# Effects of Temperature on Growth of Juvenile Spotted Seatrout and Snook

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*Abstract:* Juvenile spotted seatrout *Cynoscion nebulosus* (48–73 mm TL) and snook *Centropomis undecimalis* (43–63 mm TL) were subjected to 35- and 42-day growth trials, respectively, at 5 different temperatures. Respective test temperatures were 11.5°, 15.5°, 22.0°, 28.0°, and 32.0° C, and 15.5°, 21.0°, 28.0°, 32.0°, and 37.0°C. Salinity was 20‰ for both trials. Optimum temperature for growth of both species apparently occurs at ≥28.0° C. Spotted seatrout specific growth rate (2.39%) and mean total length (TL) (78 mm) was greatest at 28.0° C, while specific growth rate (0.54%) and mean TL (67 mm) at 11.5° C was less than at all other temperatures. Specific growth rate of juvenile snook at 37.0°, 32.0°, and 28.0° C (1.20%, 1.46%, and 0.93%, respectively) was significantly greater than growth at 21.0° and 15.5° C (0.31% and −0.15% respectively). Snook mean TL at trial conclusion was greatest at 32.0° C (62 mm) and least at 15.5° C (52 mm).

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Recent advances in controlled spawning and saltwater pond culture of spotted seatrout (Colura 1974, Arnold et al. 1976, Porter and Maciorowski 1984) and snook (Maciorowski et al. 1986, Roberts 1986) have allowed production of juveniles for limited stocking to enhance wild populations (Dailey 1988) and for experimentation. Information on temperature tolerances and growth optima is needed to increase fingerling production for stock enhancement. Availability of large numbers of spotted seatrout and snook juveniles would allow duplication of the red drum enhancement program currently underway in Texas (Matlock et al. 1986, McCarty et al. 1986, Dailey 1988).

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However, temperature effects on recreationally important estuarine fishes such as spotted seatrout and snook are poorly defined. Taniguchi (1981) reported 28° C as the optimum temperature for hatching success and larval survival of spotted seatrout. Spotted seatrout juveniles 71–123 mm total length (TL) die at temperatures below 7° to 3° C (Texas Parks and Wildl. Dep., unpubl. data), and temperatures above 23° C are necessary to stimulate spotted seatrout spawning (Brown-Peterson et al. 1988). Snook ranging 125–145 mm TL reportedly die at 12.5° C (Shafland and Foote 1983). The present study contrasts the effect of various temperatures on short-term (5–6 weeks) growth of juvenile spotted seatrout (48–73 mm TL) and snook (43–63 mm TL).

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## Methods

Spotted seatrout larvae were obtained by strip-spawning adult fish after hormone injection (Colura 1974); snook larvae were provided by the Florida Department of Natural Resources. Larvae were pond cultured by previously described methods (Porter and Maciorowski 1984, Maciorowski et al. 1986). Spotted seatrout (22 days old) and snook (31 days old) juveniles were transferred to separate 2,200-liter recirculating seawater holding tanks equipped with under gravel filters, water chillers, and immersion heaters. Spotted seatrout were acclimated to 18° C and 35‰ salinity for 5 weeks, and snook to 23° C and 15‰ salinity for 7 weeks prior to testing. Salinities approximated those in ponds from which fish were harvested.

The temperature exposure system consisted of 5 pairs of 63 × 44 × 17-cm recirculating water baths, each pair equipped with a single 130-liter temperature adjustment chamber. Each water bath contained 3 4.5-liter glass aquaria (6 aquaria per test temperature). Temperature adjustment chambers were equipped with 1000-W quartz immersion heaters (Sethco Inc., Hauppauge, N.Y.) and 0.17- or 1-HP water chillers (Frigid Units, Inc., Toledo, Ohio). Heating and chilling units were used singly and in combination with temperature controllers (Yellow Springs Instrument Co., Yellow Springs, Ohio) to maintain test temperatures ± 0.75° C with the exception of the 37.0° C treatment which varied ± 2° C due to an equipment failure. Test temperatures were 11.5°, 15.5°, 22.0°, 28.0°, and 32.0° C, and 15.5°, 21.0°, 28.0°, 32.0°, and 37.0° C for spotted seatrout and snook, respectively. Each 4.5-liter glass aquarium was supplied with air through an airstone and a 420-ml corner filter containing aquarium filter floss. Approximately one-third of the water in each aquarium was replaced daily with appropriately tempered seawater. Filter floss was changed every other day.

Temperature exposure consisted of 3 segments: a pre-test acclimation period during which dead or moribund fish were replaced, a temperature adjustment period in which temperatures were reduced or raised 4° C per day from ambient to attain test temperatures, and the growth period representing the time interval at test temperatures (Table 1).

A total of 18 fish (3 fish × 6 replicate aquaria) were used at each test temperature for each species. Fish were netted from the holding tank, anesthetized with a commercial fish calmer (Hypno, Jungle Laboratories, Cibolo, Texas), measured to the nearest mm (standard length (SL) and TL), and weighed to the nearest 0.01 g. All fish were dipped in a 5-mg/liter chelated copper solution (Cutrine, Applied Biochemists, Inc., Mequon, Wis.) to prevent infestation of *Amyloodinium* sp. which had previously been a problem at high test temperatures. After being measured and weighed, 3 fish were randomly assigned to each test aquarium. Fish were anesthetized, weighed, and treated with copper as described previously on a weekly basis throughout the temperature exposure regime (Table 1). Fish lengths (SL and TL) and condition factor (Everhart et al. 1975) were determined only at test initiation and termination to reduce handling stress.

During laboratory acclimation, all fish were fed frozen brine shrimp (San Francisco Bay Brand, Inc., Newark, Calif.), chopped shrimp, a 48% protein trout food (Silver Cup No. 2, Murray Elevators, Murray, Utah), and a 32% protein floating pellet (Hikari Cichlid Gold Baby Pellet, Kyorin, Co. Ltd, Himeji, Japan) *ad libitum*. Both spotted seatrout and snook were offered live brine shrimp nauplii as supplemental feed. Spotted seatrout were weaned from live food within 7–10 days after transfer to the laboratory. Snook received live brine shrimp nauplii throughout the laboratory acclimation period.

After transfer to test system aquaria, fish were fed 32% protein floating pellets. Spotted seatrout (48–73 mm TL) were fed at 5% of body weight during pre-test acclimation, temperature adjustment, and initial week of the growth period. The feeding rate was increased to 10% of body weight daily for the remainder of the test to accommodate fingerlings held at 32.0° C which exhibited continued weight loss at the 5% rate. Snook (43–63 mm TL) were initially fed the same pelleted feed at 10% of body weight during pre-test acclimation, temperature adjustment, and the first week of the growth period. As with spotted seatrout, snook fingerlings exhibited an initial weight loss at all temperatures. Pelleted feed was supplemented with frozen brine shrimp at an additional 10% of fingerling body weight after the first week of the growth period.

**Table 1.** Spawning and culture history, exposure regime, and test temperatures (°C) for spotted seatrout and snook growth experiments.

| | Spotted Seatrout | Snook |
|---|---|---|
| Spawning date | 07 Jul 1986 | 22 Aug 1986 |
| Pond culture | 09–30 Jul 1986 | 24 Aug–24 Sep 1986 |
| Laboratory acclimation | 30 Jul–22 Sep 1986 | 24 Sep–14 Nov 1986 |
| Test acclimation | 22–30 Sep 1986 | 14–17 Nov 1986 |
| Adjustment | 30 Sep–06 Oct 1986 | 17–24 Nov 1986 |
| Growth | 06 Oct–10 Nov 1986 | 24 Nov 1986–5 Jan 1987 |
| Test temperatures | 11.5, 15.5, 22.0, 28.0, 32.0 | 15.5, 21.0, 28.0, 32.0, 37.0 |

Data were subjected to an outlier test (Sokal and Rohlf 1981) prior to statistical comparisons. Where appropriate, single classification analysis of variance (ANOVA) for unbalanced designs was used to compare mean SL, TL, weight, survival, condition factor, and specific growth (Jobling 1983) of fish at each individual temperature treatment at study initiation and termination. Specific growth rates were calculated from the equation:

$$G_w = \frac{\log_e W_t - \log_e W_0}{t} \times 100$$

where $G_w$ is specific growth rate in body weight per day (%), $W_0$ is weight at initiation of the growth period, $W_t$ is weight at conclusion of the growth period and t is time in days (Jobling 1983). Data sets that did not meet ANOVA assumptions after standard statistical transformation were rank transformed and subjected to ANOVA (Conover and Iman 1981). Test data sets displaying significant differences were analyzed by Student-Neumann-Keuls multiple range test (Sokal and Rohlf 1981). Polynomial regression analysis was applied to the temperature-specific growth relationship and a regression model describing the relationship was developed for both species (SAS Institute, Inc. 1986). All other statistical analyses were performed using the Statistical Analysis System (SAS Institute Inc. 1987).

## Results

Temperature had a significant effect on spotted seatrout and snook growth (Tables 2 and 3). Spotted seatrout mean specific growth was significantly greater at 28° C than at all other temperatures. Initial spotted seatrout mean SL, TL, and weight were not significantly different between fish selected for different temperature treatments ($F = 1.03$, 1.43, and 1.17, respectively, $P > 0.05$). Spotted seatrout final mean SL, TL, and weight were significantly greater at 28.0° C than at other test temperatures except 22.0° C; means at 22.0° C were significantly greater than those at 11.5° C (Table 2).

Initial snook mean SL, TL, and weights were not significantly different between fish selected for different temperature treatments ($F = 0.61$, 0.89, and 0.82, respectively, $P > 0.05$). Snook mean specific growth rates at 28.0°, 32.0°, and 37.0° C were greater than growth rates at 21.0° and 15.5° C, whereas growth at 15.5° C was negative (Table 3). The maximum specific growth rate for spotted seatrout (2.39% at 28.0° C) was higher than the maximum rate for snook (1.46% at 31.9° C), but occurred at a lower temperature. Final mean SL, TL, and weight of snook were significantly greater at 37.0° C than at all other temperatures except 32.0° C (Table 3). Juvenile snook mean SL, TL, and weight was significantly less at 15.5° C than at all other test temperatures. Both species lost weight during test acclimation and temperature adjustment periods, however, weight loss was more pronounced at higher test temperatures (Figs. 1, 2).

Although temperature had a significant effect on growth, it did not affect survival. There was no significant difference in the mean number of fish surviving

**Table 2.** Mean (± SD) standard length (SL), total length (TL), weight (Wt), condition factor ($K_{SL}$), and specific growth ($G_w$) of juvenile spotted seatrout at test conclusion. $N$ = sample size at each temperature. [Values within rows with common letters are not significantly different ($P > 0.05$)].

| Parameter | Transformation | Nominal test temperatures (°C) 11.5 | 15.5 | 22.0 | 28.0 | 32.0 | F value |
|---|---|---|---|---|---|---|---|
| SL (mm) | RD | 57 ± 4.5A | 59 ± 4.7AB | 63 ± 5.2BC | 67 ± 5.9C | 59 ± 4.7AB | 8.37*** |
| TL (mm) | RD | 67 ± 5.2A | 69 ± 4.8AB | 74 ± 5.6BC | 78 ± 6.3C | 71 ± 5.6AB | 10.37*** |
| Wt (g) | LT | 2.36 ± 0.54A | 2.69 ± 0.65AB | 3.1 ± 0.65BC | 3.74 ± 1.01C | 3.1 ± 0.65AB | 7.48*** |
| $K_{SL}$ | RD | 1.27 ± 0.09A | 1.29 ± 0.10A | 1.24 ± 0.07A | 1.23 ± 0.07A | 1.29 ± 0.11A | 1.31 NS |
| $G_w$ (% wt/day) | RD | 0.54 ± 0.29A | 1.29 ± 0.26B | 1.75 ± 0.17C | 2.39 ± 0.33D | 1.29 ± 0.49C | 23.38*** |
| $N$ | | 12 | 18 | 17 | 14 | 12 | |
| Survival (%) | | 67 | 100 | 94 | 78 | 67 | |

LT = Data log transformed before analysis.
RD = Raw data analyzed.
NS = Not significant at $P > 0.05$.
*** = Significant at $P > 0.001$.

**Table 3.** Mean (± SD) standard length (SL), total length (TL), weight (Wt), condition factor ($K_{SL}$), and specific growth ($G_w$) of juvenile snook at test conclusion. $N$ = sample size for each temperature. [Values within rows with common letters are not significantly different ($P > 0.05$)].

| Parameter | Trans-formation | Nominal test temperatures (°C) 15.5 | 21.0 | 28.0 | 32.0 | 37.0 | F value |
|---|---|---|---|---|---|---|---|
| SL (mm) | RT | 40 ± 2.3A | 43 ± 2.3B | 45 ± 5.6BC | 48 ± 6.1CD | 48 ± 3.0D | 10.17*** |
| TL (mm) | RT | 52 ± 2.9A | 56 ± 2.9B | 58 ± 7.3B | 61 ± 3.6C | 62 ± 7.5C | 11.76*** |
| Wt (g) | RT | 0.87 ± 0.15A | 1.15 ± 0.20B | 1.32 ± 0.61B | 1.68 ± 0.76BC | 1.53 ± 0.28C | 8.83*** |
| $K_{SL}$ | RD | 1.35 ± 0.17A | 1.38 ± 0.16A | 1.39 ± 0.09A | 1.40 ± 0.12A | 1.46 ± 0.20A | 1.01 NS |
| $G_w$ (% wt/day) | RD | −0.15 ± 0.31A | 0.31 ± 0.33A | 0.93 ± 0.56B | 1.46 ± 0.59B | 1.20 ± 0.56B | 11.06*** |
| *N* | | 13 | 16 | 17 | 16 | 11 | |
| Survival (%) | | 72 | 89 | 94 | 89 | 61 | |

RT = Data rank transformed before analysis.
RD = Raw data analyzed.
NS = Not significant at $P > 0.05$.
*** = Significant at $P > 0.001$.

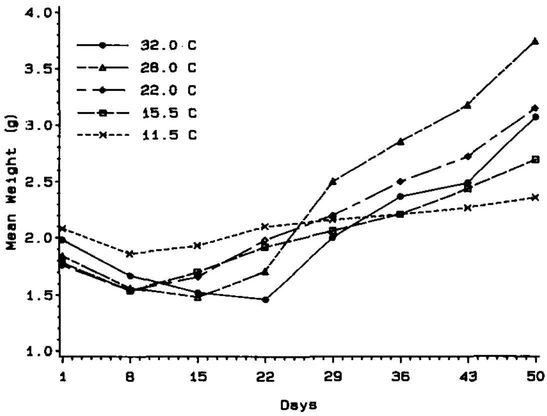


**Figure 1.** Spotted seatrout mean weights at 5 test temperatures (°C).

per aquarium at different temperatures for either spotted seatrout ($F = 2.58$, $P > 0.05$) or snook ($F = 1.13$, $P > 0.05$).

Measurements from 1 spotted seatrout held at 32.0° C were discarded as the only surviving fish in the aquarium had previously cannibalized a second fish. Results of an outlier test (Grubb's test statistic = 4.147, $P > 0.001$) (Sokal and Rohlf 1981) for this individual were also significant. The polynomial regression equation describing the specific growth-temperature relationship was $G_w = 2.107073 + 0.301103\ C - 0.005326\ C^2$, $r^2 = 0.77$ where C is temperature. Snook growth was best described by the equation $G_w = 2.664488 + 0.199588\ C - 0.002451\ C^2$, $r^2 = 0.61$.

## Discussion

The optimum test temperature for spotted seatrout growth, i.e. temperature at which the highest growth rate occurred in this study, is comparable to that found by

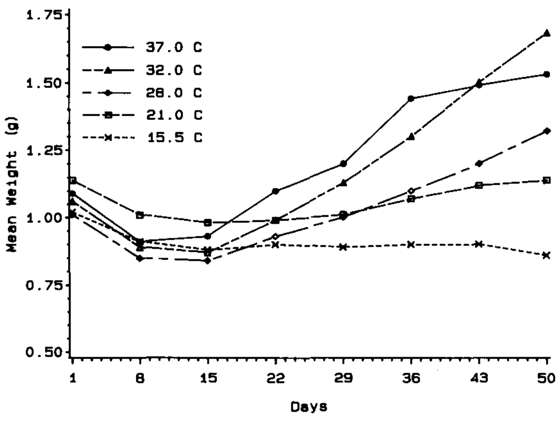


**Figure 2.** Snook mean weights at 5 test temperatures (°C).

Taniguchi (1981) as optimal for hatching success and larval survival, and approximates the average summer (April–October) mean monthly temperatures juveniles could be expected to encounter in the Texas bays (28.3 ° ± 2.8° C) (Rice et al. 1988). An optimum temperature for snook growth was not determined in this study, although the range where the optimum temperature (28°–37° C) can be expected was delineated. Testing within this range for snook growth should lead to a more precise optimal temperature estimate.

Specific growth rate-temperature curves for spotted seatrout and snook followed a general right-skewed unimodal pattern typical for juveniles of many species (Brett 1979, Cox and Coutant 1981, Coutant and DeAngelis 1983). The pattern is one of slow or no growth at low temperatures, increasing growth as temperatures rise until a maximum rate is reached, and decreasing growth as temperatures continue to rise (Fig. 3).

Spotted seatrout grew faster than snook as indicated by noticeably greater specific growth rates (Fig. 3). This observation is supported by spotted seatrout and snook pond culture trials. Porter and Maciorowski (1984) found spotted seatrout stocked at $1 \times 10^6$ fry/ha attained 35–41 mm TL in 22 days. Snook stocked at 218,000–275,000 fry/ha required 30 days to reach 22 mm TL and 40 days to reach 38–41 mm TL (Maciorowski et al. 1986). Mean water temperature (27.5° C) in spotted seatrout culture ponds approximated the temperature found best for their growth in this study. Mean water temperature in snook culture ponds was 28.2° C.

Study results indicate induced spawning of spotted seatrout should be scheduled so fry are available for pond culture when water temperature is near optimum levels for growth. Culture of fry near optimum temperatures would result in shorter culture periods by reducing the time required for fish to reach stocking size. Survival and production should increase as shorter culture periods provide less opportunity for fish deaths. Scheduling snook spawning for seasons when peak water temperatures occur and spotted seatrout spawning for periods when temperatures are moderate may increase fingerling production of both species. This schedule would take advantage of the apparent greater tolerance by snook of warm tempera-

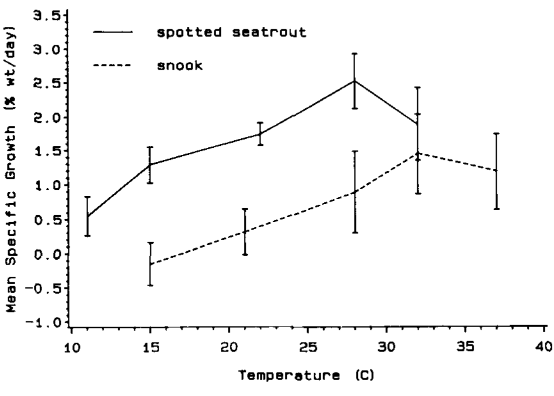


**Figure 3.** Mean specific growth rate for spotted seatrout and snook at selected temperatures. Vertical lines indicate ± 1 SD.

tures indicated by the wide temperature range over which no difference in growth was observed.

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