



Foraging trips of female South American sea lions (*Otaria flavescens*) from Isla Chañaral, Chile

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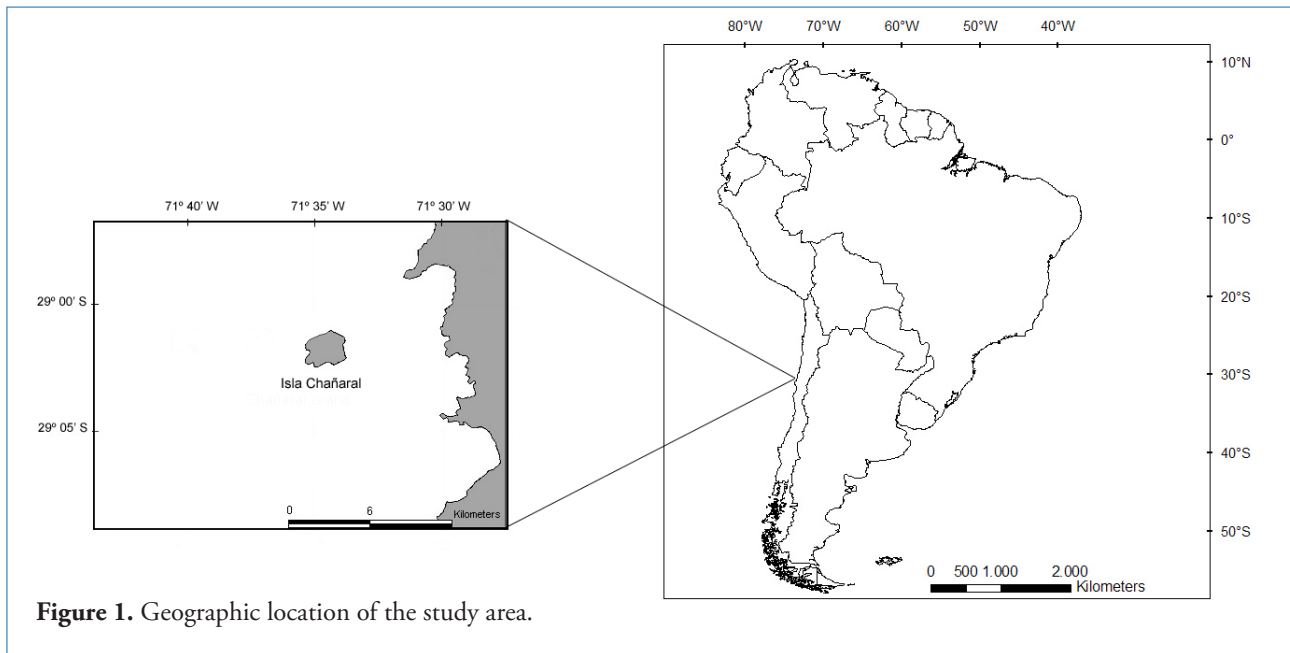
Depending on whether they are capital or income breeders, pinnipeds have different strategies of nursing and maternal care (Atkinson, 1997; Riedman, 1990; Boyd, 2000). In capital breeders such as most phocids, lactation is of short duration (4-50d), after which pups are weaned (Ofstedal *et al.*, 1987; Boness and Bowen, 1996; Hammill, 2002). By contrast, otariids are income breeders with a relatively long cycle of maternal care (4mo to 3yr). Thus lactating otariid females must divide their time between offspring on land and foraging trips in the ocean (Bonner, 1984; Ofstedal *et al.*, 1987; Campagna and Le Boeuf, 1988). The time spent on land with the pup ranges from 0.5 to 4d (Ofstedal *et al.*, 1987) following the initial perinatal attendance period. This time is variable among species (*e.g.*, Harcourt *et al.*, 1995; Francis *et al.*, 1998; Arnould and Hindell, 2001; Rehberg *et al.*, 2009) and depends on the age of the pup (Riedman, 1990). There is also considerable variation in the duration of foraging trips, which ranges from 0.6d in the Steller's sea lion (*Eumetopias jubatus*) (Rehberg *et al.*, 2009) to 23d in the Juan Fernández fur seal (*Arctocephalus philippii*) (Francis *et al.*, 1998). This variability in both duration of foraging trips and attendance periods could be affected by intrinsic factors, such as the age of the pup (Ofstedal *et al.*, 1987) and external factors such as the productivity of the area (Francis *et al.*, 1998, Bailleul *et al.*, 2005) which may vary seasonally (Harcourt *et al.*, 2002) or with unpredictable environmental oscillations such as El Niño (Ofstedal *et al.*, 1987; Soto *et al.*, 2006).

The productivity of the area is one of the determining factors in the duration of foraging trips in lactating females (McCafferty *et al.*, 1998). Variation in availability and abundance of prey may generate changes in foraging behavior

(Boyd *et al.*, 1994; Harcourt *et al.*, 2002). For example, studies on the Antarctic fur seal (*A. gazella*) have compared foraging behavior between years with high and low productivity in the same site (McCafferty *et al.*, 1998), as well as between areas of high and low productivity in the same year (Staniland *et al.*, 2010), demonstrating that females make shorter foraging trips and shorter dives in years and areas with high productivity. Thus, it is expected that duration of foraging trips of lactating females will vary inversely with the productivity of the area (Francis *et al.*, 1998).

The South American sea lion (*Otaria flavescens*) has one of the widest distributions of all sea lions. In South America it is found both on the Pacific (Perú and Chile) and the Atlantic (South Brazil, Uruguay and Argentina) coasts (Vaz-Ferreira, 1982). The Atlantic and Pacific coasts have considerable differences in productivity, which are reflected in commercial fisheries harvests. For example, between 1960 and 2002 captures in the southeastern Pacific (Perú and Chile) averaged 8 million t annually, while in the southwestern Atlantic (Brazil, Uruguay and Argentina) in the same period, the average annual harvest was only 500,000t (FAO, 2003). This large difference in productivity between oceans is due principally to the influence of the Humboldt Current near the coast in the Pacific Ocean, which maintains one of the most productive fishing zones of the world (Neira and Arancibia, 2004) and thus provides abundant food for the South American sea lion population.

Considering published information for other species of otariids (Francis *et al.*, 1998; McCafferty *et al.*, 1998; Arnould and Hindell, 2001; Rehberg *et al.*, 2009; Staniland *et al.*, 2010) and the greater biological productivity of the Pacific



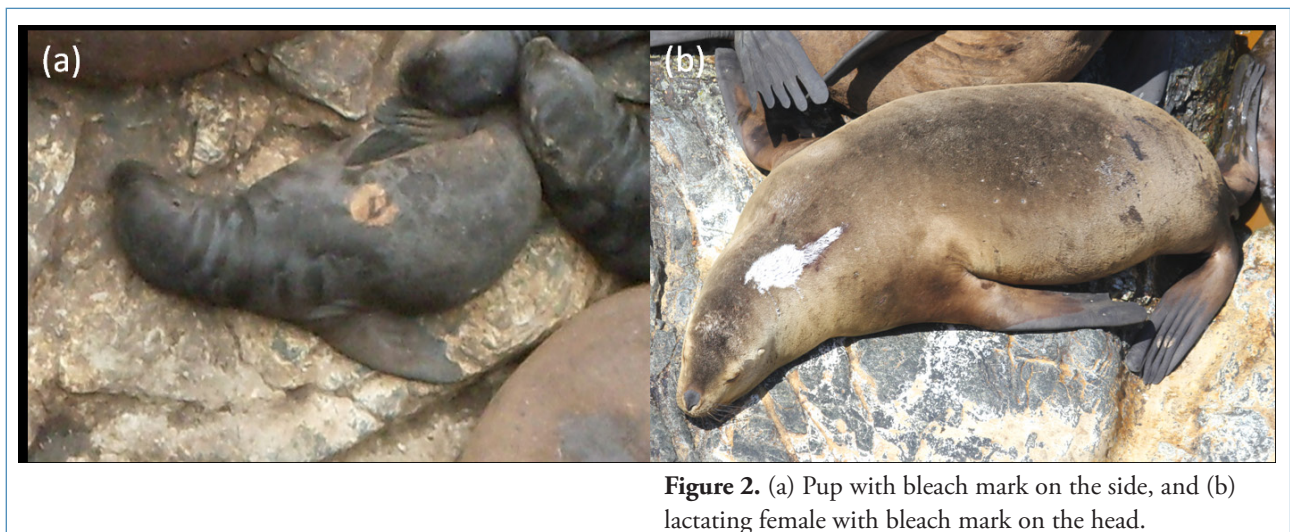
coast, we should expect that duration of foraging trips of lactating females in Chile should be of shorter duration than those lactating females of the Atlantic coast (Sherman, 1994). However, there is only information on duration of foraging trips in the Atlantic coast; where trips averaged 0.9d (range: 0.6-1.2d) in the Falkland/Malvinas Islands (Thompson *et al.*, 1998), and 3.4d (range: 2.6-3.9d) in the continental shelf of Argentinean Patagonia (Campagna *et al.*, 2001). The aim of the present study was to characterize, for the first time in Chile, the duration of foraging trips of lactating female South American sea lions off the north-central Chilean region, and to compare them with those from the Atlantic coast.

This study was performed in the reproductive colony of South American sea lions located at Isla Chañaral (29°02'S, 71°36'W), which is part of the Reserva Marina Isla Chañaral and the Reserva Nacional Pingüino de Humboldt, in north-central Chile (Figure 1). The colony was divided into four sectors; sectors A and B, comprising mostly adult males and solitary sub-adult males, and sectors C and D, where

reproductive harems were found. We selected Sector D as the study area because of easier access and visibility for observations.

We marked a total of five lactating females and 15 newborn pups using a modification of a previously used methodology (Kirkwood *et al.*, 2005; Soto *et al.*, 2006). A 5ml mixture of bleaching powder and hydrogen peroxide (commercially known as Blondor (Wella), a product for human hair) was placed in previously emptied chicken eggs, and dropped on the animals from about 10m above them. We also identified one female and two pups by natural marks (scars and injuries). Using both natural and artificial markings, we constructed an identification catalog and assigned a number to each individual. Figure 2 shows an example of a marked female and pup. We were able to successfully follow the movements of six lactating females and six pups, including three mother-pup pairs.

From 2 to 18 February 2010 we recorded the presence/absence of the marked females in the colony. Every day



observations were made by three investigators in two intervals of two hours, from 10:00 to 12:00h and from 15:00 to 17:00h. Identification and behavioral observations were made using Leupold 7x50 binoculars.

We considered a foraging trip to be the time period from the first to last interval in which a marked lactating female was not observed. Presence in the colony was measured as the time period from the first interval a female was observed in the colony until the last interval her presence was recorded. This time period was approximated and expressed in days (*i.e.* one and two consecutive intervals are considered as one day, three and four intervals are considered as two days and so on). If pups were observed without their mothers we assumed the mothers were feeding in the ocean.

We compared trip time and presence time by means of the non-parametric Spearman correlation analysis, since the data did not satisfy the requirements of normality and homoscedasticity (Zar, 1996). The analysis was performed using the statistical software Statistica 7.0 (StatSoft Inc., 2004).

During the study period, we recorded a total of 48 foraging trips, with a mean (\pm SD) of 8 ± 1.4 trips per female. The duration of these trips was from 1 to 4d; the most frequent duration was 1d, representing 52% of the trips (Figure 3a). These trips alternated with periods in which the females stayed on land with their pups (attendance period); with a duration of 1 to 4d, most frequently (55%) 1d (Figure 3b). We did not find a significant correlation between the foraging trips duration and the attendance period on land ($r = -0.066$; $p > 0.05$).

Although our results are still preliminary, with a low number of marked females and only at the beginning of lactation, this is the first study of the duration of foraging trips and attendance period on land of lactating females of *O. flavescens* in the Chilean coast. Boness and Bowen (1996), based on existing studies of feeding in different species of pinnipeds, suggested that duration of foraging trip varies between sea lions and fur seals. Foraging trips of fur seals species have been described as lasting from 3 to 23d, albeit individual trips as short as 3.4h have been recorded (Arnould and Boyd, 1996; Francis *et al.*, 1998; Harcourt *et al.*, 1995; 2002; McCafferty *et al.*, 1998; Arnould and Hindell, 2001). In contrast, the duration of foraging trip of sea lions usually last 1 to 4d (Campagna and Le Boeuf, 1988; Thompson *et al.*, 1998; Campagna *et al.*, 2001; Rehberg *et al.*, 2009), which is similar to that recorded in this study.

The duration of foraging trips we recorded is also consistent with the results of Thompson *et al.* (1998) for the same species in the Falkland Islands, but is considerably shorter than found by Campagna *et al.* (2001) in Argentinean Patagonia. The differences in duration of foraging trips found in these two studies from the Atlantic are reflected in the different distances that the females traveled from the haul-out to their foraging area. The females marked by Thompson *et al.* (1998) travelled a mean distance of about 46km, with a

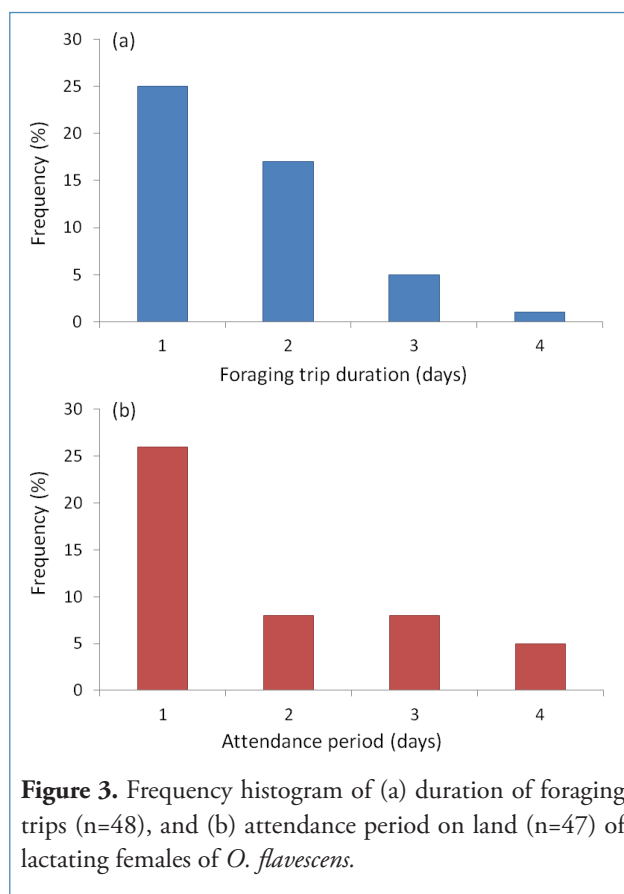


Figure 3. Frequency histogram of (a) duration of foraging trips (n=48), and (b) attendance period on land (n=47) of lactating females of *O. flavescens*.

maximum of 125km. By contrast, Campagna *et al.* (2001) recorded a mean distance of 206km with a maximum of 524km, reaching distances of 19 to 258km from the colony. Although in our study we did not record the distance traveled by the females, the results from the Atlantic suggest that the lactating females of the Isla Chañaral do not have to go very far from the rookery to feed.

The similarity between our results and the study by Thompson *et al.* (1998) may be due to the fact that the Falkland/Malvinas Islands area, as well as Isla Chañaral, corresponds to an area of high productivity. The study area is part of the Humboldt Current system and is located near a highly dynamic coastal upwelling zone that results in one of the most productive fishing industries in the world (Montecino *et al.*, 1996; Montecino and Quiroz, 2000). This region is also a nutritional source for a diverse group of marine birds and mammals (Pérez *et al.*, 2006; Sepúlveda *et al.*, 2007). The Falkland/Malvinas Islands are very close to the shelf-break front, with highly productive waters. That area is one of the most important fishing grounds of the South Atlantic, being an important feeding area for many marine mammals and seabirds (Foro para la Conservación del Mar Patagónico y áreas de influencia, 2008). This great productivity may allow females of *O. flavescens* to feed in areas near the colonies, thus decreasing the time they spend away from their offspring (Thompson *et al.*, 1998). As mentioned above, the relationship between the productivity and duration

of foraging trips has been found in other species of otariids, in which lactating females in the presence of abundant food make shorter foraging trips, with shorter dives and longer periods on land (McCafferty *et al.*, 1998). However, as our study occurred only during early lactation we cannot rule out the demands of young pups constraining foraging trip time for their mothers.

The lack of a relationship between duration of foraging trip and attendance period on land with the pups was also reported for this species (Campagna *et al.*, 2001) and for other species of otariids (Bailleul *et al.*, 2005). However, due to the small sample size, our results should be taken with caution. Other factors may generate variation in both variables, such as the productivity level of the feeding areas (Bailleul *et al.*, 2005) and the age of the pup (Arnould and Hindell, 2001; Harcourt *et al.*, 2002), which should be evaluated in future studies.

For future studies in this area, it is necessary to consider a greater sample size and longer observation periods, in order to obtain a more complete understanding of the duration of foraging trips. The use of satellite marking may also allow us to identify the foraging areas of this species off north-central Chile, to determine the distance covered in each trip, to determine the time foraging trip ends and the arrival time at the rookery, and thus to provide a more complete description of the foraging process and the duration of the foraging trips. These studies should be accompanied by monitoring of abundance and availability of prey species, since this may have a direct relation to the behavior of lactating females during foraging trips.

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