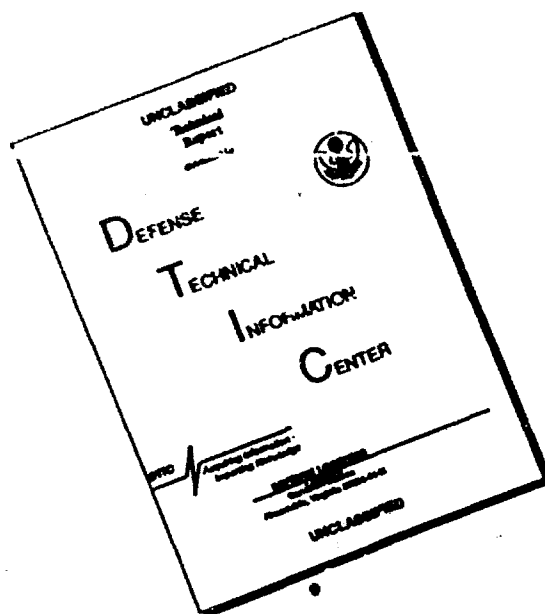


DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188	
AD-A267 522		ed to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and lection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including ters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA work Reduction Project (0704-0188), Washington, DC 20503.	
		2 REPORT DATE June 1993	3 REPORT TYPE AND DATES COVERED Professional Paper
4 TITLE AND SUBTITLE ASSESSING THE THERMAL LIMIT OF BOTTLENOSE DOLPHINS: A Cooperative Study by Trainers, Scientists, and Animals		5 FUNDING NUMBERS PR: MM40 PE: 0603709N WU: DN788737	
6 AUTHOR(S) T. M. Williams, J. E. Haun, W. A. Friedl, R. W. Hall, L. W. Bivens		8 PERFORMING ORGANIZATION REPORT NUMBER	
7 PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Command, Control and Ocean Surveillance Center (NCCOSC) RDT&E Division San Diego, CA 92152-5001		10 SPONSORING/MONITORING REPORT NUMBER DTIC ELECTE AUG 3 1993	
9 SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Sea Systems Command Washington, DC 20362		11 SUPPLEMENTARY NOTES	
12a DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b DISTRIBUTION CODE	
13 ABSTRACT (Maximum 200 words) Although bottlenose dolphins (<i>Tursiops truncatus</i>) may be exposed to ocean water temperatures ranging from 6°C to 27°C, little is known regarding their preferred environmental temperatures. Consequently, it is difficult to predict the "ideal" water temperature for the animals in captivity. To determine the range of thermally neutral water temperatures for these cetaceans, we examined the thermoregulatory physiology of adult bottlenose dolphins (body weight = 136 kg) trained to rest in a water filled box. Metabolic rate, body temperature, skin temperature, and heat flow were measured over a 10°C range of water temperatures. The results indicate that the lower critical water temperature (T_{lc}) for bottlenose dolphins is variable; T_{lc} was less than 6°C for San Diego dolphins in the winter and 11-16°C for Hawaiian animals in the summer. Further cooperative research will enable us to anticipate the thermal requirements of both large and small cetaceans in captivity.			
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Published in <i>Journal of Proceedings International Marine Animal Trainers Association</i> , Fall 1992, pp. 16-17.		Accession For NTIS CRA&I DTIC TAB Unannounced Justification	
14 SUBJECT TERMS marine biosystems AMBS		15 NUMBER OF PAGES A-1 20	
17 SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18 SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	
19 SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED		20 LIMITATION OF ABSTRACT SAME AS REPORT	

UNCLASSIFIED

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ASSESSING THE THERMAL LIMITS OF BOTTLENOSE DOLPHINS:

A COOPERATIVE STUDY BY TRAINERS, SCIENTISTS, AND ANIMALS

by Terrie M. Williams, Jeffrey E. Haun, William A. Friedl, Richard W. Hall, and Lester W. Bivens
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The following paper was presented by Dr. Terrie Williams at the 1991 IMATA Conference in Concord, California. The paper generated significant interest, not only among the conference attendees, but also among the general public. As always, the paper will be printed in the Conference Proceedings, however, because of the interest expressed, we have printed it here in *Soundings* as well.

SUMMARY

Although bottlenose dolphins (*Tursiops truncatus*) may be exposed to ocean water temperatures ranging from 6°C to 27°C, little is known regarding their preferred environmental temperatures. Consequently, it is difficult to predict the "ideal" water temperature for the animals in captivity. To determine the range of thermally neutral water temperatures for these cetaceans, we examined the thermoregulatory physiology of adult bottlenose dolphins (body weight = 136 kg) trained to rest in a water filled box. Metabolic rate, body temperature, skin temperature, and heat flow were measured over a 10°C range of water temperatures. The results indicate that the lower critical water temperature (T_{lc}) for bottlenose dolphins is variable: T_{lc} was less than 6°C for San Diego dolphins in the winter and 11 - 16°C for Hawaiian animals in the summer. Further cooperative research will enable us to anticipate the thermal requirements of both large and small cetaceans in captivity.

INTRODUCTION

The purpose of our study was to examine the thermoregulatory capabilities of the bottlenose dolphin. There were several reasons for undertaking such a project. First, although dolphins have been housed in seaquaria for decades we know very little about their basic physiology. Should water temperatures of sedentary animals be the same as for active animals? What temperatures do the animals prefer? Should the diet of the dolphin be changed to account for seasonal temperature fluctuations? A second reason for this study centered around increased concerns about global warming and its impact on wild dolphin populations. How will such temperature shifts affect the distribution, population size, and even survivability of cetacean species in the wild? Will it require innovative management decisions or conservation plans?

With these questions in mind, we began a research program at Naval Ocean Systems Center in Hawaii. We were interested in the basic thermoregulatory response of adult bottlenose dolphins (*Tursiops truncatus*). The responses to shifts in water temperature were investigated; measurements included body temperature, skin temperature, insulating characteristic of the blubber layer, heat flow across the body wall, and metabolic rate. To accomplish this work, we needed exceptional cooperation between the animals, scientists, and trainers.

METHODS

Approach. The goal of this study was to determine the thermal neutral zone (TNZ) of the bottlenose dolphin (Fig. 1). This zone defines the range of water temperatures that are considered the most comfortable for the resting animal. It is delineated by the range of environmental temperatures that require the least amount of physiological effort to maintain a stable body temperature. The TNZ is represented by the flat portion of the metabolic curve shown in Figure 1.

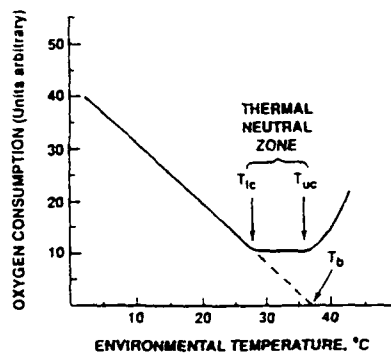


Figure 1. Oxygen consumption in relation to ambient temperature for a theoretical mammal. The flat part of the curve represents the thermal neutral range of temperatures. This range is delineated by the lower critical temperature (T_{lc}) and the upper critical temperature (T_{uc}) (Redrawn from Bartholomew, 1977).

At higher temperatures the animal must actively dissipate excess heat. For terrestrial animals the avenues of heat loss include panting and sweating. At temperatures below the thermal neutral zone, and hence below the lower critical temperature (T_{lc}), animals must generate additional heat to remain warm. Usually, this results in an increase in metabolic rate.

Physiological Measurements. Details of the training and instrumentation are presented in Wright (1991). Two adult, post-absorptive dolphins housed in San Diego (mean water temperature = 15.4°C) were used in these studies. Briefly, oxygen consumption was determined by open flow respirometry (Williams, 1987) while the dolphins rested in an insulated box. Water temperature in the metabolic box was controlled by a salt water heat exchanger and ranged from 3.6 to 17.3°C. Each experiment was conducted at a single water temperature and lasted for 2 - 3 hours. Following metabolic measurements heat flow was determined with a 1" diameter heat flux transducer (Thermometrics Corp., San Diego) held against the skin. Skin temperature was measured with a thermocouple embedded in

the transducer. Measurement sites included the mid-lateral body wall on the trunk, dorsal fin, pectoral fin, and underside of the fluke. Core temperature was measured with a digital thermometer and rectal probe. Blubber thickness of the dolphins was determined by ultrasound (Scanoprobe II) before the experiments. Six sites along the body wall were measured and averaged. To determine seasonal variation in blubber thickness, we also made monthly measurements of thickness for 10 dolphins housed in open water pens in San Diego, and 10 dolphins housed in Hawaii.

RESULTS AND DISCUSSION

We found that bottlenose dolphins from San Diego maintained a stable body temperature over the range of water temperatures tested. Core temperature was approximately 37°C and did not change with water temperatures from 3.6 to 17.3°C. Skin temperature remained within 0.6°C of the water temperature.

Heat flow varied with anatomical site, and was consistently higher for the trunk of the body than for peripheral sites (pectoral fins, dorsal fin, and flukes). Interestingly, measurable levels of heat from the peripheral sites of resting animals only occurred at ambient water temperatures (temperatures similar to the pen water). At lower water temperatures, heat flow from the periphery was remarkably reduced (Fig. 2). In contrast, heat flow from the trunk of the body increased with lower water temperatures. Figure 2 demonstrates

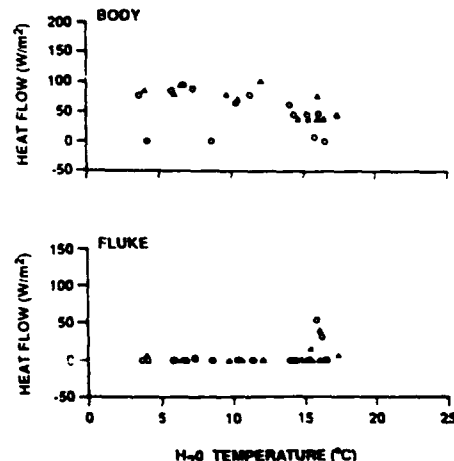


Figure 2. Heat flow in relation to water temperature for bottlenose dolphins from San Diego. The upper graph denotes measurements taken from the side of the body, the lower graph shows measurements from the underside of the fluke. Note the variability in heat flow from the fluke at 16°C, the acclimation water temperature of the animals.

seasonal trends for the flukes and body wall of the San Diego dolphins. These animals were acclimated to ocean temperatures of approximately 16°C. At this temperature heat flow occurred from both the fluke and the body wall. At water temperatures below 16°C, heat flow was absent from the flukes. We observed a gradual increase in heat flow from the trunk as water temperature declined.

These results can be applied to husbandry protocols for stranded cetaceans. If a seaquarium is presented with an unusual species of cetacean or a cetacean of unknown thermal history, heat flow measurements can be used to determine the preferred water temperature of the resting animal. Water temperature of the holding pool should start at ambient conditions and be raised or lowered just to the point that heat flow occurs intermittently at peripheral sites. Water temperatures that permit heat flow from both peripheral and body wall sites will ensure that the water is not too cold. However, care should be taken not to overheat the water. Measurements should be taken on resting animals, as activity will affect the level of heat flow from peripheral sites. Occasional measurements of rectal temperature will confirm the thermal stability of the animal.

Over long periods of exposure to cool water temperatures, dolphins control heat loss from the body wall by altering the insulation provided by blubber. This is demonstrated by comparing seasonal changes in blubber thickness for dolphins acclimated to water temperatures in San Diego and Hawaii. Like the coats of arctic foxes and desert kit foxes, the thickness of the insulating layer of dolphins changes with acclimation temperature (Fig. 3). Both San Diego and Hawaii dolphins showed seasonal changes in blubber thickness. The layer was thinnest during warm seasons and thickest during cooler winter months. Yet, at comparable seasons, the blubber layer of animals in Hawaii remained thinner than the layer for counterparts in San Diego. Note that Worthy (1991) has recently shown that the fat content of cetacean blubber also shows seasonal variations. Thus, both the quality and quantity of insulation can change in dolphins.

The importance of proper insulation can be demonstrated for wild dolphins. During the 1989/1990 winter, a sudden and prolonged decrease in water temperature along the Texas coast was followed by the stranding of 23 dolphins in East Matagorda Bay. Necropsy results from these animals revealed blubber thicknesses that were approximately 40% lower than normal (Miller, submitted). It is likely that these animals came into



Figure 2. Costa examines some of the equipment used to test the thermoregulatory limits of *Tursiops truncatus* at the Naval Ocean Systems Center laboratory in Kaneohe Bay, Hawaii.

the winter with a poor insulating layer. The result was that the dolphins were incapable of handling the unique thermal challenge created by the decrease in water temperature.

Changes in insulation will alter the range of temperatures comprising the thermal neutral zone of mammals (Bartholomew, 1977). We observed this for bottlenose dolphins. From our metabolic studies we found that the lower critical temperature (T_L) of San Diego dolphins was approximately 6°C; 10°C below ambient water temperature in the holding pens. This compares to T_L of 11–16°C for bottlenose dolphins measured in Hawaii during the summer when ambient water temperatures averaged 27–28°C (Costa, pers. comm.).

In summary, the thermoregulatory system of dolphins is flexible, and depends on routine water conditions. Animals acclimated to temperatures in San Diego show no change in core body temperature or metabolic rate with acute exposure to water temperatures within 10°C of ambient conditions. Longer periods of exposure promote changes in the quality and quantity of the insulating blubber layer. Future research and continued cooperation between trainers, animals, and scientists will provide additional information that is critical for establishing the thermal requirements of both wild and captive dolphins. ■

ACKNOWLEDGEMENTS

The authors wish to thank D. Costa, J. Liao, M. Reddy, M. Fong, and the members of the Training and Animal Care staff at NOSC who assisted with this study.

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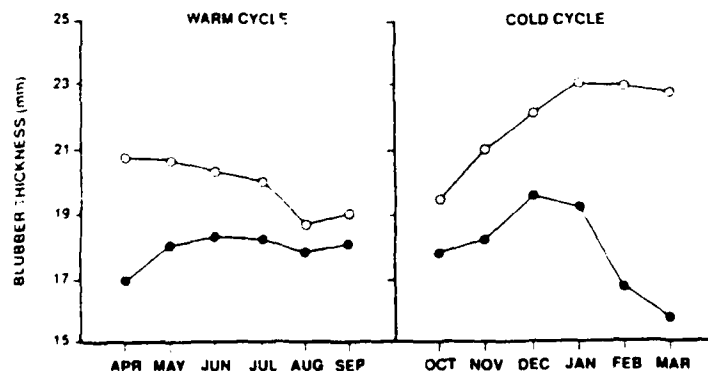


Figure 3. Blubber thickness in relation to month of the year for San Diego (○) and Hawaii (□) bottlenose dolphins. Each point represents the mean value for 10 animals.



May is pupping season, and the California coastline is covered with female harbor seals and their pups. This photo was taken last spring along Monterey Bay, just north of Carmel-by-the-Sea.