggs, Larvae and Young of the Striped Bass (Roccus saxatilis (Walbaum)) in connection with the Problem of its Acclimitization in the USSR," J. of Ichthology, 235-278 (1971)

Regan found that young striped bass between 3-8 weeks after hatching reveal a clearly-expressed selective capacity in relation to *Cyclops* and subsequently to *Ceriodaphnia*. The fish consumed small quantities of *D. magna*, but failed to consume *Bosmina*.

These conclusions are further supported by data gathered in connection with raising striped bass in hatcheries. For instance, at the Richmond Hill Hatchery, 1968 stomach analysis data showed the copepods were taken predominantly by all fingerlings up to 2.25 inches and that the smaller fish depended more heavily upon them.

Heubach, et al. (1962) studied the food habits of young of the stripers and included as one group, fish which were below 1" in length. These investigators concluded:

> In general, the percentage frequency of copepod occurrence was greater in small bass than lage ones, while the frequency of occurrence of larger plankton, *Neomysis* and *Corophium*, was greater in larger bass. The occurrence of cladocera did not appear to be related to fish size. Larger bass generally had more organisms in their stomachs.
>
> The influence of salinity on the relative abundance of copepod genera in the diet of bass was readily recognizable. At stations with a high mean salinity, *Eurytemora* was the dominant genus. As the salinity decreased upstream, the observed percentages of fresh-water genera, *Diaptomus* and *Cyclops*, increased.
>
> The percentage of the total bass population utilizing each food organism was estimated by multiplying the percentage of the bass population in each area[3] by the average percentage occurrence of the food item in all bass and totaling the percentages. These percentages of frequency of occurrence were: *Neomysis*, 59 percent; copepods, 50 percent; cladocerans, 23 percent; and *Corophium*, 12 percent. Since these estimates are based on two net surveys which sampled only the major areas inhabited by young-of-the-year bass, the true picture would be slightly different.

4. Temperature Relationships

Striped bass eggs and larvae have a comparatively narrow temperature range for optimum development. Under experimental conditions an 85% yield of larvae is observed when eggs are incubated at a temperature of between 58° and 73°F (Albrecht, 1964). In the Russian experiments, in which larvae two days old were kept until transition to active feeding, the optimum temperature for their survival lay in the range 61-66°; a temperature below 50°C and above 73°C was undoubtedly lethal (Table 3).

However, within the optimum temperature range a significant correlation is noted between temperature, and the rate of resorption of the yolk and sac and the time at which death ensues from starvation. It may

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Heubach, W., Toth, R.J., McCready, A.M., "Food of Young of the Year Striped Bass , *Roccus Saxatilis*, in the Sacramento - San Joaquin River System", California Fish and Game, 49:4, 1963, p. 229

Albrecht, A.B., "Some Observations on Factors Associated with Survival of Striped Bass Eggs and Larvae", California Fish and Game Journal, 50(2):100-113 (1964) be seen that even slight differences in temperatures (in the range 3-5°F) have a significant effect on the rate of resorption of the yolk and the oil droplet; and that at lower temperatures the process of resorption is protracted; and the period for which the larvae survive when fasting is significantly increased. It has been hypothesized that under natural conditions in some years, lower temperatures within the favorable range may promote increased survival of the larvae by providing them with a longer period in which to seek food on transition to active feeding.

Similarly a faster than normal rise in temperatures could have the opposite effect. Evidence as to the possible importance of this factor was presented by Shannon and Smith (1967), and Shannon (1969). The more important conclusions which were derived from their tests revealed the following; (1) Hatching percentage for freshly fertilized eggs decreased as water temperature exceeded 70°F; (2) the greatest percentage of normal fry developed in the 60°F test presumably due to decreased metabolism at this low temperature; (3) mortality in 65°F test increased 72 hours after hatch (Shannon, 1968); (4) mortality in 70°F test was heavy 60 hours after hatch, (5) mortality in 75°F test was heavy 45 to 60 hours after hatch; and (6) mortality of fry appears to be associated with the developmental stage rather than age.

Shannon, E.H., and Smith, W.B., "Preliminary Observations of the Effect of Temperature on Striped Bass Eggs and Sac Fry", Proceedings of the 21st Annual Conference of the Southeastern Association of Game and Fish Commissioners, 1967

Shannon, E.H., Proceedings of the 23rd Annual Conference of the Southeastern Association of Game and Fish Commissioners, 1967

Table 3. Cumulative mortality of 25 striped bass larvae at different water temperatures in the period before transition to active feeding (Doroshev, 1971)

DAY	Temperature (°F)				
	47-50	64.5	59-66	71.5-75	79-80.5
1	0	0	0	0	0
2	0	0	0	0	0
3	1	1	0	0	0
4	9	0	1	0	7
5	15	1	2	4	18
6	-	0	0	8	-
%	100	8	12	48	100

Source: Doroshev, S. I., "Biological Features of the Eggs, Larvae and Young of the Striped Bass (Roccus saxatilis (Walbaum)) in Connection with the Problem of its Acclimitization in the USSR", J. of Ichthology, 235-278 (1971)

Ref

1) Bogdanov, A.S., Dorocher, S.I., Karpevich, A.F., "Experimental Transportation of Salmo gairdneri and Roccus Saxatilis from the U.S.A. for Acclimitization in Bodies of Water in the U.S.S.R."; Voprosy Ikhtiologii, 7:1., 1967.

2) Stevens, R.E., "A Report on the Operation of Monks Corner Striped Bass Hatchery, 1961-65", South Carolina Wildlife Resources Department Report, 1967