tribution and abundance. In analysis of survey data, these results are a first approximation of correction factors that could be applied to aircraft and shipboard observations to provide more accurate estimates of harbor porpoise abundance, although caution should be exercised because of variable sighting conditions or animal behavior.

Further work on survey methodology should examine the effect of eye height, survey speed, and meteorological conditions upon survey results. Gaskin (1977) has discussed sea state and cloud coverage as factors in survey results, and Scott and Gilbert (1982) have examined several variables affecting aerial surveys, but the effects of glare on shipboard surveys and observer variability merit further attention. Also, the estimation by observers of distances from sighted porpoise to survey vessel needs clear definition for open-ocean surveys (Eberhardt 1978). Nevertheless, if survey methods similar to those described here are adhered to during the course of a survey, the results reported here are applicable, and useful in estimating porpoise abundance more accurately.

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SCOTT D. KRAUS

The New England Aquarium
Central Wharf
Boston, MA 02110

JAMES R. GILBERT

School of Forest Resources
University of Maine
Orono, ME 04469

JOHN H. PRESCOTT

The New England Aquarium
Central Wharf
Boston, MA 02110

TOLERANCE OF FIVE-DAY-OLD WINTER FLOUNDER, *PSEUDOPLEURONECTES AMERICANUS*, LARVAE TO THERMAL SHOCK[1]

The winter founder, *Pseudopleuronectes americanus* (Walbaum), is an important commercial and recreational fish generally found in waters with temperatures of 0° to 25°C and salinities of 4 to 30 ‰ (Pearcy 1962). The winter flounder ranges from northern Labrador to Georgia, but is most commonly found from the Strait of Belle Isle, northern shore of the Gulf of St. Lawrence, to Chesapeake Bay. A separate spawning population, or race, is found on Georges Bank (Bigelow and Schroeder 1953). Smith et al. (1975) indicated that there is a progression in spawning time from south to north initiated by increasing water temperature. Spawning generally occurs in estuaries and shoal waters in winter and early spring (Bigelow and Schroeder 1953) at temperatures of 3° to 10°C and salinities of 15 to 35‰ (Rogers 1976).

[1]Contribution No. 345, Marine Sciences Research Center, State University of New York, Stony Brook, NY 11794.

Clusters of adhesive demersal eggs, 0.74 to 0.88 mm, are laid on sandy bottom (Bigelow and Schroeder 1953). Upon hatching, the planktonic larvae are 3 to 3.5 mm long. Metamorphosis occurs when the larvae reach lengths of 8 to 9 mm. The larvae remain free-swimming until prior to metamorphosis, when they become bottom oriented (Bigelow and Schroeder 1953).

In the planktonic state the larval stages are susceptible to the hazards of entrainment by steam electric generating stations, which usually use once-through cooling because it is the most economical method for condensing exhaust steam from turbines. However, cooling requires the passage of large quantities of water through the steam condensers. During its passage the temperature of the water is elevated by 5.5° to 23.3°C, while residence time may be as much as half an hour or longer, depending on the geometry and operational methods of the cooling system (Committee on Entrainment 1978).

The present study determines the temperature-time combinations which produce a thermal shock leading to significant mortalities in 5-d-old winter flounder larvae.

Materials and Methods

Winter flounder, collected from Narragansett Bay, were induced to spawn artifically by injecting freeze-dried carp pituitary hormone in saline into the back muscle below the dorsal fin (Smigielski 1975). Hormonal treatments were repeated daily until the mature ova were released. The fish were then stripped by hand. Fertilized eggs were secured from two females. An even layer of eggs was deposited on the bottom of a plastic bowl and then milt from several males was added. After fertilization, a dense suspension of diatomaceous earth (50 g/l) was mixed with the eggs to retard clumping (Smigielski and Arnold 1972). After the fertilized eggs remained in the slurry for 10 min, they were washed on a 550 μm mesh screen. The eggs were then transferred to a hatching jar where they remained until being transported from the Environmental Research Laboratory of the U.S Environmental Protection Agency, Narragansett, R.I., to Flax Pond Laboratory, Old Field, N.Y. To ensure maintenance of the spawning (acclimation) temperature during transport, the eggs were placed in plastic bags and maintained in an insulated container holding seawater. Aeration was continuous, using a battery-operated air pump.

At Flax Pond Laboratory, the eggs were placed in incubation baskets at the 5° C spawning temperature and acclimated to reduced salinity. The spawning salinity at Narragansett Bay was 31‰, while at Flax Pond the salinity was 27‰, a typical salinity for Long Island Sound in this region. The fertilized eggs remained in the incubation baskets until after hatching. Five-day-old larvae were then transported about 8 km to the Marine Sciences Research Center.

Larvae were pipetted in to 27 two-compartment hatching boxes, consisting of a polyvinyl chloride frame (7.5 × 6.0 × 16.0 cm) covered with monofilament bolting cloth, 243 μm mesh opening. In each compartment of a hatching box, 15 to 69 larvae were placed, providing 27 samples and their replicates. The hatching boxes were then placed in one of four partially filled 114 l aquaria, having a salinity of 27‰, and immersed in a constant temperature water bath system set at an acclimation temperature of 5° C. The constant temperature water bath system is a rectangular plywood box, measuring 2.4 m × 1.2 m × 0.45 m, filled with fresh water. Water temperature was controlled by thermostatically regulated refrigeration units and monitored with a continuous recording thermometer. The water was circulated by two submersible pumps.

For each test exposure, a hatching box with its larvae was placed in a polyethylene foam container holding 12 to 15 l of seawater for 4, 8, 16, 32, or 64 min. The excess temperature, ΔT, over the acclimation temperature of 5° C, in the initial trial was 22° C. For each subsequent trial, the ΔT was increased by an increment of 2° C until a final ΔT of 30° C was attained. Temperature in each container was monitored and maintained by the addition of hot or cold water of 27‰ salinity. Following each exposure period, the hatching boxes were returned to the acclimation aquaria (5° C) where they were held for 24 h after which survival/mortality counts were made. A larva was counted as living if it showed transparency or heart beat; otherwise, it was considered to be dead (Table 1). Of the 27 hatching boxes, two were chosen as controls. These controls received no thermal shock, but were handled in a manner similar to the experimental boxes.

Results

The larval survival/mortality counts (Table 1) for samples and their replicates were converted to square root transformations, $\sqrt{N + 0.5}$, and compared using the Chi-square test (Sokal and Rohlf 1969). Samples did not differ materially ($\chi^2 = 3.841$, df = 1, $P < 0.05$). It was therefore feasible to combine the samples to enlarge the sample size.

The data for each hatching box sample (Table 1) were converted to percentages of corrected mortality

(% surviving experimental/% surviving controls × 100). The values were then plotted as a function of mortality. Figure 1, a three-dimensional graph representing total temperature [acclimation + excess temperature (ΔT)] and excess temperature (ΔT), and exposure period (time) versus corrected mortality, shows relatively little or no mortality of 5-d-old winter flounder larvae exposed to a thermal shock of 22°C for exposures up to 32 min. Significant mortality occurred at Δ22 and at exposures between 32 and 64 min. These conclusions are substantiated by the Chi-square test (Table 2).

TABLE 1.—Survival/mortality counts for winter flounder larvae found in compartments of hatching box for ΔT-*t* levels (°C-min) from Δ22-4 to Δ30-64. Criteria for viability were transparency and heart beat.

	Left compartment		Right compartment	
ΔT-*t*	Alive	Dead	Alive	Dead
Control 1	45	0	—	—
Control 2	37	1	21	4
22-4	25	3	43	0
8	39	0	41	0
16	37	3	31	2
32	23	4	40	3
64	39	10	22	11
24-4	40	21	42	9
8	18	16	39	15
16	34	6	39	9
32	18	18	29	20
64	0	15	1	56
26-4	10	14	63	6
8	0	23	10	46
16	0	49	0	36
32	0	36	0	52
64	0	49	0	47
28-4	0	50	0	52
8	0	49	0	42
16	0	34	0	48
32	0	37	0	48
64	0	48	0	43
30-4	0	29	0	22
8	0	47	0	38
16	0	17	0	64
32	0	45	0	50
64	0	46	0	50

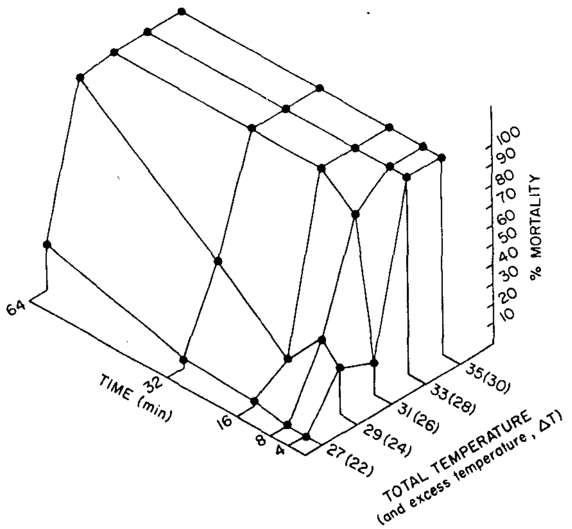

FIGURE 1.—Three-dimensional graph for 5-d-old winter flounder larvae representing total temperature [acclimation temperature + excess temperature (ΔT)] and excess temperature (ΔT), and exposure period (time) versus corrected mortality.

Mortality at lower excess temperatures, ΔT's of 22°, 24°, and 26°C, appears to be a function of time. This is shown in Figure 1 by sharp increases in mortality between Δ22-32 (ΔT-*t*) and Δ22-64. Sharper increases in mortality are found at Δ24 between exposures of 16 and 64 min, and Δ26 between 4 and 8 min. These increases in mortality are also represented in Table 2 by increases of Chi-square values of an order of magnitude. Total mortality was found in all samples when ΔT's exceeded 26°C and exposure times exceeded 8 min.

TABLE 2.—Chi-square probability values of counts of viable winter flounder larvae compared with dead larvae in treatments versus controls.

	Time (min)				
ΔT(°C)	4	8	16	32	64
22	0.016	3.805	0.411	1.948	17.370
24	20.175	30.277	8.158	44.118	156.411
26	13.067	130.533	173.893	176.876	184.924
28	190.919	179.902	170.790	173.893	179.902
30	138.100	173.839	169.770	183.922	184.924

*P≤0.05.

Discussion

Flounder larvae appear to be resistant to acute thermal shock. This is substantiated by Barker et al. (1981), Valenti (1974), Carpenter (unpubl. data), and Hoss et al. (1974). Barker et al. (1981) acclimated smooth flounder, *Liopsetta putnami*, to 4°C and exposed them to ΔT's of 21.4°, 23.6°, 25.8°, 28.0°, and 30.2°C for periods of 5, 30, and 60 min. Significant differences in mortality were encountered at a ΔT of 23.6°C and at exposures between 30 and 60 min. Valenti (1974) simulated entrainment at the proposed Shoreham (New York) Nuclear Power Station, using winter flounder larvae similar in age to those used in the present study. Acclimation temperatures of 0°, 3°, 6°, 9°, and 12°C were used with ΔT's of 8°, 10°, 12°, and 14°C and exposures of 0, 5, and 13 min. Significant differences in mortality were detected only in those larvae acclimated to 3°C and exposed to a ΔT of 14°C for 13 min. Carpenter (unpubl. data), using older winter flounder larvae (18-22-d-old) in simulating entrainment at Millstone (Connecticut) Nuclear Generating Station, used an

[2]Permission was granted from the author to use the data.

acclimation temperature of 8°C, ΔT of 13°C, and exposures varying from 1 to 6 h. Depending on age, mortality ranged between 60 and 100%. The oldest larvae experienced total mortality. Hoss et al. (1974) compared the field-collected larvae of three species of flounder (*Paralichthys dentatus*, *P. lethostigma*, and *P. albigutta*) with the larvae of Atlantic menhaden, *Brevortia tyrannus*; spot, *Leiostomus xanthurus*; and pinfish, *Lagodon rhomboides*, and found the flounders most resistant. The flounders acclimated to 15°C withstood a thermal shock of 18°C for periods of 40 min with a survival rate of 30%.

The results of a number of studies (e.g., Schubel et al. 1978) indicate that resistance to thermal shock is age-dependent, with yolk-sac larvae being more tolerant than postyolk-sac larvae. Power plants should be designed and operated to sustain the most sensitive developmental stages of ichthyoplankton. Tests similar to the one described here should be made before site-specific tests are performed and before design and operating criteria are set. Sublethal effects, although not considered in this paper, should also be considered in the establishment of the excess temperature that will be utilized in a given season. Such sublethal effects reduce the chances of survival by entrained ichthyoplankton.

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NORMAN ITZKOWITZ
J. R. SCHUBEL

Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794

MOVEMENTS OF ROCKFISH (*SEBASTES*) TAGGED IN NORTHERN PUGET SOUND, WASHINGTON

Recreational scuba divers and hook-and-line fishermen in northern Puget Sound (Fig. 1) have taken an annual catch of 150,000 bottomfish of all species; four species of Pacific rockfish (*Sebastes*) account for about 70% of the catch (Washington Department of Fisheries 1977-1980). These four species are copper rockfish, *S. caurinus*; quillback rockfish, *S. maliger*; black rockfish, *S. melanops*; and yellowtail rockfish,

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