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SALINITY AND TEMPERATURE TOLERANCE LIMITS FOR LARVAL SPOTTED SEATROUT, *CYNOSCION NEBULOSUS* C. (PISCES: SCIAENIDAE)

by

Sabine Alshuth and R. Grant Gilmore
Harbor Branch Oceanographic Institution
5600 U.S. 1 North
Fort Pierce, Florida 34946

Abstract

Salinity and temperature tolerance limits for the estuarine spawning spotted seatrout, *Cynoscion nebulosus*, from the Indian River Lagoon, east Florida, were evaluated by examining egg hatching rates, 24-hour and 2-week larval survival. Laboratory-reared larvae from eggs collected at known spawning sites during 1992 and 1993, spawned at salinities ranging from 24 to 27.5 ppt, were used for our experiments. Eggs were exposed to various temperatures (20°, 25° and 30°C) and salinities (0-50 ppt), covering 33 combinations. At 0-15 ppt eggs sank to the bottom, above 20 ppt eggs floated to the surface at all temperatures. Temperature-salinity influence on hatching success and larval survival showed poor hatching rates at salinities <10 ppt over all temperatures. Best conditions for hatching and 24-hour larval survival were 25 ppt and 30°C. Survival to 24 h was influenced by both temperature and salinity. Poorest survival was at 20°C and 5 ppt. Temperature was associated with significant differences in 2-week larval survival. The lowest temperature (20°C) resulted in reduced survival rates. Over all conditions highest survival was at 25 ppt and 30 ppt.

Temperature and salinity effect on larval growth rates was significant; growth at 20°C was much slower than at 25° or 30°C and varies inversely with salinity. At 30°C high cannibalism occurred during postflexion, resulting in increased growth rates.

INTRODUCTION

Temperature and salinity are important physical factors controlling the distribution of teleosts (Holliday 1969). Tolerance of a broad range of salinities is important for estuarine spawners such as spotted seatrout (*Cynoscion nebulosus*), which are likely to experience large salinity fluctuations. Spotted seatrout are distributed throughout the Indian River Lagoon of Florida. They are abundant in the estuarine environment which they use for feeding, spawning and as nursery ground. These fishes seldom move great distances and remain within their natal estuary (Moffett 1961; Iversen and Tabb 1962). Planktonic larvae settle to the bottom from the plankton, and growth thereafter occurs in shallow water over seagrass beds (e.g. Pearson 1929; Springer and Woodburn 1960; Tabb 1961; Gilmore 1977; Brown 1981; Rutherford et al. 1989; Chester and Thayer 1990).

Spotted seatrout spawn from early spring to late fall (Mok and Gilmore 1983). In the Gulf of Mexico, most spawning occurs from early April until late October with two seasonal spawning peaks in spring and summer (McMichael and Peters 1989), whereas in southwest Florida earlier spawning in mid-March has been reported (Peebles and Tolley 1988), although Jannke (1971) suggested that spawning occurs throughout the year in Everglades National Park. The seasonal variation in spawning is caused by several as yet undefined biotic and abiotic factors which may also influence egg hatching, larval survival and growth and consequently juvenile recruitment, the survivors of the larval period.

Spotted seatrout are euryhaline and occur in water salinities ranging from as low as 0.2 ppt to as high as 75 ppt (Herald and Strickland 1949; Simmons 1957), with highest abundances usually occurring at intermediate salinities (5-20 ppt, Gunter 1945; 15-35 ppt, Tabb 1966). Spawning salinities, however, are probably less variable than salinities tolerated by non-spawning adults. Spotted seatrout spawn in intermediate to high salinity waters within the estuary, but not in brackish waters (Powell et al. 1989; Gilmore 1992).

Variations in environmental factors such as temperature and salinity could affect egg incubation and larval survival, and ultimately recruitment and year-class strength. For most larval fish, basic biology, including the effects of environmental factors on survival and growth, is poorly understood and little is known about the upper and lower limits of temperature and salinity and their effects on survival of eggs and early larval stages, or on early development and growth. Few studies on spotted seatrout, however, have demonstrated optimal salinity conditions for egg and yolk sac larval survival to be 28.1 ppt at 28°C (Taniguchi 1981) and both upper and lower salinity tolerance limits showed an age-linked pattern, decreasing to a minimum tolerance range (6.4 to 42.5 ppt) at age 3 days after hatching at 28°C (Banks et al. 1991).

The present study on temperature and salinity effects on spotted seatrout larval survival and growth was carried out to increase our knowledge of environmental tolerances and habitat needs of recruits in their natural environment. The impact of temperature and salinity changes in estuarine systems upon fish populations recruitment is complex. In order to quantify some of the parameters involved in response to such environmental fluxes, this investigation had the following objectives: (1) to determine egg and larval mortality levels under various controlled salinity and temperature regimes; and (2) to determine temperature and salinity effects on larval growth. The ranges of temperature (20° - 30°C) and salinity (0 - 50 ppt) selected for our experiments are representative of conditions occurring in coastal waters during the spawning period.

MATERIAL AND METHODS

Spotted seatrout eggs were collected during the spawning seasons 1992 and 1993 with a 1 meter diameter ring plankton net (335 µm) from surface waters at two of the most productive spawning sites in the Indian River Lagoon, Intracoastal Waterway Marker # 80 in Wabasso and # 168 in Vero Beach (see Fig.1).

Hydrophones were used to record vocalization of adult male spotted seatrout and to isolate estuarine spawning sites which then allowed characterization of estuarine spawning areas. Adult males produce distinctive vocalization, starting at sunset and lasting two to three hours, which are known to be associated with spawning.

Physical oceanographic parameters at the principal spawning site were monitored continuously with a submerged hydrolab unit and current meters. Furthermore, oceanographic parameters such as surface temperature, salinity and dissolved oxygen were studied at each hydroacoustic and planktonic station with portable field gear.

Laboratory-reared larvae from spotted seatrout eggs spawned at salinities ranging from 24 ppt to 27.5 ppt and temperatures from 27° to 29°C were used for our experiments. On arrival in the laboratory, the living ichthyoplankton samples were immediately sorted under the microscope and the fertilized planktonic eggs transferred by pipette to the experimental tanks. Eggs were incubated at three different temperatures (20°, 25° and 30°C) in 20 liter tanks (45 cm diameter, 20 cm height), each containing 100 to 150 eggs, filled with filtered seawater of different salinities (0 ppt, 5 ppt, 10 ppt, 15 ppt, 20 ppt, 25 ppt, 30 ppt, 35 ppt, 40 ppt, 45 ppt and 50 ppt). Test salinities were made with filtered seawater, diluted with distilled water for hyposalinity conditions. Hypersaline seawater was prepared by incubating tanks for 48 hours at 30°C; thus evaporation resulted in concentration to approximately 55‰. Treatment water for tolerance tests' salinity was adjusted by mixing the filtered seawater, hypersaline water and destilled water. Our experimental set-up covered 33 different temperature-salinity conditions, studied in duplicates and triplicates.

Larvae were raised up to the second week in a separate holding chamber (22 cm diameter, 10 cm height) inside the 20 l tanks. The holding chambers were made from 300 µm Nitex net glued to a PVC pipe cylinder; the Nitex net forming the bottom and the pipe the sides of the container. Aeration was provided outside the holding chamber to avoid producing turbulence and bubbles within the chamber but allowing for oxygen diffusion into the chamber. During the first week, the water was not changed, except for the addition of small amounts of water with the food organisms. During the subsequent weeks, about 50% of the water was changed once a week. Additionally, temperatures were checked daily and maintained within 0.5°-1°C. Salinity was measured daily using a refractometer and adjusted by adding distilled water to the experimental tanks. At 30°C, salinities were adjusted twice a day. Illumination from fluorescent room lamps with a photoperiod regime of 12 hours light and 12 hours darkness was used.

First feeding larvae were fed with cultured algae and cultured rotifers (*Brachionus plicatilis*). After five to seven days larvae fed on brine shrimp *Artemia salina*.

Larval survival at all temperature-salinity conditions was estimated daily. Percentage hatch, percentage survival of the larvae to 24 hours and two week survival was calculated to determine the influence of temperature and salinity. Larvae were sampled every day for growth measurements during the first week, later at irregular intervals, at the following temperature-salinity conditions: 20°C with 10 ppt, 20 ppt, 30 ppt, 25°C with 10 ppt, 20 ppt, 25 ppt, 30 ppt, and 30°C with 10 ppt, 20 ppt and 30 ppt. On each sampling day total lengths of seven to twelve live larvae were measured.

RESULTS

I. Influence of Salinity and Temperature on Egg/Larval Development under Laboratory Conditions

A. Fertilized eggs - 0 - 20 hrs. after fertilization: Spotted seatrout eggs enter the water column two to three hours after sunset and spawning activity was observed to 2400 hr at temperatures of 25°C to 33°C and salinities of 18 ppt to 33 ppt.

Salinity influence: At salinities 0-15 ppt eggs sank to the bottom, above 20 ppt eggs floated to the surface at all temperatures.

Temperature influence: Water temperature affected hatching time of seatrout eggs: At 25°C hatching occurred 18 hours after fertilization, whereas at 30°C hatching took place 13 hours after fertilization.

B. Hatching yolk sac larvae - 13 - 24 hrs. after fertilization: Spotted seatrout yolk sac larvae hatch at a mean length of 1.65 mm TL with unpigmented eyes and a clear primordial marginal fin.

Salinity influence on survival: The best conditions for hatching were salinities ranging from 25 ppt to 30 ppt which resulted in 100% hatching (Fig.2). Higher salinities above 45 ppt resulted in relatively high mean hatching rates of 85-93% hatching, whereas lower salinities below 10 ppt showed poor mean hatching success with 50 to 88.3% (Tab.1). No hatching was observed at salinity 0 ppt; all eggs died (Tab.1; Fig.2).

Temperature influence on survival: Hatching success was affected by temperature with a lower mean hatching rate of 78.6% at 20°C, whereas at 30°C mean hatching success was 85.6% over all salinity conditions (Tab.1).

Temperature-salinity combination - general impacts: Higher salinities above 45 ppt resulted in relatively high mean hatching rates at 25° and 30°C with 90 to 97%, whereas at 20°C, eggs seemed to be more sensitive to extreme salinity conditions: high hatching rates were only observed at salinities ranging from 10 ppt to 35 ppt; above 45 ppt mean hatching success was only 70%, below 10 ppt only 50% hatching was observed (Tab.1). Temperature-salinity influence on hatching success and larval survival showed poor hatching rates at salinities <10 ppt over all temperatures and poor hatching rates associated with lower temperatures (20° to 25°C), (Fig.2).

C. Post-hatch yolk sac larvae - 1 -5 days after hatching: The yolk sac stage was completed at a total length of 2.6 mm.
Salinity influence on survival: Salinity influence on 24-hour larval survival resulted in highest survival with 100% at 25 ppt (Tab.1). Salinities ranging from 15 to 35 ppt showed relatively high mean survival above 90%. Increased mortality was observed at salinities below 10 ppt with 86.6 to 48.3%. Above 40 ppt mean larval survival decreased from 84.7 to 71.7% (Tab.1).
Temperature influence on survival: Temperature also affected 24-hour larval survival: At low temperature of 20°C only 73.4% mean survival was observed, whereas higher temperatures resulted in higher mean survival rates with 79% at 30°C (Tab.1).
Temperature-salinity combination - general impacts: 24-hour larval survival was influenced significantly by both temperature and salinity. Lower temperatures (20° and 25°C) and low salinities (below 10 ppt) were associated with poor survival of the yolk sac larvae resulting in only 50% mean survival. Poorest survival was at 20°C and 5 ppt with 48.3% mean survival. The best conditions for 24-h larval survival were 25 ppt and 30°C with up to 100% survival (Tab.1).

D. First-feeding pre-flexion larvae - 4 - 8 days after hatching: First feeding occurs at 2.6 mm total length. This developmental stage is associated with highest mortality.
Salinity influence on survival: Salinity influence on survival of first-feeding larvae showed no significant differences (Figs.3 a-c). Lower salinity of 10 ppt resulted in lowest survival rates of less than 5% at day five (Fig.3), whereas at higher salinities of 30 ppt larval survival was higher at day five with 75 to 90%

mean survival and high mortality took place later at eight to ten days after hatching (Figs. 3a-c).

Temperature influence on survival: Temperature affected larval survival at first feeding: At 20°C mean larval survival was low with less than 5% (Fig.3a). At 25°C mean survival at first-feeding was higher with 28.3% (Fig.3b), whereas at 30°C a mean survival rate of 78.3% was observed (Fig.3c).

Temperature-salinity combination - general impacts: Temperature-salinity influence on survival of first-feeding larvae showed poorest survival of first-feeding larvae at low salinities (10 ppt) over all temperatures and higher mortalities associated with lower temperatures. Highest mean mortalities of up to 93% occurred at five days after hatching at 20°C (Figs. 3a-c).

E. Flexion larvae - 15 - 20 days after hatching: Notochord flexion in spotted seatrout larvae was observed at 6.8 mm total length.

Salinity influence on survival: Salinity influence on 2-week larval survival resulted in highest mean survival rates of 14% at 25 ppt, followed by high survival of 5.6% at 30 ppt (Tab.1). At lower salinities (20 to 5 ppt) mean larval survival decreased from 8 to 0%. At higher salinities above 35 ppt only 5.6 to 0.3% of spotted seatrout larvae survived. No survival was observed after 2 weeks at 50 ppt (Tab.1).

Temperature influence on survival: Temperature was associated with significant differences in 2-week larval survival (Fig.4). The lowest temperature (20°C) resulted in lower mean survival rates of only 0.2% at 13 days after hatching (Tab.1) with no larval survival after 2 weeks (Fig.3a). Highest mean survival rates were observed at 30°C with 8.3% and at 25°C with 4.5% (Tab.1).

F. Late larvae and juveniles 22 - 25 days after hatching: Metamorphosis to the juvenile stage occurred in spotted seatrout larvae at 16.3 mm total length.

Salinity influence on survival: Salinity influence on postflexional and juvenile spotted seatrout survival at 25 days after hatching showed relatively high mean survival rates at 25 and 30 ppt with up to 9.5%. No major differences were observed at lower salinities (20 - 10 ppt) with low mean survival of 0.2% (Figs. 3a-c). No survival at metamorphosis was observed at salinities above 35 ppt.

Temperature influence on survival: At 30°C highest survival rates were observed at 20 ppt and 30 ppt which resulted in high mortality after 25 days (Fig.3c). No larvae raised at 20°C survived over a 30-day period (Fig.3b). At 25°C

highest survival rates with 20% were observed after metamorphosis at 30 ppt (Fig.3b), whereas less than 1% of the larvae survived at 10 and 20 ppt.
Temperature-salinity combination - general impacts: At 25°C, 30 ppt salinity resulted in distinct low larval mortality rates with 20% survival over a 30-day-period. Survival was relatively low at 10 ppt and 20 ppt, with highest mean survival rates of 0.5% at 10 ppt, however, low larval survival was observed at these salinity conditions.

II. Influence of Salinity and Temperature on Larval Growth under Laboratory Conditions

C. Post-hatch yolk sac larvae - 1 -5 days after hatching:

Salinity influence on growth: Salinity influence on growth during the yolk sac stage was not observed (Figs. 5a-d). Larval lengths are very short at hatching (1.65 mm TL) compared to one-day old larvae with 2.52 mm TL at a mean growth rate of 0.875 mm day^{-1}, correlated with high yolk absorption. However, growth decreases from day two to day-five old larvae from 0.051 to 0.007 mm day^{-1} and is very slow until larvae start feeding at all salinities (Figs. 5a-d).
Temperature influence on growth: Temperature was responsible for the duration of the yolk sac stage: At 25°C larvae absorbed their yolk within five days after hatching, their eyes became pigmented and the mouth was developed, whereas at 30°C completion of the yolk sac stage takes place after three days.

D. First-feeding pre-flexion larvae - 4 - 8 days after hatching:

Salinity influence on growth: No salinity influence on larval growth rates at first feeding was observed (Figs. 5a-d).
Temperature influence on growth: First feeding occurs within four days after hatching at 30°C and up to eight days after hatching at 20°C.

E. Flexion larvae - 15 - 20 days after hatching:

Salinity influence on growth: Salinity influence on growth in flexion larvae was significant at higher temperatures of 25° and 30°C with higher growth associated with lower salinities (Tab.2; Figs. 5a-d). At 25°C mean total lengths of 5.85 mm were observed at 10 ppt, whereas at 30 ppt larvae measured only 4.26 mm. Lengths measurements at 30°C and 10 ppt have shown mean larval lengths with 12.68 mm compared to shorter lengths at 30 ppt with only 5.98 mm (Tab.2).

Temperature influence on growth: Notochord flexion occurs at 18 days after hatching at 25°C. At 30°C flexion stages were observed at 15 days after hatching, whereas at 20°C flexion occurred after 20 days. At this stage higher growth was correlated significantly with higher temperatures: Highest growth was observed at 30°C (Tab.2; Figs. 5a-d).

Temperature-salinity combination - general impacts: Temperature and salinity were associated with significant differences in survival of 2-week-old larvae. The best conditions for 2-week larval survival were at 30°C and salinity ranges from 25 ppt to 30 ppt. Over all conditions highest mean survival was at 25 ppt with 14% mean survival (Tab.1).

F. Late larvae and juveniles 22 - 25 days after hatching:

Salinity influence on growth: Salinity effect on spotted seatrout growth at metamorphosis was significant; growth varies inversely with salinity and was much slower at 30 ppt compared to 10 ppt (Figs. 5a-d).

Temperature influence on growth: Metamorphosis to the juvenile stage occurred 25 days after hatching at 25°C, at 30°C after 22 days. Growth increased rapidly from flexion to metamorphosis at 25°C, reaching an exponential growth at all temperatures (Figs. 5a-d). Although highest growth rates were shown under these conditions, high mortality was correlated with high cannibalism at the end of the postflexional larval stage.

DISCUSSION

The investigation of temperature and salinity effects on spotted seatrout larval survival demonstrated that both parameters were important for 2-week larval survival but not very important for egg hatching and 24-hour larval survival. Spotted seatrout larvae develop successfully to feeding larvae at salinities of 15 to 35 ppt. Temperature and salinity effects on egg buoyancy demonstrated that at 0-15‰ eggs sank to the bottom, above 20‰ eggs floated to the surface at all temperatures. Temperature-salinity influence on hatching success and larval survival showed poor hatching rates at salinities $\leq$ 10 ppt over all temperatures. Although larval survival was observed at low salinities in the laboratory, we would expect high mortality of eggs developing on the bottom in natural populations.

24-hour larval survival was influenced by both temperature and salinity. Lower temperatures (20° and 25°C) and low salinities (below 10 ppt) were associated with poor survival. Best conditions for hatching, 24-hour- and 2-week larval survival were 25 ppt and 30°C. Tanigushi (1981) found that eggs could be fertilized at salinities from 5 to 60 ppt, but embryos died after the 2- to 8-celled stages of development at 5 ppt and $\geq$ 50 ppt. Hypersalinity ($\geq$40 ppt) and a temperature of 20°C adversely affected a reduced hatching success of spotted seatrout eggs (Gray et al. 1991). This study of Gray et al. 1991 contradicts our results and previous findings of Gray and Colura (1988), who reported 0% hatch at salinities above 45 ppt. Sciaenid eggs can be affected by increased salinity levels (McCarty et al. 1986). Studies of temperature and salinity effects on spotted seatrout eggs have focused primarily on hatching success, survival, and growth potential (Tanigushi 1981, Gray and Colura 1988). Spotted seatrout eggs exposed to temperatures ranging from 20 to 32°C died at salinities between 35 and 45 ppt (Gray and Colura 1988). Tanigushi found that salinities above 50 ppt adversely affected development of larval spotted seatrout. Differences in hatching success may be due to different methodologies or to natural variation in the local seatrout population.

In this study, spotted seatrout larvae demonstrated that temperature and salinity were associated with significant differences in 2-week survival. No larval survival was observed at the lowest temperature (20°C) and at 50 ppt, whereas highest survival rates were at 30°C. Over all conditions highest survival was at 25‰. Although relatively few studies have been concerned with salinity effects on larval spotted seatrout, Taniguchi (1981) reported an optimum temperature of 28.0°C and optimum salinity of 28.1 ppt and predicted 100% survival from 18.6 to 37.5 ppt. Banks et al.(1991) demonstrated the efficient osmoregulation abilities of spotted seatrout larvae, and delimits their narrowest tolerance range (6.4 to 42.5 ppt), occurring on day 3.

Field data provide firm support for spotted seatrout tolerance limits. Estuarine spawners such as spotted seatrout will be subjected to wide ranges in salinity during a long spawning season, however, our studies indicate that spotted seatrout spawned when temperatures range between 25 and 32°C. In south Texas spotted seatrout spawning took place at lower temperatures between 20 and 32°C (Brown-Peterson et al. 1988) and salinities are 30 ppt or higher (Rice et al. 1988). Arnold et al. (1976) reported spawning in the laboratory at salinities between 26 and 30 ppt at 26°C. Tucker and Faulkner (1987) documented conditions under which Indian River spotted seatrout will voluntary spawn in captivity were toward the high end of the range reported for natural spawning: 27.7-32.5°C in 1985 and 28.1-31.9°C in 1986.

Previous field studies indicated collections of larval spotted seatrout within the salinity limits of 8-40 ppt (Rutherford et al. 1986). These values place seatrout among the more euryhaline sciaenid larvae. In comparison, silver perch (*Bairdiella chrysoura*) have been collected at salinities varying from 2 - 37.4 ppt (Johnson 1978). Red drum (*Sciaenops ocellatus*) have been collected within salinities ranging from 8-35 ppt (Rutherford et al. 1986) and develop successfully to feeding larvae at salinities of 10-40 ppt (Holt et al. 1981). In contrast, the apparently more stenohaline atlantic croaker (*Micropogonias undulatus*) larvae have been captured only on the continental shelf at salinities of 28-36 ppt (Powels and Stender 1978). Differences in salinity response could be explained as being primarily nongenetic adaptations to the spawning salinity (Kinne 1962, Holt et al. 1981). Holt et al. (1981) indicated that red drum eggs exposed to different salinities may have been acclimated to higher salinities since salinities were very near the salinities of the maturation and spawning tanks. Altered upper limits to the range tolerated by larvae from different spawning salinities indicated parental and/or early acclimation effects are important (Banks et al. 1991).

Temperature became increasingly important for survival and growth as larvae develop. Highest 2-week larval survival was found at 30°C. Spotted seatrout larvae were not able to metamorphose at 20°C; no survival was observed after 2 weeks. Temperature and salinity effect on larval growth rates was significant; growth at 20°C was much slower than at 25° or 30°C. Extremely high growth rates at 30°C were the result of cannibalism, which occurred during postflexion. Previously, cannibalistic behavior was only observed in cultured spotted seatrout (Arnold et al. 1978, Tucker 1988), but no evidence exists, whether cannibalism occurs in the wild.

Apparently contradictory results showed salinity effect on growth which varies inversely with salinity. The question now arises whether highest growth rates are correlated with highest survival rates? As our studies indicate spotted seatrout can more likely adapt to hypersalinity conditions (up to 40 ppt) during the early larval stage, but as larvae grow and develop, there is a tendency of higher survival at lower salinities to 10 ppt towards the juvenile stage. Our previous studies have shown that spotted seatrout egg diameters were correlated inversely with salinities (Alshuth and Gilmore 1993). This might explain different larval growth rates, if total lengths of yolk sac larvae may also differ.

Optimal conditions for spotted seatrout eggs and larvae were found to be at 25° to 30°C temperature and 20 to 30 ppt salinities. These ranges are very near the minimum and maximum values at which wild spotted seatrout eggs and larvae have been collected in central east Florida (Alshuth and Gilmore, unpubl.). Indian River Lagoon spotted seatrout spawn from spring, April-June, to fall, September-October, with principal activity typically occurring in May/June and August/September. May/June marks the end of the cool dry season, water temperatures warm up (monthly means in Indian River Lagoon between Sebastian and St. Lucie Inlets: 25° - 30°C, Gilmore 1977) and salinities are marine or polyhaline (monthly means in Indian River Lagoon between Sebastian and St. Lucie Inlets: 31 - 35 ppt, ibid.). August/September is the peak of the wet season when salinities are lowest (monthly means in Indian River Lagoon between Sebastian and St. Lucie Inlets: 22 - 30 ppt, ibid.) and temperatures at their annual peak (monthly means in Indian River Lagoon between Sebastian and St. Lucie Inlets: 29° - 30°C, ibid.). Subsequently, historical mean salinities range from 22 to 35 ppt and temperatures from 25° to 30°C within the Indian River Lagoon system during the period spotted seatrout spawn. Field temperatures taken when plankton tows were made for larval fish ranged from 15.0°C (13 December 1993) to 32.0°C (8 July and 4 August 1993), mean of 28.3°C, salinities from 12.0 ppt (1 July 1992) to 35 ppt (8 July 1993), mean of 25.8 ppt.

Based on these results we hypothesize that spotted seatrout spawning success and subsequent year-class strength will be adversely affected by the onset of high water temperatures. Our data indicate that a sudden temperature decrease from 25° to 20°C during the early spawning season, which is not unlikely in the Indian River Lagoon, will cause high larval mortality. Salinity in the natural situation is likely to fluctuate more rapidly towards brackish than hypersaline conditions during the wet summer season. Thus it is surprising to observe that these larvae show greater ability to adapt to hypersaline conditions during their early development than to brackish or lower salinities. On the other hand we only occasionally observed any spawning activity in salinities below 20 ppt

(Gilmore 1992) and this correlates with the adult spawning behavior: sound investigations of soniferous spotted seatrout have shown that during salinity declines adults usually migrate toward the ocean inlets for spawning at higher salinities (Gilmore et al., in prep.).

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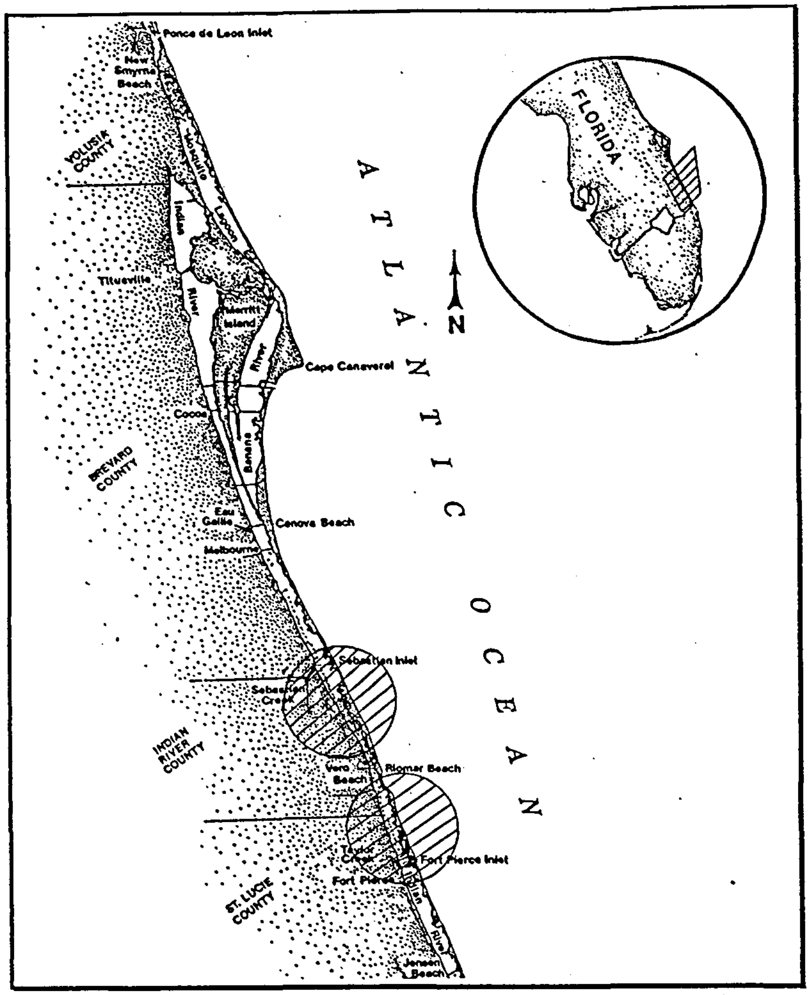

***Fig.1:** Sampling sites in the Indian River Lagoon, central-east Florida.*

Item	0‰	5‰	10‰	15‰	20‰	25‰	30‰	35‰	40‰	45‰	50‰	20°C	25°C	30°C
% hatch	0	50.1	88.3	95.6	99.3	100	100	99.3	95.6	93	85	78.6	82.9	85.6
% 24-h survival	0	48.3	86.6	95.5	98.6	100	97	90	84.7	71.7	50	73.4	73.6	79.0
% 2-wk survival	0	0	2	4.6	8	14	11.7	5.6	1	0.3	0	0.2	4.5	8.3

***Tab.1:** Mean percentage hatch, 24-h survival, and 2-week survival of spotted seatrout over all conditions.*

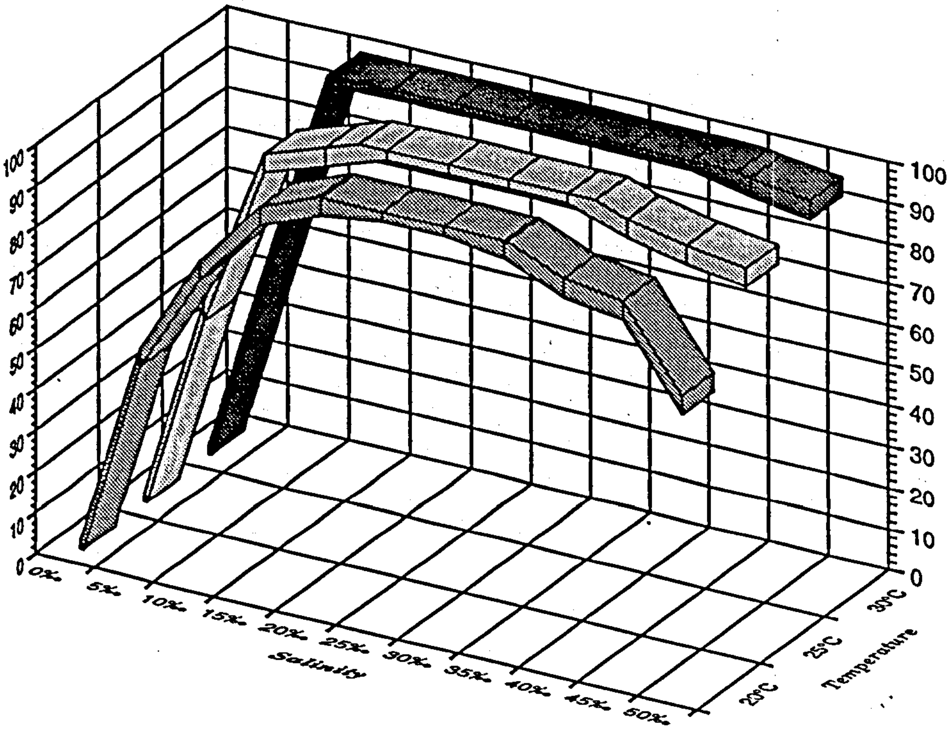

Fig.2: Hatching success at different temperature-salinity conditions.

Salinity (‰)	20° Mean	20° SD	20° n	25° Mean	25° SD	25° n	30° Mean	30° SD	30° n
10	none	survived		5.85	0.165	5	12.675	0.975	6
20	none	survived		4.86	0.307	16	8.407	2.350	10
25	none	survived		4.562	0.823	11	no measurements		
30	none	survived		4.262	0.632	13	5.98	1.242	13

Tab.2: Total lengths (in millimeters) of spotted seatrout larvae that survived 2 weeks.

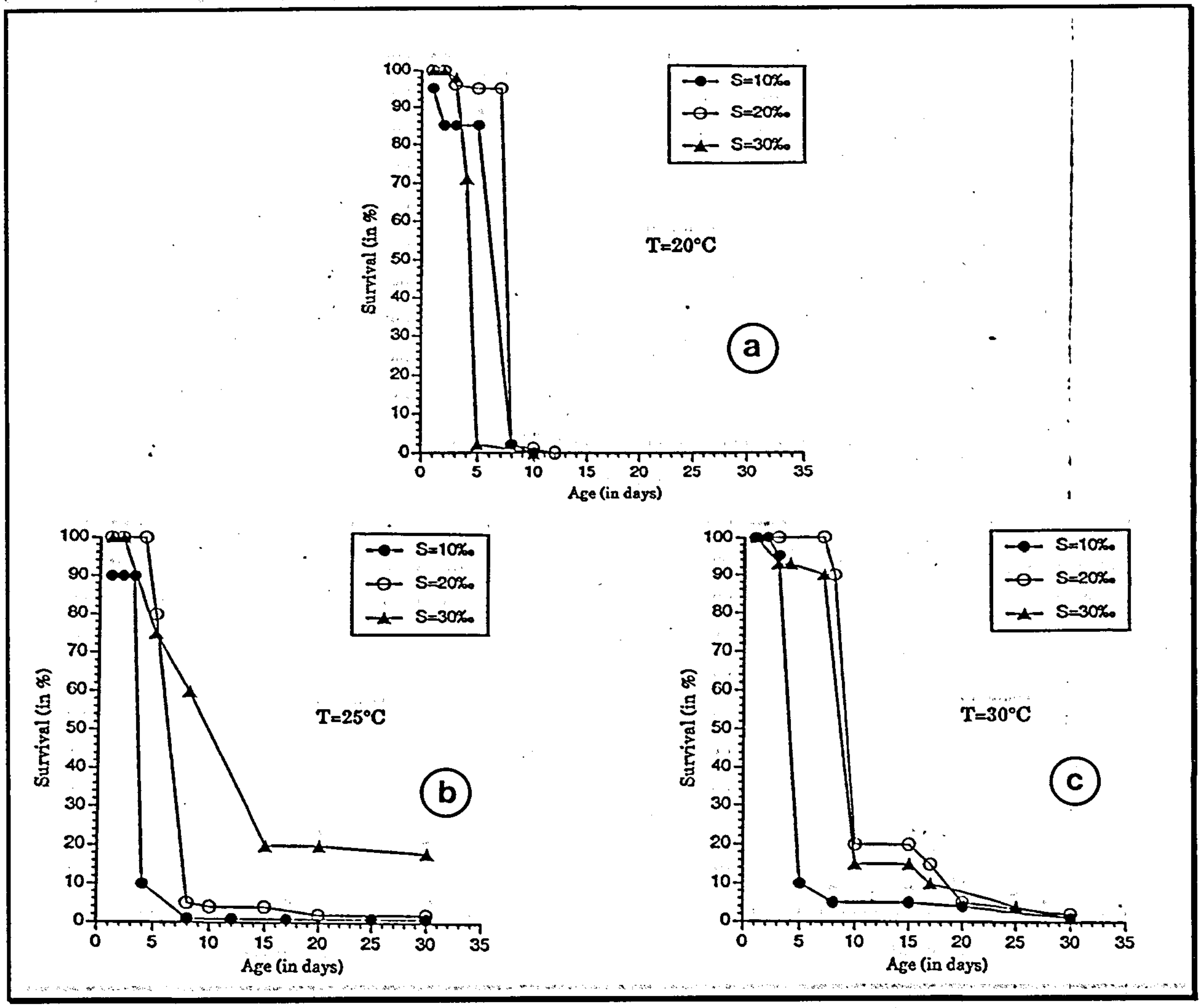

Fig.3: *Relationship between larval survival rates (in %) and age in days over a 30-day period at different temperature-salinity conditions.*

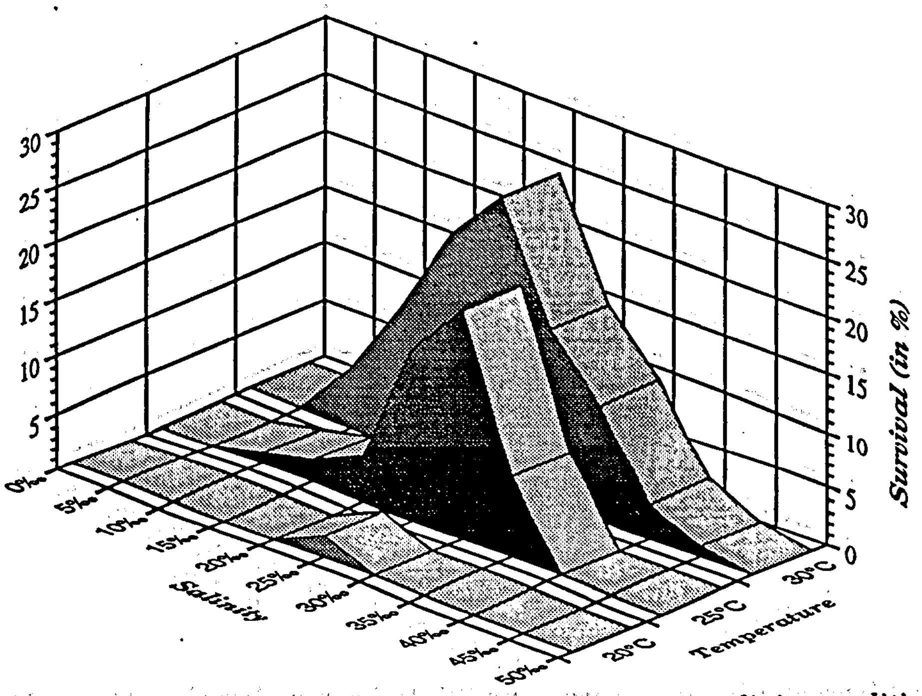

Fig.4: *2-week larval survival at different temperature-salinity conditions.*

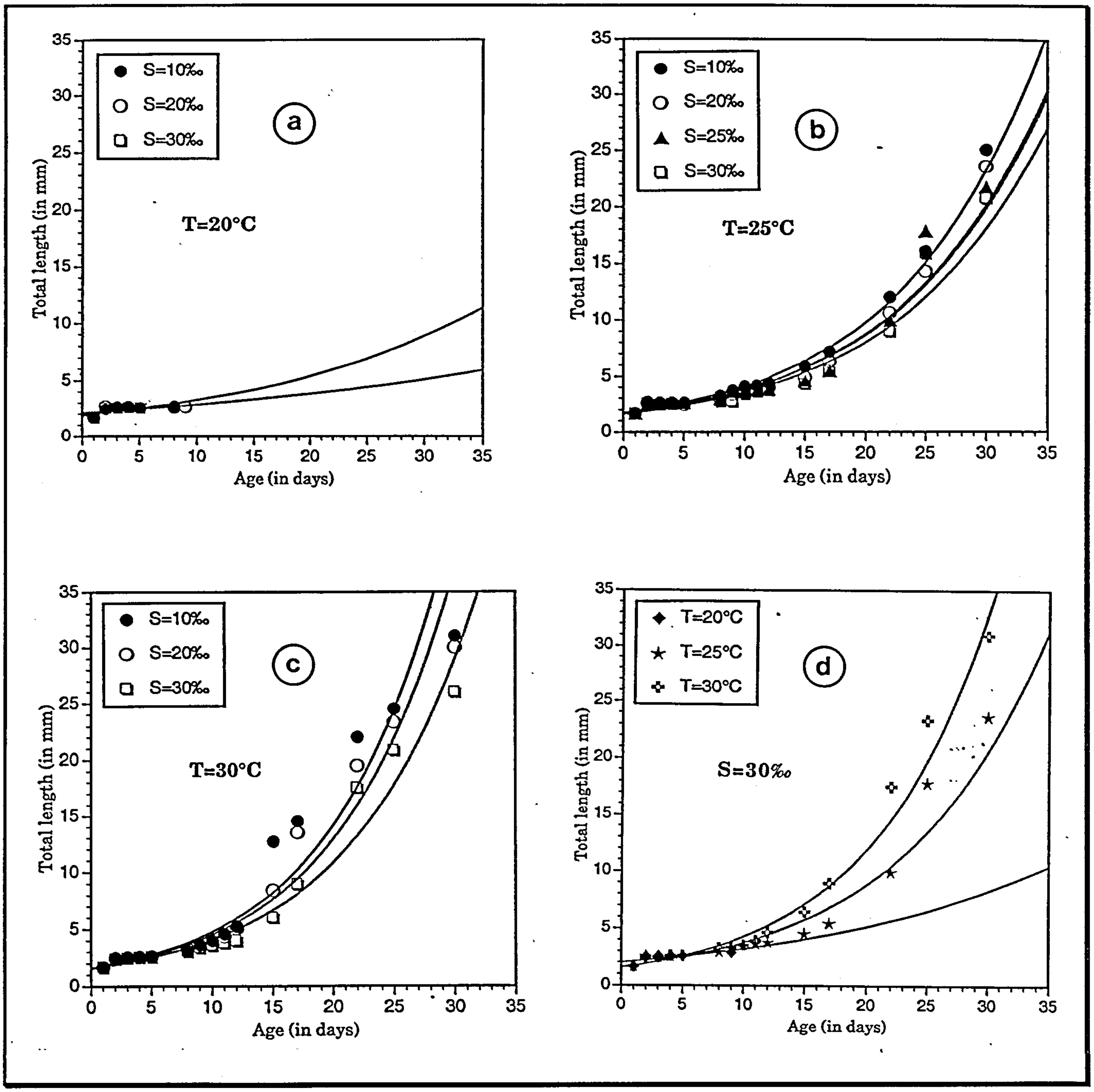

***Fig.5:** Relationship between total length and age in days over a 30-day period at different temperature-salinity conditions. Points are mean values of 10 larvae.*