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Short Note

Serum Progesterone Concentration in Female South American Fur Seals (*Arctophoca australis*) During the Breeding Season

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Sexual and reproductive cycles are modulated by endocrine signals through a complex hormone system which involves a synergistic action between several endocrine organs and target tissues. These hormones are also influenced by environmental factors that determine their regularity in time, establishing seasonal or continuous reproductive cycles (Lamming, 1984). Although pinnipeds represent a very heterogeneous biological group within marine mammals, they share the characteristic of being seasonal breeders. In otariids (fur seals and sea lions), parturition and estrous are highly synchronized in a 2 to 3 mo period (Berta & Sumich, 1999). The South American fur seal (*Arctophoca australis*; previously *Arctocephalus australis*) (SAFS) (Berta & Churchill, 2012) belongs to the family Otariidae and is a native pinniped widely distributed in South America. Uruguay has the largest population (300,000 individuals; Páez, 2000) with reproductive colonies located on small islands along the Atlantic coast (Vaz-Ferreira, 1982). The breeding season (parturition and mating) extends from the end of November to the beginning of January (Ponce de León, 1983); the peak of births was estimated to occur in mid-December (Franco-Trecu, 2005) and mating between 5 to 7 d postparturition (Ponce de León, 1983). As in other otariids, pregnancy in SAFS lasts 11 to 12 mo, including 3 to 5 mo of embryonic diapause. Uterine implantation starts during the decreasing photoperiod (Boshier, 1981; Daniel, 1981; Berta & Sumich, 1999), which, in SAFS, apparently occurs between March and April (Vaz-Ferreira, 1979). Despite several articles that described reproductive hormone dynamics in pinnipeds through different moments of the reproductive cycle (Gales et al., 1997; McKenzie et al., 2005; Browne et al., 2006; Greig et al., 2007; Villegas-Amtmann et al., 2009; Bergfelt et al., 2010), few studies have related hormone concentration to reproductive behavior encompassing the final stages of pregnancy, parturition, estrous, ovulation, and the onset of embryonic diapause, which is a short period for pinniped species (Boyd, 1983, 1991; McKenzie et al., 2005; Mellish & Iverson, 2005).

Although basic studies have been conducted on SAFS' ovarian structure (Corcuera, 1989; Katz et al., 2009; Katz, 2011), female reproductive tract histology (Katz, 2011), and reproductive behavior (Franco-Trecu, 2010), there are still many information gaps regarding its reproductive physiology. Progesterone (P4) is the hormone that provides useful information on the reproductive cycle in mammals since it is indicative of ovarian (luteal/placental) function and/or determines pregnancy status. As far as we know, there are no reports on endocrine determination in SAFS associated with its reproductive cycle. In this context, the objectives of the present work were (1) to determine P4 concentration in *A. australis* adult females during the breeding season, and (2) to associate P4 concentration with the reproductive behavior (parturition and mating).

All procedures were done according to the Ethics Committee in Animal Experimentation (CHEA) guidelines. Sampling was performed at the reproductive colony of Isla de Lobos (35° 01' 38" S, 54° 52' 55" W), Maldonado, Uruguay. The study was done in a rookery area known as "El Muelle" on the northeast part of the island, where about 300 pups are born each year (Franco-Trecu, 2005).

From the beginning of the breeding season (3 December 2006), females were recorded if they

were observed giving birth, if they presented placental scars through the atrium/cloaca, or if they had a newborn pup (fresh umbilical cord or still attached to the placenta). Eleven fur seals were marked from a distance using paint on the parturition day. A follow-up of marked females was done for 82 d (until 23 February 2007) by two observers who performed daily scans at hourly intervals from 0700 to 1000 h and from 1700 to 2000 h (Martin & Bateson, 1993). Presence and behavior (i.e., parturition, mating, lactation, duration of foraging trips) were recorded whenever a female was spotted (Franco-Trecu, 2005, 2010). Observations were made during those hours because, during the hottest hours of midday and early afternoon, most animals get into the sea (Franco-Trecu, pers. obs.). Paint-marked females were captured for tagging and sampling. While for 10 of them the parturition date had already been recorded when marked, one of them was still pregnant and gave birth 18 d after capture (Figure 1). Each animal was led to a cage and injected with a mixture of midazolam (Midapine®, Vetcross Laboratory) (0.25 to 0.35 mg/kg) and ketamine (6 mg/kg) (Vetanarcol®, König Laboratory) into the gluteal muscle region. After reaching the sedative effect, females were transferred to a stretcher where they were tagged (Allflex N°4®), measured, and blood sampled from the caudal digital veins. Blood samples were centrifuged, and serum was aliquoted and stored at -20° C until further processing in the laboratory.

Serum P4 concentration was determined by solid phase radioimmunoassay (RIA) using a DPC commercial kit (Diagnostics Products Corporation, Los Angeles, CA, USA) and measured against human standards. The serum was assayed directly, and no extraction was performed, as previously validated in California sea lions (Greig et al., 2007) and Galapagos sea lions (Villegas-Amtmann et al., 2009). It is important to note that as progesterone has the same molecular structure in different species (Meikle & Forsberg, 2001), the same assay (reagents) has been used successfully with the serum of sheep (Tasende et al., 1996; Sosa et al., 2009; Viñoles et al., 2009), goats (Moroni et al., 2007), llamas (Bianchi et al., 2007), mares (Kalpokas et al., 2010), and cows (Meikle et al., 2001; Adrien et al., 2011). The minimum detectable level was 0.12 ng/mL. The intra-assay coefficient of variation for low (0.77 ng/mL), medium (1.94 ng/mL), and high (7.7 ng/mL) controls were 4.2, 1.8, and 10.5%, respectively. Average and standard error of the media (X ± SEM) were calculated for P4 levels of females grouped according to parturition status: either from parturition day (n = 5) or 2 d postparturition (n = 4). Samples obtained from females at 18 d before parturition and 1 d postparturition were considered separately.

Date of parturition was recorded for all the females sampled, while mating was recorded for six of them (Figure 1). The period from parturition to mating ranged from 3 to 7 d (Table 1). P4 concentrations were above the minimum detectable level in all analyzed samples and were determined after a log-logit transformation of the

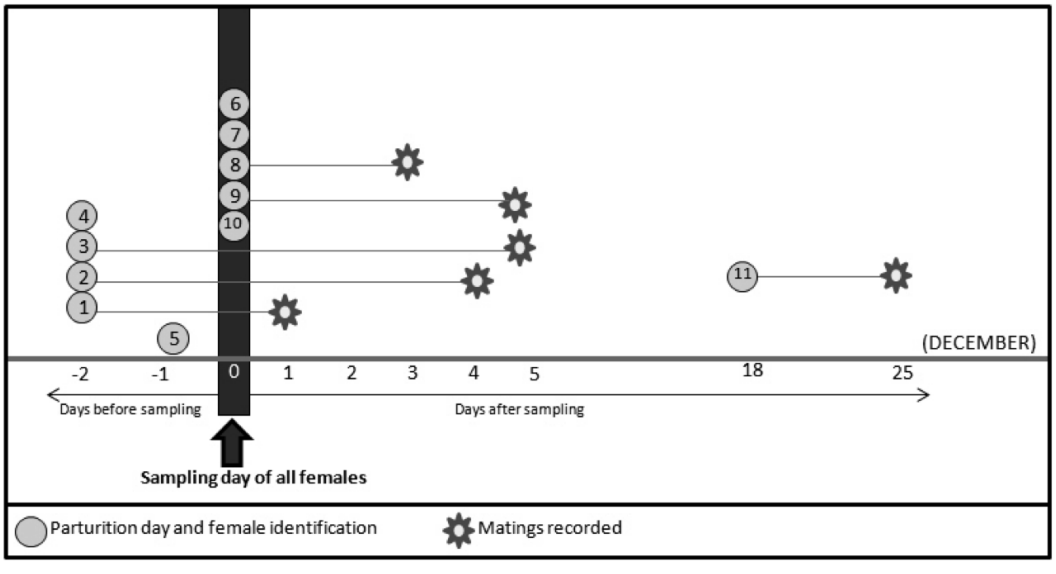

Figure 1. Diagram of parturition, mating, and sampling events in female South American fur seals (*A. australis*) during the breeding season (December) in Uruguay

standard curve; concentration varied from 0.6 to 55.4 ng/mL (Table 1). The only female sampled in the final stage of gestation (18 d prepartum) had an elevated P4 concentration (22.0 ng/mL). Females sampled at the parturition day (n = 5) showed a highly variable P4 concentration (from 0.7 to 18.6 ng/mL) averaging 6.3 ± 3.5 ng/mL, while females at 2 d postparturition (n = 4) had low hormone concentrations (from 0.6 to 1.2 ng/mL), with an average of 0.9 ± 0.1 ng/mL. In addition, one of the females showed a high P4 concentration on the first day after parturition (55.4 ng/mL).

The present work constitutes the first study to evaluate serum P4 concentration during the reproductive season in wild adult SAFS. The results obtained show a variable P4 concentration (from 0.6 to 55.4 ng/mL) at the parturition and peripartum periods coinciding with the end of pregnancy and the early follicular phase of the estrous cycle. The P4 concentration found in the female sampled 18 d before parturition is consistent with what would be expected for the end of the gestation period as reported in harbor seals (*Phoca vitulina*) (Raeside & Ronald, 1981), but not as low as described in other otariid species (Boyd, 1991; Greig et al., 2007; Villegas-Amtmann et al., 2009). However, the highest P4 concentration was recorded in a female 1 d postparturition. Similar results were found in grey seals (*Halichoerus grypus*) during the parturition period ([P4] = 10 to 70 ng/mL); the authors considered the placenta as the main source of P4 and estradiol since the maximum hormone concentrations were observed in animals which had not expelled the placenta (Mellish & Iverson, 2005). However, immunohistochemical studies of the placenta in other pinniped species determined that it lacks the necessary enzymes for progesterone synthesis, and that the *corpus luteum* (CL) is the only source of this hormone throughout gestation (Ishinazaka et al., 2001, 2002). Accordingly, the CL functional activity is probably much more intense in some females, and P4 concentration is maintained at a higher level even if luteolysis is taking place. Nevertheless, in SAFS we do not have evidence to determine whether the CL, the placenta, or both synthesize P4 in the final stages of pregnancy. Finally, the low P4 concentration detected in postpartum females coincides with CL atresia and *corpus albicans* formation reported by different authors (Craig, 1964; Yoshida et al., 1978; Boyd, 1983, 1991; Ouelette & Ronald, 1985; Corcuera, 1989; Tedman, 1991; Bester, 1995; Odendaal et al., 2002).

In general, once the inhibitory effect of P4 on the hypothalamic-pituitary-ovarian axis is finished, a rapid release of pituitary gonadotrophins takes place, associated with follicular development, an increased estrogen synthesis, and culminating with ovulation (McDonald, 1989). In the Antarctic fur seal (*A. gazella*), a peak of 17 β-estradiol level has been recorded between 6 to 10 d postparturition, which is associated with estrous and mating (Boyd, 1991). In SAFS, despite the fact that serum estrogen levels were not measured, the mating behavior recorded between 3 to 7 d postparturition fit these physiological phenomena corresponding to the follicular phase of the estrous cycle. Although observation of mating was missed in several animals, during eight reproductive seasons (2004 to 2011), multiple matings were recorded only three times (Franco-Trecu, unpub. data), so simple mating is considered to be the rule for SAFS.

In sum, this is the first report of P4 determination in wild adult SAFS. P4 concentrations during the final stages of pregnancy and early postparturition period reported in this study are similar to other pinniped species (Boyd, 1991; Mellish & Iverson, 2005). Endocrine and behavioral

Table 1. Parturition to mating period and P4 concentration in *A. australis* during the breeding season (December) in Isla de Lobos, Uruguay

Female identification	Days between parturition to sampling	Days between parturition to mating	P4 ng/mL
1	-2	4	0.6
2	-2	6	0.8
3	-2	7	1.2
4	-2	NO	0.8
5	-1	NO	55.4
6	0	NO	9.7
7	0	NO	0.7
8	0	3	18.6
9	0	5	0.8
10	0	NO	1.7
11	+18	7	22.0

NO = not observed

studies are complementary tools to assess pregnancy diagnosis (McKenzie et al., 2005; Bergfelt et al., 2010), reproductive patterns and seasonality (Villegas-Amtmann et al., 2009), regulation of embryonic diapause and delayed implantation (Boyd, 1991; Browne et al., 2006), and interannual differences in reproductive success of a wild population (McKenzie et al., 2005; Gibbens, 2009); therefore, they can be applied as a research strategy to pinniped colonies with different population dynamics such as *A. australis* in South America (De Oliveira et al., 2006; Bartheld et al., 2008; Páez, 2000, 2006). Given the low number of samples used in our study, we consider it necessary to perform further detailed studies of reproductive hormones, not only with an increased sampling number and frequency but also at different stages of the reproductive cycle so as to determine the endocrine mechanisms involved in reproductive physiology in this species.

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