

SHORT COMMUNICATION

PERCEPTION OF ABRUPT TEMPERATURE DECREASE
BY RESTRAINED SKIPJACK TUNA,
KATSUWONUS PELAMIS

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Abstract—1. Decreasing temperature stimuli produced responses and threshold similar to those produced by increasing temperature stimuli in a previous study with skipjack tuna, *Katsuwonus pelamis*.

2. Restrained skipjack tuna signaled by deceleration of heart rate that they could perceive abrupt temperature decreases (0.5°C/sec) as small as 1–2°C.

3. Temperature stimulation of the oral–branchial cavity was more effective in eliciting responses than stimulation of the dorsal, anterior quadrant of the body surface.

INTRODUCTION

PERCEPTION of temperature increases by skipjack tuna, *Katsuwonus pelamis*, determined by classical cardiac conditioning was not acute, ca. 1–2°C (Dizon *et al.*, 1974). In addition stimuli directed into the oral–branchial cavity were more effective in eliciting responses than stimuli directed onto the dorsal, anterior quadrant of the body surface based on analyzable data from only nine fish.

Our present experiment tests whether skipjack tuna are more sensitive to a decrease in temperature than they were to an increase, and provides additional data on the sensitivity of the skin on the back versus the oral–branchial cavity.

MATERIALS AND METHODS

Thirty-five skipjack tuna (average weight 1.4 kg) were tested for heart-rate decelerations in response to temperature decreases. The technique of cardiac-deceleration testing has been described in detail by Dizon *et al.* (1974).

Briefly, tuna were removed from the holding tanks, secured in a test apparatus with Velcro† and immobilized with a muscle relaxant (gallamine triethiodide, 1 mg/kg). Each fish was subjected to two streams of water (8 l/min): one in the oral–branchial cavity (mouth) and one directed at the dorsal anterior quadrant of the body (back). We trained the fish to slow their heart rate in response to a thermal stimulus. As a conditioning stimulus (CS), the temperature of the stimulus stream, water directed either to the back or to the mouth, was abruptly reduced 5° below ambient. It was followed by the unconditioned stimulus (US), a momentary cessation of the gill-perfusion flow, to which the fish responded (unconditioned response, UR) with an immediate lull in heart beat followed by several irregularly spaced beats. During testing, heart rate

and stimulus temperature were continuously monitored and recorded. Fish were generally tested for 30 trials; inter-trial intervals were 2–4 min. During the inter-trial interval, temperature of the streams were 24°C, the same as the holding tanks.

During a trial, temperature of the stimulus stream was reduced by pumping iced methyl alcohol through the outer jacket of a counter-current heat exchanger. The stimulus stream flowed through the exchanger's inner tube, a 10-m segment of 2-cm copper water piping. We felt that the fish would not be stressed by 2 hr exposure to copper leached from the exchanger during the water's brief transit, an unwarranted assumption since fish that respired copper-contaminated water (the mouth-stimulated group) did not survive as well as the back-stimulated group.

Because spontaneous decelerations occurred, the frequency of responses during the inter-trial period was compared to frequency of responses during the times when the temperature was decreasing but before the gill perfusion water was shut off (Dizon *et al.*, 1974). A responding fish should exhibit a higher frequency of response during the stimulus period than during the inter-trial.

RESULTS AND DISCUSSION

Figure 1 shows good examples of heart-rate deceleration (possibly a conditioned response, CR) in response to a temperature stimulus (CS) delivered to the oral–branchial cavity. The responses occurred at about 2°C below ambient. In the second panel, the gill perfusion water was shut off (US) at 5.2°C and another response occurred (UR).

To obtain an estimate of thresholds, responses for each fish were grouped by 1°C intervals (0–1°, 1–2°, 2–3°, 3–4°, or 4–5°). Frequency of response for each fish was determined as a function of stimulus stream temperature by dividing the number of responses in each interval by total time for that interval. The median frequency of response for all fish in each treatment group and 95% confidence limits on the median (Mood & Graybill, 1963) were determined for each temperature interval (Fig. 2). As observed previously with increasing temperature stimuli (Dizon *et al.*, 1974), frequencies of response varied significantly with temperature only for the mouth-stimulated fish (Friedman

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‡ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

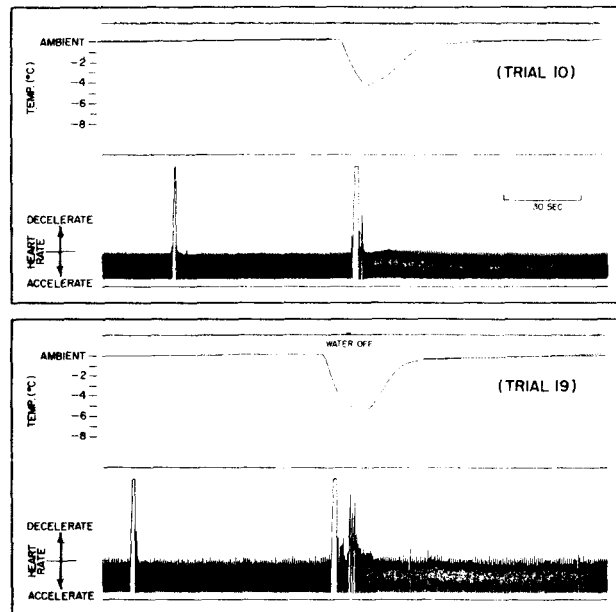


Fig. 1. A recording from a skipjack tuna showing abrupt deceleration of heart rate accompanying a decrease in temperature of the gill perfusion water and prior to reinforcement.

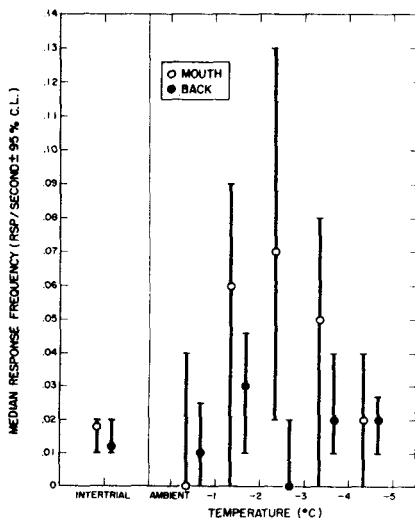


Fig. 2. Median response frequencies and 95% confidence limits of skipjack tuna before temperature stimulation (intertrial period) and during temperature stimulation by 1°C intervals. Open circles: temperature stimulation delivered to oral-branchial cavity (mouth), $n = 17$. Closed circles: temperature stimulus delivered to the dorsal, anterior body surface (back), $n = 18$.

two-way AOV by ranks, $P < 0.05$; Siegel, 1956). Median response frequency of the 17 mouth-stimulated fish was maximal in the 2-3°C interval but an increase can be noted in the 1-2°C interval.

The threshold for response, 1-2°C below ambient, was similar in magnitude to that observed for skipjack tuna exposed to temperature increases (Dizon *et al.*, 1974) but was somewhat higher than those observed for other non-marine, non-pelagic fishes trained to discriminate temperature decreases. Thresholds for a decrease in temperature are available for trout (0.1°C) and catfish (0.5°C) (Bardach & Bjorklund, 1957) and a minnow (1°C) (Dijkgraaf, 1940). While 1°C is not a realistically low threshold, skipjack tuna are expected from these data to be equally sensitive to increases and decreases in temperature.

Combined data from all mouth-stimulated fish produced a significant difference (Kolmogorov-Smirnov one-sample test; Siegel, 1956) between response frequencies during trials and intertrials ($n = 17$, $P < 0.01$); combined data from all back-stimulated fish did not ($n = 18$, $P < 0.10$). The difference in probability levels (0.01 vs 0.10) implies that the fish responded more consistently to mouth stimulation than back stimulation. The median per cent increase in response frequency during temperature stimulation for each fish and each treatment was determined and tested with a one-tailed Mann-Whitney U -test (Siegel, 1956). Mouth-treatment scores ranked significantly above back-treatment scores ($U = 87$, $P = 0.025$). That is, thermal stimulation of the mouth was more likely to produce a response than like stimulation of the back. We suggest either: (1) Thermal stimuli delivered to the mouth of the tuna are nociceptive, which would explain the reliability with which responses appear in restrained fish despite stressing conditions of the experiment. (2) There may well be a direct thermal effect upon the anterior brainstem

(Crawshaw *et al.*, 1973) when temperature changes occur within the mouth.

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Key Word Index—Temperature perception; Tunas; Thermoregulation; Classic conditioning.
