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BUOYANCY REGULATION IN DEEP DIVING WHALES

By

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CLARKE[1] has suggested that the spermaceti of the sperm whale serves as a buoyancy regulator by cooling as the whale dives into seawater of greater density. According to calculations presented[1] a whale of 31,435 kg would have an increased lift of 79.5 kg on a dive from 22.3° C water to the deeper (1,000 m) colder water of 7.8° C. It is further suggested[1] that other cetacea having similar spermaceti organs[2] may adjust buoyancy in the same way.

To achieve these results it must be assumed that the volume of the whale remains constant during the dive. In experiments with a smaller odontocete *Tursiops truncatus* trained to make controlled voluntary dives in the open ocean we have shown that the shape of the animal changes drastically at depth[3]. As the dolphin dives down the flexible thorax starts to collapse and at a depth of 300 m thoracic collapse is very marked (Fig. 1).

It seems, however, that thoracic collapse is important primarily in respiratory physiology[3]. The normal swimming thrust of the animal is such that any out-of-neutral buoyancy values of these small proportions (0.5% of body weight[1]) are unlikely to be very significant.

A 200 kg dolphin has a respiratory air volume of 10 to 11 l. At a depth of 300 m the compression of respiratory gas would account for approximately 10 kg difference in buoyancy compared with the animal on the surface. If Clarke's[1] sperm whale dives with just 100 l. of air in its lungs (10 to 30% of lung volume[1]) the buoyancy difference caused by compression of pulmonary gas, with resultant thoracic collapse, would be greater than could be accounted for by freezing 1,450 kg of spermaceti and much less expensive in terms of energy.

Cooling of peripheral tissues has been demonstrated during dives by other aquatic mammals[4]. No doubt the temperature of at least the more peripheral spermaceti is cooled. Clarke's hypothesis, however, specifies several physiological events not observed in other diving mammals. These include: (1) dilation of the skin blood vessels when the dive is commenced; (2) cessation of bradycardia and vasodilation while the animal is still at depth; (3) passage of water into the nares. The first two specifications appear to be contrary to the oxygen conserving mechanisms that are primary factors in allowing for prolonged diving[5,6].

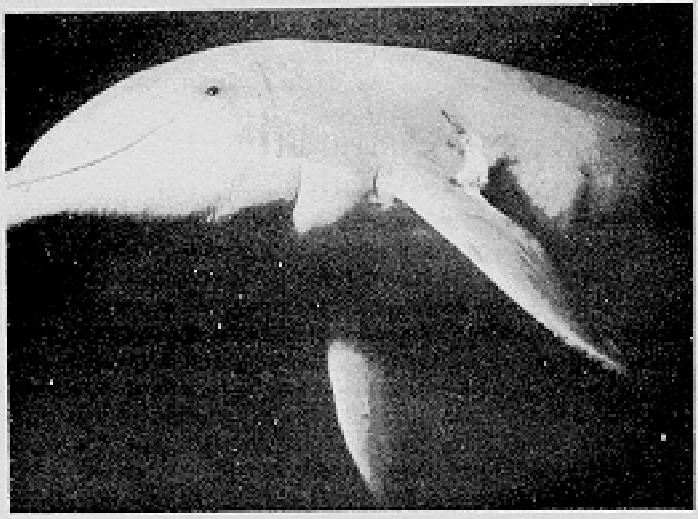

Fig. 1 The dolphin pushes a plunger at the end of a diving test switch at 300 m. This animal had been trained to dive on acoustic command in the open ocean especially for the purpose of studying its diving physiology. The photograph was taken when the dolphin reached the switch and pushed the plunger with its rostrum. (Photograph by courtesy of the US Naval Undersea Center and the Underwater Photographic Unit at Point Mugu.)

Many of the deep dives into waters of 7.8° C or colder are feeding forays. The whale is taking food (primarily squid) into its stomach in large quantities. This food is in thermal equilibrium with the seawater and poses an additional heat drain not previously considered.

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