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Open ocean diving test with a trained porpoise (*Steno bredanensis*)*

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Abstract—Diving tests were conducted with a free swimming rough-tooth porpoise (*Steno bredanensis*) off Pokai Bay, Oahu, Hawaii, in which the porpoise was trained to dive and depress a lever-actuated buzzer suspended from a calibrated cable. Fifty-one dives were made in 1¾ hr, the deepest to approximately 30 m. At this depth 18 sec were required from surface to receipt of the signal. The buzzer was thought to have attracted sharks, which frightened the animal away.

INTRODUCTION

RATHER little information exists on the diving capabilities of cetaceans. The sperm whale (*Physeter catodon*) is known to dive to 620 fathoms (1134 m) from records of the deepest of several individuals that had tangled in submarine communication cables (HEEZEN, 1957). Average dives in this species require about 1 hr (CALDWELL and CALDWELL, *in press*). Whalers' observations suggest that the bottlenose whale (*Hyperoodon ampullatus*) may submerge for twice this period, while finback whales (*Balaenoptera physalus*), carrying manometers, were found to descend a maximum of 194 fathoms (355 m) (SCHOLANDER, 1940).

Delphinids have longest-timed dives of about 15 min (KLEINENBERG, 1956), and measured depths have primarily been shallow, usually less than 30 m (SLIJPER, 1958). The Pacific bottlenose porpoise (*Tursiops gilli*) has been estimated to descend to 50 m or more during capture (NORRIS and PRESCOTT, 1961). From stomach contents, CADENAT (1959) estimates dives of *Tursiops truncatus* to reach 200 m or more.

Observations by one of us (NORRIS) suggest regular descents by the eastern Pacific pilot whale (*Globicephala scammoni*) as deep as 366 m during feeding. These large delphinids move into the nearshore waters of Santa Catalina Island, California during the spawning season of the squid, *Loligo opalescens*. The squids aggregate on the bottom in great numbers, spawn and die during the winter and early springtime. Pilot whales can be found diving and feeding upon these squid from close inshore out into relatively deep water. Such whales have been seen rising to the surface after a dive, with squids still in their mouths. Feeding pilot whales typically remain in one general area, diving and returning to the surface for prolonged series of respirations. It is then that they can be caught as they refuse to submerge until several

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breaths have been taken. On three occasions, while on board oceanarium collecting-boats, pilot whales have been found in such groups in approximately 366 m of water, as determined by fixes on a navigational chart. On two of these occasions the whales were accompanied by a small group of Pacific bottlenose porpoises, which dove with the whales upon the approach of the boat but stayed below, on the average, 3 min, while the whales remained submerged for about 6 min.

Such records suggest that 30 m does not represent a useful figure for diving capability in delphinids and that further experimentation is desirable. Although most timed dives made by smaller delphinids are of short duration, usually less than 4 min (for example, see NORRIS and PRESCOTT, 1961), there is no way of knowing if field observations of diving depth, frequency, and time, represent strong efforts by the animals or if, instead, much unused capacity remains.

EXPERIMENTAL PROCEDURE

Obviously more detailed data are needed before useful generalizations can be made. Toward this end the authors trained a captive rough-tooth porpoise (*Steno bredanensis*) which had been captured 4 km off Makua Valley, Oahu, Hawaii, on May 16, 1964. The animal, an adult (approx. 2 m) female named "Pono," was trained for a period of 4½ months. For the purposes of the experiment she learned the following behavioral routine. Since we planned to lead her out to sea, she learned to come to us upon hearing a recall signal, which consisted of a pulsed broad-band signal centering on 3 kc/sec (NORRIS, 1965). This signal was played from an underwater speaker that could be lowered into the water at any point along the rail of the vessel. Next she learned to press the lever on a submersible buzzer (Fig. 1) which produced a buzzing sound audible to her and which also actuated a buzzer or a galvanometer on deck through the suspending cable*. Thus, by measuring the cable length, which was coded at 7·6 m intervals, we were able to tell the approximate depth to which the porpoise dived. Two cross-checks were planned for deep dives. One was a pressure-actuated tone generator, whose signal varied between 45–55 kc/sec as a linear function of depth. Another was a manometer with a small amount of water soluble dye placed inside the open end of the tube. The pressure of increasing depth pushed water and dye into the tube. As the animal surfaced the dye remained behind in the tube at its maximum depth level. To attach this gear, the porpoise was trained to accept an instrument harness. Tests of the sound generator when carried at or near the surface by the porpoise showed that signals could be transmitted reliably for well over 300 m in a horizontal plane. Previous tests of a very similar instrument in the Antarctic showed excellent response at more than 300 m of depth (DEVRIES, 1964). Finally, as a retrieval means, we taught "Pono" to swim into a stretcher upon command and to allow herself to be hoisted free of the water. On October 6, 1964, "Pono" was taken to Pokai Bay, a cove on the lee side of Oahu Island, where a breakwater provides an anchorage for small craft. The animal was released into the bay and taken through her behavioral repertoire.

*An Edwards model 470, 3-6 V doorbell mechanism was sealed with epoxy resin in a small glass jar. Pressure from the porpoise's snout actuated a lever to which a small magnet was attached. As the magnet swept past a reed magnetic relay the circuit was closed, producing a buzz at the level of the porpoise, and also sending an electrical impulse up to the deck where a similar buzzer was actuated, or where the galvanometer registered. The buzzer emitted 100-150 pulses per sec.

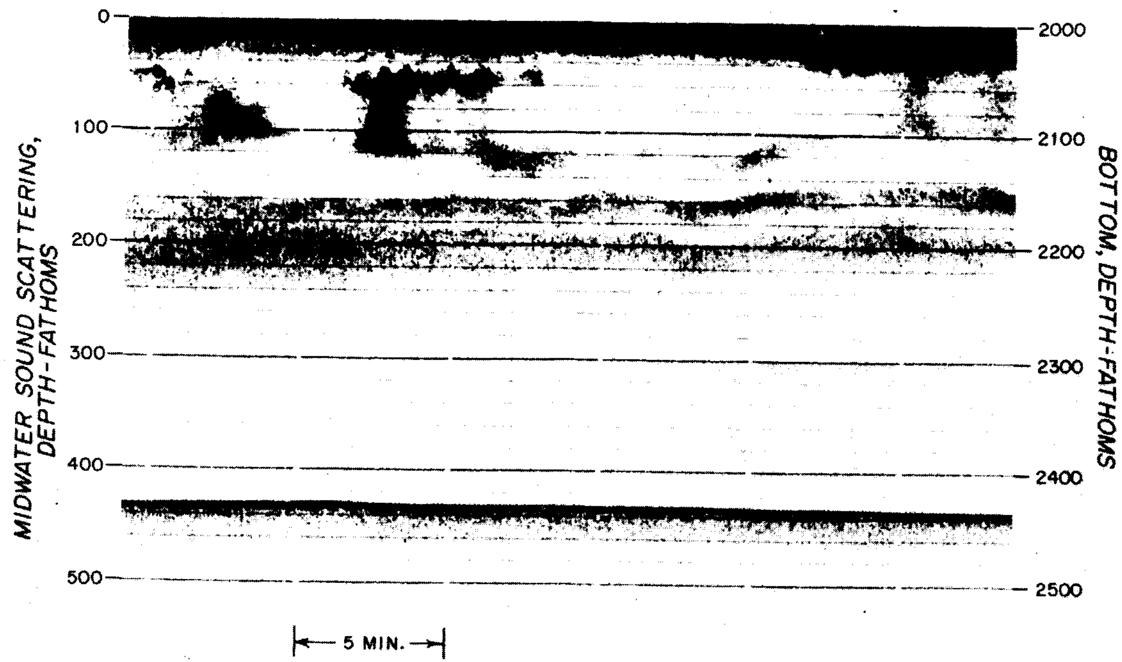

Fig. 2. Echo-sounder record made near "American Scout Seamount." The sounder was operated on the 500-fathom scale so that five 500-fathom increments of information are superimposed on the record. The mid-water sound scatterers are in the first (0–500) increment, the bottom in the last (2000–2500).

The recall console and speaker were placed in a skiff and " Pono " was led through the harbour to the Oceanic Institute collecting vessel *Imua*, a 15 m Hawaiian sampan. We boarded the *Imua*, leaving " Pono " in the sea. The recall speaker was hung over the side of the ship and every few minutes used to recall " Pono." In the time between recalls she swam with her trainers or, in their absence, leaped about the boat or dove to the bottom (5–6 m) where she retrieved bits of flotsam such as old towels, bits of seaweed, and pieces of paper. She was recalled twice when she seemed interested in following the motors of passing skiffs. Subsequently she showed no further tendency to roam, in spite of the passage of several small craft, and stayed close aboard during most of the day while we readied our gear. In the late afternoon she was led into her stretcher and hoisted from the stern of the *Imua*, placed in a skiff and taken ashore, where she spent the night in a small plastic swimming pool on the dock. Next morning she was released in the bay and taken quickly to the *Imua*. The anchor was hoisted and we headed out toward the 300 m depth contour, 2·4 km offshore, with " Pono " following us, coming alongside when the recall signal was played, taking her reward fish, and otherwise spending much of her time in the wake just aft of the rudder. She occupied herself during part of the voyage by carrying strands of seaweed on her flippers and dorsal fin.

At the 300-m contour the engines were stopped and the vessel allowed to drift in the still glassy sea. " Pono " quickly showed signs of apprehension by making rapid sorties away from the starboard side of the vessel, some taking her as far as 100 m away. When recalled, however, she responded readily.

RESULTS

At approximately 10 : 15 a.m., after reaffirming her behaviour toward the lever diving apparatus, we began the diving experiment (Table 1). The procedure required her to dive upon receipt of a start signal (a pat on the snout), to depress the lever at the end of the calibrated line until a signal was clearly produced at depth and on deck, and then to return to the surface for a food reward. Time intervals were recorded between surface respirations : (1) from the last such respiration to the moment a signal was produced at the diving lever, (2) the time required to resurface, and (3) the time between surfacing and the first breath. Many times " Pono " did not breathe immediately upon surfacing but waited several seconds. The measured line was lowered in increments and held at each depth until several dives were completed. " Pono " did not always wait for her start signal and made many spontaneous dives. With the lever at 38 m our control over " Pono's " behaviour became erratic and successful descents were not made. It was decided to begin anew at the surface as we suspected that the rapidly changing criterion for success was affecting her performance.

In the second series of dives, starting at 10 : 45 a.m., depth increments were added more slowly, and she made dives varying in depth between 7·6 and 30·5 m. She also made approximately 21 unsignaled dives for a total of 51 dives.

Finally, with the apparatus at 30·5 m depth, " Pono " refused to dive again and began rapidly circling ahead of the boat, slapping the water sporadically with both her flippers and her flukes, signs of agitation well known to porpoise trainers. Some of these sorties took her long distances from the boat. At this time we noticed three

Table 1. *The diving characteristics of a rough-tooth porpoise,* Steno bredanensis

Time	*Dive No.*	*Depth* (m)	*Respirations preceding dives* (sec. apnea)	*Time down* (sec)	*Time up* (sec)	*Time to first resp. at surf.* (from time of descent-sec)	*Unsignaled dives fol.*
10 : 15	1	9·5	—	11	—	20	1
	2	12·0	—	15	—	—	—
	3	15·0	—	—	30	38	—
	4	30·5	10, 8	18	28	38	1
10 : 45	5	—	—	—	15	15	—
	6	3·0	—	—	10	10	—
	7	4·5	—	—	15	20	—
	8	4·5	11	—	14	14	—
	9	4·5	—	—	11	11	—
	10	4·5	—	13	16	20	—
	11	7·5	—	8	14	23	—
	12	7·5	—	10	23	30	1
	13	7·5	4, 3	8	13	13	1
	14	7·5	—	8	12	— (dove at once)	1
	15	7·5	7	15	20	24	—
	16	12·0	—	13	19	24	1
	17	12·0	—	10	16	19	1
	18	12·0	7	10	15	20	1
	19	12·0	4	11	16	16	1
	20	15·0	4	18	24	24	—
	21	15·0	9, 5	didn't ring buzzer	18	25	—
	22	15·0	10, 16	12	18	23, 4	1
	23	15·0	4	12	18	25	1
	24	15·0	33	14	23	27	6
	25	15·0	7	12	18	18	1
	26	15·0	4	15	23	33	—
	27	15·0	4	20	30	40	—
	28	23·0	6	18	27	27	—
	29	23·0	8, 4, 8	16	25	25	6 ?
12 : 00	30	30·5	unsignaled dive-no time recorded - - - - - -				1

small sharks circling close around the diving buzzer cable, possibly 12 m below the surface. We made preparations to hoist " Pono " and hauled in the diving apparatus, but she refused to come in to the recall speaker, and continued to swim rapidly near us in an agitated manner. Finally, she turned directly out to sea and was gone. As we turned the *Imua* in pursuit we saw the dorsal fin and tail tip of a large (about 4 m total length) shark coming directly toward the place where the *Imua* had been drifting. While in pursuit we saw " Pono " leap a final time about 1·5 km ahead of us, and then we saw her no more. She was reported next morning circling a small fishing boat near the experimental area, but we were unable to locate her after diligent searching with the recall system. It seemed likely to everyone that the pulsing low-frequency buzzer had attracted the sharks, particularly in view of the recent work of WISBY, *et al.* (1963), in which a similar signal was effective in such attraction. Perhaps the juices of reward fish added to this attraction.

DISCUSSION

Several features of the tests, even though they were quite incomplete, are instructive. Before beginning the tests we were suspicious that *Steno bredanensis* is primarily a diving species. When seen at sea, schools are extremely difficult to follow. They travel submerged most of the time and when approached will dive for long periods. Our collectors report that they have timed such dives at 15 min duration. The rough-tooth porpoise is extremely barrel-chested, and their large eyes protrude markedly to the sides of the head allowing a wide field of binocular vision. All captives of this species (four animals) have been irregularly blotched with round whitish scars that may have come from encounters with large deep-water squid.

Our suspicions were supported by two features of the tests. First, the large number of dives (51) made during the 1¾ hr of testing is impressive, not only for the number but for the effortless way in which these dives were performed. There was little doubt in anyone's mind on board the *Imua* that " Pono " was not being pressed to maximum performance. Second, the manner in which each dive was performed was also impressive. After the start command was given, " Pono " took one or two breaths, including a characteristic one just before submergence, a quick breath that often broke the normal breathing rhythm; then she dove with her lungs filled as nearly straight down the cable as she could go, reached the bottom, and positioned her body in a semi-horizontal position required for lever pressing (Fig. 1), all in a few seconds. For example, she took 16–18 sec to complete this maneuver from surface to signal at 23 m (dives 28 and 29). Her ascent was so nearly vertical that all one could see from deck was the circumference of her body, head in the middle and tail beating below, rising toward us in the clear water. Many times after reaching the surface she did not " blow " immediately, but levelled out under the surface and swam for a few seconds before breathing. There was more tendency for simultaneously surfacing and breathing on the deepest dives. Her deepest dive took her through 3 atmospheres pressure in about 18 sec.

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