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SHORT NOTE

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Diving patterns of a Ross seal (*Ommatophoca rossii*) near the eastern coast of the Antarctic Peninsula

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Abstract In January 1987 we documented the diving patterns of a female Ross seal (*Ommatophoca rossii*) in the marginal pack-ice zone near the eastern coast of the Antarctic Peninsula for 2 days using a microprocessor-based time-depth recorder. The seal hauled out during the day and dived continually when in the water at night. Dives averaged 110 m deep and 6.4 min long; the deepest dive was 212 m and the longest 9.8 min. Dives were deepest near twilight and shallowest at night; this pattern suggests that the seal's prey, presumably mid-water squid and fish, may have been making vertical migrations or changing predator-avoidance behavior in response to diel light patterns. The dives of this Ross seal were substantially deeper, on average, than those of crabeater seals (*Lobodon carcinophagus*), which forage in the same areas on Antarctic krill (*Euphausia superba*).

The Ross seal (*Ommatophoca rossii*) has a circumpolar distribution within the Antarctic pack-ice zone. Although the densest concentrations of Ross seals had previously been observed in the southeast Atlantic sector (Hall-Martin 1974; Wilson 1975; Condy 1976, 1977; Erickson and Hanson 1990), data from the early 1990s suggest that seal abundance in that sector declined over the previous 20 years (Bester et al. 1995). Ross seals are believed to be the least abundant of Antarctic phocids, and were recently estimated to number about 131,000 (Erickson and Hanson 1990). Many aspects of the species' behavior and biology remain unknown because of its relatively low abundance and distribution in pack-ice areas, which has limited researchers' access. Pupping and breeding occur in the austral spring months of October and November (Solyanik 1964; Øritsland 1970; Tikhomirov 1975; Thomas et al. 1980; Skinner and Westlin-van Aarde 1989). Virtually all observations during the non-breeding season have been of solitary seals (Erickson et al. 1971; Gilbert and Erickson 1977; Laws 1984; Bengtson et al. 1995), although small groups have been reported: Mawson (1942) observed six Ross seals together on pack ice in January 1914, near the Haswell Islands (66°32′S, 93°00′E), and Zenkovich (1962) saw three Ross seals together on a single ice floe in February near the Balleny Islands (at approximately 67.5°S, 165°E). Examination of stomach contents (e.g., Øritsland 1977; King 1969) suggests that Ross seals eat mostly mid-water squid (Moroteuthidae, Onychoteuthidae, Oegopsidae) and fish (e.g., Myctophidae, Bathydraconidae). Skinner and Klages (1994) reported that the fish *Pleuragramma antarcticum* and the squids *Psychoteuthis glacialis* and *Alluroteuthis antarcticus* are important food items for Ross seals off Queen Maud Land. Analyses of stable isotope ratios ($^{15}N/^{14}N$ and $^{13}C/^{12}C$) in Ross seal tissues have provided additional evidence that this species consumes prey such as squid and fish that are relatively high in the food web (Rau et al. 1992). Here we describe the diving patterns of a Ross seal studied in the marginal sea-ice zone of the western Weddell Sea during the austral summer.

We captured a female Ross seal (standard length = 219 cm, axillary girth = 131 cm) on a small ice floe (approximately 10 m diameter) at 1530 hours (local solar time) on 10 January 1987 near the eastern coast of the Antarctic Peninsula (64°05.91′S, 56°48.24′W). A microprocessor-controlled time-depth recorder (TDR) (Wildlife Computers Mark I[1], Redmond, Wash) was fastened to the seal's dorsal pelage

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

using quick-setting resin epoxy (Devcon EK-40, Cambridge, Mass.) (Fig. 1). The general design and operation of the TDR, as well as methods for capturing and restraining pack-ice seals, have been described elsewhere (e.g., Bengtson and Stewart 1992). The TDR was programmed to measure and store depth data (± 2 m resolution) every 5 s. Following its release at about 1600 hours, the seal entered the water at approximately 2130 hours on 10 January; it ranged freely until its recapture to recover the TDR at 1430 hours on 12 January 1987, approximately 10.4 km northeast of the initial capture site. During that period, the seal undertook two bouts of continuous diving lasting 8 h and 4 h each, with an interim haulout period of 17 h (Fig. 2).

For the present analysis, only dives to depths of 10 m or greater were considered. This depth threshold was chosen: (1) because of precision limitations in the TDR's depth transducer in correctly measuring the depth of relatively shallow dives, and (2) of the five dives recorded to depths of less than 10 m, four occurred outside the main diving bouts and were therefore thought to be associated with activities not comparable to the rest of the record (e.g., surface swimming just before haulout). Virtually all of the 97 dives made during the 2 dive bouts were characterized by: (1) a rapid descent to maximum depth; (2) a sustained time (on average about half of the entire dive duration) being spent at maximum depth; (3) a rapid ascent to the surface; and (4) a brief rest period at the surface before

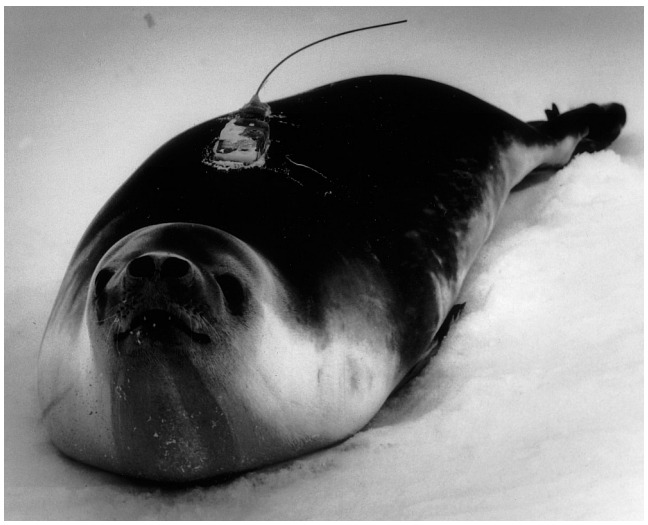
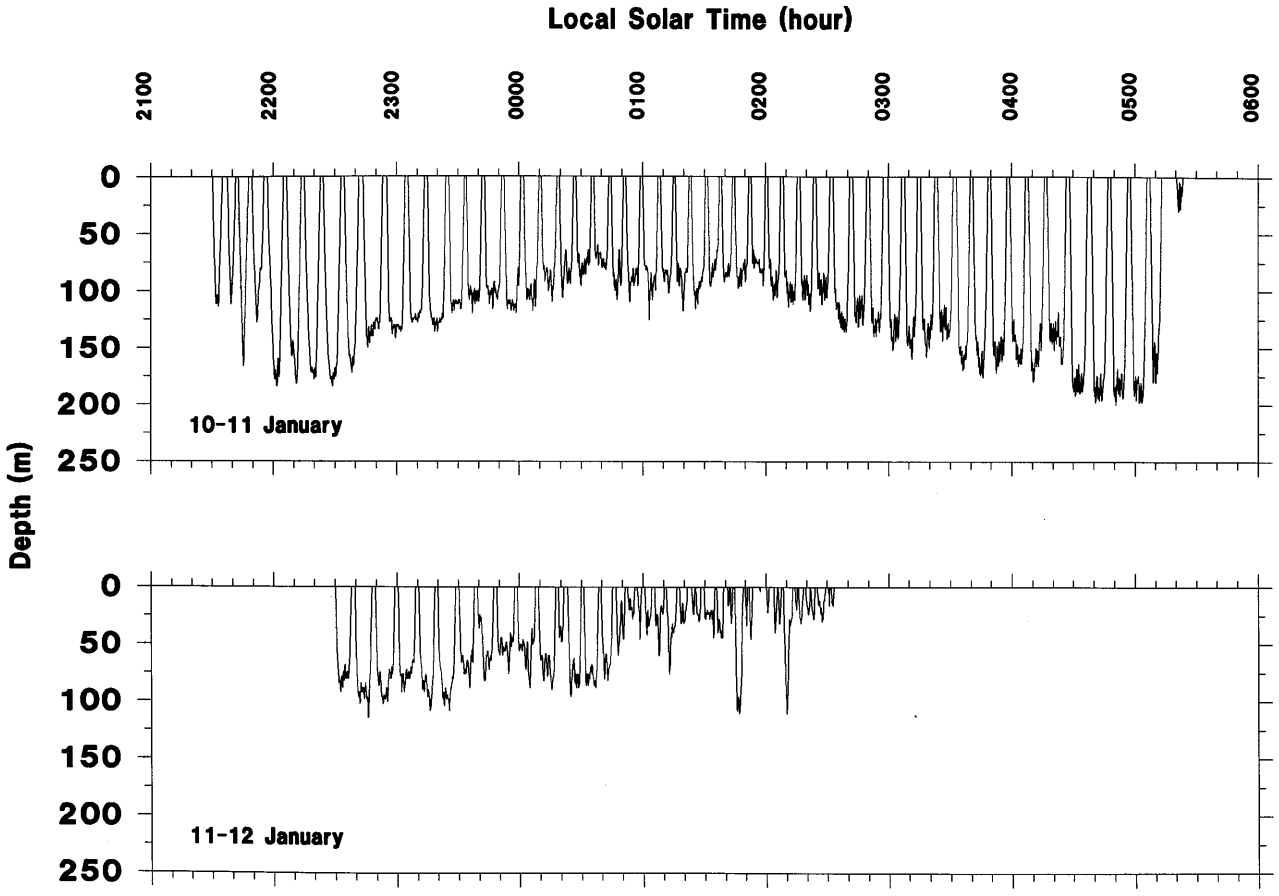


Fig. 1 Female Ross seal, instrumented with a time-depth recorder (10 January 1987; photo by B. Stewart)

Fig. 2 Dive record for two nights of diving by a female Ross seal (10–12 January 1987). The seal was hauled out on an ice floe whenever it was not engaged in a diving bout (e.g., prior to about 2130 hours on 10 January, and after about 0530 hours on 11 January)



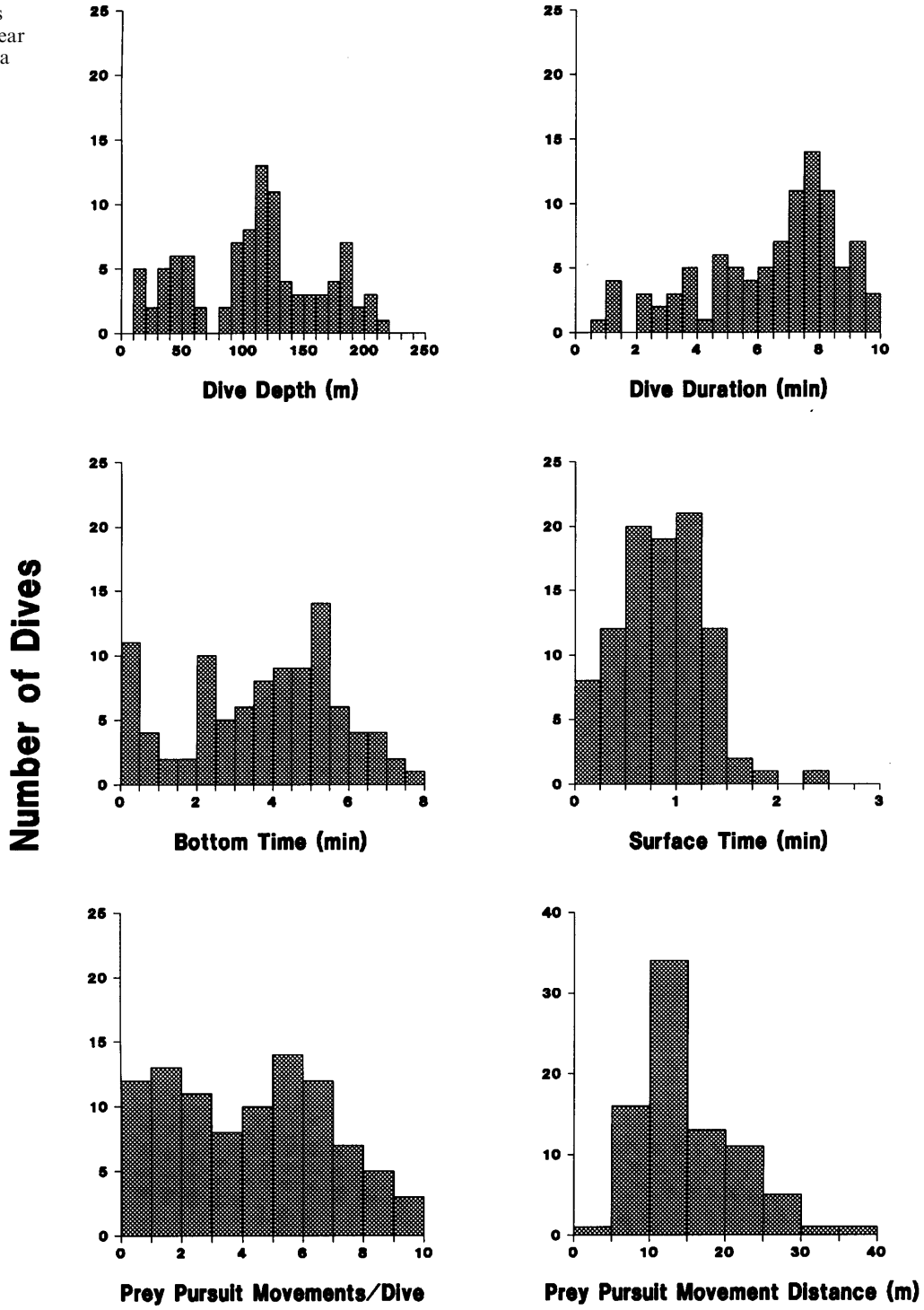


Fig. 3 Characteristics of dives made by a female Ross seal near the eastern Antarctic Peninsula (10–12 January 1987)

diving again (Table 1, Figs. 2, 3). Average dive depth was 110 m, with the deepest dive recorded at 212 m. Average dive duration was 6.4 min, with the longest at 9.8 min. Inter-dive surface periods averaged 0.8 min. There was no difference between descent and ascent rates during dives (paired sample t-test, $P > 0.05$), which averaged 1.3 m/s. Dives were shallowest and shortest between midnight and 0200 hours (one-way ANOVA, $P < 0.001$; Fig. 2). During the relatively long bottom times for dives, the seal made a series of vertical excursions, which have been referred to as prey-pursuit movements (PPMs) in crabeater seals (*Lobodon carcinophagus*) (Bengtson and Stewart 1992). Figure 4 illustrates some Ross seal dives in which PPMs were performed, some of which covered a range of as much as 40 m (Table 1, Fig. 3). If these movements indeed reflect hunting behavior during foraging dives, the dive records obtained in this study suggest that there may

Table 1 Dive characteristics for 97 dives made by a female Ross seal studied near the eastern Antarctic Peninsula 10–12 January 1987 (*SE* standard error; *PPM* prey pursuit movement; *N/A* not applicable)

Dive parameter	Statistic				
	Mean	SE	Median	Minimum	Maximum
Depth (m)	109.8	5.5	116.0	N/A	212
Duration (min)	6.4	0.2	7.1	0.9	9.8
Bottom time (min)	3.7	0.2	4.2	N/A	7.7
Surface interval (min)	0.8	0.04	0.83	0.08	2.3
Rate of descent (m/s)	1.3	0.04	1.4	0.4	2.0
Rate of ascent (m/s)	1.4	0.05	1.4	0.33	2.3
Number of PPMs/dive	3.9	0.3	4.0	0	10
PPM distance (m)	15.8	0.9	13.8	4.3	40

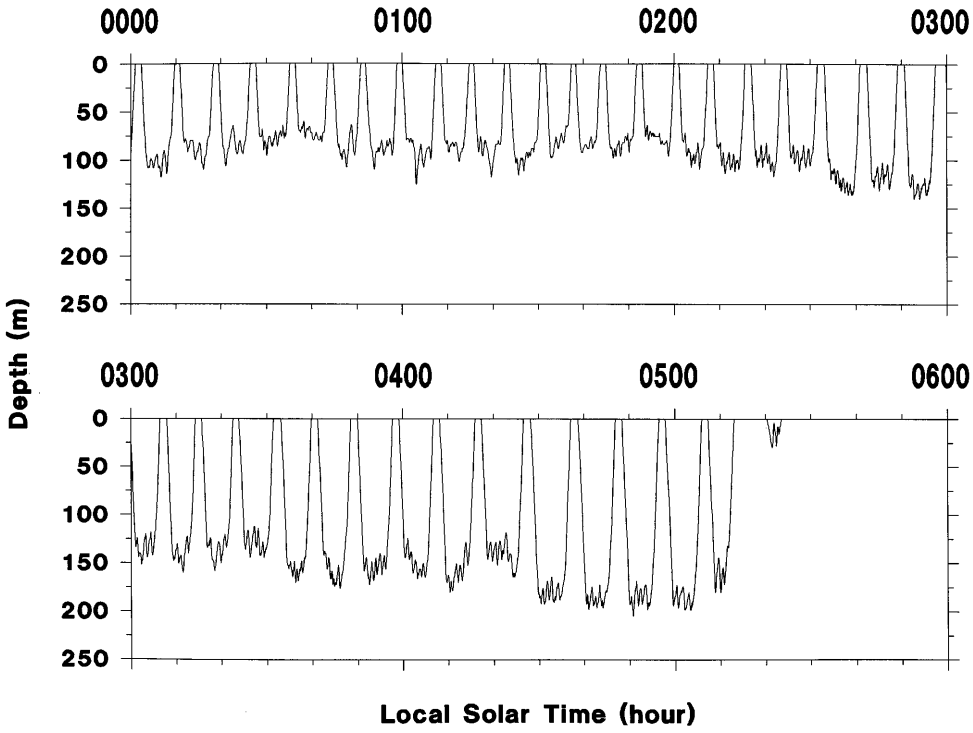


Fig. 4 Details of selected Ross seal dives, illustrating prey pursuit movements

have been considerable behavioral interactions between the Ross seal and its prey.

From a physiological perspective, the dives recorded for this seal were not unusual, in that they appear to be well within the expected aerobic dive limit (ADL) for a pinniped of this body size. This individual's ADL was estimated as 10.7 min, calculated using length/girth/mass regressions for Antarctic seals (Hofman 1975; Castellini and Kooyman 1990) and a body mass-ADL regression for phocids (Lydersen et al. 1992). Furthermore, all inter-dive surface intervals were relatively brief and there was no significant correlation between those intervals and dive duration (Pearson $r = -0.026$, $P = 0.77$). These findings support the general hypothesis that most pinniped dives are associated with aerobic metabolism alone (e.g., Kooyman 1989; Ponganis et al. 1993).

The seal's diel haulout and diving patterns suggest that it may have been feeding on vertically migrating prey or responding to changes in its prey's predator-avoidance behavior (e.g., caused by changing ambient light levels and visual detection of predators). Although Ross seals are thought to primarily eat mid-water squid and fish, similar diel diving patterns have been reported in nearby areas for crabeater seals (Bengtson and Stewart 1992), which are specialist predators on Antarctic krill (*Euphausia superba*). However, most foraging dives of crabeater seals were to depths of only about 30 m compared with this Ross seal's foraging dives to 80–140 m. Therefore, although the timing of changes in diel vertical dive patterns is similar between these two pinniped species, the differences in overall foraging depths are likely to be related to differences in diet, with Ross seals routinely eating vertically migrating mid-water squid and fish. The water depths in the area occupied by the seal during the study period were less than 225 m, suggesting that, although the seal's deepest dives could have been near to the sea bottom, most dives were to middle-range depths in the water column.

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