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Estimates of Bottom Temperature From Fish Captured in Lobster Traps

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ABSTRACT—Preliminary field experiments have shown that the internal body temperature of fish captured in lobster traps is a reasonable indicator of actual bottom temperature if the internal temperature is measured by insertion of a thermistor through the anal vent as soon as the fish is brought on deck, and if the fish captured are over 65 cm (≃25 inches) in length. Fish as small as 32 cm (≃12.5 inches) can be utilized provided they are caught in isothermal or shallow water (<40 m) which involves a short hauling time to the surface. This procedure provides fishermen with an inexpensive technique for determining bottom temperatures.

Introduction

The distributional relationships between some commercially important species, like lobster or red crab, and temperature have been well documented (Schroeder, 1959; Cobb, 1976). These relationships have also been noted by some fishermen, and many recognize the potential of increased catches by correlating temperature data with their fishing strategy.

Because of widespread interest in a simple method for determining bottom temperatures, Richard Allen, captain of the MV *Jennie and Jackie*, related to the authors a technique for estimating bottom temperatures which had been suggested to him by John Bordon, captain of the MV *Orin C.*, and Raymond Palombo, captain of the MV *Kristen and Michael*. This technique involved the insertion of a thermometer into the anal vent and measuring internal body temperature of various bottom-dwelling fishes that were caught in lobster traps. Because bottomfish cannot regulate their internal temperature (Carey et al., 1971), the idea of correlating their internal temperatures with bottom-water temperatures appeared plausible. Two problems made it difficult to ascertain bottom temperature by this method. First, and most serious, was the lack of actual bottom temperature data with which to compare the internal temperatures and, secondly, the movement of the fish frequently broke the thermometer. With the help of Allen, we designed an experiment as part of our Ship of Opportunity Program (SOOP) that provided the necessary bottomwater temperature data and measurements of the internal body temperatures of many fish.

Methods

An expendable bathythermograph (XBT) system and an electronic Digitemp system[1], in conjunction with a Tripp Lite Power Verter, provided the means for measuring bottomwater and internal temperature and for converting the 12-volt DC power supply of the MV *Jennie and Jackie* to 110-volt AC power. The Digitemp system, utilizing a thermistor encased within a protective metal shield about 11.5 cm (4.5 inches) in length and 3 mm (⅛ inch) in diameter, alleviated the problem of glass thermometer breakage.

Bottom temperature and internal fish temperature data were collected on 1 and 2 August 1978 at four different trap locations on the continental shelf and upper slope off southern New England, one south of Nantucket Shoals at 38 m (21 fm) depth, and three in the area of Block Canyon at depths ranging from 249 to 268 m (136-147 fm) (table 1). At the shallow station nearly all the fish caught in traps were sculpin (*Myoxocephalus* sp.) with a few hake (*Urophycis* sp.). The deeper traps contained mostly hake and some tilefish, *Lopholatilus chamaeleonticeps*. A total of 35 fish were used for determination of internal temperatures. Because of their relative abundance, only temperature data collected from sculpin and hake were used in this report.

At each station, as the first lobster traps were being hauled to the surface, the air temperature was read and recorded. Whenever a fish was in a trap as it surfaced, it was grabbed with a gloved hand by the gills and snout and the Digitemp thermistor probe inserted through the anal vent as deep into the fish's body as probe length would permit. As soon as the temperature stabilized (after about 15-20 seconds) it was recorded; then the length of the fish was measured and recorded. If more than one fish was in a trap, only the largest individual was selected.

Results and Discussion

The internal temperature measurements taken from fish captured from the station at 38 m (21 fm) accurately reflected bottom temperature. The average internal temperature of eight sculpin ranging in length from 32 to 51 cm (12.5-20 inches) was 12.8°C (standard deviation ±0.10°C) which is identical with the observed bottom temperature (Table 1). The observations are similar to those of Simpson (1908) and Britton (1924) who found the internal temperatures of various species of fish taken at depths of less than 30 m to fall within 0.7°C of local water temperature as measured by reversing thermometer. At this

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[1] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

shallow station the water column was nearly isothermal (Fig. 1A), and traps reached the surface relatively fast (within 1 to 2 minutes), thus there was very little change in the internal fish temperature during retrieval.

Fish captured from depths ranging between 249 and 268 m had internal temperatures ranging from 9.5° to 12.1°C while bottom temperatures ranged only from 9.0° to 9.6°C (Table 1). The XBT observations made at these three stations show that as the traps were brought to the surface, all the fish were exposed to similar increases in temperature (Fig. 1B, C, D). In depths between 200 and 50 m the fish were exposed to temperatures ranging from about 10.0° to 14.1°C. Above 20 m a strong thermocline existed and temperatures rose sharply to nearly 24.0°C at the surface. The time required for hauling traps and captured fish to the surface was 6-8 minutes.

For the purposes of this study it was assumed that the body temperature of the fish represented an integration of the bottom temperature and variations within the water column. The differences between observed internal fish temperatures and bottom temperature are assumed to reflect a relationship between fish size and the water column temperatures experienced by the fish during ascent. The similarity of vertical temperature gradients and depths encountered at the three deep stations allowed the data to be combined.

The capacity of a fish body to act as an insulator, or retain an initial temperature, is considered to be proportional to the ratio of the surface area, over which heat is absorbed or radiated, to volume. The surface area of a fish may be approximated by the square of its length (L^2) times a constant, and volume approximated by cube of length (L^3) times a constant (Ricker, 1975; Fabens, 1965). Thus, the change in internal temperature of a fish (ΔT) is proportional to functions of length, or

$$\Delta T \propto \frac{L^2}{L^3}$$

$$\text{or, } \Delta T \propto \frac{1}{L} \cdot$$

That is, the internal temperature change of a fish is inversely proportional to its length. Therefore, variations in temperature encountered through the water column will tend to have more effect on smaller fish than larger fish. The data taken from the deep stations verified this notion, showing a tendency for the internal temperature of large fish to more closely resemble bottom temperature than small fish.

Table 1.—List of data collected from four trap locations showing the water depth, XBT and station number, bottom temperature, type and length of fish caught, internal temperatures of fish, and the difference between internal temperature and bottom temperature.

Water depth M(F)	XBT per stn.	Bottom temp. (BT) °C (°F)	Fish	Length cm (in)	Internal temp. (IT) °C (°F)	ΔT (IT-BT) °C (°F)	Date
38 (21)	11/40	12.8 (55.0)	Sculpin	51 (20.0)	12.7 (54.9)	0.1 (0.1)	1 Aug 1978
			"	42 (16.5)	12.7 (54.9)	0.1 (0.1)	
			"	41 (16.0)	12.9 (55.2)	0.1 (0.2)	
			"	39 (15.2)	12.9 (55.2)	0.1 (0.2)	
			"	36 (14.2)	12.8 (55.0)	0.0 (0.0)	
			"	34 (13.2)	12.8 (55.0)	0.0 (0.0)	
			"	33 (13.0)	12.8 (55.0)	0.0 (0.0)	
			"	32 (12.5)	12.9 (55.2)	0.1 (0.2)	
			Ave	38 (15.4)	12.8 (55.0)		
249 (136)	14/19	9.5 (49.1)	Hake	65 (25.5)	9.5 (49.1)	0.0 (0.0)	2 Aug 1978
			"	60 (23.5)	10.2 (50.4)	0.7 (1.3)	
			"	58 (22.7)	9.8 (49.6)	0.3 (0.5)	
			"	57 (22.5)	9.5 (49.1)	0.0 (0.0)	
			"	49 (19.3)	10.6 (51.1)	1.1 (2.0)	
			"	48 (19.0)	11.0 (51.8)	1.5 (2.7)	
			"	48 (19.0)	10.3 (50.5)	0.8 (1.4)	
			"	42 (16.5)	11.9 (53.4)	2.4 (4.3)	
			Ave.	53 (20.9)	10.4 (50.8)		
252 (138)	15/5	9.6 (49.3)	Hake	58 (22.7)	10.1 (50.2)	0.5 (0.9)	2 Aug 1978
			"	56 (22.0)	10.6 (51.1)	1.0 (1.8)	
			"	52 (20.5)	11.1 (52.0)	1.5 (2.7)	
			"	50 (19.7)	10.7 (51.3)	1.1 (2.0)	
			"	50 (19.7)	10.8 (51.4)	1.2 (2.1)	
			"	49 (19.3)	11.1 (52.0)	1.5 (2.7)	
			"	46 (18.0)	10.9 (51.6)	1.3 (2.3)	
			"	43 (17.0)	12.1 (53.8)	2.5 (4.5)	
			"	42 (16.5)	12.0 (53.6)	2.4 (4.3)	
			Ave.	50 (19.7)	11.0 (51.8)		
268 (147)	12/18	9.0 (48.2)	Hake	63 (24.8)	10.2 (50.2)	1.2 (2.0)	2 Aug 1978
			"	60 (23.5)	9.9 (49.8)	0.9 (1.6)	
			"	60 (23.5)	9.5 (49.1)	0.5 (0.9)	
			"	52 (20.5)	10.9 (51.6)	1.9 (3.4)	
			"	49 (19.3)	10.7 (51.3)	1.7 (3.1)	
			"	48 (19.0)	10.8 (51.4)	1.8 (3.2)	
			"	47 (18.5)	11.7 (53.1)	2.7 (4.9)	
			"	45 (17.7)	11.6 (52.9)	2.6 (4.7)	
			"	43 (17.0)	11.9 (53.4)	2.9 (5.2)	
			Ave	52 (20.5)	10.8 (51.4)		

There is a significant relationship between fish length and the difference between internal and bottom water temperatures. The equation for the line describing these data was found by regression analysis to be: $\Delta T = (274.9/L)-4.04$, where ΔT = the temperature change during ascent and L = fish length (Fig. 2). From this relationship the equation and resulting regression line may be applied such that an estimate of bottom temperature can be determined from the internal temperature of a hake. For example, given verticle temperature gradients and depth ranges, similar to those considered here, bottom temperature can be determined from a hake of 50 cm in length by subtracting 1.4°C (2.3°F) from the measured internal temperature. Similarly, for the hake of 55 cm, a 1.0°C (1.8°F) subtraction from internal temperature is required, and for a fish 70 cm, no temperatue correction is needed. The standard error of the estimates of temperature difference is such that bottom temperature can be

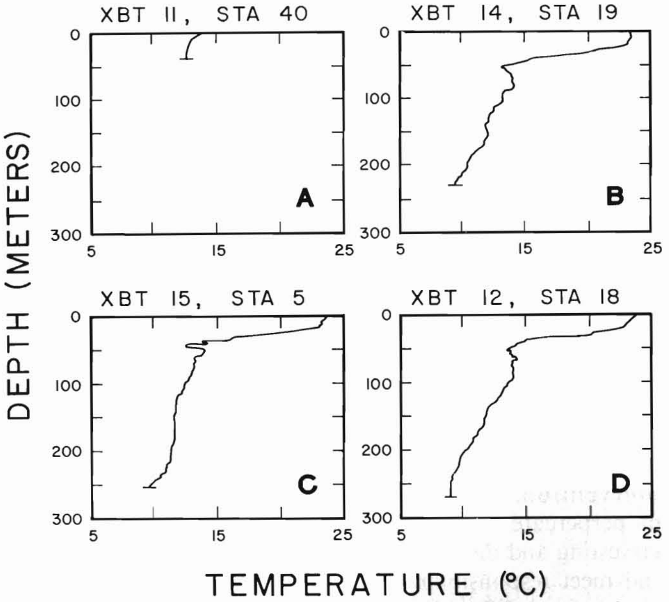

Figure 1.—XBT traces taken at trap locations. A, south of Nantucket Shoals. B-D, near Block Canyon.

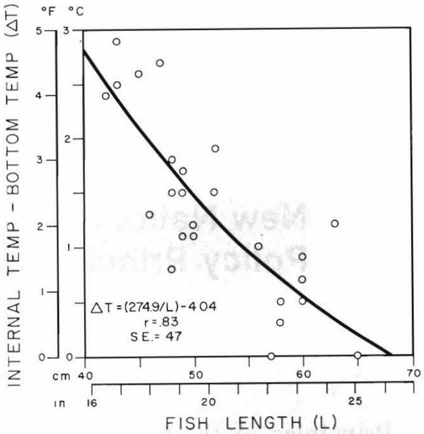

Figure 2.—Relationship between the difference in internal and bottom temperatures and fish length. The correction value (ΔT) can be obtained from the equation, or by extending a line from the horizontal axis (fish length) to the diagonal regression line, and then over to the vertical (ΔT) axis. The correction value is then subtracted from observed internal temperatures.

estimated using Figure 2 to within ±0.5°C (0.9°F) for hake of lengths from 40 to 70 cm.

It should be noted that during this study the differences between bottom and surface temperatures of the three deep stations were greater than those found during most of the year, indicating that during the time of the experiment the maximum internal temperature changes (ΔT) should have been encountered.

Under these extreme temperature gradients (approximately 15.0°C), fish over 60 cm in length gave internal temperatures within 1.2°C of observed bottom temperature. Smaller changes in internal temperature should occur during times of the year when the water column temperature gradient is less extreme. Such a case was observed at the 38 m depth station where the water was nearly isothermal and very small changes in internal temperature were found. Therefore, during most of the year the internal temperature of fish over 60 cm in length will be within ±1 °C of the bottom temperature.

Conclusions

These preliminary results suggest that an inexpensive determination of bottomwater temperatures may be ascertained from the internal tempertures of bottom-dwelling fish. Several problems still exist. First, seasonal water column temperature fluctuations will change the nature of internal temperature changes. Secondly, the amount of time required to bring a fish from the bottom to the surface is dependent on depth, and only two depths are considered here. More precise knowledge of timing (winch speeds, hauling time, etc.) and trap spacing VS depth of water would be necessary to develop a more precise relationship over a wider range of fish sizes and conditions. Further study would be required at different times of the year, of other species of fish, and over several more depths before the full utility of this method could be established.

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