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Swimming speeds of Atlantic mackerel, *Scomber scombrus*, under
laboratory conditions: relation to capture by trawling

by

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Abstract

Swimming speeds of Atlantic mackerel, *Scomber scombrus*, were measured under various laboratory conditions including day-night cycles of light and different thermal regimes. Under preferred conditions of temperature, the fish swam continuously day and night but showed a clearly defined rhythm of activity, swimming faster by day than by night. When temperature departed from preferred levels, swimming speed increased, reflecting avoidance behavior of the animals and their capability to move in response to thermal change. Although average cruising speeds recorded under various experimental conditions were well below the average trawling speed of a fishing vessel, Atlantic mackerel have the capability to swim at burst speeds high enough to avoid capture for a limited time. Other possible factors affecting catchability of mackerel are discussed.

Introduction

The degree to which a species of fish is susceptible to capture will depend upon the animal's ability to detect the apparatus employed for capture and, if detected, the nature of the response. If the equipment is not sensed, or if it does not represent a biologically pertinent stimulus to which the animal will respond, capture success will simply depend upon whether the equipment is in the proper location relative to the fish. For continually swimming, highly mobile species, such as Atlantic mackerel, *Scomber scombrus*, the towing speed of the boat must be faster than the swimming speed of the fish. Consequently, determination of the average swimming speed of the animal under various environmental conditions can be used to predict capture success.

However, if the animal detects the presence of the apparatus and an escape response is elicited, knowledge of the maximum potential speed attainable, a primary component of the escape response in pelagic fishes, will also relate to predictive success.

In this paper, we have presented the swimming speeds of Atlantic mackerel, measured under various laboratory conditions including day-night cycles of light and different thermal regimes comparing those which are preferred with those which are avoided. We have also included for discussion other behavioral components for which we have little data but which we surmise may play a role in capture susceptibility.

Materials and Methods

Studies were performed on six groups of Atlantic mackerel, *Scomber scombrus*, varying in number from eight to 14 fish, and ranging in total length from 25 to 48 cm with an average of 38 cm. The fish were captured by rod and reel with barbless hooks at temperatures ranging from 7.5° and 10.8° C during either vernal

or autumnal migrations. They were transported to the laboratory in a specially-designed, elliptically-shaped, holding tank. Handled in this manner, the only discernible injury to the fish was to the mouth parts, from hooking, which under laboratory conditions, quickly healed.

All experiments were performed in 121-kl aquarium in which light, temperature, and water quality were controlled (Olla et al., 1967). An artificial lighting system simulated daily changes in light intensity which ranged from 0.75 to 3000 lux during the light period and held at 0.5 lux during the dark period. Photoperiods were held constant at either 15.3 ± 0.2 h or 10.6 ± 0.2 h, reflecting the natural photoperiod at time of capture. Water temperatures from 7.4° to 28.6° C were controlled by room temperature, while temperatures from 1.9° to 7.3° C required the use of a thermal exchanger and associated refrigeration unit. At the time that the fish were introduced, temperatures in the aquarium were within 0.5° to 3.0° C of the capture temperature. Acclimation to captivity was determined by the degree of stability as reflected in swimming speed and feeding. Temperature was raised or lowered, depending on the experimental plan, at rates ranging from 0.02° to 0.10° C/h. Details of each experiment are described in Olla et al. (1975).

The fish were fed live grass shrimp, *Palaemonetes vulgaris*, introduced in a manner which permitted measurements of speed and satiation (Olla et al., 1975).

Measurements of swimming speeds and school length (as an indicator of cohesiveness) were made hourly both day and night. The median of five consecutive times to swim 335 cm (cm/s) was used for swimming speed analysis. The length of the school was measured using the time for the entire school to pass a point at the observed speed.

Results and Discussion

Swimming Speed

Day and Night

The fish swam continually both day and night, swimming faster by day than by night (Olla et al., 1975) (Fig. 1). The diurnal rhythm in swimming speed was similar to that observed in earlier studies on another pelagic species, the bluefish, *Pomatomus saltatrix* (Olla and Studholme, 1972).

The fact that the fish swam continually was related primarily to: 1) the lack of a hydrostatic organ requiring active motion to remain in the water column, and 2) ram gill ventilation necessary because of the apparent inability of active gill ventilation in adults to meet the blood oxygenation demand (Roberts, 1975). There may be other behavioral and physiological reasons for the animals being obligate swimmers, but discussion of the subject is beyond the scope of this paper.

Schooling, as measured by school length, was also manifested in a day-night rhythm. However, particular groups of fish showed opposite degrees of cohesiveness. While one might be grouped tightly by night and loosely by day, another showed exactly the reverse. This lack of consistency in cohesiveness between groups could not be explained.

At temperatures ranging from 7.3° to 15.8° C, which we considered to be within the preferred range of the mackerel (Olla et al., 1975), speeds for all groups averaged 35.8 cm/s by day (range 30.2 to 40.6 cm/s) and 29.4 cm/s by night (range 25.4 to 32.5 cm/s; Fig. 1).

Feeding

Animals which were deprived of food for 4 days showed a gradual increase in average speed from the day after being fed until the next feeding. Preliminary analysis showed there to be an increase of about 4%, reflective of increased searching activity.

When food was introduced following deprivation, resulting in the animals being in an elevated state of motivation to feed, swimming speeds recorded as the fish swam towards prey increased as much as 235% over average daytime speeds. The highest speed attained while pursuing prey under these conditions was 120 cm/s (Fig. 1). Given the restrictions of the aquarium, it is highly probable that, if prey more mobile than shrimp were introduced, speeds attained during pursuit would have been a good deal higher.

Avoidance Temperatures

Whether temperature departed upward or downward from preferred levels, the swimming speed of the fish showed an increase (Fig. 2B). This increase we interpreted as reflecting thermal avoidance. Maximum sustained speeds (speed that could be maintained over a period of several days) averaged about 53 cm/s from 21.0° to 25.5° C, and 47 cm/s from 2.1° to 3.4° C (Fig. 1; Fig. 2B). At stressful high and low temperatures, the distinct day-night rhythm of swimming speed was no longer present (Olla et al., 1975). The priority for avoidance obviously took precedence over the inherent daily rhythm. We surmise that the same phenomenon would be expressed in the sea if stressful thermal regimes were encountered.

Similar increases to departures from preferred temperature were observed in earlier work on bluefish (Fig. 2A), and were also interpreted as reflecting thermal avoidance (Olla and Studholme, 1971). Investigators including Rozin and Mayer (1961), Fry (1971), Neill et al. (1972), Stevens (1973) and Neill and Magnuson (1974) have discussed the ability of some fishes to regulate their internal body temperature by the active avoidance or selection of particular thermal regimes. This type of response has been called behavioral thermoregulation. However, not all species or life stages of a species may possess this capability (for discussion see Olla et al. (1975) and Olla and Studholme (1976).

Burst Speeds

In tests of swimming speeds conducted in swimming chambers on a variety of marine fish, Blaxter and Dickson (1959) found the maximum burst speeds of Atlantic mackerel (33 to 38 cm) to be 189 to 300 cm/s (Fig. 1). Our own observations indicate that free-swimming mackerel in the aquarium are capable of burst speeds in excess of 335 cm/s (Fig. 1) but as yet we have not been able to quantify the maximum.

As pointed out by Saburenkov and Pavlov (1971), the duration for which a particular speed can be maintained is an important parameter in relating this measure to catchability. In examining the data presented by Blaxter and Dickson (1959), mackerel, 35 to 36 cm in length, at 16° to 17° C, could maintain burst speeds for about 43 s before total exhaustion.

Catchability as Related to Swimming Speed

It is apparent that average swimming speeds of Atlantic mackerel, even when stimulated by food or at avoidance temperature where maximum sustained speed is 1.9 km/h, are well below trawling speeds of a fishing vessel which usually averages 5.6 to 7.4 km/h. However, burst speeds are another matter. Even the limited number of experiments of Blaxter and Dickson (1959) and our own preliminary observations indicate that Atlantic mackerel have the capability to swim at speeds in excess of 12 km/h, rapid enough to avoid most trawling operations. However, the maintenance of that speed is only for about 43 s, followed by complete fatigue (Blaxter and Dickson, 1959).

Other Probable Factors Affecting Catchability

Day-Night Movements

The relationship of differential catchability to day-night rhythms of activity, schooling patterns, feeding, and vertical position in the water column has long been recognized for many marine species (see Woodhead, 1966, for discussion). As stated earlier, mackerel swim continuously day and night, and possess a clearly defined rhythm of swimming activity with average daytime cruising speeds being faster than nighttime speeds (Olla et al., 1975). Even though they possess a clearly defined rhythm of activity which may be reflected in vertical movements, because of the opportunistic feeding habits of this species, it is highly probable that their distribution in the water column may be strongly influenced by the type and abundance of fodder organisms available at any given time or location.

Day-Night Responsiveness

The nighttime reduction in activity observed in mackerel may reflect a change in the level of responsiveness to their environment, as it does, though to a much greater degree, in certain demersal species (Olla et al., 1975; Olla

and Studholme, 1976). The level of a particular behavioral response to a stimulus is an overt manifestation of the animal's physiological capability to respond. Responsiveness to external stimuli, which may vary both on a daily as well as a seasonal basis (reproduction and migration) may bear upon the fish's vulnerability to capture.

Although mackerel show a high level of responsiveness at night when compared with species that are totally quiescent, they nevertheless still appear to be less responsive at night than during the day. In our experiments, when mackerel were subjected to a continual increase in temperature (0.5^o C/day) from an initial acclimation temperature of 13.3^o C, the fish increased swimming speed in response to the increasing temperature (Olla *et al.*, 1975) (Fig. 2B). However, nighttime speeds appeared to lag behind the increase in daytime speeds. The day after the increase began (14.0^o C), average daytime swimming speeds increased 15% from acclimation speeds and continued to increase. However, it required 8 days (17.0^o C) for average nighttime speeds to show a similar increase. The delay in the response to elevated temperature during nighttime may be a manifestation of lowered responsiveness. When temperatures reached levels which were stressful, i.e., approaching lethality, no such delay was present and the rhythm broke down as the fish swam at high speed both day and night.

Seasonal Responsiveness

From preliminary observations in the laboratory, it also appears that responsiveness, at least to changes in temperature, may be affected by gonadal development and the corresponding physiological changes accompanying migration. Again, using average swimming speed as an indicator of responsiveness, we subjected a group of mackerel to two identical temperature increases (12.8^o to 15.8^o C, 2.2^o C/day) with the first increase occurring at the end of January and the second at the end of March when gonadal maturation was occurring. In both cases the fish responded to the change in temperature with an increase in activity. However, the swimming speeds attained during March were 16% higher than those observed in January. Accompanying this higher level of activity was the development of a startle response by the fish to the initial presence of observers. This increased level of irritability and responsiveness may influence the fish's vulnerability to capture.

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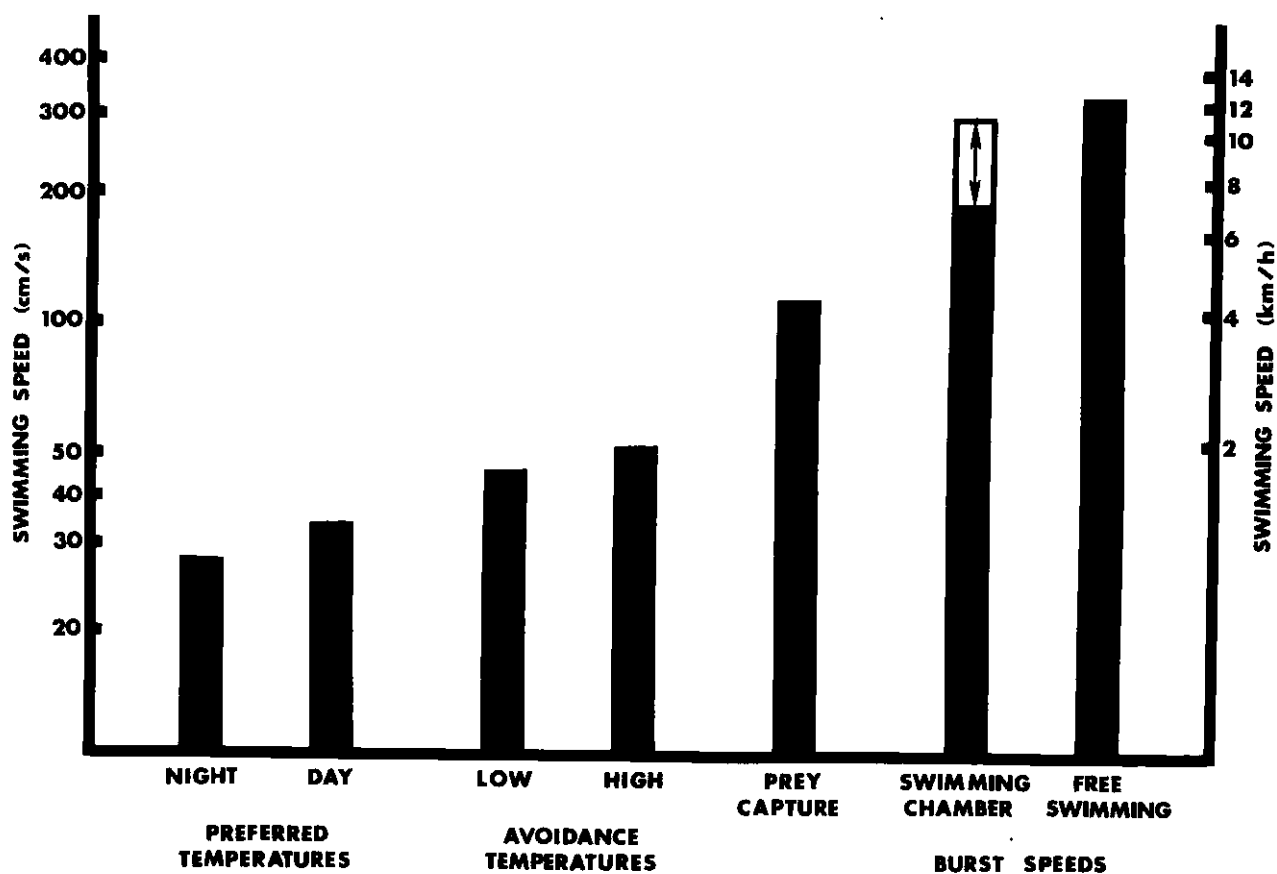


Fig. 1. Atlantic mackerel swimming speeds observed under laboratory conditions showing: mean day and night speeds within preferred temperatures; mean speeds at low and high avoidance temperatures; prey capture speed during feeding; burst speeds: swimming chamber (based on data from Blaxter and Dickson, 1959) and free-swimming.

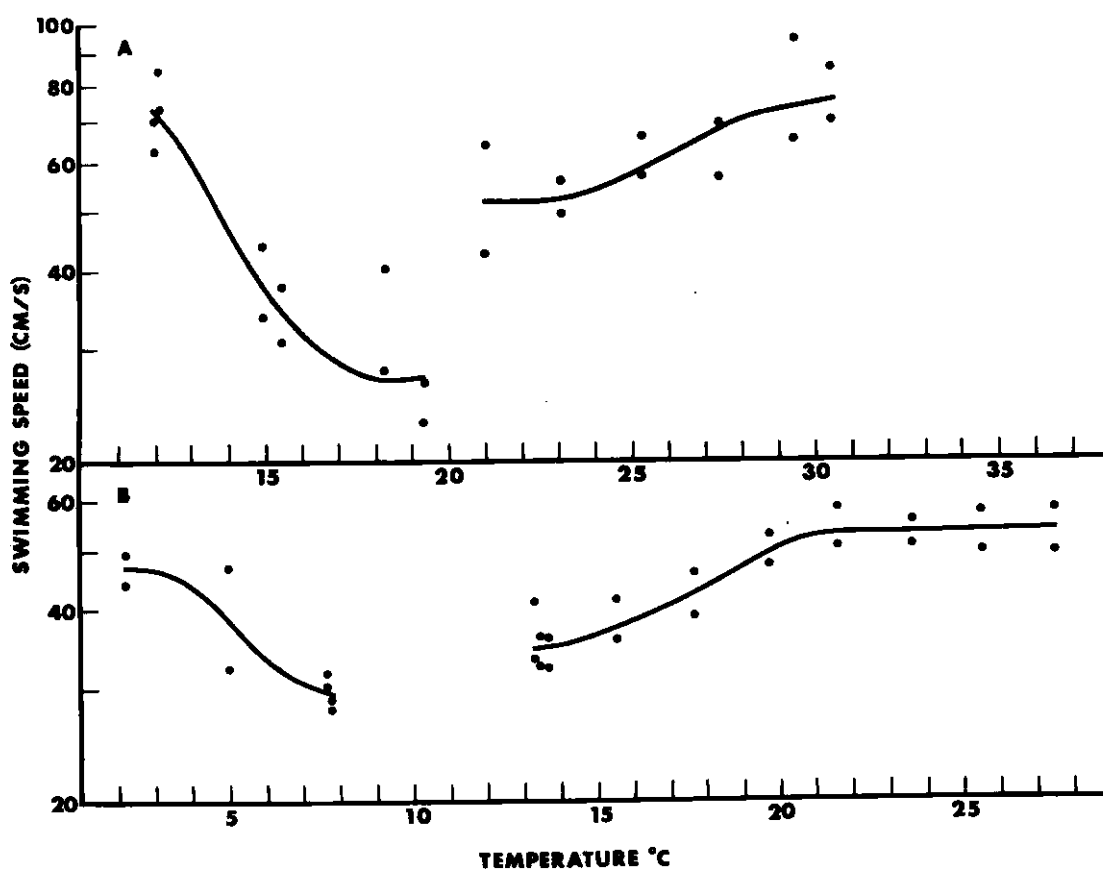


Fig. 2. Activity recorded during low and high temperature experiments for: A) adult bluefish, and B) adult Atlantic mackerel. Points represent the high and low mean swimming speeds for 4 or 5-day periods at the mean temperature for each period. Relation between activity and temperature is indicated by a median curve (after Olla, Studholme, Bejda, Samet, and Martin, 1975).