Short Note

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Estimated population size of two South American sea lion male haulouts from the northern coast of Argentina

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Abstract: Knowledge of the real size of any wild population is an essential tool to take management and conservation measures and even more so when the population studied may have potential conflicts with humans. Because of this, the objective of this study was to estimate the population size of two South American sea lion male haul-outs using mark-resighting techniques. The results showed that on average, the estimated total number of animals tripled the number of animals recorded by direct counting. These findings demonstrate that it is necessary to continue researching population estimate methods to apply when taking conservation measures in the future.

Keywords: Argentina; mark-resighting; NOREMARK; *Otaria flavescens*; pinnipeds; population estimates.

The interest in estimating the population size of any wild animal species has a long history, and dates back to at least the 17th century (Nichols 1992). Because the number of individuals counted is less than the number of individuals present in the study area (Schwarz and Seber 1999), accurate population size estimation is key for making population management decisions related to population growth, ecological adaptations and conservation issues (Bailey 1951, Nunney and Elam 1994, Shawn Smallwood and Schonewald 1998). Mark-recapture techniques were developed in the 1930s–1940s (White et al. 1982; White 1996), yet mark-resighting techniques offer several advantages over the traditional capture recapture method, including lower costs, less time investment, and the fact that it is less invasive (Minta and Mangel 1989, McClintock and White 2009). In addition, mark-resighting methods can include individuals with different probabilities of being sighted (Bowden and Kufeld 1995, Fattorini et al. 2007).

We conducted this study in two male southern sea lions (SSL) haul-outs located within the harbors of Puerto Quequén (PQ; 38°35′ S, 58°42′ W) and Puerto Mar del Plata (PM; 38°02′ S, 57°31′ W), Buenos Aires Province, Argentina (Figure 1), two of the main harbors and tourist cities of the northern coast of Argentina.

Puerto Mar del Plata (PM) and Puerto Quequén (PQ) have male South American sea lion (*Otaria flavescens* Shaw, 1800) haul-outs that have existed for at least 40 years (Rodríguez 1996, Giardino 2006). PM was gradually colonized in the 1960s, with a dramatic increase in the mid-1980s, while the PQ colony began to settle in the late 1980s, probably originating from specimens from Mar del Plata (Rodríguez 1996, Westergaard et al. 1999).

These permanent haul-outs are formed mainly by juvenile (3–5 years) and subadult (5–7 years) males (Giardino 2014), and are located at almost equal distances (ca. 1000 km) from two of the most important focal breeding areas of this species in the south-west Atlantic Ocean (Uruguay and Northern Patagonia).

The South American sea lion has recovered from a dramatic decline in the 1930s–1950s (Godoy 1963, Crespo and Pedraza 1991, Dans et al. 2004) and most of the studies on population estimates were carried out in breeding colonies and were based primarily on counted pups (Crespo and Pedraza 1991, Dans et al. 2004) or

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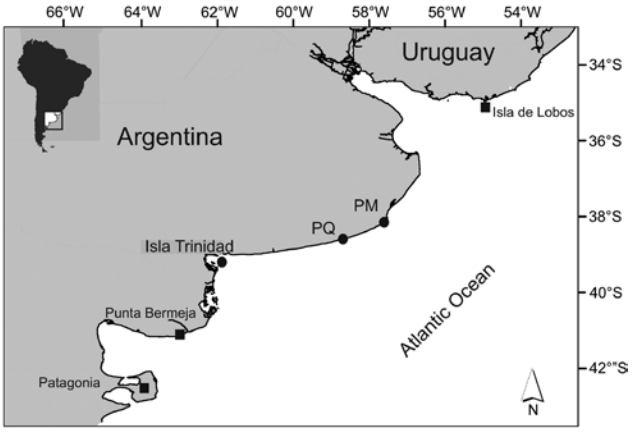

Figure 1: Location of SSL non breeding rookeries of SSLs at Puerto Quequén (PQ; 38°35′ S, 58°42′ W) and Puerto Mar del Plata (PM; 38° 02′ S, 57° 31′) in northern Argentina. References:
•=Non breeding rookeries.
■=breeding rookeries.

aerial and land visual surveys of reproductive males and females (Dans et al. 1996, Bartheld Villagra et al. 2006, Grandi et al. 2008, Grandi et al. 2012). Additional estimation studies were carried out in a non-breeding colony of this species in Brazil (Pavanato Julião 2010) and in Isla Trinidad, Argentina (Petracci et al. 2010). To determine whether mark-resighting techniques provide a more accurate population estimate, we applied this method in two *O. flavescens* haul-out settlements of the northern coast of Argentina and compared our estimates to those obtained by visual methods.

Data collection for SSL population size estimates was undertaken from March 2004 to October 2010. Eight hundred and forty specimens were marked individually (Table 1) with an alphanumeric system using ammonium/hydrogen peroxide bleach (Gentry and Holt 1982, Erickson et al. 1993). This product was applied with

Table 1: Number of identified animals, estimation period (days), median number of *O. flavescens* counted ashore±standard deviation (Max-min) and population estimation with 95% confident limits from Puerto Mar del Plata (PM) and Puerto Quequén (PQ) haulouts per month and year.

	Year	Month	Estimation period (days)	Number of marked animals in the period	Median number observed±DS (Max-min)	Estimate	95% Confidence limits	Proportion observed *vs* estimated
PQ	2004	March	6	111	116.5±25.4 (83–144)	257.0	(233–283)	2.2
		March	6	117	110.2±20.2 (77–132)	274.0	(249–302)	2.5
		March	3	122	112±13.2 (102–127)	284.0	(253–310)	2.5
		April	15	127	106.1±15.8 (78–130)	285.0	(264–3080	2.7
		April	14	127	91.5±15.8 (74–125)	353.0	(311–400)	3.9
	2005	March–April	6	137	122.8±12.6 (131–104)	556.0	(464–666)	4.5
	2008	August	11	107	125.3±28.1 (100–191)	421.0	(370–478)	3.4
		November	7	135	109.3±12.1 (93–123)	453.0	(398–517)	4.1
	2009	July	7	85	175±37 (122–224)	502.0	(430–587)	2.9
		September–October	12	85	315.3±90.6 (169–451)	886.0	(759–1034)	2.8
		November	6	85	223.5±23.49 (184–251)	743.0	(618–895)	3.3
	2010	March	15	121	232.8±36.9 (148–290)	1000.0	(859–1164)	4.3
		September	8	75	286.3±49.49 (214–362)	808.0	(729–896)	2.8
		October	6	76	396.8±59.5 (329–490)	1636.0	(1275–2101)	4.1
	Mean		8.7			604.1		3.3
PM	2007	June	6	70	244.0±10.01 (236–275)	620.0	(481–798)	2.5
		July	6	93	274.0±28.13 (273–298)	591.0	(493–709)	2.1
		July–August	5	100	267.0±21.82 (253–284)	656.0	(517–833)	2.4
		August	7	100	261.0±35.05 (220–309)	595.0	(495–715)	2.3
		August–September	6	122	264.0±28.32 (214–293)	997.0	(788–1261)	3.8
		September	6	147	232.0±32.71 (207–244)	850.0	(656–1101)	3.7
		October	9	147	282.0±22.46 (256–296)	724.0	(606–866)	2.6
		October–November	9	147	261.0±33.77 (221–295)	1000.0	(800–1251)	3.8
	2008	June–July	15	21	249.1±33.3 (177–297)	875.0	(578–1328)	3.5
		September–October	16	21	264.6±57.8 (194–362)	782.0	(552–1108)	2.9
		October–November	9	21	247.2±52.7 (165–305)	1119.0	(724–1730)	4.5
	2009	August	12	51	231.3±32.1 (175–273)	496.0	(422–583)	2.1
		October	5	51	249.6±27.5 (226–293)	1009.0	(779–1307)	4
	2010	August–September	10	25	287.2±30.5 (240–348)	561.0	(470–670)	1.9
	Mean		8.6			776.8		3.0

a stamp mounted on a 2 m pole on the dorsal pelage behind the fore flippers while the animals were resting on the beach or on artificial substrate. Every year, animals from both harbor were marked because bleach marks were clearly visible only for about 1 year (Giardino et al. 2013), remaining legible until the following annual molt, normally completed by May. After marking, a file was created for each individual animal in which age, location and natural marks were recorded, complemented with sketches and digital images of each resighting; these were particularly useful just before the molting season, when the animals began to lose fur. Different marking sessions were initiated before the corresponding period of estimation (Table 1).

The non-breeding harbor colonies were monitored during 14 periods in PQ and 14 periods in PM (Table 1). Between these periods, daily counts were made by 1–2 trained observers through focal observations to detect marked sea lions; three daily observation sessions were performed (early morning, noon and afternoon) with a mean duration of ca. 1 h each. The size of the mark (16×28 cm) and proximity to the animals (<100 m) favored detection and identification of bleached animals.

To estimate the *O. flavescens* populations from both harbors, we used the NOREMARK program (White 1994), based on mark-resighting results from surveys. For each year we made separate estimates of PM and PQ numbers based on peak daily counts of marked and unmarked SSLs observed at monitored colonies during the non-breeding season (March to November). This period was chosen because during this time, the population can be considered geographically and demographically closed.

If the identified SSL was not observed, it was considered as not detected within the study area (variable taken into account by the chosen estimator). This avoided violating the assumption of closed population, since the detection of marked animals in the rookeries is close to 100%, due to the clarity and size of the brand and the high resighting effort. We generated estimates using the Bowden mark-resighting method implemented in NOREMARK software (White 1996). Bowden's estimator considers that resighting probabilities can vary with "sighting" occasions and that each animal can have its own chance of capture (individual heterogeneity in sighting probability). Moreover, it allows for sampling with replacement, which permits double counting of both marked and unmarked individuals, and finally all animals may be used in the analysis even when they are not individually identified, but only known to be marked (Bowden and Kufeld 1995). We compared these NOREMARK population estimates with the number of animals counted and we applied regression analysis.

Applying the Bowden estimator, we found that Puerto Quequén SSL population size was 604 on average and Mar del Plata SSL population size was 777. We determined that the relationship between the number of animals counted and the average population size was about 1:3 (Table 1), with slightly higher values for Puerto Quequén (PQ). The ratio between the number of animals observed and estimated numbers remained relatively constant throughout the study period, ranging between two and four times more individuals estimated than directly counted.

Both rookeries showed a population increase throughout the study period. The population size for PQ quadrupled between 2004 and 2010, while the population size for PM increased by <30% in the same period (Table 1).

The relationship between the animals observed and estimated in Puerto Quequén had a good fit with contrasting values obtained for Puerto Mar del Plata (Figure 2).

Studies on population estimates are basic requirements in conservation biology, and the main source of information on population dynamics (Bart et al. 1998): moreover, they are key for predicting population trends (Langdon 2001). Based on simulations with Bowden estimator in NOREMARK program, we found that the number of SSL estimates for both rookeries (PM-PQ) was nearly 1400, indicating that the Southern sea lions population of the Buenos Aires Province would at least triple the number of animals that can be counted in the rookeries. Population size estimated for PQ showed a positive trend,

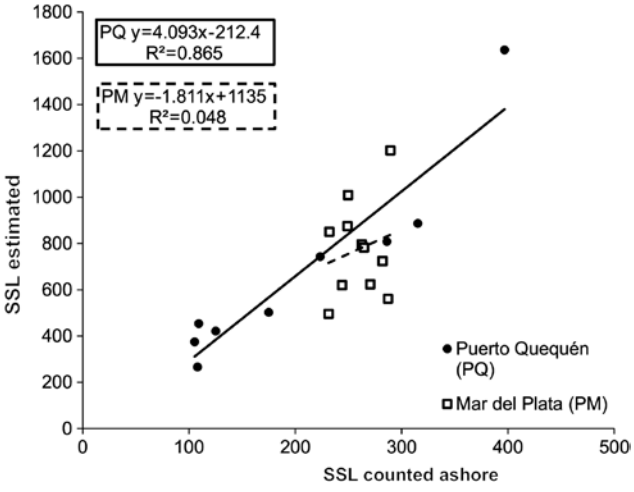

Figure 2: Relationship between the number of animals found on land (SSL counted) and the number of *O. flavescens* estimates with NOREMARK (SSL estimated) for Puerto Quequén and Mar del Plata.

suggesting that the number of animals will probably increase in future years.

The difference between counted animals and animals estimated by the program at rookeries is related to the natural cycle on shore and to foraging trips to open sea (Werner and Campagna 1995, Thompson et al. 1998, Campagna et al. 2001, Riet-Sapriza et al. 2013, Rodríguez et al. 2013, Giardino 2014). Sea lions must periodically leave the rookeries in search of food, so that some animals remain on land and may be observed and counted, while others are feeding offshore and are not recorded when the census is performed.

Northern Patagonia holds a maximum number of breeding *O. flavescens* males of ca. 4700 (Grandi et al. 2012) while the Uruguayan stock is of ca. 1900 (Alberto Ponce de León, personal communication). In the breeding season (November–March; Campagna 1985, Ponce de León and Pin 2006) 87% of SSLs from PM and PQ travel to Patagonia and Uruguay to mate (Giardino et al. 2016), as we estimated that PQ-PM have nearly 1400 sea lions. Based on these results, about 1200 animals were added to the breeding colonies every year, contributing to around 18% of the gene stock of this species in the region.

Since these colonies hold more animals than those that can be observed and counted directly, these results provide a different point of view of South American sea lion haulouts from Buenos Aires Province, and should be taken into account when making conservation and management decisions (Shawn Smallwood and Schonewald 1998, Solberg et al. 2006, Morley and Van Aarde 2007, Curtis et al. 2009). Potential anthropic conflicts such as competition with fisheries (Crespo et al. 1997, Hückstädt and Kraus 2004, Sepúlveda and Oliva 2005, Szteren and Lezama 2006, Sepúlveda et al. 2007, Szteren 2007) and interaction with domestic animals (Osman and Pavés 2006) could have a greater impact than was previously thought.

Mar del Plata and Puerto Quequén are tourist cities, in which around three million (Schenkel and Almeida García 2015) and 110,000 visitors, respectively arrive every summer. Rookeries are points of touristic atraction, so that the risk of transmission of zoonoses like tuberculosis, N1H1 and of different parasites is high (Bernardelli et al. 1996, Beron Vera et al. 2004, Kiers et al. 2008, Bastida et al. 2011, Arbiza et al. 2012, Bos et al. 2014, Timi et al. 2014).

To better understand the sea lion populations, it is essential to carry out similar researches at other locations. Although our current data indicate that the regression formula can only be applied to the Puerto Quequén haulout, we hope to produce population estimate techniques that can be applied to all sea lion populations.

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