

14 Diving Behavior of Galapagos

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INTRODUCTION

The general purpose of this study was to compare, for the first time, the diving behavior of two sympatric otariids, the Galapagos sea lion and the Galapagos fur seal. Because of their sympatry, resource partitioning may be critical to the coexistence of these species. Since both species live in a tropical environment where food resources are not likely to be abundant, and since both species live on the same islands and may feed in overlapping areas, competition for food resources has probably shaped different foraging strategies in the two species. We tried to characterize these patterns by collecting the same data for sea lions as previously presented for fur seals. This chapter on sea lions has also been included to suggest some general behavioral differences between sea lions and fur seals.

MATERIALS AND METHODS

The study was conducted in October and November 1980 at a site about 1 km east of Cabo Hammond, Fernandina Island (Fig. 1.12). The physical characteristics of the general region were described in Chapter 11. The sea lion colony, consisting of 300 to 400 animals, was situated on an ancient, exposed lava flow of low relief with many tidepools that were protected by an outer ridge of lava 5 m above sea level. The tidepools graded into a sandy beach mixed with many boulders. Much of the inland area was covered by low shrub, *Cryptocarpus pyriformis*, in the shade of which some animals spent the whole day. Thus the area used by sea lions extended about 200 m inland. Groups of fur seals were found wherever piles of large boulders interrupted the flat relief of this low lava.

TDRs were attached to four sea lion females ranging in mass (estimated) from 50 to 100 kg. Each was suckling a 1- to 2-month-old pup when captured in early morning hours on the inland edge of the colony. Each was drugged to a level of staggering mobility with an estimated dosage of 2–4 mg kg⁻¹ of ketamine mixed with 0.3–0.4 mg kg⁻¹ xylosine (Trillmich and Wiesner, 1979; Trillmich, 1983). Animals were then restrained with a neck stock and fitted

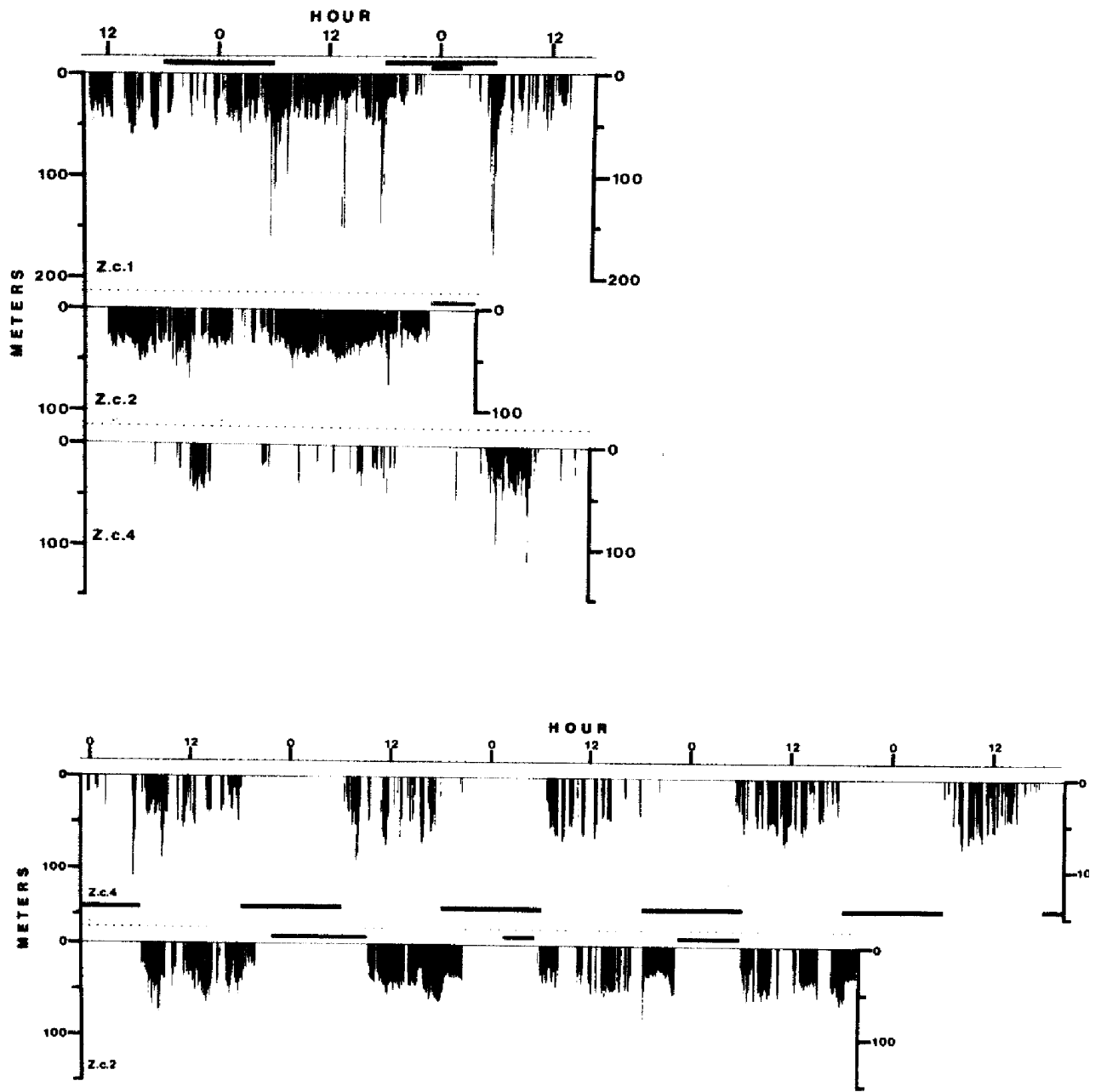


Fig. 14.1. Dive records of the Galapagos sea lion. The heavy broken line above the hourly time intervals is the time between sunset and sunrise. Heavy lines between the hourly time intervals and the dive baseline indicate rest periods.

TABLE 14.1. Summary of Galapagos sea lion dive records.

<i>Female no.</i>	<i>Mass (kg)</i>	<i>Total dives</i>	<i>Record length (h)</i>	<i>Time at sea (h)</i>	<i>Average depth (m)</i>	<i>Maximum depth (m)</i>	<i>Maximum duration (min)</i>
1	60	547	61	56	38	186	6.0
2	50	1,620	142	97	37	146	5.0
3	100	143	11*	10.5	—	20	—
4	90	589	222	145	37	115	6.0

* Recorder leaked after 11 hours at sea.

with a chest harness to which the TDR and a radio transmitter were attached (Chapter 2). The procedure from drugging to release required about 30 minutes, 15 minutes of which were spent waiting for the drug to take full effect.

Returned females were detected and located with a radio receiver equipped with a directional antenna. The instruments were usually recovered at night by carefully stalking to within 1–2 m of the unrestrained animal and cutting the harness off with a knife placed in the curve of a shepherd's hook mounted on a 1.5-meter-long staff.

RESULTS

Females left the colony 1 to 2 hours after harness attachment and usually returned at night. The capture, attachment of the harness, and release disturbed other sea lions only within 25 m of our activities. A few animals showed some interest in the TDR as instrumented females walked past.

The study produced four records, three complete and one incomplete (the TDR of female 3 failed after 11 hours at sea), totaling 436 hours of recording time and 2,899 dives (Table 14.1). The time at sea represented 67% of recording time. The females showed remarkable similarity in the average depth of dives (all at either 37 or 38 m) and maximum duration of dives (5 or 6 min), and only slightly more variation in maximum depths (range 115–186 m; Table 14.1). The average dive durations were <2 minutes. This average excluded many dives of less than 30 seconds which were below the TDR's time base resolution (Chapter 2), and which occurred with such frequency that the end of one dive obscured the start of the next. For such dives we measured depth only.

The activity patterns at sea showed some effects of capture. All first trips to sea after capture were unusually long, and dive episodes were erratic (Fig. 14.1 top). These first trips averaged 47

Galapagos Sea Lion

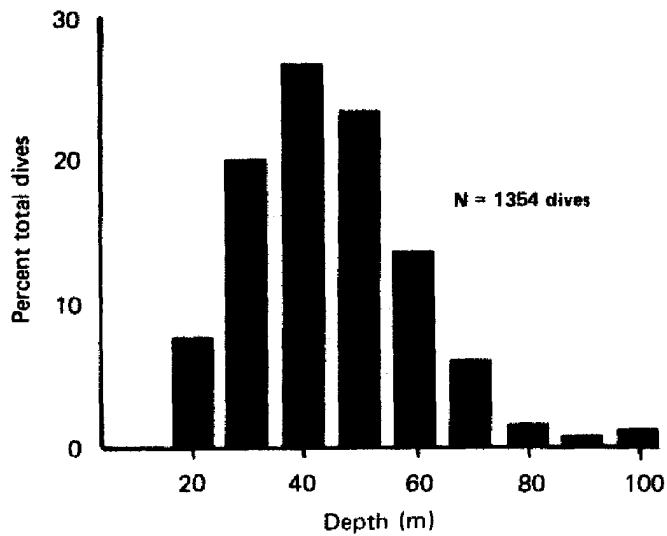


Fig. 14.2. Frequency distribution of dive depth for Galapagos sea lions. Bars are labeled with the deepest dive of the increment (20 = 11–20 m). N is the total dives in the analysis.

Galapagos Sea Lion

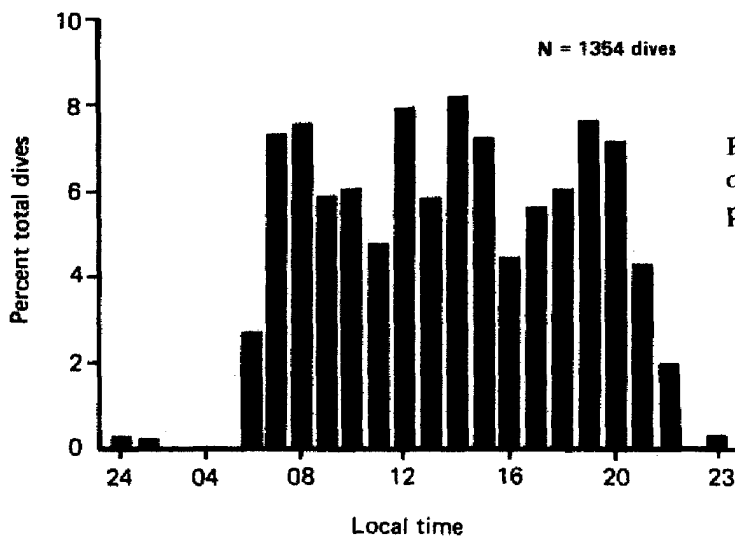


Fig. 14.3. Frequency distribution of dives by hour of day for Galapagos sea lions.

hours, while later trips lasted between 15 and 17 hours (Fig. 14.1 bottom, Table 14.2). The shorter trips, used in all analyses here, were similar in duration to the attendance data from undisturbed females on Santiago Island (Chapter 13).

The diving pattern on these apparently normal trips showed that females made between 90 and 200 dives, or 5 to 13 dives h^{-1} per trip. More than 50% of all dives were to depths of less than 40 m

Galapagos Sea Lion

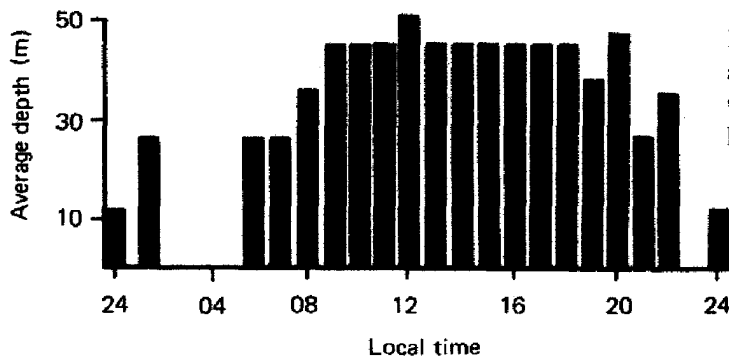


Fig. 14.4. The most frequently attained dive depth relative to time of day for the Galapagos sea lion.

(Fig. 14.2), and almost all diving occurred during daylight hours (Figs. 14.1 bottom, 14.3). Night diving was more common just after sunset than just before sunrise, and all diving activity usually ceased from 2200 to 0500 hours.

Dive depths varied less by hour of the day than for most other species. The most frequent dive depth from 2200 to 0700 hours, when few dives were made, was 30 m (Figs. 14.4, 14.5). Throughout the day and early night (0800 to 1800), when most diving occurred, the preferred dive depth was constant at 45 m. A composite plot of dives by depth and hour of day clearly showed a midafternoon and an early evening peak of activity (Fig. 14.6).

Rest at sea was relatively infrequent. Sea lion 2 did not rest while at sea, and sea lion 1 rested for only 3% of the time (Fig. 14.1). The dive record for sea lion 4 was too faint to partition into resting and swimming periods.

Transit times were very brief. The sea lions began to dive within an hour after leaving the colony, and sea lion 2 began within 10 minutes (Table 14.2). The time between the last dive and the return to shore was about twice as long as the outbound transit time.

Dive-bout criteria, derived as described in Chapter 2, ranged from 12 to 35 minutes (Table 14.3). The average dive-bout durations were between 3 and 4 hours. Sea lion 4 had on average the shortest bouts even though her dive-bout criterion was longest. In all three animals the median dive-bout durations were less than the average durations, showing that dive-bout distribution was skewed toward shorter bouts (1 to 3 hours). In this case sea lion 4's median was less than the median for sea lion 2. Within a dive bout, females made between eleven and twenty-four dives per hour and averaged 2.9 dive bouts per trip (Table 14.3).

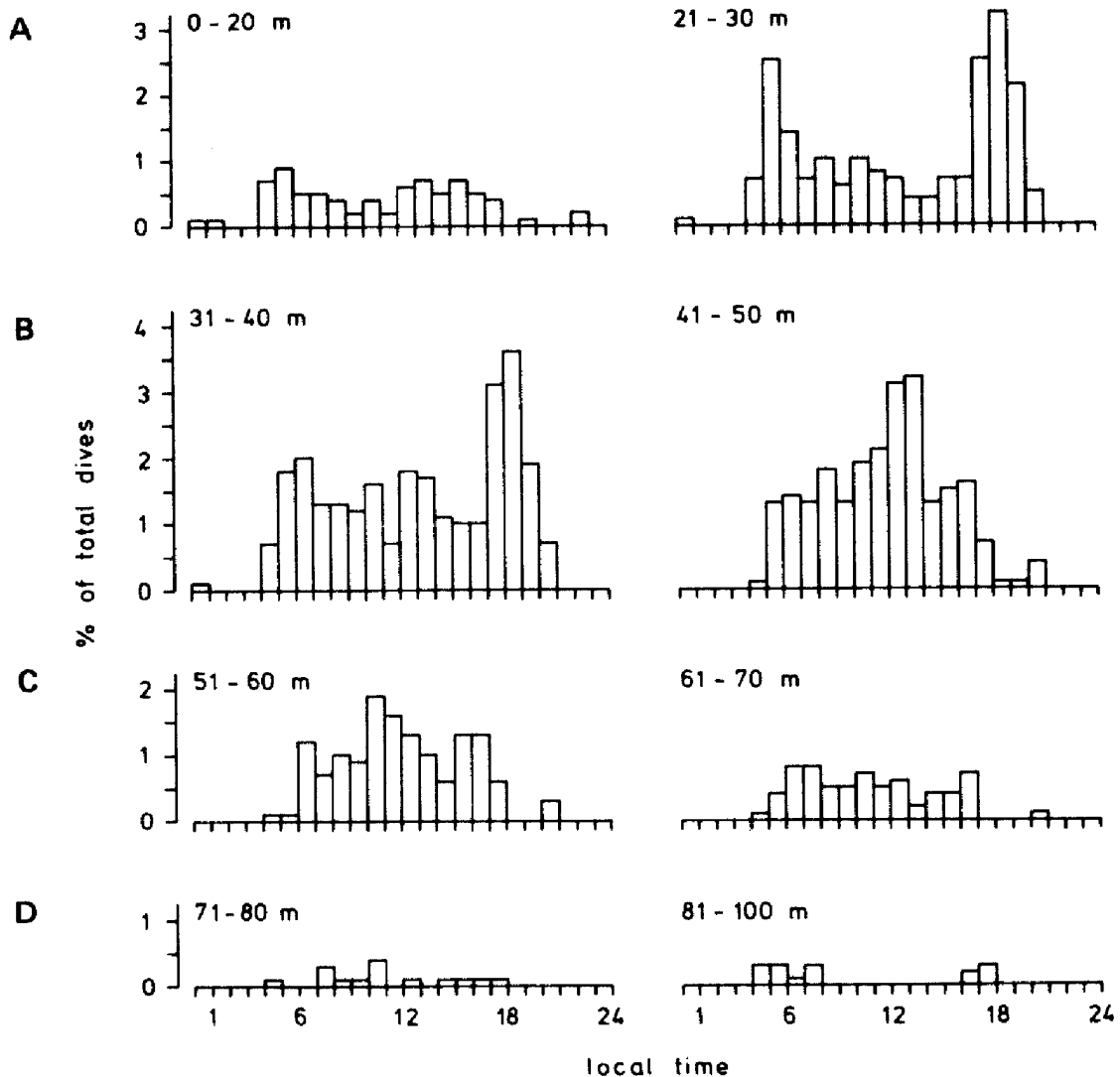


Fig. 14.5. Frequency analysis of dive depth by time of day for Galapagos sea lions.

DISCUSSION

Time Partitioning

Data from the first trip to sea are eliminated from the analysis of time partitioning because behavior was abnormal. Animals on first trips uncharacteristically dived both day and night (Fig. 14.1 top) and stayed at sea abnormally long compared to both later trips and to attendance patterns of undisturbed animals (Chapter 13). We are uncertain whether this unusual behavior resulted because the sea lions had been drugged, or from capture alone. These effects sug-

TABLE 14.2. Activity patterns during trips to sea for Galapagos sea lions.

Female no.	Trips to sea	Trip duration (h)	Dives/trip	Dives/h	Rest (%)	Transit times	
						Outbound (min)	Inbound (min)
1	2	16 (1)	92 (1)	6	3	51 (2)	120 (2)
2	5	15 (4)	198 (4)	13	0	10 (5)	29 (5)
3	—	—	—	—	—	30 (1)	—
4	6	17 (5)	85 (5)	5	—	54 (6)	133 (6)
Average		15.7	125	—	—	36	94

Notes: Data exclude first trip to sea, which averaged 47 hours and 10 dives/hour for numbers 1, 2, and 4. Numbers in parentheses equal the sample size.

TABLE 14.3. Characteristics of Galapagos sea lion dive bouts.

Female no.	Dive-bout criterion (min)	Dive bouts	Average bout duration (h)	Median bout duration (h)	Bouts/trip	Dives/h within bout
1	13	12	3.3	1.5	3.4	17.0
2	12	19	3.8	2.9	3.2	24.0
3	—	1	—	—	—	19.0
4	35	18	2.8	2.2	2.1	11.0
Average	—	—	3.3	2.2	2.9	17.7

Note: Data exclude first trip to sea. See note in Table 14.2.

gest that in future studies a few days may be required to eliminate abnormal behavior due to handling.

The distance from the colony to sea lion feeding areas was estimated from assumed swimming velocities. Open sea swim velocities of sea lions are unknown, but a trained 35 kg sea lion at our laboratory (Chapter 15) easily maintained a rate of 2.5 ms^{-1} . Since instrumented sea lions were much larger, we estimated that their swim velocity was easily 3 ms^{-1} , or a relative rate of about 1.8 body lengths s^{-1} . At that rate the elapsed time from departure to the first dive would place the feeding areas about 1.8 to 9.7 km from the colony. The distances would be somewhat greater than these estimates if the first dives were exploratory and did not indicate the usual feeding areas. The final dives before returning ashore were more likely to have ended a feeding bout than initial dives were to begin one. Consequently, return transit times may have given better estimates of the distance to feeding areas than the outbound transit

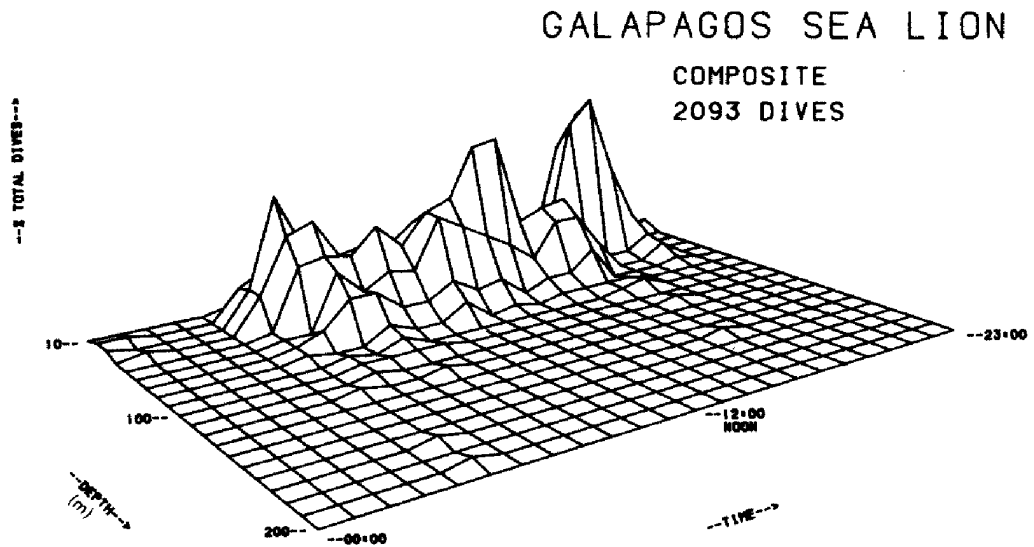


Fig. 14.6. Three-dimensional plot of dive depth, time of day, and number of dives for three Galapagos sea lion dive records combined.

times. Using the same assumptions, these distances were calculated to be 5.2 to 24 km from the colony, or about three times the estimated outbound distances. These distances are similar to those estimated for the Galapagos fur seal (19 km).

Apparently the encumbrance of the harness and TDR did not affect the attendance pattern in this species. The trip durations averaged 15.7 hours (Table 14.2), which was close to the 12-hour sea time in five sea lion females whose departures and returns were continuously recorded. They also approximated eighteen other observations, given in Chapter 13, where average shore time was 12 hours and average sea time (in twenty-eight cases) was 18 hours.

Feeding Behavior

The prey of the Galapagos sea lion is unreported. However, numerous reports exist of food preferences in the California sea lion. Some of these reports deal with the predation of males in the northern parts of their range (Morejohn et al., 1978; Bailey and Ainley, 1981/1982; Ainley et al., 1982). Others have addressed the food habits of animals, mostly females, in the southern parts of their range (Fiscus and Baines, 1966; Antonelis et al., 1984). The latter authors found that among California sea lions at San Miguel Island, squid (*Loligo opalescens*), Pacific whiting (*Merluccius productus*), and juvenile rockfish (*Sebastes* spp.) represented over 90% of the catch.

The average weight of individual fish and squid was estimated to be 45 g, a value we use later in calculating hunting success.

The Galapagos sea lion's preferred dive depth was about two times greater than that of the Galapagos fur seal (Tables 14.1, 12.1). Apparently the sea lion compensated for daytime diving by foraging at greater depths for its prey. Nevertheless, the Galapagos sea lion's dive effort may be less than that of California sea lion females at San Miguel Island, which frequently dive to 200 m and which were active almost continually on 2- to 3-day feeding trips (Feldkamp, pers. comm.).

The strong preference for diurnal feeding in the Galapagos sea lion may indicate a food preference, a temporal change in the type of food available, or some inability (behavioral or physiological) to dive at night. Their diving starts abruptly between 0500 and 0600 hours (Figs. 14.3, 14.6), just before the 0600 sunrise. This well-defined start may indicate hunger, prey accessibility, or a combination of both. Diving activity at this time peaked at the 21 to 30 m interval (Figs. 14.4, 14.5a, 14.6). Diving ended just as abruptly at about 2000 hours (Fig. 14.6).

During the hours when sea lion feeding overlapped with that of fur seals (1900 to 2300 hours; Fig. 12.3) the sea lions fed at greater depths (20–40 m versus 0–20 m; Figs. 14.4, 14.5a, b; Figs. 12.4, 12.5). It appears that although the species overlapped in time they did not overlap in depth. We do not know whether they overlapped in feeding areas or types of prey taken. No information is available on the depth of the deep scattering layer in the Galapagos Islands in the daytime, although in other areas it is usually below 100 m. The tendencies for Galapagos sea lions to dive in the daytime and to attain a median depth of only 45 m suggest that sea lions do not prey on the deep scattering layer. In contrast, the tendency for Galapagos fur seals to dive at night and the correlation between night diving and the lunar cycle suggest that components of the deep scattering layer may be taken when they are near the surface. The Galapagos sea lion and fur seal may compete for prey species only in the evening hours as the deep scattering layer rises.

Deep dives (>80 m) were infrequent in the Galapagos sea lion (3% of all dives; Fig. 14.2), but may have been unusually important, judging from the time of their occurrence. Most deep dives occurred from 0400 to 0800 hours, and from 1600 to 1800 hours (Figs. 14.5d, 14.6), a time of much diving activity. These deep dives may help seals find the horizontal and vertical locations of prey patches.

The dive intensity of the two species was comparable. During dive bouts the Galapagos sea lion dived at a rate of 11 to 24 dives h^{-1} (Table 14.3) compared to 16 dives h^{-1} for the fur seal (Table 12.3). The rate of diving within bouts for sea lions was twice the rate for the entire trip, indicating that about 50% of the sea time was spent in dive bouts. A comparable value for the fur seal was about 6 dives h^{-1} per trip (Table 12.2).

The success rates of feeding trips can be estimated from several assumptions. First, we assume that Galapagos sea lions, like California sea lions, take prey of 45 g, and that a 100 kg female suckling a pup requires 15% of its body weight per day for maintenance. If 15 kg of prey are required, and each item weighs 45 g, then 333 prey items are necessary per feeding trip. If the sea lion makes 100 to 200 dives per 16-hour feeding trip (Table 14.2), and each dive is successful, then it must catch 1.7 to 3.3 fish or squid per dive. This value is close to the 0.5 to 5 prey items per dive calculated for the Galapagos fur seal (Chapter 12).

If Galapagos sea lions make more unsuccessful dives than the Galapagos fur seal, the number of prey captured per dive would have to be greater, and the sea lion should have a higher rate of diving in a bout, longer bouts, more dives per bout, or some combination of these trends. Instead, it appears that the species were about equally successful. The sea lion dive bouts were only slightly longer than those for the fur seal (3.3 versus 2.9 hours), and their dive rate within a bout was also only slightly greater (17.1 versus 15.7 dives h^{-1}). Perhaps a greater absolute breath-hold limit, resulting from larger body size (Chapter 15), has permitted the Galapagos sea lion to dive deeper more successfully and thus work in the daytime. On the other hand, the success of the Galapagos fur seal may lie in its ability to hunt more effectively at night.

SUMMARY

The diving behavior of Galapagos sea lions was studied near Cabo Hammond, Fernandina Island, in October and November 1980. Records were obtained for thirteen trips to sea of four females. The first trip to sea of each female was unusually long due to use of drug immobilization and was thus excluded from analysis. The duration of subsequent trips was 15.7 hours, about the same as the 0.5-day trips of uninstrumented females. The outbound transit times averaged 36 minutes, and return times averaged 94 minutes. Females fed mostly in the daytime (25% of dives were at night), with peaks

of dive activity in midday and early evening. Using a dive-bout criterion of 12 to 35 minutes, females averaged 2.9 dive bouts per trip to sea. The bouts had an average duration of 3.3 hours, and the dive rate within bouts was 17.7 dives per hour (with rates as great as 25 dives per hour in some bouts). The portion of dive bouts spent submerged was not calculated. All dive bouts were shallow, around 37–38 m. The number of dives per trip to sea ranged from 85 to 198. During a dive, animals spent no measurable time at the greatest depth attained. Dives were so brief that the durations of shallow dives could not be measured accurately. The maximum duration of deep dives was 5 to 6 minutes. The mean depth of all dives was 37 m, and the maximum depth attained was 186 m. The most frequent dive depth was 45 m during the hours of peak dive frequency (0800 to 1800). The relationships between depth and duration of dives, and between the depth of dives and interdive intervals, were not calculated. The activity budget at sea included 1.5% resting, 35% swimming, and 63.5% diving. Resting occurred with such low frequency that temporal patterns were not analyzed.