

Rate of post mortem temperature loss in a striped dolphin (*Stenella coeruleoalba*)

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It is sometimes useful for researchers to be able to estimate the time of death of a dolphin. In captive dolphins which are not under continuous observation, knowing the time of death is important, for example, in estimating the digestion rate of the last food fed or for assessing the results and effects of any medication administered. Knowing the approximate time of death of stranded dolphins can be useful in assessing what environmental factors, such as tide, may have influenced stranding, or if all animals in a mass stranding died at about the same time.

In the study of dolphin incidental captures in passive fishing gear, the approximate time of death of entrapped dolphins may provide valuable insights into the reasons for capture. Several sources now suggest that traditional methods of preventing dolphin capture in passive fishing gear, such as the attachment of acoustic or visual enhancers to nets, are at best ineffectual and may, in fact, be counter-productive (Peddemors, Cockcroft & Wilson, 1990; Dawson, 1990). It may be better to investigate the biological, environmental and physiographic factors implicated in captures for each specific fishery and species, in an attempt to make gear more selective and reduce by-catch.

In this context, Cockcroft (in press) examined the biological and gross environmental and physiographic factors implicated in the incidental capture of bottlenose dolphins in shark gill-nets set off Natal, South Africa. This study indicated that specific sex and size classes of bottlenose dolphins were more at risk of capture because of distributional differences. Additionally, seasonal sea temperature and daily current direction were apparently correlated with capture, possibly because these environmental factors influence prey distribution and occurrence around the nets. Unfortunately, the time of death of captured dolphins was not known, so the influence of short term environmental fluctuations, such as diurnal light and dark sequences or tidal rhythms, could not be examined. For this reason, the ability to determine time of death may be an important tool in establishing methods of capture prevention.

The death of captive dolphins provides an ideal opportunity to establish a body cooling coefficient

through the measurement of *post mortem* body temperature decline over time. At 08.05 on August 31, 1990, FRIZBEE a rehabilitated striped dolphin *Stenella coeruleoalba*, 224 cm in length and 91 kg in weight, died in the Port Elizabeth Oceanarium, South Africa, after some 12 months of a recurrent illness. The decline in Frizbee's body temperature over the next eight hours was recorded (Figure 1), using a digital thermometer and extended thermistor probe, inserted through the anal opening about 45 cm into the body. Temperature was first recorded 25 minutes after death and thereafter at irregular intervals, none of which was more than 20 minutes apart. Water temperature, also recorded at hourly intervals, remained constant (15°C) throughout the day.

From an initial high of 34.6°C, body temperature declined remarkably smoothly over the observation period, as did the difference between body temperature and water temperature (Figure 1). At a body temperature of approximately 23°C and a difference between body and water temperature of about 8°C, however, there appears to be a slight inflection in the curves, suggesting a slight change in the cooling coefficient. Nevertheless, the decline in the difference between body and water temperature has a high correlation ($r=0.9997$) to a negative exponential curve of the form $Y = \exp(2.97071 - 0.0026355 \times X)$ (Figure 2). As the difference between body and water temperature approaches about 2°C, the predictive curve flattens markedly, probably making any predictions beyond this point unreliable (Figure 2).

Several factors may have biased the observed cooling rate: although FRIZBEE's body temperature was only measured some 20 minutes after death (34.5°C), it is unclear why it was lower than the apparently normal temperature (37-38°C) of free-ranging dolphins (Whittow, Hampton & Ohata, 1978). However, this may have been due to illness and is unlikely to have affected the observed cooling rate. Also, FRIZBEE was very lean, with markedly atrophied dorsal axial musculature, though his mid-lateral blubber thickness was some 18 mm. The influence of muscle thickness on cooling rate is unknown, but the relatively thick blubber layer

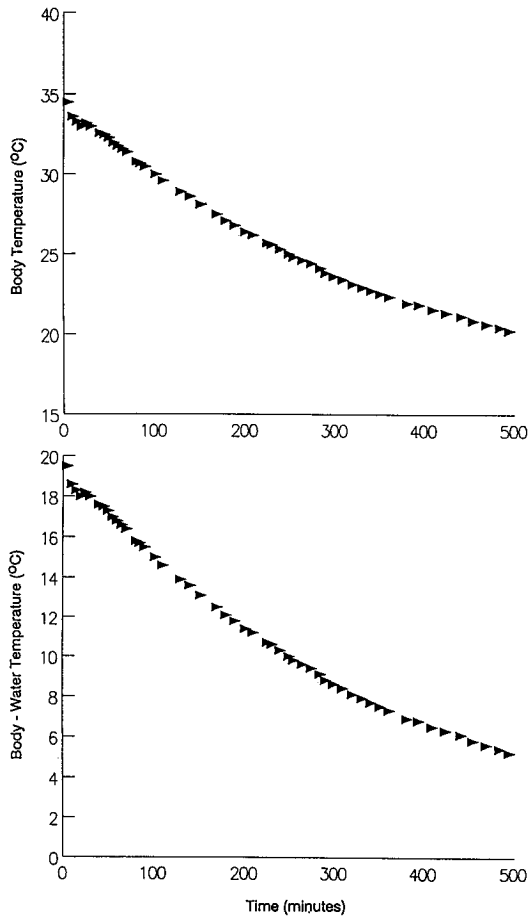


Figure 1. The decline in both core body temperature and the water and core body temperature difference in a dead dolphin.

suggests that the cooling coefficient may not be unduly affected.

These data indicate that measurement of *post mortem* body temperature, provided it is more than 2°C above ambient water temperature, can be used to estimate the time of death. However, as cooling rate is probably dependant upon and directly proportional to blubber thickness and the weight or volume to surface area ratio of the various sizes or species of dolphin, the rate of cooling observed here can be used as a general guide only.

The decline in the difference between body and water temperature also allows an assessment of the amount of energy required to maintain body temperature at basal metabolic rate. For animals living at widely differing body and water temperatures, the energy required to maintain body temperature is likely to be substantially greater than when body and

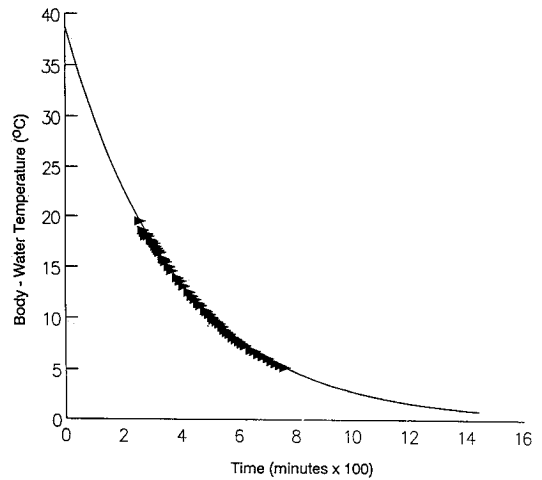


Figure 2. Observed differences between water and core body temperature (triangles) and predicted differences (solid line— $Y = \exp(2.97071 - 0.0026355 \times X)$) over time.

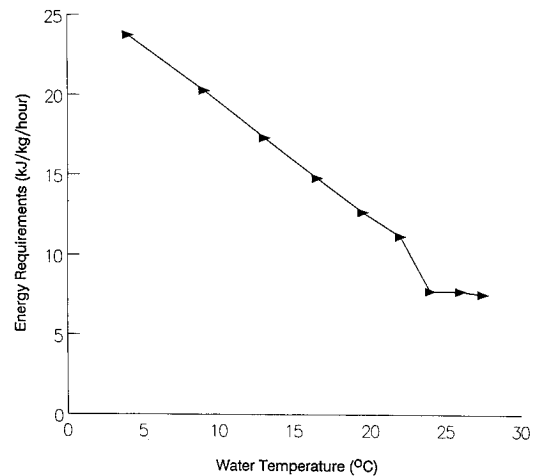


Figure 3. Calculated hourly energy requirements (kJ/kg) to maintain body temperature at varying water temperatures.

ambient water are almost the same. On the assumption that the specific gravity of a dolphin is one, calculations from the derived curve suggest that dolphins living in water of 0°C would need approximately 23.9 kJ kg⁻¹ per hour of energy to maintain a body temperature of about 37°C (Figure 3). For those living at water temperatures of 15°C and 25°C, the energy requirements are 12.2 kJ kg⁻¹ per hour and 6.3 kJ kg⁻¹ per hour, respectively (Figure 3).

These calculations obviously assume that the cooling coefficient for a 100 kg dolphin is typical and they take no account of volume to surface area ratios of larger or smaller dolphins, the insulative properties of blubber (Worthy & Edwards, 1990), metabolic sources of heat, or any effects of possible cooling through extremities (Irving, 1969). Nevertheless, in view of the daily energy consumption (34 MJ for bottlenose dolphins, Ross & Cockcroft, 1990), these calculations infer that the daily energy needed for body temperature maintenance is small, even the projected 573 kJ required by animals living at 0°C. This is especially so as any metabolic activity would produce heat (Irving, 1969). These conclusions imply that blubber may be equally important for other reasons, such as an energy storage facility, as it is for its insulative value.

At water temperatures above about 22°C, the calculated amount of energy needed to maintain body temperature decreases markedly (Figure 3), implying that dolphins inhabiting water around this temperature may be thermoneutral. Hampton & Whittow (1976) showed a possible increase in the metabolic rate of spinner dolphins (*S. longirostris*) at temperatures below 26°C, but no decline in deep body temperature down to 17°C, suggesting that these dolphins had a lower critical temperature of around 25°C. Interestingly, Indian Ocean bottlenose dolphins are thermoneutral at around 20°C, but require a substantially greater daily energy input to maintain body weight at water temperatures below this (Ross & Cockcroft, 1990). The similarity of the apparent thermoneutral zones of spinner and captive bottlenose dolphins, suggests that, generally, at temperatures below 22°C, energy requirements for body temperature maintenance may increase.

However, given the wide range of water temperatures in which dolphins are found, there are likely to be exceptions to this generality. For those dolphins inhabiting tropical, warm waters the dissipation of excessive heat may be necessary and, consequently, the evolution and development of heat transfer structures may be advantageous. Similarly, dolphins living in very cold water are likely to have adapted to minimize heat loss. Other than comments on the

influence of scales of size (surface area) and the effect of activity on temperature maintenance, adaptations to maintain homiothermy have been little explored in the literature, although there is some evidence of their occurrence. Worthy & Edwards (1990) found that the blubber of harbour porpoises (*Phocoena phocoena*) was less conductive and, therefore, more insulative, than that of spinner dolphins, implying an adaptation to the colder water which the former inhabit. In light of the relative absence of any information on homiothermic adaptations, however, it seems reasonable to assume that the cooling coefficient calculated here can be used, generally, to estimate the time of death of most dolphin species.

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