SALINITY STRESS AND SWIMMING PERFORMANCE OF SPOTTED SEATROUT

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Abstract: Specific swimming speeds (L sec^{-1}) of spotted seatrout (*Cynoscion nebulosus*) were linearly related ($S = -0.16+0.93X$) to tail-beats/sec (x) over speeds ranging from about 1.5 - 4.0 length/sec. Maximum sustained swimming speeds were measured at salinities ranging from 10 to 45 ppt in intervals of 5 ppt. At about 20 to 25 ppt, maximum sustained swimming speeds were close to 4 lengths/sec, but performance was reduced at salinities above or below this range. At 45 ppt, maximum sustained speeds were only about 2 lengths/sec. These results indicate that maximum sustained swimming performance can provide an effective method for evaluating salinity stresses.

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Freshwater diversions and variations in rainfall often result in wide salinity fluctuations in many coastal regions. Because of the wide range of salinities encountered by coastal fishes, it is useful from the viewpoint of fisheries management and water quality control to develop a simple and effective means of evaluating the salinity regimes for the various species.

Studies on the swimming performance of spotted seatrout at various salinities indicate that an evaluation of its salinity range is possible in terms of its maximum sustained swimming performance (Wohlschlag and Wakeman 1978). This commercially and recreationally important species occurs over a wide range of coastal and estuarine waters.

This study is based on the rationale that metabolic scope for activity (Fry 1947) is usually reduced at less than optimal conditions. This reduced metabolic power would be expected to result in decreased maximum sustained swimming performance. Maximum sustained swimming performance is defined as the highest speed that can be maintained for at least 200 minutes (Brett 1967). Although there is little information on the sustained swimming performances of coastal fishes, extensive studies of swimming in salmonoid fishes indicate that the maximum sustained swimming speed of salmonoids generally ranges from 3 to 4 body lengths/sec under optimal conditions (Brett 1964).

The purpose of this study is to measure maximum sustained swimming speeds of *C. nebulosus* over a range of salinities that are commonly found along the south Texas coast, and to determine the optimal salinity for sustained swimming performance of this species. A related report on metabolic components and salinity stress for this species is in Wohlschlag and Wakeman (1978). Since survival and growth problems associated with higher salinities are likely to be increased at summer temperatures (Cech and Wohlschlag 1975), these experiments were conducted at 28 C, a normally prevailing summer temperature in coastal Texas waters.

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MATERIALS AND METHODS

Experimental fish

Fish used in this study were taken from the Lydia Ann Channel near Port Aransas, Texas, during July, August and September 1976. During these months, water temperatures were about 28 C and salinities usually about 25 ppt. These fish ranged from 45 to 769 g and 17.4 to 43.5 cm in total length. They were captured at night under flood lights by hook and line fishing techniques, and transferred as soon as possible to circular holding tanks about 1.8 m in diameter. For acclimation, the fish were held at 28 ± 1 C and at the desired salinity for at least 2 days. If the experimental salinity required a salinity change of more than 5 ppt, a longer acclimation period was used so that salinities were not changed more than 5 ppt over a 2 day period. Fish were not fed during the final 2 days of acclimation. During the last 12 hours of the acclimation period, the water within the tank was circulated by means of a pump at about 10 to 20 cm/sec to accustom the fish to continuous swimming.

Experimental procedure

Sustained swimming experiments at salinities ranging from 10 to 45 ppt (in intervals of 5 ppt) were conducted in a modified "Blazka" type swimming chamber (Blazka et al. 1960; Fry 1971). This chamber, which has been described in detail previously (Wohlschlag and Wakeman 1978) is diagrammed in Fig. 1. Flow velocity within the chamber

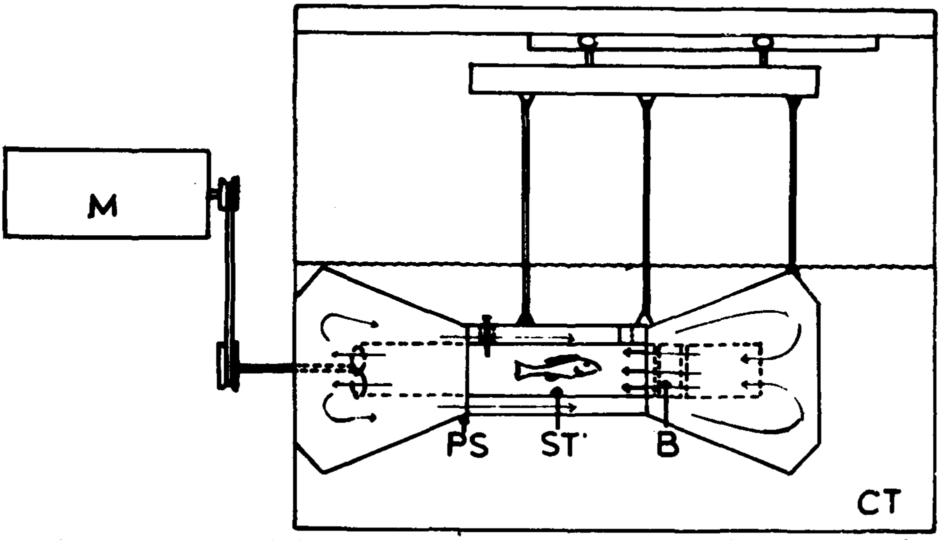

Fig. 1. Diagram of 207 liter chamber used to study the characteristics of fish swimming. M — 10 hp, variable speed motor; I — impeller; B — flow linearizing baffles; ST — transparent acrylic swimming tunnel; PS — posterior screen; CT — constant temperature water bath.

was controlled by means of an impeller driven by a 10 hp, constant torque, variable speed motor, so that any desired speed could be selected.

After a fish had been introduced into the chamber, and given about an hour to adjust to its new surroundings, the water flow within the swimming tunnel was set at a velocity equal to about 1.5 body lengths/sec (L sec^{-1}). The fish was allowed to swim at this speed for 10 min. During this time, tail-beat frequency in beats/sec was determined by visually measuring the time required for 20 tail-beats. A tail-beat was defined as one complete oscillation of the caudal fin. The velocity was then gradually increased in increments of about 0.3 L sec^{-1} at 5 min intervals. Tail-beat frequencies were determined for each increase in velocity, after allowing 3 minutes for the fish to adjust to the new swimming speed.

In this manner, velocity was increased until a critical speed was reached at which tail-beats abruptly became erratic, and smooth regular movement of the caudal fin ceased. Preliminary studies with this species had established that swiming speeds below this critical velocity could be maintained for at least 200 minutes, but at speeds very slightly above the critical level, these fish usually showed fatigue and fell back against the posterior screen of the swimming chamber in less than 5 minutes. Thus the maximum sustained swimming speed was recorded as the highest velocity at which the fish continued to swim smoothy with no break or irregularity of its tail-beat frequency. In most of these experiments, each fish swam smoothly at maximum sustained speed for a period of at least 60 minutes before the experiment was terminated.

Using combined data from salinities of 15, 20 and 25 ppt, specific swimming speeds were plotted against tail-beat frequency, and a linear relationship between these 2 variables was established.

To evaluate the effect of salinity variations on swimming performance, maximum sustained swimming speeds attained at each salinity level were averaged (Fig. 3), and these means were plotted against salinity.

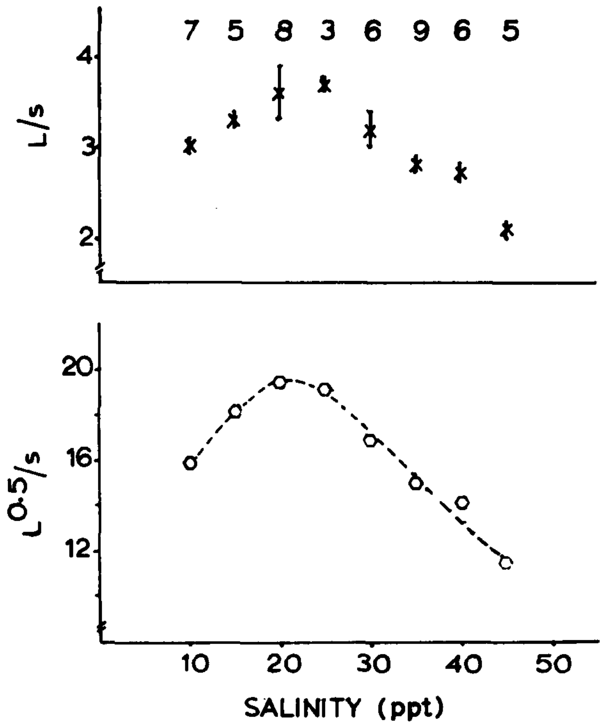

Fig. 3. Mean maximum sustained swimming speeds of spotted seatrout at various salinities at 28°C. *Top panel – Swimming speeds in body lengths/set. Vertical bars* represent ± one standard error. The number of individual measurements is indicated at top of graph. Bottom panel — Swimming speeds as square roots of body length/sec. Curve fitted by eye. (Data from Wohlschlag and Wakeman 1977).

RESULTS AND DISCUSSION

Forward thrust in *C. nebulosus* is generated by a propulsive wave passing backwards along the body. Gray (1933) has analyzed the characteristics of this type of swimming. The length of the propulsive wave appears to be about equal to the body length, and thus the swimming mode of this species could be classified as either anguilliform or subcarangiform (Webb 1975). This swimming mode is similar to that of salmonoids.

Specific swimming speeds have been plotted against tail-beat frequencies in beats/sec (Fig. 2). Speeds ranged from 1.6 to 3.99 lengths/sec. Frequencies at speeds lower than 1.5 lengths/sec were not studied because at such velocities tail-beats tend to be erratic, and changes in tail-beat amplitude probably become more important than frequency (Bainbridge 1958, Webb 1971). Over the range of swimming speeds studied, the relationship between tail-beat frequency and specific swimming speed appeared to be linear (Fig. 2). The calculated least squares regression equation was $S = 0.16 + 0.93\ X$ (where S is swimming speed in length/sec and X is tail-beat frequency in beats/sec). Comparison with Stasko and Horral's (1976) regression equation for sockeye salmon ($S = 0.34 \pm .72\ X$) suggests that for a given specific speed a lower tail-beat frequency is required by spotted seatrout. This, however, may be related both to the differences in body length between the seatrout (17.4 - 43.5 cm) and the salmon (51 - 56 cm), and to the slower specific swimming speeds of the salmon. Such equations may prove useful in studying

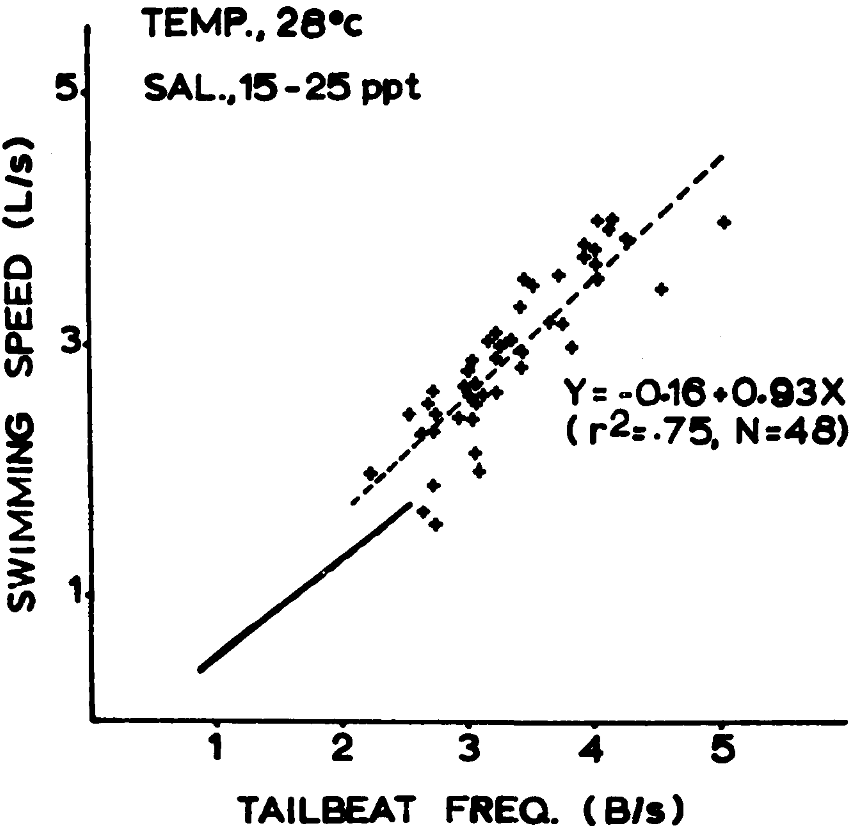

Fig. 2. Relationship between specific swimming speed and tail-beat frequency. Dashed curve is for spotted seatrout (this study) and fitted by linear regression. Solid curve is for sockeye salmon (adapted from Stasko and Horrall 1976).

activity levels of fish in their natural habitat, if the tail-beat frequencies in free-ranging fish can be monitored with attached continuous-wave transmitters (Stasko and Horrall 1976).

Average maximum sustained swimming speeds in lengths/sec have been plotted against salinity in Fig. 3. The highest average maximum sustained swimming speed was 3.66 lengths/sec at 25 ppt. The highest individual sustained swimming speed was measured at 20 ppt in a 23 cm fish at 3.99 lengths/sec. Because swimming performance appears to be approximately proportional to the square root of body length in a number of species (Bainbridge 1962, Brett 1964, Fry and Cox 1970), the averages of maximum sustained swimming speeds expressed as square roots of body length/sec were also plotted against salinity in the lower panel of this figure. From these graphs, it appears that the optimal salinity range for *C. nebulosus* is between 15 and 22 ppt at 28 C. Swimming performance was reduced at salinity levels above or below this range. This reduction in performance became particularly evident as salinities approached 45 ppt, where the average maximum sustained swimming speed was only about 2 lengths/sec.

Observations over several years of sustained south Texas coastal and estuarine collecting indicate that *C. nebulosus* was essentially unavailable at salinities above 45 ppt or below 10 ppt. These observations agree with published life history information (Guest and Gunter 1958, Tabb 1966). This species survives with natural foods in our laboratory for several weeks at salinities above 45 ppt. However, this does not appear to be within the normal, natural salinity range of this species, possibly because metabolic scope for activity is reduced to the point where insufficient energy is available for effective foraging and food assimilation. These observations and the results of this study suggest that the minimum energy output required for long-term survival of the spotted seatrout may be about equal to that required to maintain a maximum sustained swimming speed of about 2 body lengths/sec.

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