12 Diving Behavior of Galapagos Fur Seals

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INTRODUCTION

The purpose of this study was to determine the offshore feeding characteristics of females which were suckling pups. Since this species is not migratory and is one of the smallest marine mammals, it was of particular value to determine the: (1) duration of trips to sea; (2) time to reach the feeding area; (3) common feeding depths; (4) duration of feeding periods; (5) dive frequency rate within bouts; and (6) preferred feeding times for comparison with larger, migratory species.

The study was done at Cabo Hammond, Fernandina Island (Fig. 1.12), during October and November 1980, the *garua* or drizzle season in the Galapagos. Fernandina, one of the driest of the islands, had only a few mornings of overcast or drizzle. Details about the weather and physical features of the island are described in Chapter 11. Because the dive study was conducted during a single lunar cycle, the powerful lunar cycle effect, seen in the duration of shore visits (Chapter 11), could not be assessed in offshore feeding behavior.

METHODS

Capture and recapture techniques were the same as described in Chapter 2. The Galapagos fur seal, however, showed less response to humans than any other marine mammal in our experience, perhaps because it is fully protected. The females were easily hoop netted, and because of their small size (25–30 kg) we could carry them a few meters away from the colony to attach and remove the recorders. Once this 10- to 15-minute procedure was completed, the seal would return immediately to its pup. Soon thereafter an observer could sit near the seal to determine whether the recorder was well mounted. Captures and recaptures caused little disturbance to the remainder of the colony.

As in all other species, except the South African fur seal, baseline chatter caused by the 300 psi bourdon tube was distinct enough to indicate when the seal went to sea, when it rested at sea, and when it

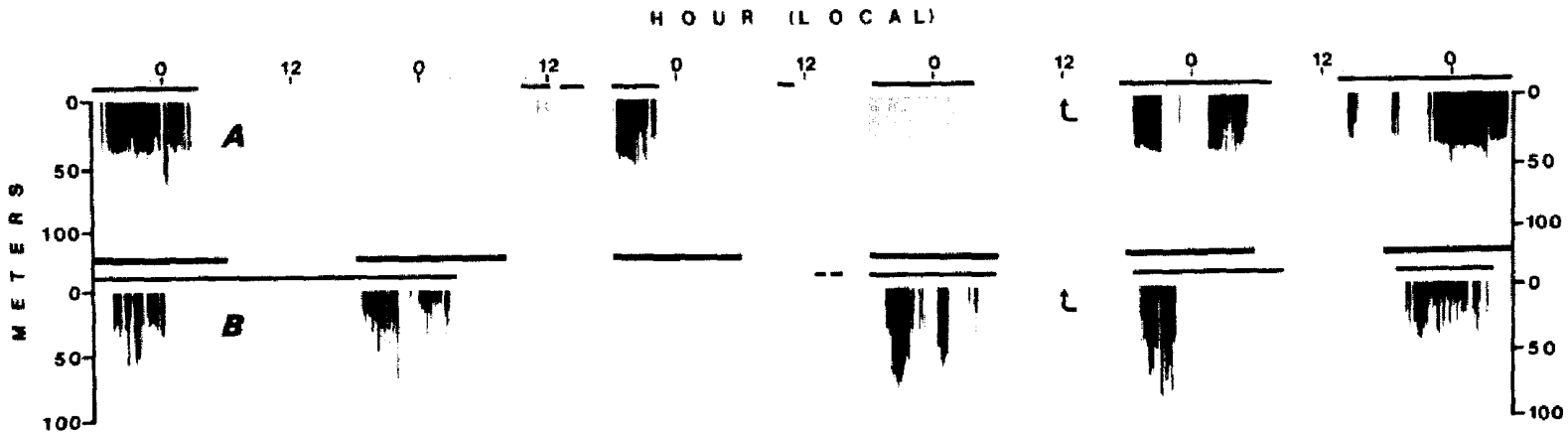

Fig. 12.1. Dive records of Galapagos fur seals over a 6-day period. A is seal 3; B is seal 6. The heavy broken line bisecting the diagram is the time between sunset and sunrise. Heavy lines between the hourly marks and the dive baseline indicate the periods of swimming. The curved arrow indicates where a 24-hour period ashore was deleted.

TABLE 12.1. Summary of Galapagos fur seal dive records.

Female no.	*Total dives*	*Record length (h)*	*Average depth (m)*	*Maximum depth (m)*	*Maximum duration (min)*
1	214	78	11	65	3.6
2	209	156	17	68	6.1
3	607	160	36	112	7.7
6	415	161	39	98	3.6
7	1	278	—	110	—
8	81	24	45	99	2.6
9	124	62	58	85	3.9
11	246	120	29	75	3.0
13	358	146	21	115	—
15	211	294	11	35	5.2
16	162	246	19	55	5.0
17	91	98	18	65	2.4
18	53	140	20	75	4.0
20	111	120	16	95	3.0
Total	2883	2083	—	—	—
Average	206	149	26	82	
SD ±	162	78	14.3	23.7	

was ashore (Chapter 2). Thus the TDR records could be partitioned into time spent ashore, resting at sea, swimming at the surface, and diving.

RESULTS

Seals came and went to sea in a routine manner; their dive activity was intense, and swimming and diving patterns at sea were continuous (Fig. 12.1). Of the seals studied, numbers 7, 15, and 17 appeared to have suffered about 10% weight loss while the TDR was attached. A total of 2,883 dives was recorded in fourteen dive records (Table 12.1). Many additional dives, perhaps made during surface feeding, were too shallow (5 m) and too brief (30 seconds) to be resolved by the recorder. The average depth recorded of all distinct dives was 26 m, the median was 24.5 m, and the maximum was 115 m. Most of the dive durations were so brief that a reliable measure was not possible. Therefore, only a few of the maximum durations were measured to derive an upper limit. Maximum dive durations ranged from 2.4 to 7.7 minutes (Table 12.1).

For much of the time that the recorders were attached, the seals were ashore. The total sea time per trip averaged 16.4 hours (not

TABLE 12.2. Activity patterns during trips to sea for Galapagos fur seals.

Female no.	Trips to sea	Trip duration (h)	Dives/trip	Dives/h	Rest (%)	Time to first dive (min)	Ashore from last dive (min)
1	2	11.4	107	9.4	0	192	108
2	2	58.0[a]	105	1.8	26	150	—[b]
3	4	12.5	152	12.2	0	135	129
6	5	10.5	83	7.9	0	39	96
8	1	24.0	81	3.4	0	540	288
9	2	17.0	62	3.6	3	86	—[b]
11	3	20.0	82	4.1	0	50	66
16	5	27.0	30	1.1	2	160	—[b]
17	3	13.0	30	2.3	0	99	100
18	2	21.0	26	1.2	0	180	180
20	1	7.6	111	14.6	0	120	36
Average		16.4	79	5.6	—	159	125
SD		6.4	39.7	4.7	—	13.6	78

[a] Not included in average.

[b] Could not determine from the record when the seal returned ashore.

including the 58-hour trip of seal 2, which was well outside the normal range of 7.6–27 hours; Table 12.2). In some cases a female did not return to shore after a night of diving but continued to swim throughout that night and the following day (seal 6; Fig. 12.1). In other instances seals came ashore elsewhere for short periods. Most seals swam constantly while at sea (Table 12.2; Fig. 12.1) with the exception of seal 2, which rested 26% of its time at sea, mostly during the day.

After the seals departed from the colony, the average time before diving bouts began was 2.7 hours; the average time from the end of the last dive bout until the seals returned to shore was 2.1 hours (Table 12.2). Dive bouts were defined by a log survivor curve (Chapter 2) with the second inflection point at 25 minutes. The probability of ending an interdive interval was significantly correlated with average diving depth ($r^2 = 0.9$; $p < 0.05$; $N = 5$ females), indicating that shallow dives were on average followed by shorter interdive intervals. This effect can be seen even within a single dive bout. For seal 3, dives to more than 60 m were followed by significantly longer surface intervals than were dives to 40 m (Mann-Whitney U-test; $p < 0.001$).

The average dive frequency within bouts was 15.7 dives h^{-1}, and bouts lasted an average of 2.9 hours (Table 12.3). Since on average

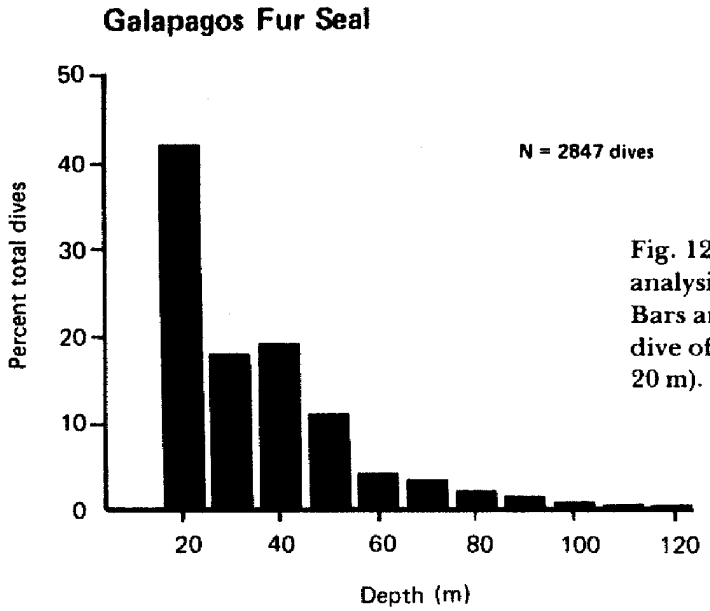

Fig. 12.2. Dive-depth frequency analysis of Galapagos fur seals. Bars are labeled with the deepest dive of that increment (20 = 11–20 m).

TABLE 12.3. Characteristics of Galapagos fur seal dive bouts.

Female no.	*Dive bouts*	*Average bout duration (h)*	*Bouts/trip*	*Dives/h within bout*
1	3	5.6	1.5	21.4
2	4	2.4	2.0	16.0
3	3	3.7	0.8	21.9
6	8	3.6	1.6	13.7
8	3	1.9	3.0	12.8
9	3	2.1	1.7	13.9
11	5	2.5	1.7	14.2
16	3	3.1	0.6	16.1
17	3	1.5	1.0	13.1
18	1	1.6	0.5	13.1
20	1	4.4	1.0	14.0
Average	3.4	2.9	1.4	15.7
SD	1.9	1.3	0.7	3.1

1.4 such bouts (Table 12.3) occurred on trips to sea that averaged 16.4 hours each, obviously much time was spent at the surface.

The frequency distribution for dive depths showed a single peak at <20 m (40% of all dives; Fig. 12.2), a marked drop and shoulder at depths of 21–50 m (10%–20% of all dives), and another distinct drop in dives deeper than 51 m (10% of total dives).

The frequency distribution for diving by hour of the day showed

a strong tendency for nocturnal foraging (Fig. 12.3). Diving began after 1800 hours (sunset) and ended by 0600 hours (sunrise). Diving was most intense between 1900 and 2300 hours.

Three different analyses for the relationship between dive depth and hour of the day showed no marked shifts in dive depths over time (Figs. 12.4, 12.5). Most dives of <20 m occurred before midnight. This was true of dives in all other depth ranges as well, although dives between 31 and 50 m seemed to have a bimodal distribution, with the greatest number occurring before 2300 hours.

DISCUSSION

The swimming speeds of this species are unknown, but based on its size we estimate this velocity to be 2 ms^{-1} (see also Chapter 15). If no surface feeding (i.e., unrecorded dives) preceded the distinct dives and if seals swam directly to their feeding areas, then the average distance to feeding areas was 19 km (range = 4.7–65 km; Table 12.2).

Some of the night swimming in this species may have been related to feeding at the surface. If so, feeding may have begun earlier and continued longer than the distinct dives on the record indicate. These shorter transit times would place the feeding areas closer to the colony than the above estimates suggest. However, four factors argue against the occurrence of daytime surface feeding as a precursor to night feeding: (1) most of the night activity was spent diving—swimming without diving occurred mainly during the day; (2) seals preferred departing to sea shortly before dark and returning soon after daylight (Chapter 11 and Fig. 12.1); (3) if food had been readily available at the surface during the daytime, the local sea lions that dive during the day to average depths of 37 m (Table 14.1) should also have taken advantage of it; and (4) no clearly defined gaps occurred between evening dive bouts characterized by decreasing depths and dawn bouts characterized by increasing depths, as in the Antarctic fur seal (Chapter 7). These observations suggest that (1) the fur seal's hunting strategy resulted in at least 10–20 m deep dives; (2) during the day prey species descended as light levels increased; and (3) the seals' swim activity represented needs other than feeding.

The ratio of time spent at sea to time spent on shore was calculated for each female to estimate the efficiency of feeding and suckling cycles. Seals number 1, 3, 6, and 20, which went to sea nightly and returned to shore the following day, were among the most ef-

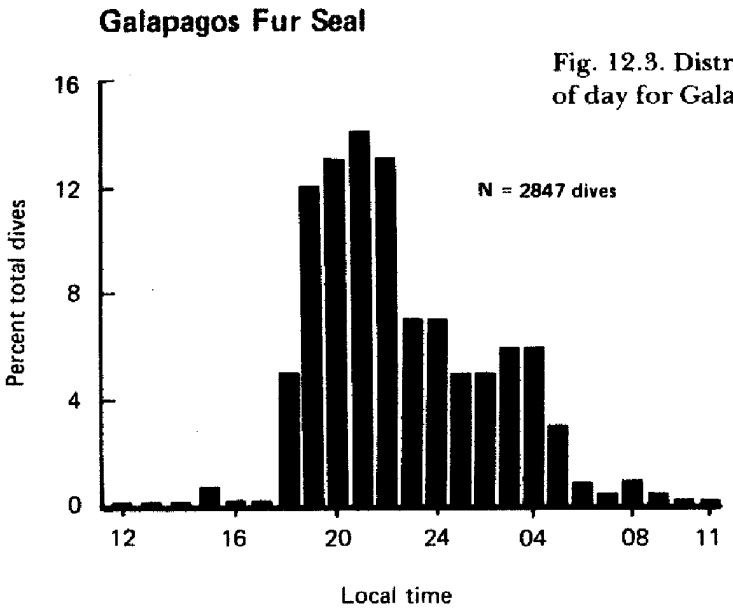

Fig. 12.3. Distribution of dives by hour of day for Galapagos fur seals.

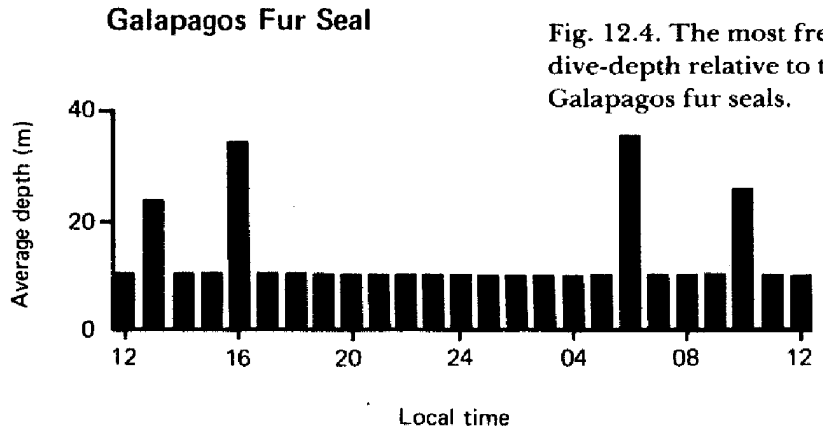

Fig. 12.4. The most frequently attained dive-depth relative to time of day for Galapagos fur seals.

ficient. Another ratio, dive time to time at sea, showed that the same seals were also more efficient than others in sea time spent diving (70% versus 10%–50% ratio for seals 8, 9, 16, and 17). If our arguments concerning surface feeding are correct, then most of the surface swim time of females 8, 9, 16, and 17 probably represented search or transit time during which few prey were captured.

FEEDING BEHAVIOR

Regurgitations collected from seven adult fur seals contained squid and fish remains, but only the squid remains were analyzed.

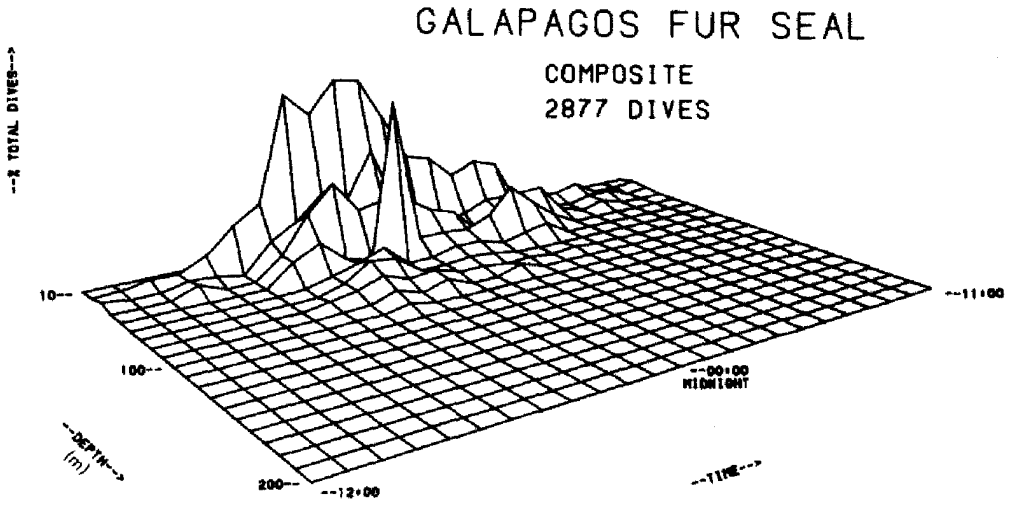

Fig. 12.5. Three-dimensional frequency analysis for depth of dive, time of day, and number of dives. The figure includes data for fourteen individual females.

The predominant species by number and mass was *Onychoteuthis banksi* (Clarke and Trillmich, 1980). The average mass of these squid, based on beak size, was 12 g. The second most prominent squid were in the family Ommastrephidae and their average size, based on beak size, was 150 g. Both species occur near the surface.

The dive habits of the seals probably reflect the most common depth ranges of the prey species identified (squids). Most dives were to depths shallower than 30 m and occurred before midnight (Fig. 12.5). Dives between 30 and 40 m were less abundant but were of nearly uniform distribution throughout the night. If seals hunt by sight, the occasional dive to these depths may help them locate prey patches by silhouetting them against the night sky. The rare dives deeper than 50 m occurred most often between 2100 and 2200 hours, but lacked a clear pattern from which their function could be inferred. Perhaps these dives functioned to locate prey patches before the seals had completed their ascent to the surface.

The success of prey capture was estimated using several assumptions: (1) dive bouts lasted an average of 2.9 hours and totaled 46 dives per bout; (2) since there were 1.4 bouts per night (Table 12.3), there were 64 dives per night-feeding session; (3) the energetic requirements of mothers was 17% of body weight per day (this value is an overestimate for Galapagos fur seals as it is based on northern fur seals for which pups grow twice as fast, water and air temperatures are much lower, and females spend much longer periods at

sea); and (4) the fur seal's mass was 30 kg. If the food requirement is 17% of body mass, then 5 kg of prey were captured per day.

Based on these assumptions, if food were caught on every dive the average amount taken per dive would be 78 g, an average of seven *O. banksi* per dive or one Ommastrephidae every other dive. However, it is not likely that every dive is successful in producing food. The success rate of king penguins, *Aptenodytes patagonicus*, has been estimated as only 10% of all dives (Kooyman et al., 1982). However, these birds commonly dive to depths >50 m. If the success rate of these fur seals were only 10%, then about 780 g of squid or fish (sixty-five squid if all were *O. banksi*) would have to be caught on each successful dive. For such small prey it seems more likely that the number caught per dive would be smaller and the number of successful dives greater than these estimates. If the prey were Ommastrephidae, then four to five squid per dive on 10% of the dives may have been cost effective, even on deep dives where the chances of failure may be greater.

It is likely that deep dives are less successful than shallow dives because there is less light and the search time is longer. Seals begin deep dives without knowing precisely where the prey is. A search phase would be required during or after descent which would leave little time for pursuit of prey after its detection. Prey that were not captured would have more time to escape before the seal's subsequent dive. Seals may be able to see prey by ambient light or bioluminescence at the start of dives to 20 m or less. The success rate of deep versus shallow dives is discussed in a more detailed, comparative way in Chapter 15.

SUMMARY

The diving behavior of Galapagos fur seals was studied near Cabo Hammond on Fernandina Island, Galapagos archipelago, in October and November 1980. Records were obtained for thirty trips to sea made by fourteen individuals. The average duration of trips, 16.4 hours, was within the range of durations for uninstrumented females (0.5 to 1.3 days). The outbound transit times averaged 2.7 hours, and return transit times averaged 2.1 hours. Females averaged 79 dives per trip to sea but ranged from 26 to 152, depending on trip length. The nightly pattern of diving was not strongly bimodal but tended to have peaks at dawn and dusk. About 95% of all dives occurred at night. The dive-bout criterion was 25 minutes. Females averaged 1.4 dive bouts on each trip to sea. Bout durations

averaged 2.9 hours, and the dive rate within bouts was 15.7 dives per hour. The portion of dive bouts spent submerged was not calculated. All dive bouts were shallow. Dives were continuous descent and ascent, with no time spent at the maximum depth. The dive durations were too brief to measure accurately. However, the longest dives were measured to determine maximum dive duration (7.7 min). The mean depth of all dives was 26 m, with a maximum of 115 m. The most frequently attained dive depth was less than 20 m. The relationship between depth and duration of dives was not calculated. However, the shallowest dives tended to be the briefest, and these were followed by the shortest interdive intervals. The activity budget on trips to sea comprised 2.8% resting, 24% diving, and 73.2% swimming. The temporal occurrence of rest bouts was not measured.