

FIGURE 3.—Respiratory demand (Gooding and Neill see footnote 2) versus respiratory supply (Brown and Muir 1970; Stevens 1972) as a function of swimming speed in a 40-cm, 1.4-kg skipjack tuna. Respiratory demand increases geometrically while respiratory supply increases arithmetically with increasing swimming speed. When oxygen concentration decreases it is more efficient to increase ram ventilation by increasing gape rather than simply swimming faster.

fairly rapid rise in the water column at a relatively low energetic cost. Yellowfin tuna, in contrast, are just not stressed at the levels of saturation employed in our experiments. Yellowfin tuna should be able to occur in the anoxic water in or below the thermocline and since in the eastern central Pacific Ocean anoxic, cool waters are as inhospitable as the upper too warm waters, skipjack tuna may find no suitable habitat.

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A NONLETHAL LAVAGE DEVICE FOR SAMPLING STOMACH CONTENTS OF SMALL MARINE MAMMALS

Historically, the only expedient and successful method for determining the species upon which marine mammals feed has been to kill the animal, remove its stomach, and examine the contents in the laboratory (e.g., Wilke and Nicholson 1958; Tautsumi et al. 1961; Shomura and Hida 1965; Fiscus and Baines 1966; Fitch and Brownell 1968; Imler and Sarber 1947). This method, however, does not always work. For example, when actively feeding marine mammals are harpooned or shot, they sometimes regurgitate most or all of their food. While regurgitation by live captured marine mammals is possible, it does not appear to be a significant problem. Of the last 10 cetaceans that I have captured alive and later released unharmed, none has regurgitated during the capturing, handling, or releasing process. Although some researchers have reported on stomach samples from stranded marine mammals (e.g., Houck 1961; Fitch and Brownell 1968), these samples may not be representative of feeding habits of active healthy organisms.

Passage of the Marine Mammal Act in 1972 has made it necessary to develop techniques beside killing if we are to continue certain types of marine mammal research. A useful tool for determining feeding habits of delphinids and certain small pinnipeds would be a portable stomach pump device capable of being used in the field. To be effective, this device must be capable of removing small identifiable bits of food such as otoliths, scales, preopercular bones, squid beaks, or other

skeletal elements from the stomach of a pinniped, or forestomach of a small cetacean. I do not consider it essential to be able to remove whole fish or squid from marine mammal stomachs, as several recent or current marine mammal food habit studies have successfully utilized the above-mentioned skeletal elements for prey species identification (Fitch and Brownell 1968; Evans 1975; Burns and Lowry 1976).

Soft tissue digestion in pinnipeds and small cetaceans is normally quite rapid, thus it is possible to remove partially digested skeletal elements from the stomachs of live animals a few hours after the animal has eaten; and yet, because such elements as otoliths, preopercular bones, and squid beaks tend to resist this rapid digestion, they are still available for removal several hours after being consumed. In this paper I report on development and testing of a lavage designed to sample marine mammal stomach contents without killing the animal.

Methods

Several design criteria were considered essential. The lavage unit had to be effective in removing skeletal elements, simple to operate, portable, and capable of being used without injuring the animal. Discussions with persons who had pumped human stomachs or were familiar with the characteristics of marine mammal digestive tract anatomy resulted in the decision to utilize a water-driven aspirator to create suction. A 30-mm outside diameter by 1.0-m long Rousch Equine¹ endotracheal tube was modified for use as the irrigation and content removal device. These two pieces were coupled to a machined Plexiglas stomach content collection chamber with short sections of clear vinyl tubing. A ball valve was attached to the aspirator for vacuum control. The completed unit utilized normal city water pressure (35–50 psi) delivered through a 12-mm diameter rubber hose to the ball valve as driving source for the aspirator. A small hand pump was connected to the irrigation port on the side of the entubation tube so that warm (25°–35°C) water could be pumped into the animal's stomach to create a slurry which could be easily removed by light suction. To facilitate removal of this slurry,

the entubation tube was modified by sealing the distal end (stomach end) with a machined Nylon plug, opening a side suction port (8.9 cm long by 1.25 cm wide) in the side of the tube 5 cm back from the Nylon plug, and removing the inflation cuff to allow passage of the irrigating solution into the stomach opposite the suction port. The assembled unit is detailed in Figures 1 and 2. The completed unit was tested in the laboratory using a 2-liter beaker in place of a marine mammal stomach.

Marine mammals were first tested at the Naval Undersea Center and Sea World, Inc. in San Diego, Calif., in December 1975. A total of five animals were lavaged, including two California sea lions, *Zalophus californianus*, two Pacific white sided porpoise, *Langenorhynchus obliquidens*, and one bottlenose porpoise, *Tursiops truncatus*. Animal weights ranged from 70 kg for the smallest *Z. californianus* to 210 kg for the *T. truncatus*. All animals except a 100-kg *Z. californianus* had fasted for at least 24 h prior to being lavaged. The

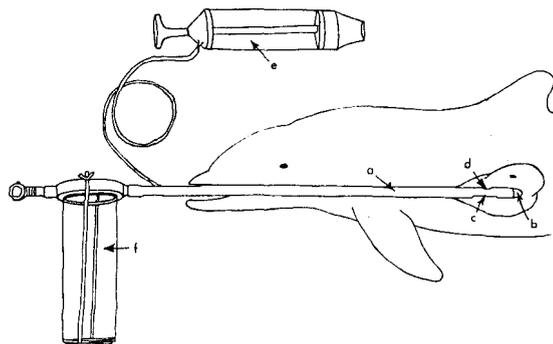


FIGURE 1.—Schematic of lavage device. Entubation tube (a), Nylon end plug (b), side suction port (c), irrigation port (d), irrigating solution hand pump (e), stomach content collection chamber (f).

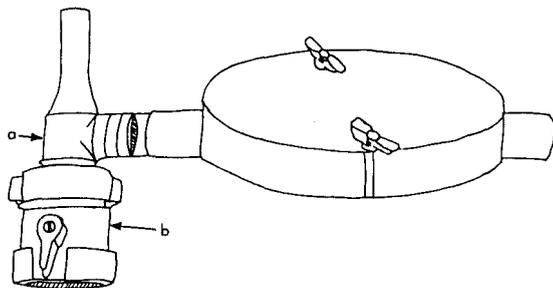


FIGURE 2.—Oblique view of the aspirator (a) and control valve (b) attached to the top of the collecting chamber of lavage device.

¹Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

100-kg sea lion had been fed 5 kg of surf smelt, *Hypomesus pretiosus*, 3 h prior to being lavaged.

Successful lavage required two procedures: 1) restraint of the animal and 2) entubation, irrigation, and suction. Restraint varied greatly depending on whether a pinniped or cetacean was to be lavaged. Delphinids are generally easy to restrain. The procedure many investigators have used with success utilizes a canvas sling and U-shaped pipe frame to hold the animal (Ridgway 1972). Normally the use of a sling is sufficient restraint, however A. B. Irvine (pers. commun.) has also used a wooden step ladder covered with closed cell foam padding and padded straps to restrain large or especially aggressive delphinids. This latter procedure requires that the animal be gently lowered onto the padded ladder and then immobilized with the padded straps. Pinnipeds are more difficult to restrain in the field than delphinids. Squeeze cages (Ridgway 1972) are generally effective, but are normally too cumbersome and heavy to use at sea. During the lavage test in San Diego, the squeeze cage was used with success, though considerable care was taken to avoid being severely bitten. Use of the padded wooden ladder and straps as a restraining technique for pinnipeds in the field appears reasonable but needs testing.

With the animal successfully restrained, we proceeded with entubation after lubricating the entubation tube with a jelly lubricant. The plugged end of the tube was gently pushed down the animal's esophagus. After completing the entubation I waited a few moments to make sure the animal was breathing normally. If the animal gagged or abnormal respiration was evident, I quickly but gently removed the tube. If respiration was normal, I connected the content collection chamber and irrigation solution hose and pumped about 300 ml of warm water into the stomach. Warm water was used to avoid thermal shock to the stomach. I then opened the vacuum control valve and applied suction to the stomach. As suction began to remove the stomach content slurry, more irrigating solution was pumped into the stomach. In this manner a 2- to 3-liter food sample was collected in a period of about 5 min. When I felt I had collected sufficient material for test purposes, I shut off the suction, ceased pumping irrigating solution, and gently removed the stomach tube. The stomach contents were filtered from the slurry using a small hand vacuum pump and then preserved in 70% alcohol.

Results

Using the above procedure otoliths, muscle myomeres, skeletal bones, and scales were collected from all five marine mammals. The animals tested were returned to their tanks unharmed and were doing well several days later.

Discussion

Using the equipment described and associated procedure it was possible to remove almost all of the diluted stomach slurry by suction; and by rotating the tube while suctioning, it was possible to vacuum the rugae of the stomach in order to collect otoliths and squid beaks which tend to accumulate in these folds. J. E. Fitch of the California Department of Fish and Game has used fish otoliths as a means to identify prey species on a routine basis. With experience it is possible to correlate size of otoliths and approximate sizes and weights of the intact fish. The Alaska Department of Fish and Game is presently establishing such an otolith reference collection, allowing not only identification of otoliths but also estimation of intact prey length and weight (L. F. Lowry pers. commun.).

The limiting factor in the use of this device appears to be the ability of the capture personnel to restrain specimens. Pinnipeds over 150 kg are probably too large to be effectively restrained mechanically, and are therefore very difficult or impossible to entubate. Cetaceans, perhaps as large as 500 kg, can be effectively entubated and lavaged since these animals are generally much more easily restrained out of water than the pinnipedia. In addition, certain pinnipeds, e.g., *Erignathus barbatus*, *Phoca hispida*, *P. fasciata*, feed to a greater or lesser degree on soft-bodied crustaceans, and these prey organisms would probably be effectively destroyed by suction and passage through the entubation tube (L. F. Lowry pers. commun.).

I have made no mention of the use of chemorestraining techniques because I feel that these methods are still unsuited for general use in the field, especially with cetaceans. With proper supervision, they have proven effective for restraining captive pinnipeds. In August 1972, I used a chemorestraining solution of Ketamine-Atropine on *Z. californianus* in the field. Although dosages were at the level recommended by marine mammal research veterinarians, I found the drugs

to be too slow acting to be generally effective for stopping highly mobile pinniped species before they could reach the sea. Two major drawbacks to chemorestraints in a field situation are judging animals' size adequately for effective dose determination, and the time required for the animal to recover sufficiently to be able to swim unassisted and maintain pace with the herd or pod from which it was captured. Should future work develop either drugs or techniques which allow safe and semi-instantaneous chemorestraint of any marine mammal species, then these drugs or techniques would be extremely useful when used in connection with the stomach pump. Until such drugs are available, I believe physical restraint is indicated during the lavage procedure.

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