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REPRODUCTIVE BIOLOGY OF THE INLAND SILVERSIDE, MENIDIA BERYLLINA IN SOUTHERN ILLINOIS

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ABSTRACT

The potential use of the inland silverside, *Menidia beryllina*, as forage for sportfishes in southern Illinois reservoirs is largely dependent on the ability to produce abundant offspring north of its native range. We investigated the reproductive biology of the inland silverside and found that its breeding season in southern Illinois begins in late April or early May. When inland silverside density is high the breeding season ends in July, however, when density is relatively low the breeding season can continue into October. Two spawning peaks occur if the breeding season continues into October: the first in May or June and the second, much smaller peak, in September. First generation inland silverside are capable of reproducing and can account for extension of the breeding season into October. The reproductive potential of the inland silverside in southern Illinois is greater than that of the brook silverside, *Labidesthes sicculus*; they produced approximately six times more larvae than the brook silverside in predator-free ponds. Inland silverside can build up a large population within 1 year of stocking and many prove efficacious as forage for sportfishes in some southern Illinois reservoirs.

INTRODUCTION

The inland silverside is utilized as forage by sportfishes in waters where it is abundant (Echelle and Mense 1966; Moyle and Holzhauser 1978; Moser 1968). It

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lives in coastal and freshwater habitats from Maine to southwestern Gulf of Mexico and its interior range extends as far north as the confluence of the Mississippi and Ohio rivers (Gilbert and Lee 1980). One specimen was taken in April 1978 from the Mississippi River near Grand Tower, Illinois. No other specimen has been found in Illinois (Burr et al. 1988). The interior range does not normally extend beyond the southern United States because the inland silverside is unable to tolerate relatively cold temperature (Hubbs et al. 1971; Stoeckel and Heidinger 1988). Its usefulness as forage north of its native range is largely dependent on the ability to build up large populations quickly following winter die-offs. This study addresses some of the factors that influence the inland silverside's reproductive capacity in southern Illinois.

The inland silverside is fecund as exemplified by the build up of a very large population within 1 year after it was stocked into a California reservoir (Cook and Moore 1970). Females spawn several times during the breeding season (Mense 1967), and may be capable of producing clutches of eggs daily during the breeding season (Hubbs 1976). Inasmuch as the inland silverside is a multiple spawner, seasonal fecundity is a function of mean number of eggs laid per day and length of spawning season.

Reports on duration of the spawning season vary. Mense (1967) and Hubbs and Bailey (1977) report that spawning in Lake Texoma, Oklahoma, typically occurs from late March or early April to mid-July. However, Taber (1969) collected recently hatched larvae as late as September in Lake Texoma. Hildebrand (1923), Cook and Moore (1970), and Fisher (1973) found evidence, in the form of small fry, that the inland silverside spawns as late as September in North Carolina and north central California.

In a lab study, Hubbs and Bailey (1977) correlated temperature $\geq$ 31°C with termination of spawning of the inland silverside. Field evidence that spawning of inland silverside in Lake Texoma, Oklahoma, ceases at high temperature includes a low frequency of ripe adults during an extremely warm June, followed by a high frequency of ripe adults in mid-July after temperatures had moderated (Hubbs and Bryan 1973). Hubbs and Bailey (1977) also collected ripe adults 2 weeks later than normal during an unusually cool summer. Inasmuch as cessation of spawning is correlated with high temperature, we speculated that summer temperatures cooler than those of the inland silverside's native range may increase the length of the inland silverside's spawning season.

Young-of-the-year reproduction can contribute significantly to the reproductive capacity of forage fishes. For example, reproduction by young-of-the-year threadfin shad, *Dorosoma petenense*, can lead to the build up of extremely large populations within several months when adults are stocked in the spring at low density (Heidinger and Imboden 1974). Cook and Moore (1970), Hubbs and Dean (1979) and Hubbs (1982) have found what they considered to be ripe young-of-the-year inland silverside, but recruitment from first generation inland silverside has not been documented in the literature.

This study was undertaken to evaluate the reproductive biology of the inland silverside in southern Illinois by estimating the number of larvae produced throughout the breeding season, determining the duration of the spawning season, and assessing whether young-of-the-year can reproduce. In addition, we compared the length of the spawning season of the inland silverside with that of the commonly occurring brook silverside, *Labidesthes sicculus*.

MATERIALS AND METHODS

Study Sites

Fish culture ponds free of other fish and two privately owned ponds with established fish communities were used in this study. The fish culture ponds range in size from 0.04 to 0.06 hectars. The mean depth of these ponds is 0.8 m, maximum depth is 1.8 m and the water supply flows by gravity from a 55-hectare reservoir located above the ponds. Knapp's Pond is a 1.2-hectare, privately owned pond constructed for recreational use. It has a maximum depth of 3.5 m. Vegetation in the pond covers only about 5% of the surface in mid-summer. The fish community is typified by many bluegill, *Lepomis macrochirus*, < 125 mm in total length (TL), and moderate numbers of largemouth bass, *Micropterus salmoides*, and channel catfish, *Ictalurus punctatus*. Other taxa occasionally observed in the pond include the warmouth, *Lepomis gulosus*, green sunfish, *Lepomis cyanellus*, golden shiner, *Notemigonus crysoleucas*, blackstriped topminnow, *Fundulus notatus*, common carp, *Cyprinus carpio*, yellow bullhead, *Ictalurus natalis*, and *Lepomis* hybrids. Petersen's Pond is also a privately owned pond constructed for recreational use. It is 3.0-hectares in area with a maximum depth of 3.0 m. This pond is typified by a substantial number of bluegill ≥ 150 mm TL and largemouth bass < 300 mm TL. Other taxa occasionally observed were the lake chubsucker, *Erimizon sucetta*, and *Lepomis* hybrids. Vegetation consists of several stands of cattails, *Typha* sp., and dense beds of other macrophytes, primarily *Ceratophyllum* spp., that normally cover greater than 60% of the surface in mid-summer.

All bodies of water used in this study are located north of the native range of the inland silverside (37° 00′ latitude north). The sample sites are located in southern Illinois between 37° 30′ and 38° 30′ latitude north.

Procedure

Inland silversides overwintered indoors were stocked into all experimental ponds in the spring of 1980. The fish culture ponds and Petersen's Pond were restocked in 1981. Brook silversides were also stocked into a fish culture pond in 1981. In 1981, biweekly meter net samples were taken to determine the duration and intensity of spawning of the silversides with respect to time and temperature. Triplicate meter net (1.0 m diameter, 0.9 mm bar mesh, 2.5 m long cone) samples were taken on each sample date in Knapp's Pond and Petersen's Pond. We towed the meter net behind a small boat and outboard at a mean velocity of 0.85 m/sec.

To avoid contact with the substratum in the shallow fish culture ponds, the meter net was modified by placing floats opposite each other so that half of the net was above the water's surface. The net was pulled the length of the pond by hand at a rate of approximately 0.9 to 1.0 m/sec. A flowmeter (General Oceanics, Inc.® digital model 2030) was used for all samples to determine the distance over which the net traveled. Because the fish culture ponds are small, only one meter net sample was taken in each pond on each sample date to prevent oversampling. All meter net samples were collected at night since other researchers have found the distribution of larvae of other species to be more uniform at night (Netsch et al. 1971; Tuberville

1979). In addition, Taber (1969) reported higher catches of larval inland silverside at night.

Initial meter net samples did not contain larval inland silverside, but 2 weeks later inland silverside as long as 15 mm TL were captured. Consequently, inland silverside $\leq$ 15 mm TL were considered to be indicative of recent spawning, and the number of larvae $\leq$ 15 mm TL was considered a minimum estimate of larvae produced during each 2 week period.

To determine if the open-water meter net samples taken at night were unbiased indicators of larval inland silverside abundance, stratified samples were taken on 7 July 1981 in Knapp's Pond. The samples were stratified according to time and depth. Paired samples were taken approximately every 3.5 hours from dawn until after dark; six offshore and six inshore samples were taken. Offshore samples were taken with a meter net towed behind a small boat and outboard similar to the routine samples, and inshore samples were taken with a meter net modified in the same manner as that used in sampling the fish culture ponds. Inshore samples were taken as near to shore as was practical. We also took a series of shoreline seine samples on 7 July to determine relative abundance of the 1980 size class of inland silverside.

Largemouth bass populations of the two private ponds were analyzed to determine if substantial differences between structures of the predator populations existed. Mark and recapture estimates of density were made using the Chapman modification of the Schnabel method (Ricker 1975). Fish were captured by electrofishing and marked with fin clips. Mean weight of a representative sample of fish was multiplied by estimated number to approximate the weight of largemouth bass in each pond. Number and weight values were standardized to number and kg/hectare, respectively.

Ability of young-of-the-year to reproduce was determined by stocking a known number of inland silverside fry in June into a fish culture pond. This experiment consisted of two trials. In 1980, 200 fry were stocked, and in 1981, 400 fry were stocked. The stocking procedure consisted of capturing inland silverside fry with a bucket, counting the fry and releasing them into a pond which did not contain inland silverside. The pond was drained in October and the number and length-frequency distribution of the inland silverside recovered were determined. If the number of inland silverside recovered in the fall was greater than the number stocked in the spring, reproduction by young-of-the-year was considered to have occurred.

RESULTS

Inland silverside overwintered indoors as well as outdoors in ponds reproduced in the spring and summer of 1980 and 1981. In 1980, inland silverside reproduction was confirmed in the fish culture ponds and in Knapp's Pond when numerous young-of-the-year were captured in the summer and fall. Larvae $\leq$ 15 mm TL were collected from May through October 1981 in Knapp's Pond, and from April through July 1981 in fish culture ponds. Density of inland silverside larvae collected was greatest in mid-May in Knapp's Pond (63/100 m^3, Figure 1) and in mid-June in the fish culture ponds (3 pond mean of 3,994/100 m^3, Figure 2). No inland silverside was collected from Petersen's Pond in either 1980 or 1981.

Brook silverside larvae ≤ 15 mm TL were collected from mid-June to mid-July 1981 in a fish culture pond (Figure 2). The total number of brook silverside larvae collected over the 1981 sampling period (1,505/100 m^3) was approximately six times less than that of inland silverside larvae (9,116/100 m^3) even though the mean density of adults stocked was approximately six times greater in the brook silverside pond (10,000/hectare vs. 1,600/hectare).

In the fish culture ponds, the spawning season of the inland silverside lasted approximately 3 months longer than that of the brook silverside. The brook silverside began spawning approximately 2 months later and stopped spawning approximately 1 month earlier than the inland silverside (Figure 2). A comparison of duration of spawning season between inland silversides in the fish culture ponds (Figure 2) and those in Knapp's Pond (Figure 1) shows that the spawning season in Knapp's Pond, although reduced in intensity, continued for an additional 3 months, into September.

Mean densities of paired samples of inland silverside larvae collected during the diel sampling trial on 7 July were approximately equal for all daytime samples (inshore = 13, 25, 13 and 38/100 m^3; offshore = 0, 0, 2 and 0/100 m^3). Dusk and night samples were also similar (inshore = 204 and 217/100 m^3; offshore = 30 and 11/100 m^3). The ratio of larvae captured during the day versus larvae captured at dusk and night was 1:10, while the ratio of larvae captured offshore in open water versus larvae captured inshore was 1:12.

An analysis of the largemouth bass population structures indicated that while density of fish in terms of weight was greater in Knapp's Pond with 100 kg/hectare vs. 83 kg/hectare, density in terms of numbers was greater in Petersen's Pond with 565/hectare (95% confidence interval = 369-903) vs. 406/hectare (95% confidence interval = 339-488). Length-frequency distributions emphasize the disparity between structures of the two pond's largemouth bass populations (Figures 3 and 4). The oldest age class of fish captured in Petersen's Pond averaged only 276 mm TL while largemouth bass in Knapp's Pond frequently exceeded 300 mm TL.

Reproduction by young-of-the-year fish was confirmed as number of inland silverside recovered was greater than number of inland silverside stocked in both trials. In the first trial, length-frequency data of fish recovered from the fish culture pond stocked with fry in mid-June 1980 showed a bimodal distribution (Figure 5). The transfer of 400 fry to a fish culture pond in June 1981 also led to reproduction by first generation offspring and we again observed a bimodal length-frequency distribution in the fall (Figure 6). Larvae were not abundant in this pond until 11 September. Based on growth rate and size of larvae at that time, spawning of young-of-the-year occurred in early to mid-August, when temperature was ≤31°C.

DISCUSSION

The ability of stocked inland silverside to survive in Knapp's Pond but not in Petersen's Pond is attributed to greater predator pressure in Petersen's Pond. Petersen's Pond is characterized by a crowded, slow-growing largemouth bass population, whereas Knapp's Pond has a relatively balanced population (see Figures 3 and 4). A portion of largemouth bass populations in ponds with crowded populations may have to be removed to permit establishment of a breeding populations of inland silverside.

Density of inland silverside in Knapp's Pond was considerably less than that in the predator-free fish culture ponds. The overall ratio between Knapp's Pond and the fish culture ponds was 1:52. Some of this difference is undoubtedly related to predation on eggs and larvae in Knapp's Pond, but some may also be attributable to sampling technique. The fish culture ponds are small, uniform and shallow, and estimates of larvae in them were considered to be accurate. However, in Knapp's Pond, differences in density of larvae apparently existed between open water and shoreline areas. Based on the series of samples taken on 7 July, open water samples as well as daytime samples underestimate density of larval inland silverside. Visual avoidance of sampling gear is the most probable reason that daytime catches were ten times lower than dusk and night catches, and we attribute greater success of inshore sampling to a greater density of larval inland silverside near shore. Thus, density estimates for Knapp's Pond are probably very conservative due to exclusive open water sampling during our study. We recommend consideration for the horizontal distribution of inland silverside larvae in future studies.

Duration of the spawning season was longer for all inland silverside populations than for the brook silverside, and duration of the spawning season for inland silverside in Knapp's Pond was notably longer than the duration of those held in fish culture ponds. The difference between duration of the inland silverside's and brook silverside's spawning season can be attributed to different reproduction strategies. Brook silverside females spawn only once (Cahn 1927), whereas inland silverside females are capable of spawning daily for an extended time period (Hubbs 1976). Based on this study, annual fecundity of the inland silverside is notably greater than that of the brook silverside. The longer spawning season for inland silverside in Knapp's Pond, when compared to those in the fish culture ponds, may be a result of slightly cooler temperatures in Knapp's Pond (Figures 1 and 2). Hubbs and Bailey (1977) concluded that repeated exposure to high temperature ($\geq 31°C$) causes a cessation in spawning.

Results of young-of-the-year reproduction trials show they can reproduce if conditions are favorable. In 1980 second generation offspring were approaching the minimum reproductive sizes of approximately 51 mm (males) and 60 mm (females) in standard length as determined by Hubbs and Dean (1979). This implies that second generation offspring may also spawn under suitable conditions. The number of second generation offspring produced during young-of-the-year reproduction trials should not be interpreted as the maximum reproductive potential of first generation offspring because predators, primarily *Lepomis* spp. adults and their young, were present. Production of larvae in late summer and fall is significant, inasmuch as small forage fish would be present at a time when they typically are unavailable in southern Illinois reservoirs.

Of 540 inland silverside captured from Knapp's Pond in a series of seine samples on 7 July 1981, only one was of the 1980 size class (100 mm TL). All others were $<$ 62 mm TL which is less than the minimum size required for sexual maturity of females (Hubbs and Dean 1979). Thus, the July cessation in spawning of the inland silverside observed in this study and in Lake Texoma, Oklahoma, as noted by Mense (1967), and Hubbs and Bailey (1977), corresponds not only to high temperature but to disappearance of adults (Mense 1967; Taber 1969). Taber (1969) concluded that the spawning season of the inland silverside in Lake Texoma lasted from April to September in 1966. He also noted a reduction in spawning during August, similar to the trend we observed in Knapp's Pond, and attributed late year spawning to the remnant of the adult population even though he collected no adults in August or September. We attribute the secondary peak in larval abundance in Knapp's Pond to spawning of young-of-the-year (Figure 1). The decline in larval recruitment that occurred between the primary and secondary peaks corresponds to a low number of mature fish (i.e. very few fish of the 1980 size class remained and fish of the 1981 size class were only beginning to reach a sexually mature size). Inland silverside collected in October in Knapp's Pond ranged from 30-105 mm TL, indicating that larger fish of the 1981 year class had reached a sexually mature size. No fish of the 1980 size class were collected in the October sample.

Young-of-the-year did not reproduce in fish culture ponds in which density of inland silversides was high. We attribute lack of young-of-the-year reproduction in these ponds to slow growth and concurrent slow sexual maturation of first generation offspring. Only 29 of 2,961 juvenile inland silverside captured incidental to sampling for larvae in August and September were ≥ 60 mm TL. Of these only 7 were ≥ 70 mm TL. We believe that a density of inland silverside, great enough to restrict growth of individuals, is the primary factor controlling reproduction of young-of-the-year fish. This hypothesis is supported by an aberrant occurrence of many large, gravid first generation offspring in Lake Texoma following an unusually cold winter and substantial die-off of adult inland silverside (Hubbs and Dean 1979).

Based on young-of-the-year reproduction trials and the small secondary peak of larvae produced in Knapp's Pond, young-of-the-year inland silverside do not contribute dramatically to overall annual production of young as do young-of-the-year threadfin shad (Heidinger and Imboden 1974). Nonetheless, because fish of the 1981 size class were very abundant in the October sample for Knapp's Pond, it is apparent that the inland silverside can build up a large population within 1 year in some southern Illinois reservoirs and may prove effective as forage.

SUMMARY

The spawning season of the inland silverside in southern Illinois does not vary appreciably from that observed within its native range. Most spawning occurs before August. The disappearance of adults in July, coupled with the ability of young-of-the-year to spawn later in the year, implies that cessation of spawning in July or reduction in spawning during August is not necessarily controlled by temperature but by a lack of sexually mature fish. Based on our findings concerning young-of-the-year reproduction and size-class structures of samples collected from Knapp's Pond it also appears that a continuation of spawning through August and September is dependent primarily on maturation of age 0+ fish and not on a remnant of the adult population. Reproduction by young-of-the-year is relatively insignificant when compared to early season spawning of overwintering adults. Nonetheless, the inland silverside can build up a large population within 1 year of stocking and may prove efficacious as forage for sportfishes in some southern Illinois reservoirs.

ACKNOWLEDGMENTS

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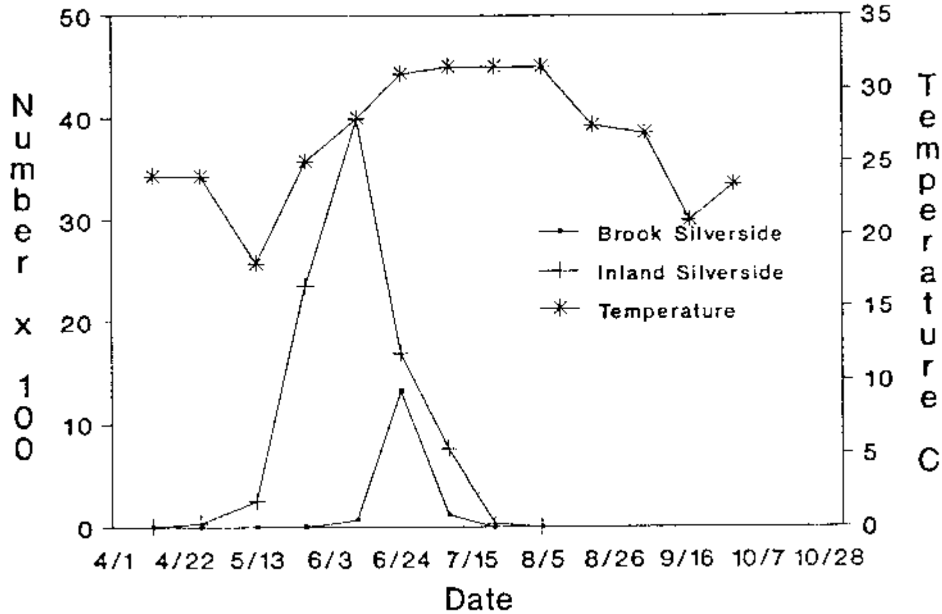

Figure 1. Number of *Menidia* larvae ≤ 15 mm in total length per 100 m^3 captured in Knapp's Pond, 1981.

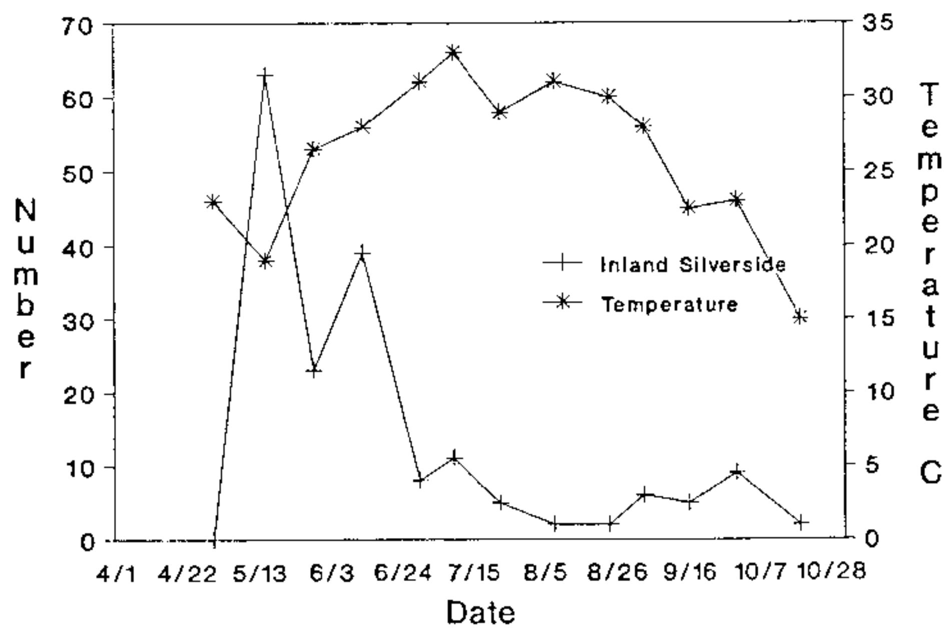

Figure 2. Number of *Menidia* (3 pond mean) and *Labidesthes* (1 pond) larvae ≤ 15 mm in total length per 100 m^3 captured in predator-free fish culture ponds, 1981.

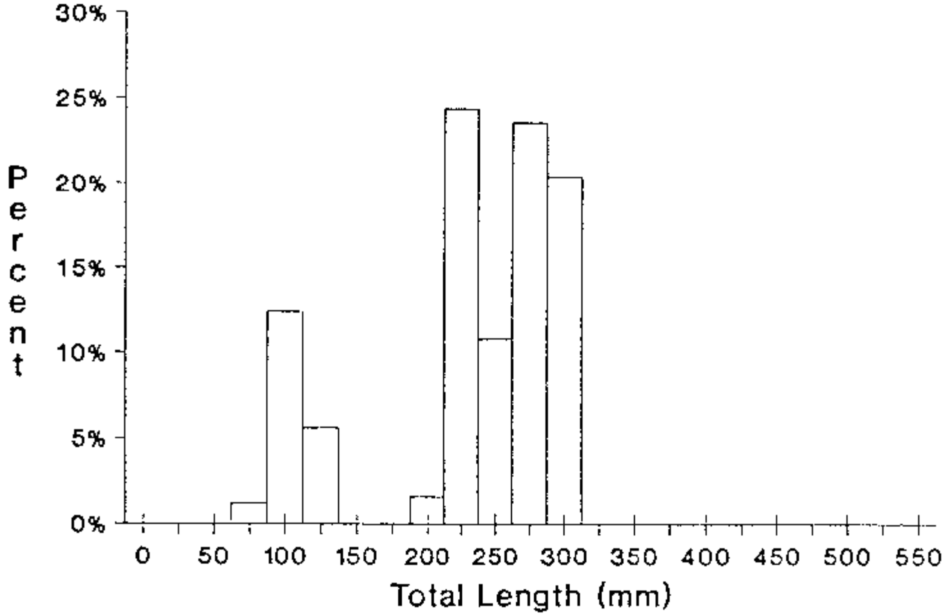

Figure 3. Length-frequency distribution of 250 largemouth bass captured from Petersen's Pond in 1981.

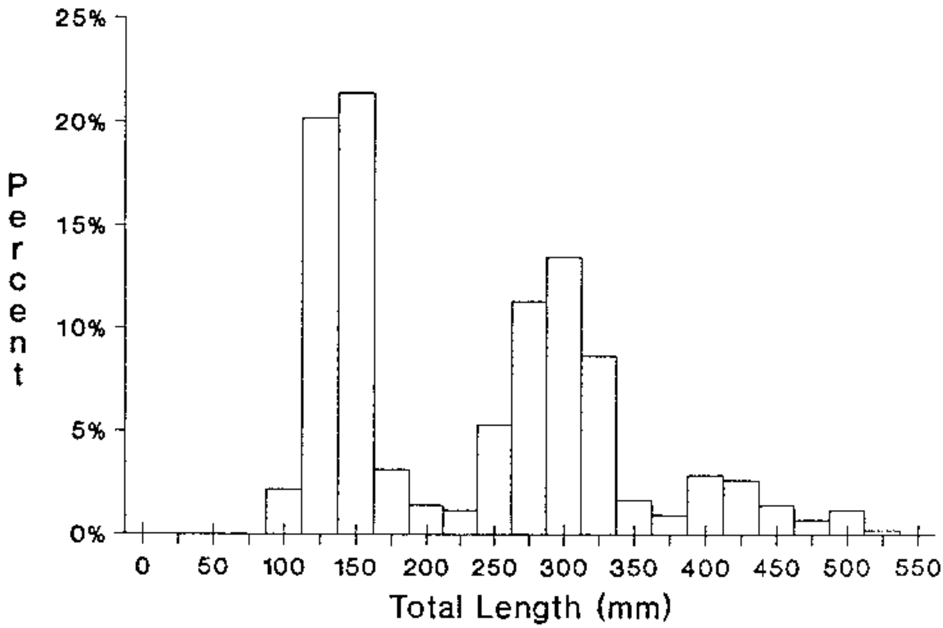

Figure 4. Length-frequency distribution of 416 largemouth bass captured from Knapp's Pond in 1981.

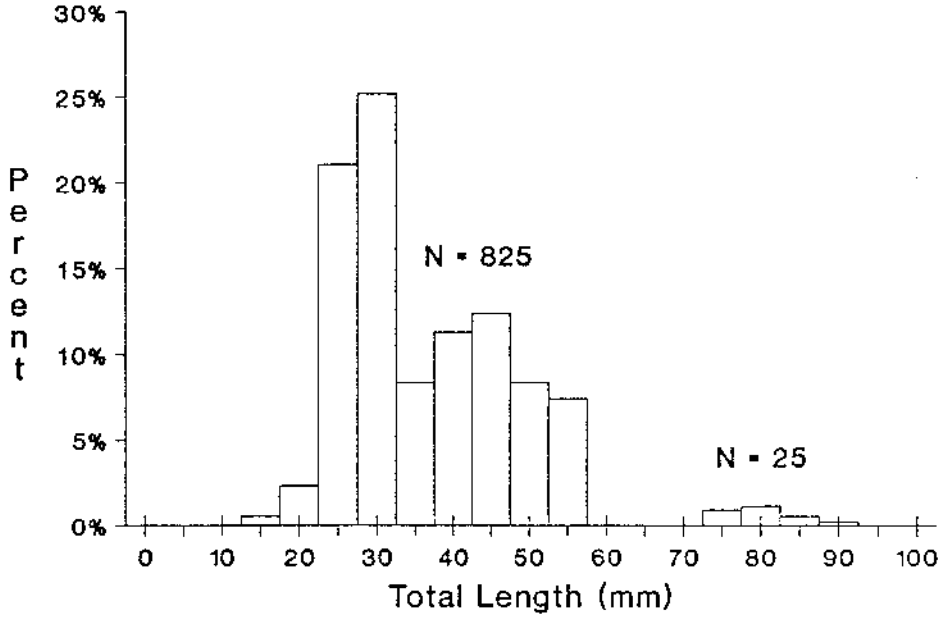

Figure 5. Length-frequency of 850 inland silverside recovered in October, 1980, from a pond stocked with 200 fry in June.

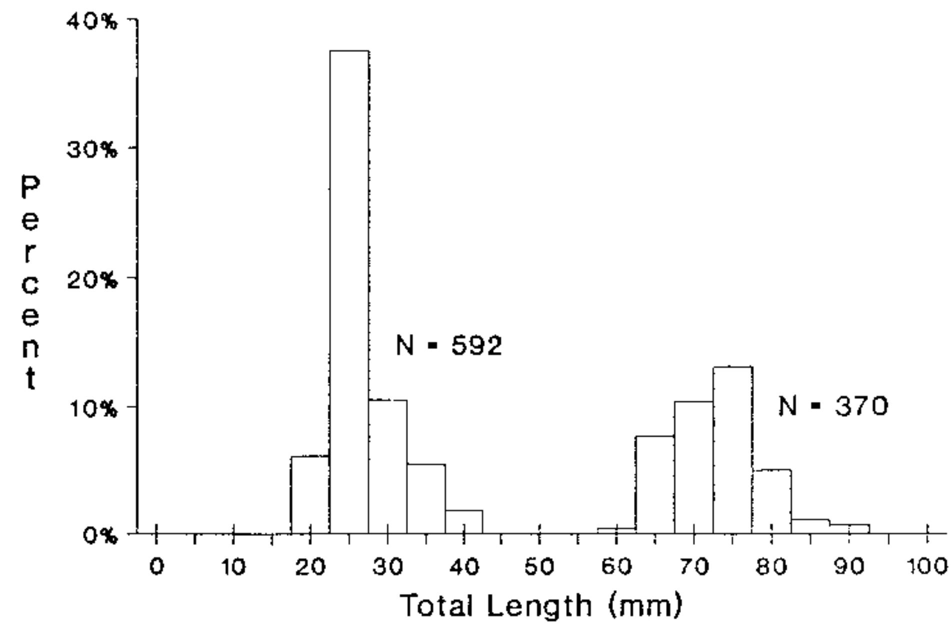

Figure 6. Length-frequency of 962 inland silverside recovered in October, 1981, from a pond stocked with 400 fry in June.