ROTIFERS AS A PRODUCTION DIET FOR STRIPED BASS FINGERLINGS[1]

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Abstract: Growth of striped bass *Morone saxatilis* fry on a diet of rotifers was studied in the laboratory and in the field. Although the rate of growth was slower when rotifers were the principal food than when other acceptable zooplankton were eaten, rotifers were judged to be acceptable as a starting diet. This was based upon the fact that survival was higher and more consistent from pond to pond than was the case when mixed zooplankton was the source of food initially. Trichlorfon as Masoten® was used in rearing ponds to reduce predaceous and competitive invertebrates and to favor development of the rotifer population.

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Acceptance of the striped bass *Morone saxatilis*, by sport fishermen and management biologists as an important game fish in fresh and brackish waters, has made striped bass an important addition to the list of species propagated by public fish hatcheries. Humpheries and Cumming (1973) reviewed earlier work in striped bass fingerling culture. Later research and field experience in rearing striped bass fingerlings has been compiled by Bonn et al. (1976) to present the essential requirements for hatchery propagation of this species. More than 13 million fingerlings were reared in 1975 (Bonn et al. 1976) and the number produced in subsequent years has continued to increase (Stevens 1979).

In spite of the overall success of public fish hatcheries in propagating striped bass fingerlings, problem areas continue to exist in rearing fingerlings in earthen ponds. While much can be done to ensure high levels of production by following the procedures of Bonn et al. (1976), variable survival rates and extreme fluctuations in yields between ponds are currently experience (Snow 1977).

In reviewing results of production hatcheries in several locations, an inconsistent rate of survival appears to be fairly common. A variety of reasons are given for the cause of the poor survival. Condition of the fry, high temperature, low oxygen, pH, disease, cannibalism, sunlight, insufficient food, and other factors either singly or in combination, have been cited.

Several influences were suspected to be the cause of the low survival percentage of striped bass fry at Auburn. The most obvious was the presence of large numbers of the larvae of phantom midge, *Chaoborus* sp., in the water supply and in the ponds shortly after fry were stocked. Tatum et al. (1964) reported that *Chaoborus* larvae were observed killing striped bass sac fry under laboratory conditions. They also showed a high incidence of *Chaoborus* larvae was correlated with poor survival of striped bass fry in earthen ponds used for their research. According to Pennak (1953), *Chaoborus* are predatory, feeding upon small Crustacea and insects. Thus, this insect might be competitive as well as predaceous.

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Other insects such as backswimmers (Notonectidae), and water boatmen (Corixidae), are competitive for food with striped bass fry, consuming entomostracans, Protozoa, and microscopic Metazoa (Pennak 1953). In addition to competing with striped bass fry for food, insects such as backswimmers, water scorpions (Nephidae), giant water bugs (Belostomatidae), and drangonly nymphs (Odonata) may also prey upon fish fry under favorable conditions. These insects are not likely to be present in newly filled ponds although adults can migrate freely from nearby established populations resulting in an early buildup in numbers under favorable conditions. Since the effects of these and other harmful invertebrate forms are well known, fish culturists apply petroleum oil to control the surface breathers and an insecticide to eliminate gill breathers (Bonn et al. 1976).

Food habits of striped bass fry and small fingerlings have been studied by several workers (Sandoz and Johnston 1965, Harper et al. 1968, Meshaw 1969, Miller 1978, Eldridge et al. 1978). Feeding begins 5-8 days after hatching at a size of 5-6 mm TL. Preferred natural foods are early instars of copepods and Cladocera while the most successful artificial diet up to an age of 15 days (8 mm TL) is brine shrimp nauplii. Older fry and small fingerlings feed on adult copepods, cladocerans, and insect larvae. Meshaw (1969) reported that rotifers were not selected by older fry and small fingerlings in ponds where other forms were present (selectively index, -0.50 to 1.00). The quantity of rotifers in the plankton samples from ponds in his study was quite low, however.

Although striped bass fry prefer to feed upon the early instars of copepods and cladocerans (Sandoz and Johnston 1965, Miller 1978), some members of these groups may be competitive. Cyclopoids have mouthparts modified for seizing and biting (Pennak 1953) and a number of species are reported to be carnivorous. Food includes Cladocera, other copepods, dipterous larvae, rotifers, and oligochaetes (Hutchinson 1967). At Auburn, a species of *Cyclops* collected as food for striped bass fry in an aquarium, attacked and killed the fish they were supposed to feed. Up to 50 individuals were seen attached to a single fry. Hutchinson (1967) states that a few species of Cyclopoida have been known to attack young urodeles and fishes much larger than themselves. Cladocera are not likely to be carnivorous but a few genera are predaceous according to Pennak (1953).

Tamas and Horvath (1976) obtained a significantly higher survival of carp fry stocked into earthen ponds when a 1 ppm treatment of the organophosphate, Flibol E was applied immediately after flooding and 1 week before stocking fry. This treatment temporarily caused a drastic reduction in the number of copepods and cladocerans. The reduction lasted 12-15 days after application of the insecticide. Since the same problem exists in striped bass rearing as they described for rearing carp fry, work was initiated at Auburn to examine the feasibility of starting striped bass fry on a rotifer diet.

The pesticide trichlorfon (dimethyl {2, 2, 2-trichloro-1-hydroxyethyl} phosphorate), commercially available as Masoten®, was used. This compound also known as Dylox, Dipterex, or Neguvon has been recommended for a number of years to control anchor parasite, *Lernaea* in bait fishes (Rogers 1968), and for control of tadpole and fairy shrimp (Hornbeck et al. 1966). McCraren and Phillips (1977) studied the effects of trichlorfon on plankton in ponds and found that phytoplankton and rotifers were unaffected by a 0.25 mg/l treatment. Their work confirmed the findings of Tamas and Horvath (1976) regarding the resistance of rotifers to trichlorfon and suggested that if striped bass fry could survive and grow on a rotifer diet, the potentially competitive and predaceous invertebrates could be suppressed improving chances of striped bass survival.

METHODS

Since the findings of Meshaw (1969) indicated that rotifers were not a preferred food of striped bass fry a laboratory study was done to determine survival and growth of striped bass fry at first feeding.

The rotifer *Brachinonus calyciflorus* (Pallas) was isolated from plankton collected in a local pond and cultured in 3.8-l glass jars or 20-l plastic pails using *Chlorella* as food. Temperature was regulated by placing the culture container in water baths maintained at 25-28°C. *Chlorella* bearing water was combined with tap water in a ratio of 2:1 by volume and seeded with rotifers at a rate of 10-15 organisms per ml. Moderate aeration with compressed air was provided and the production harvested for feeding after 3 days. Measurement 2 times of the increase in rotifer density during a 3-day period was 110 and 130 percent.

Fry were held in an aerated aquarium containing tap water with 5 ppt Instant Ocean® added until they were ready for first feeding (7 days of age). Test containers were 3.8-l glass jars supplied with 3-l tap water containing 5 ppt Instant Ocean® salt mix. Compressed air aeration was provided. Stocking rate of fry was 25 per l. Jars were cleaned and dead fish counted and removed daily.

Three trials were conducted and consisted of 4 treatments arranged in a factorial randomized design, and replicated 3 times. Treatment diets consisted of rotifers and *Chlorella*, rotifers only, *Chlorella* only and no food. Food was provided to each jar 2-3 times daily at a rate of 5 rotifers per ml. *Chlorella* treatments were given every other day to establish a concentration ranging from 10×10^4 to 20×10^4 cells per ml.

At the start of each trial, 10 fry were measured for total length (TL) and body depth (BD) using a Filar micrometer mounted on a dissecting microscope. The Filar micrometer was calibrated with a stage micrometer and measurements converted to millimeters. Upon termination of a trial, 10 fry from each replicate were measured for TL and BD. Specimens to be measured were preserved in Bouin's solution until analysis. Two trials lasting 9 days were conducted. Additionally, 1 of 6 days duration using the fry from a 9-day trial was done. Procedure for the 6-day trial was the same as for the 9-day ones except that fry were stocked at a rate of 17 fry per liter instead of 25.

Pond experiments were conducted in 1977, 1978, and in 1979. The 12 experimental units consisted of a series of 0.04 ha earthen ponds averaging about 76 cm in depth. The bottom soil was sandy Cecil clay. Water supply was from a 8.2 ha reservoir supplied primarily with runoff water. The water was soft, having a total hardness of 12 mg/l and a pH of 6.8-7.4. The reservoir contained a mixed population of game fishes and produced noticeable amounts of zooplankton during the spring months even though it received no artificial enrichment.

Preparation of the experimental ponds, except for the pesticide treatment was similar each year except in 1979 when liming was done in the early spring to all ponds having a lime requirement (10 of 12 ponds). The production cycle was begun by drying the pond bottom 3 weeks or longer. A preflooding treatment with simazine at a rate of 11.2 kg/ha (commercial product) was given and the drains closed. Initial fertilization was done the same day to provide 9.1 kg of organic nitrogen (from ground meat scrap), 9.1 kg of inorganic nitrogen, and 9.1 kg of $P^2 0^5$ per ha. Later applications of fertilizer at weekly intervals consisted of 4.5 kg per ha of organic N, 4.5 kg of inorganic N, and 9.1 kg of $P^2 0^5$. If Secchi disc reading was 45 cm or less, the weekly fertilizer application was omitted. The last dose of fertilizer was applied 2 weeks before draining. Several rates of trichlorfon as Masoten® were used. In 1977 a rate of 1.6 mg/l was applied to the filled pond 2 days before stocking the fry in one treatment and 1.6 mg/l added 2 days before and 5 days after stocking in a second treatment. In 1978 rates of 1.6 and 2.4 mg/l applied 9 days prior to stocking were tested. In 1979 a rate of 0.8 mg/l was added 10 days before stocking to all 12 ponds as the main objective of the trial was to produce as many fingerling fish from the ponds as possible. In all years, the amount of Masoten® required was mixed with a small amount of water and distributed uniformly over the water surface with a dipper.

Stocking was done with unfed 7-day-old fry at a rate of 200,000 fry per ha. Numbers were estimated by visual comparison (Snow et al. 1964). The production period was about 50 days. The fish crop was harvested by draining the pond and collecting the small fingerlings by seining and trapping as the water level was lowered. Number and weight of fish produced in each pond was determined using actual count or an estimate based upon the number-weight relationship of 3 samples applied to the total weight of fish recovered.

The effect of the pesticide on zooplankton was measured by counting organisms in samples taken at weekly or bi-weekly intervals after treatment. Locations in the deep end, midpoint, and shallow end of each pond were sampled taking 3.7 l of pond water from the surface, mid-depth and bottom levels. This was poured through an 80 micron mesh plankton net to obtain a composite sample from each pond. The material collected was preserved in 5 percent formalin and used for organism counts. Two 1-ml subsamples were later examined in a Sedgwick-Rafter counting cell and the principal groups identified and counted. Results per ml of subsample were then related to the original sample for an estimate of the standing crop of zooplankton in the pond.

In addition, fish samples were taken at weekly intervals for the first 5 weeks in 1977 for a study of food habits of fish from treated and untreated ponds. Stomachs of the preserved specimens were opened and examined microscopically. Contents were identified as to major groups and counted.

RESULTS AND DISCUSSION

Survival on the rotifer diet was significantly higher ($P < 0.01$) than the unfed or *Chlorella* diet for the first lot of fry (Table 1). This was not the case for the second lot during the first 9 days (Table 2.) When fish from this lot were continued in the feeding experiment for an additional 6 day period (Table 3), survival was significantly better ($P < 0.01$) on the rotifer diet.

Chlorella had no significant effect upon the percent survival between jars fed algae and those without it ($P > 0.05$). One lot of fry did show a significantly better ($P < 0.01$) growth rate when algae was added. The improved growth rate did not continue through the second 6-day growth trial.

In all 3 trials, growth on a rotifer diet was significantly greater ($P < 0.01$) than when rotifers were not fed. Increase in total length of fish fed rotifers averaged 0.15 mm per day. This compares favorably with a growth rate of 0.19 mm per day for 10 days reported by Carreon (1978) for a diet of *Artemia* nauplii. It is substantially less than 0.48 mm TL growth per day obtained by Bowman (1979) for a diet of *Artemia* fed for a 15-day period.

Survival percentage of fry alone is not a valid measure of the effectiveness of a diet treatment when the feeding period is of limited duration. In this experiment, fry in the second lot (Moncks Corners fry), which were unfed, survived as well as those receiving 5 rotifers per ml 2-3 times daily for the first days of feeding. Percent survival of fish in the unfed treatment did vary significantly ($P < 0.01$) when the same fry were given the same treatments for 6 more days.

Survival and Growth on a Diet of Rotifers in Ponds

Yield in numbers per ha from control ponds (Table 4) in 1977 averaged 12,087 (6.1% survival) and in 1978, 75,163 (37.6% survival). Ponds treated with trichlorfon at a rate of 0.8 mg/l 10 days before stocking in 1979 averaged 85,060 fingerlings per ha with an average survival of 42.6 percent. While the range in numbers produced per ha in 1979 was lower than desired, the lowest producing pond showed better survival than the average for 1977, and 8 of 12 ponds in 1979 showed better survival than the controls in 1978 (Table 4). This numerical yield was lower than the production reported by Parker 1979 (181,000 per ha), but his survival only averaged 29.6 percent from eight 0.02 ha ponds.

Table 1. Survival and growth of lot 1 (Morristown) fry fed 3 diets for 9 days.

Diet	Replication	% Survival	Growth (mm) TL	BD
Rotifer + *Chlorella*[1]	1	81.3	6.45	0.95
	2	82.7	6.86	1.08
	3	68.9	6.41	0.94
	Mean	77.8 a	6.57 a	0.99 a
Rotifer only	1	84.0	6.72	1.08
	2	65.3	6.33	0.96
	3	84.0	6.22	0.93
	Mean	77.8 a	6.42 a	0.99 a
Chlorella only	1	36.0	5.31	0.72
	2	37.3	5.51	0.72
	3	30.7	5.37	0.72
	Mean	34.7 b	5.40 b	0.72 b
No food	1	41.3	5.46	0.70
	2	76.0	5.50	0.70
	3	64.0	5.53	0.71
	Mean	60.4 b	5.50 b	0.70 b

[1]No significant interaction ($P > 0.05$) between the effects of rotifers and *Chlorella* on fry survival.

a,b Values followed by different letters are significantly different ($P < 0.05$).

It was obvious that a rate of 2.4 mg/l trichlorfon applied 9 days before stocking was too high a rate of treatment. A rate of 1.6 mg/l applied 2 days before stocking in 1978 showed low survival after giving good survival in 1977. Even though a bioassay showed that striped bass fry should tolerate this level (Hawke 1979), the low production obtained in both 1977 and 1978 was likely due to direct or indirect toxic effects of the pesticide. The 0.8 mg/l rate used in1979 approximated the level of Flibol used by Tamas and Horvath (1976) to control invertebrates in carp rearing ponds.

The rate of gain per ha per day (0.48 kg) from rearing ponds treated with 0.8 mg/l trichlorfon was generally lower than that obtained in untreated ponds when comparable rates of survival were obtained. It was also lower than that reported by Parker (1979) for small rearing ponds continuously aerated and heavily fertilized. He obtained a gain of 2.0 kg/ha/day which is substantially higher than the growth rate obtained from the highest producing ponds at Auburn during a 4-year period. This lower rate of gain is attributed in part to differences in water quality and pond bottom soil fertility at the 2 locations.

Table 2. Survival and growth of lot 2 (Moncks Corners) fry fed 3 diets for 9 days.

Diet	Replication	% Survival	Growth (mm) TL	Growth (mm) BD
Rotifers + *Chlorella*[1]	1	82.7	8.40	1.38
	2	89.3	8.28	1.41
	3	74.7	8.42	1.38
	Mean	82.2 b	8.37 a	1.39 a
Rotifers only	1	74.7	5.75	0.94
	2	77.3	6.08	0.98
	3	97.3	6.62	1.05
	Mean	83.1 b	6.15 a	0.99 a
Chlorella only	1	89.3	4.82	0.64
	2	93.3	4.82	0.63
	3	90.7	4.84	0.62
	Mean	91.1 b	4.83 b	0.63 b
No food	1	93.3	4.85	0.66
	2	88.0	4.89	0.67
	3	96.0	4.91	0.62
	Mean	92.4 b	4.88 b	0.63 b

[1]Interaction between effects of rotifers and *Chlorella* was highly significant ($P < 0.01$).
a,b Values followed by different letters are significantly different ($P < 0.01$).

The number of zooplankton per ml did not reach a peak until about 5 weeks after the pesticide treatment (Fig. 1). Since the fry were stocked 10 days after treatment in 1979, a 25-day lag occurred between the first feeding of the fry and development of the maximum food organism density. Laboratory studies indicate that food density should be highest in the early feeding stage. As the larvae grow and increase in strength, ability to find and capture food improves, enabling their needs to be met with lower concentration.

The number of food organisms per ml varied from a trace to 16.7 with an average of 3.0. The average is higher than the 1.86 nauplii per ml established by Miller (1976) as being the minimum prey concentration for striped bass larvae. Most of our samples (95.5%) had more organisms than the 0.1/ml density reported for natural waters in California (Eldridge et al. 1978). The average was below the 5 rotifers per ml density used by Al-Ahmad (1978) in his growth trials. He found that the food intake of striped bass fry 7, 12, and 17 days old increased as the density of food increased from 5 to 20 rotifers per ml. The increase in consumption rate was not linear, however. In other laboratory studies, Miller

Table 3. Survival and growth of lot 2 (Moncks Corners) fry fed 3 diets for 6 additional days.

Diet	Replication	% Survival	Growth (mm) TL	BD
Rotifers + *Chlorella*	1	88.0	8.98	1.53
	2	72.0	9.09	1.61
	3	68.9	9.41	1.69
	Mean	76.3 a	9.16 a	1.61 a
Rotifers only	1	71.1	7.69	1.34
	2	68.1	7.06	1.16
	3	80.0	7.63	1.36
	Mean	73.1 a	7.46 a	1.29 a
Chlorella only	1	42.0	4.40	0.67
	2	24.0	4.38	0.62
	3	62.0	4.51	0.59
	Mean	42.7 b	4.43 b	0.63 b
No food	1	42.0	4.66	0.56
	2	60.0	4.54	0.66
	3	54.0	4.55	0.66
	Mean	52.0 b	4.58 b	0.63 b

a,b Values followed by different letters are significantly different ($P < 0.01$).

(1976) and Eldridge et al. (1978) demonstrated that survival of striped bass fry is directly related to prey concentration. Thus the evidence conclusively points to the need for an optimum density of suitable food when the larvae begin to feed.

In the study of food habits of fry from treated and untreated ponds, a total of 205 specimens was examined. Of this number, stomachs of 27 or 13 percent were empty. Fry collected from ponds where trichlorfon was not used showed the food preference reported by Meshaw (1969). Copepoda were the organisms most frequently noted. The organisms most commonly present in stomachs of fry from the treated ponds were rotifers as might be expected. In pond E 26, treated with 1.6 mg/l trichlorfon, stomachs of fry collected the first 3 weeks contained only rotifers. Increase in TL of these specimens averaged 0.21 mm per day and survival in the pond at harvest was 33.4 percent of the fry stocked. For a comparable pond which received no trichlorfon, pond E 30 showed a survival percentage of 35.6 and an average increase in TL of 0.29 mm per day over the first 3 weeks. More than 80 percent of the food organisms in the stomachs of 15 specimens examined from this pond during the period were copepods, the remainder being principally Cladocera.

Table 4. Yields from ponds with and without trichlorfon treatment.

Year	Trichlorfon applied, ml/1	Number of replicates	Results[1] Yield per ha Number	Wt., kg	Percent Survival	S.D. Percent Survival	Gain kg/ha/day
1977	0	2	12,087	16.7	6.1	18.9	0.31
1977	1.6[2]	2	53,075	24.5	26.5	9.7	0.45
1978	0	4	75,162	33.2	37.6	28.5	0.69
1978	1.6[2]	4	950	0.8	0.5	0.9	---
1978	2.4[3]	4	963	0.4	0.5	0.9	0.01
1979	0.8[4]	12	85,060	28.9	42.6	12.9	0.48

[1] Average for the number of replicates.

[2] Applied to filled ponds 2 days before stocking fry.

[3] Applied to filled ponds 9 days before stocking fry.

[4] Applied to filled ponds 10 days before stocking fry.

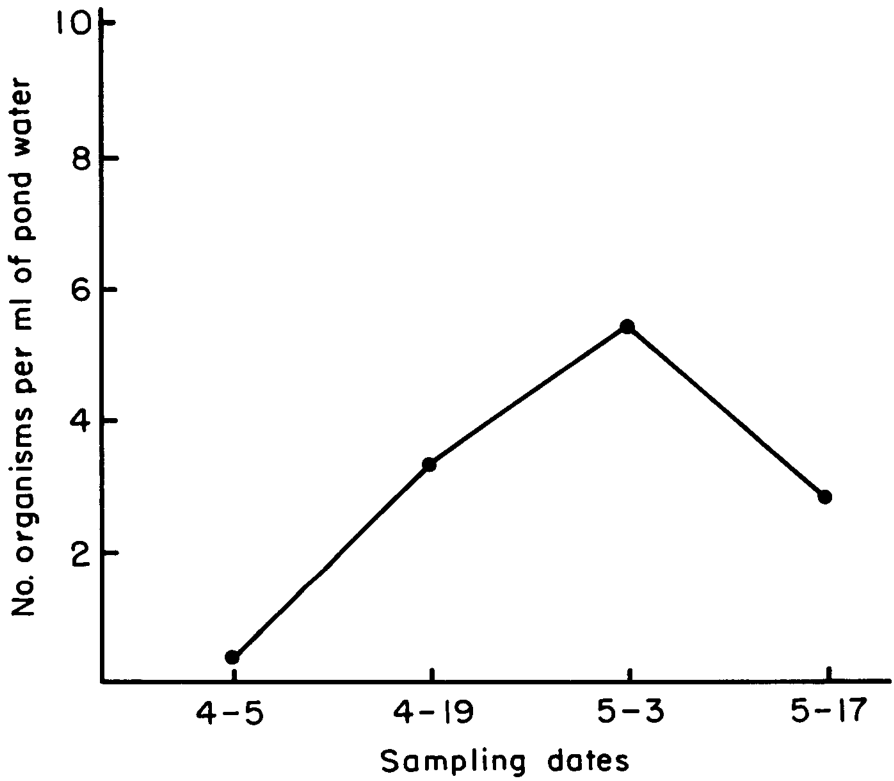

Fig. 1. Average zooplankton density in samples from 12 striped bass rearing ponds, 1979.

The average TL of fry collected from the 4 untreated ponds 6 weeks after stocking was 25 mm (Fig. 2). Those from the 7 treated ponds averaged 18.3 mm. It should be noted that the trichlorfon treatments were 1.6 and 3.2 mg/l in 1977. The optimum application appears to be closer to the 0.8 mg/l rate used in 1979 with a 3-week interval between treatment and stocking fry.

Striped bass fry showed acceptable rates of survival and made adequate growth in earthen ponds on a rotifer diet. This food supply could be provided by an application of the organophosphate insecticide thrichlorfon at a rate of 0.8 mg/l. Use of twice this rate resulted in lower survival in some cases. The pesticide eliminated most invertebrates except rotifers for 4-6 weeks. Results of this study with striped bass were similar to those reported by Tamas and Horvath (1976) for cyprinid fry except that our striped bass survival percentages were lower.

Growth rate in the treated ponds (gain/ha/day) was lower than in those where the pesticide was not used. Also the rate of growth was substantially less than reported for other locations. In spite of slower growth, however, fry reached distributable size (5 cm TL) in 50-55 days at an average numerical yield of 85,000 fingerlings per ha. Delaying stocking of fry into the treated ponds a few more days is a possibility for improving the growth rate.

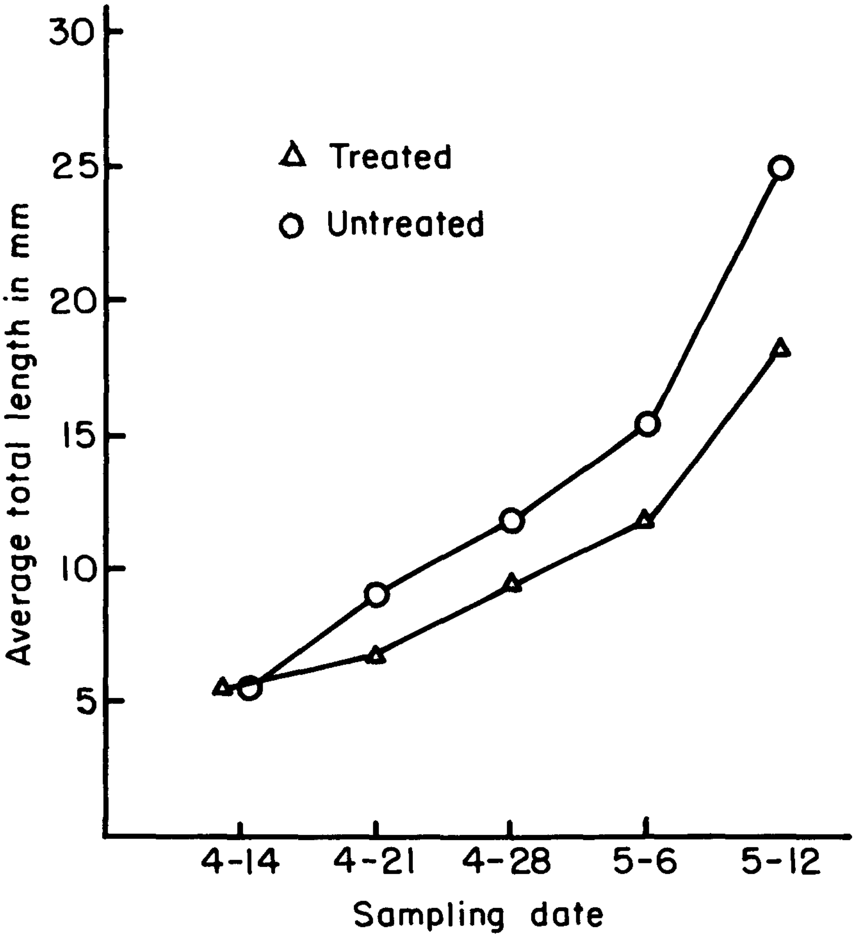

Fig. 2. Average increase in TL of specimens from 7 treated and 4 untreated ponds in the 1977 trial.

It should be noted that Masoten® is registered by the Environmental Protection Administration for use as an agricultural insecticide and as a parasiticde for bait fishes and goldfish. It is not registered for use in food fish culture at this time.

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