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RESEARCH ARTICLE

Distribution and abundance of the South American sea lion *Otaria flavescens* (Carnivora: Otariidae) along the central coast off Chile

Distribución y abundancia del lobo marino común *Otaria flavescens* (Carnivora: Otariidae) en la costa de Chile central

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ABSTRACT

The onshore distribution and abundance of the South American sea lion *Otaria flavescens* along the central Chilean coast was estimated during the period January-February 2007. Additionally, changes in population abundance during the period 1970-2007 were examined. Population surveys were based on photographs taken from boats or aircraft. A total of 16301 sea lions (CI = 16209-16375) were counted in 33 colonies (6 breeding and 27 non-breeding sites). After correction to account for the proportion of individuals at sea and for pups not seen at the time of the survey, the mean estimated abundance was 18179 (95 % CI = 17777-18851) sea lions. Population trend analysis showed that from 1970 to 1985, South American sea lions showed a positive increase of approximately 2.1 % yr^{-1}. Nevertheless, between 1985 and 1997 and between 1997 and 2007, the estimated number of sea lions showed a stable or slightly negative trend of 0.4 ± 0.1 % yr^{-1} and 0.5 ± 0.1 % yr^{-1}, respectively. We suggest that the overexploitation and decline of the principal fisheries in Central Chile could adversely impact the abundance and distribution of the South American sea lion in the study area.

Key words: census, Chilean coast, *Otaria flavescens*, overexploitation, sea lions.

RESUMEN

Se estimó la distribución y la abundancia poblacional del lobo marino común *Otaria flavescens* en la costa de Chile central durante los meses de enero y febrero de 2007. Adicionalmente, se analizaron los cambios en la abundancia de esta especie durante el período 1970-2007. Los censos poblacionales se basaron en fotografías tomadas desde embarcaciones menores o desde avionetas. Se contabilizaron un total de 16301 lobos marinos (IC = 16209-16375) en 33 colonias (6 reproductivas y 27 no reproductivas). Después de corregir por la proporción de animales en el agua y por crías no registradas al momento del censo, se estimó una abundancia promedio de 18179 (95 % IC = 17777-18851) lobos marinos en el área de estudio. El análisis de tendencia poblacional presentó que desde 1970 a 1985 la abundancia del lobo marino común mostró un crecimiento positivo de aproximadamente 2.1 % $año^{-1}$. Sin embargo, entre 1985 y 1997, y entre 1997 y 2007, el número de lobos marinos muestra una tendencia estable o ligeramente negativa de 0.4 ± 0.1 % $año^{-1}$ y 0.5 ± 0.1 % $año^{-1}$, respectivamente. Se sugiere que la sobreexplotación y la declinación de las principales pesquerías en la zona central de Chile podrían haber impactado negativamente la distribución y abundancia del lobo marino común en el área de estudio.

Palabras clave: censo, costa chilena, lobos marinos, *Otaria flavescens*, sobreexplotación.

INTRODUCTION

Marine mammals, due to their body mass and abundance, are important predators in marine food webs (Bowen 1997), playing a crucial role in the structure and functioning of some marine communities (Katona & Whitehead 1988). However, many of the marine mammal species are today adversely affected by depletion of food resources (Atkinson et al.

2008). Because the occurrence and density of these predators are dependent on whole ecosystem productivity, it is expected that a decrease in food availability for these organisms would cause a decline in abundance or an emigration of individuals to more productive areas (Bostford et al. 1997).

The South American sea lion *Otaria flavescens* (Shaw, 1800) lives across a broad latitudinal range along the South American coastline, from Peru to southern Chile in the Pacific, and from Brazil to southern Argentina in the Atlantic, including the Falkland Islands (King 1983). A population estimate for this species over its entire distributional range is about 400000 individuals, according to the last censuses carried out between 1995 and 2008 (Dans et al. 2010[1]). About 140000 sea lions have been estimated in Chile recently (Venegas et al. 2002, Sepúlveda et al. 2007, Bartheld et al. 2008, Oliva et al. 2008), which represent about 35 % of the world population. The abundance of sea lions in Chile may be associated with the influence of the Humboldt Current System, which supports one of the most productive fishing areas in the world (Neira & Arancibia 2004), therefore providing food resources for this species.

Although the Chilean coast sustains a high proportion of the total *O. flavescens* population, information on their abundance and population trends over their extensive geographical range is scarce. In the central coast of Chile (from 32º02' S to 39º37' S), population counts were first conducted by Aguayo & Maturana (1973) and Palma (1985), who estimated a population of about 13000 and 18000 individuals, respectively. Later, Aguayo et al. (1998) estimated a population of about 17200 individuals in the same area. Before these studies, no censuses were made in the central coast of Chile, but exploitation statistics during the first half of the twentieth century (e.g., 50000 sea lions exploited between 1921 and 1922) suggest that the current population size is significantly lower than before its exploitation (Sielfeld 1999).

In this context, an estimate of the size and distribution of the population is a fundamental requisite in order to make adequate decisions concerning sea lion management and conservation (Small et al. 2003). In addition, detection of changes in the overall population growth is also important to understand ecosystem dynamics (Bowen et al. 2003), and to estimate the potential influence of this species on other marine organisms, including commercial fish species (Haug et al. 2006). The objectives of this paper were to (i) show the results of censuses carried out on the *O. flavescens* population in the central coast of Chile during the summer 2007, and (ii) evaluate the population trend in the study area through comparisons with previous studies performed in the same area.

METHODS

Survey dates and study area

Surveys were made along the central Chilean coast from Los Molles (32º12' S) to Queule (39º30' S) during the austral summer (January and February) 2007. In order to determine the geographical positions of the colonies, a series of aerial surveys were performed on January 15 and 16, and on February 15 and 17. The flights were carried out in a Cessna 172 airplane at an altitude of 70-100 m and a speed of 100-150 km h^{-1}. After locating a colony, the pilot circled the site. Each colony was photographed using a digital camera Canon 1D Mark II N with a zoom lens Canon 70-200 F2.8 IS, and its geographical location was recorded using a Garmin GPSmap76.

Population surveys

From February 12 to 28, the colonies located by air were surveyed in boats of artisanal fishermen (8-12 m length). This period represents the peak of the breeding season for the South American sea lion in the Chilean coast, when most of the individuals are present at the rookery for reproduction, and almost all pups are already born (Acevedo et al. 2003, M Sepúlveda et al. unpublished data). Based on our previous experience, censuses from direct counts generally result in some errors in the abundance estimation and categorization of individuals, principally due to fleeing of sea lions in the presence of the boat, and to difficulties in the categorization due to the continuous movement of both the boat and the animals. For these reasons, population surveys were based on photographs taken from the boats, which provide a more accurate count than a direct census. For each colony a set of photographic records was taken with digital cameras Canon 20D, 30D, 1D Mark II N, zoom lenses Canon 100-400 f4.5-5.6 IS, 70-200 f2.8 IS and Sigma 100-300 F4. Photographs

[1] DANS S, W SIELFELD, A AGUAYO, G GIARDINO & MA MANDIOLA (2010) Estado y tendencia de las poblaciones. En: Crespo E, D Oliva, S Dans & M Sepúlveda (eds) Estado de situación del lobo marino común en su área de distribución: 8-15. Informe del Primer Taller de Trabajo realizado en Valparaíso, Chile, June 15-17, 2009.

were sequential and slightly overlapped to guarantee complete coverage of a site. In addition, the colonies were video recorded and geo-referenced. Due to topographic characteristics, the access to some colonies was not possible by sea. In those cases aerial surveys were performed. Table 1 indicates which colonies were photographed from the air and which from a boat.

Sea lions were counted from images using Photoshop CS2 software (version 9.0). Three independent and trained observers classified the individuals into five categories according to age and sex: adult males, sub-adult males, females (both adult and sub-adult), juveniles (both sexes, including yearlings born during the previous season), and pups (born during the reproductive season). Age and sex distinctions were determined from differences in size, body shape and/or coloration (Hamilton 1934, King 1983). Additionally, we considered a category of indeterminate individuals, which correspond to animals that could not be classified in any of the classes mentioned above. The number of sea lions in each category was counted separately. Final values were estimated by averaging the counts, with a maximum error of 10 % among observers. Counts falling out of the fixed error were repeated. The total number of sea lions in each colony was calculated by summing the number counted in each category. Confidence intervals for the mean population (95 % CI) were estimated using the overall coefficient of variation for the population and the t distribution, with $\alpha = 0.05$ and g.l. = n-1, with n = number of colonies. Colonies were classified as breeding or non-breeding (= haul-out), based on the presence or absence of newborn pups, respectively.

Population size correction

Censuses, even if conducted during the reproductive season, often underestimate the population size because of the fact that at any given time only part of the population is on shore, while an unknown proportion is at sea. Hence complete counts of all individuals, of all sexes and age classes, are almost impossible to register (Galimberti & Sanvito 2001). Thus to estimate total population size it is necessary to develop and apply a correction factor to account for the animals missed (Dans et al. 2004). Numerical models (e.g., regressions, general linear models) may be developed to adjust counts for environmental (e.g., tide height, time of day) and survey-related effects, increasing the accuracy of population size estimation (Dans et al. 2004). However, in this study, surveys were designed to count simultaneously as many colonies as possible. Thus it was not possible to survey a colony more than once, and as a result, within-day and within-season variability could not be analyzed, precluding the use of such models. For this reason, the population size correction of *O. flavescens* in the study area was based on data gathered from the literature (see below).

Within-day corrections in non-breeding colonies were made using the circadian rhythms reported by Sepúlveda et al. (2001). Considering that the number of sea lions on shore is maximal at midday hours (between 1200 and 1600 h), censuses made earlier or later than this period were corrected using the adjustment curve described by these authors. In the case of breeding colonies, Oporto et al. (1997) and M Sepúlveda et al. (unpublished data) found that daily variations in the number of sea lions are minimal. Thus, daily corrections in breeding colonies were not performed. However, because juveniles do not participate in reproduction, their abundance usually shows a variation during the day. Thus, juveniles from breeding colonies were corrected in the same way as in non-breeding colonies using the adjustment curve reported by Sepúlveda et al. (2001).

Within-season corrections were based on Acevedo et al. (2003) for a breeding colony in northern Chile. These authors found that the number of sea lions is maximal in the second and third week of February. Accordingly, in the current study censuses from breeding colonies performed out of that period were corrected fitting our data to Acevedo´s abundance curve. In the case of non-breeding colonies, no information on within-season fluctuations during the breeding season of the species was found. For this reason no weekly variation in the abundance of sea lions was assumed in non-breeding colonies.

Pups may be easily underestimated from photographs because of individual superposition in crowded colonies, their small size and the topography of rocky areas (Reyes et al. 1999). In Patagonia Argentina, Reyes et al. (1999) mentioned a 32 % underestimation of pups from photographs. Similarly, in a colony in northern Chile, M Sepúlveda (unpublished data) found that around 30 % of pups were not visible from maritime photographs. Thus, the number of pups counted in breeding colonies was corrected accordingly.

Population trend

In order to assess the population trend of *O. flavescens* in the study area, the finite population growth rate (λ) was calculated for the historic abundance data as: $\lambda = N_{t+1}/N_t$ (Begon et al. 2006). Confidence intervals (CI) for population trends were estimated for the 1997/1985 and 2007/1997 comparisons. No CI were calculated for 1985/1970 data because these censuses reported only a single observation. The rate of change in pup number was also used as a measure of the population trend, because pup counts may lead to more accurate estimates (Dans et al. 2004), and because they are also a measure of the productivity of a population (Trites & Larkin 1996). Only the number of pups from 1997 and 2007 censuses was compared, because 1970 and 1985 data did not differentiate among age classes.

RESULTS

Distribution and abundance

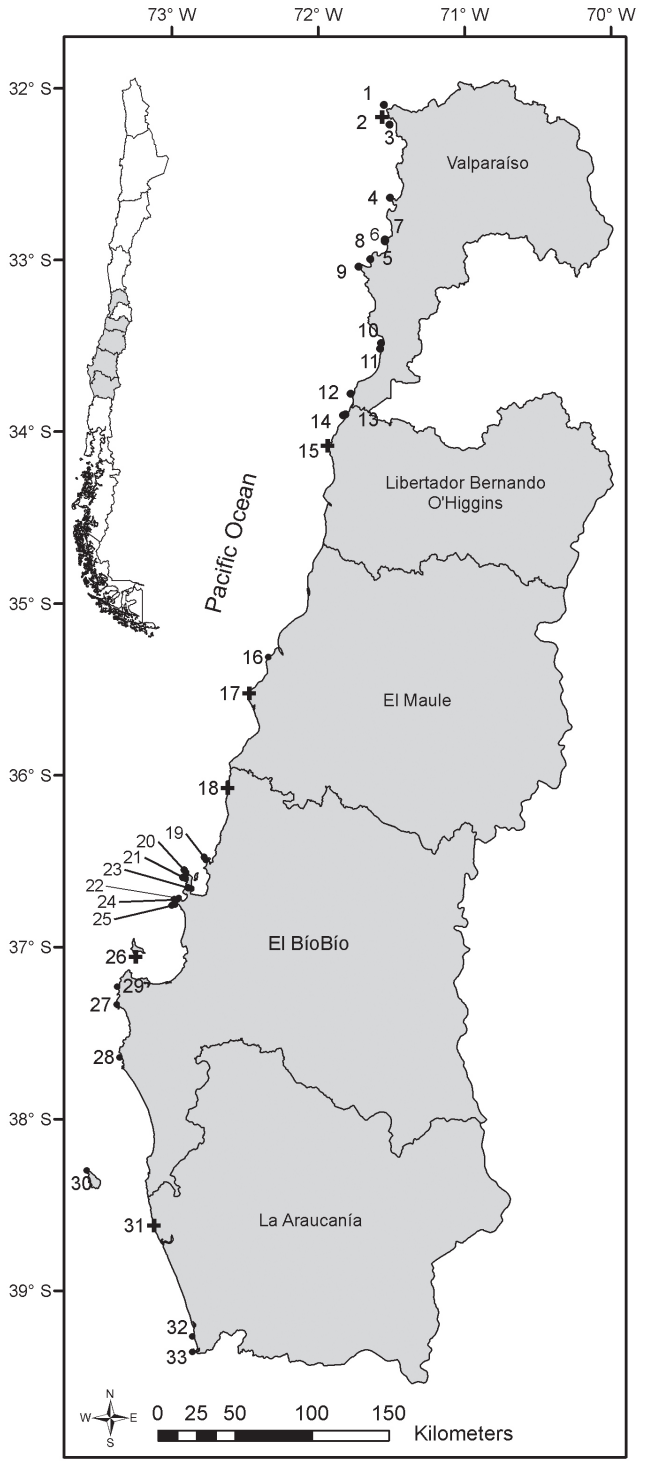
Thirty three colonies were surveyed along the central and southern coast of Chile (Table 1, Fig. 1). Most of the rookeries (81.8 %) were non-breeding colonies; we found newborn pups in only six (18.2 %) of the colonies. The mean number of sea lions counted in the study area was 16301 (95 % CI = 16209-16375), composed of 1794 adult males (95 % CI = 1766-1829); 1285 sub-adult males (95 % CI = 1254-1317); 8356 females (95 % CI = 8007-8708); 1707 juveniles (95 % CI = 1685-1727); 1262 pups

TABLE 1

Number (± SD) of South American sea lions (*Otaria flavescens*) in 33 colonies of the central coast of Chile. The reproductive condition (RC) (B: breeding; NB: non-breeding), and the kind of survey (A: air; B: boat) of each colony are also indicated. AM: adult males; SM: sub-adult males; F: females; J: juveniles; P: pups; I: indeterminate individuals.

Número (± DE) de lobos marinos comunes (*Otaria flavescens*) en 33 loberas de la costa central de Chile. Se indica la condición reproductiva (RC) (B: reproductiva; NB: no reproductiva) y el tipo de censo (A: aire; B: embarcación) de cada lobera. AM: machos adultos; SM: machos subadultos; F: hembras; J: juveniles; P: crías; I: indeterminados.

N	Colony name	RC	Survey	Age class						Total
				AM	SM	F	J	P	I	
1	Punta Negra	NB	B	3 ± 0.0	20 ± 1.0	17 ± 1.0	13 ± 1.0	0 ± 0.0	8 ± 0.6	61 ± 0.6
2	Maitencillo	B	B	5 ± 0.6	19 ± 1.0	35 ± 1.0	9 ± 0.6	8 ± 0.6	32 ± 4.2	109 ± 3.5
3	Piuquén	NB	B	26 ± 0.6	45 ± 2.1	139 ± 3.8	63 ± 0.6	0 ± 0.0	35 ± 1.0	308 ± 0.0
4	F. de Quintero	NB	A	13 ± 1.5	7 ± 1.0	46 ± 3.5	19 ± 4.0	0 ± 0.0	17 ± 3.5	102 ± 3.1
5	R. Oceánica	NB	B	3 ± 0.0	3 ± 0.6	11 ± 1.2	11 ± 1.0	0 ± 0.0	15 ± 5.3	43 ± 3.5
6	Cochoa	NB	A	0 ± 0.0	0 ± 0.0	2 ± 0.6	2 ± 0.0	0 ± 0.0	2 ± 0.6	6 ± 0.0
7	Montemar	NB	A	3 ± 0.6	1 ± 1.2	44 ± 7.2	30 ± 3.0	0 ± 0.0	10 ± 5.5	88 ± 1.0
8	Los Peines	NB	B	1 ± 0.0	0 ± 0.0	0 ± 0.0	0 ± 0.0	0 ± 0.0	0 ± 0.0	1 ± 0.0
9	P. Curaumilla	NB	B	16 ± 1.2	30 ± 1.7	66 ± 2.6	4 ± 0.6	0 ± 0.0	31 ± 3.5	147 ± 2.5
10	P. Vera	NB	A	5 ± 0.0	1 ± 0.0	0 ± 0.0	1 ± 0.0	0 ± 0.0	0 ± 0.0	7 ± 0.0
11	P. Panul	NB	B	4 ± 0.6	7 ± 0.6	0 ± 0.0	3 ± 0.6	0 ± 0.0	3 ± 1.5	17 ± 0.0
12	Matanza alejada	NB	A	1 ± 0.0	0 ± 0.0	1 ± 0.0	0 ± 0.0	0 ± 0.0	0 ± 0.0	2 ± 0.0
13	Matanzas	NB	A	15 ± 0.0	21 ± 0.6	63 ± 2.6	15 ± 1.0	0 ± 0.0	44 ± 9.1	158 ± 5.6
14	I. Pupuya	NB	A	166 ± 4.0	113 ± 5.1	566 ± 20.1	192 ± 10.0	0 ± 0.0	94 ± 10.8	1,131 ± 21.8
15	Topocalma	B	A	58 ± 3.8	15 ± 1.0	779 ± 22.1	155 ± 5.0	379 ± 13.8	56 ± 13.1	1,441 ± 35.2
16	Constitución	NB	A	17 ± 1.0	2 ± 0.0	3 ± 0.6	0 ± 0.0	0 ± 0.0	3 ± 1.0	25 ± 0.6
17	Cabo Carranza	B	A	203 ± 4.2	62 ± 2.0	1,594 ± 62.3	341 ± 9.8	57 ± 3.1	252 ± 48.8	2,509 ± 29.7
18	Cobquecura	B	B	264 ± 11.6	35 ± 1.0	1,788 ± 71.9	184 ± 6.2	592 ± 13.9	129 ± 76.9	2 ,92 ± 47.5
19	P. Cullín	NB	B	33 ± 1.5	23 ± 1.5	92 ± 3.6	38 ± 2.0	0 ± 0.0	35 ± 8.3	221 ± 2.5
20	Quiebra Ola	NB	A	9 ± 0.0	4 ± 0.6	50 ± 2.6	11 ± 1.0	0 ± 0.0	12 ± 5.3	86 ± 2.1
21	Pan de Azúcar	NB	B	9 ± 0.6	51 ± 2.5	42 ± 0.6	8 ± 0.6	0 ± 0.0	28 ± 4.9	138 ± 3.0
22	Hualpén	NB	A	80 ± 3.8	101 ± 2.5	146 ± 1.7	45 ± 4.2	0 ± 0.0	98 ± 9.5	470 ± 7.8
23	M. Talcahuano	NB	B	28 ± 1.0	13 ± 0.6	32 ± 1.5	3 ± 0.6	0 ± 0.0	17 ± 4.0	93 ± 2.3
24	P. Guapón	NB	A	7 ± 0.6	1 ± 0.0	11 ± 0.6	7 ± 0.6	0 ± 0.0	8 ± 1.2	34 ± 2.0
25	La Isla	NB	B	16 ± 0.6	77 ± 2.1	18 ± 1.0	4 ± 0.6	0 ± 0.0	35 ± 7.6	150 ± 4.4
26	I. Santa María	B	B	59 ± 2.1	66 ± 4.2	174 ± 5.5	51 ± 1.2	2 ± 0.0	156 ± 15.3	508 ± 12.1
27	Morro Carnero	NB	B	53 ± 2.0	68 ± 2.9	43 ± 1.0	5 ± 0.0	0 ± 0.0	60 ± 5.7	229 ± 6.1
28	Punta Liles	NB	A	7 ± 1.2	1 ± 0.0	0 ± 0.0	1 ± 0.0	0 ± 0.0	0 ± 0.0	9 ± 1.2
29	Roca Blanca	NB	A	211 ± 10.5	341 ± 10.6	673 ± 28.1	56 ± 1.5	0 ± 0.0	300 ± 46.8	1,581 ± 72.6
30	I. Mocha	NB	A	287 ± 4.2	95 ± 2.1	449 ± 3.2	48 ± 2.1	0 ± 0.0	230 ± 5.9	1,109 ± 1.5
31	Lobería	B	B	183 ± 1.0	36 ± 2.5	1,418 ± 45.7	355 ± 2.0	225 ± 4.0	130 ± 8.5	2,346 ± 40.6
32	P. Nihue	NB	B	7 ± 0.6	24 ± 1.5	18 ± 1.2	15 ± 1.0	0 ± 0.0	33 ± 1.0	97 ± 0.0
33	Ronca	NB	B	2 ± 0.0	3 ± 0.0	36 ± 1.2	18 ± 1.2	0 ± 0.0	24 ± 2.6	83 ± 2.1
TOTAL				1794 ± 15.5	1285 ± 15.5	8356 ± 171.0	1707 ± 10.2	1262 ± 25.1	1897 ± 160.1	16301 ± 197.2
%				10.6	7.6	49.4	10.1	11.0	11.2	



Colony name

1. Punta Negra (32°12´25.6´´S 71°32´07.1´´W)
2. Maitencillo (32°13´31.1´´S 71°31´44.1´´W)
3. Piuquén (32°14´08.0´´S 71°31´44.9´´W)
4. Farellones de Quintero (32°42´07.1´´S 71°31´56.1´´W)
5. Roca Oceánica (32°56´44´´S 71°32´58´´W)
6. Cochoa (32°56´59´´S 71°32´50´´W)
7. Montemar (32°57´25´´S 71°32´58´´W)
8. Los Peines (33°03´26.2´´S 71°39´44.8´´W)
9. Punta Curaumilla (33°05´57.6´´S 71°44´37.9´´W)
10. Punta Vera (33°33´00.6´´S 71°37´08.9´´W)
11. Punta Panul (33°34´53.0´´S 71°37´30.5´´W)
12. Matanza alejada (33°50´28´´S 71°50´25´´W)
13. Matanzas (33°57´31.0´´S 71°52´55´´W)
14. Islote Pupuya (33°57´51.9´´S 71°53´46.4´´W)
15. Topocalma (34°08´24.0´´S 72°00´37.3´´W)
16. Constitución (35°21´49.3´´S 72°28´36.4´´W)
17. Cabo Carranza (35°34´07.2´´S 72°37´25.2´´W)
18. Cobquecura (36°07´07.6´´S 72°48´19.2´´W)
19. Punta Cullín (36°32´03.2´´S 72°58´48.1´´W)
20. Quiebra Ola (36°36´08.4´´S 73°07´33.0´´W)
21. Pan de Azúcar (36°38´16.8´´S 73°08´02.5´´W)
22. Hualpén (36°44´49.1´´S 73°11´25.2´´W)
23. Muelle Talcahuano (36°41´48.5´´S 73°05´38.1´´W)
24. Punta Guapón (36°45´17.4´´S 73°12´00.4´´W)
25. La Isla (36°47´12.4´´S 73°13´09.5´´W)
26. Isla Santa María (36°57´28.3´´S 73°32´27.4´´W)
27. Morro Carnero (37°21´01.5´´S 73°40´35.9´´W)
28. Punta Liles (37°39´35.4´´S 73°40´27.0´´W)
29. Roca Blanca (37°14´48.8´´S 73°39´53.6´´W)
30. Isla Mocha (38°18´36´´S 73°57´30.6´´W)
31. Lobería (38°38´54.8´´S 73°29´00.8´´W)
32. Punta Nihue (39°18´17.7´´S 73°14´05.1´´W)
33. Ronca (39°23´49.1´´S 73°14´29´´W)

● Non-Breeding Colony
✚ Breeding Colony

Fig. 1: Map of the study area showing the geographic position of the 33 colonies of *Otaria flavescens* in the central coast of Chile. Non-breeding colonies are indicated by black dots; breeding colonies by black crosses.

Mapa del área de estudio que muestra la ubicación geográfica de 33 loberas de *Otaria flavescens* en la costa central de Chile. Los círculos negros indican las loberas no reproductivas; las cruces negras las loberas reproductivas.

(95 % CI = 1198-1326); and 1897 indeterminate individuals (95 % CI = 1569-2225) (Table 1). The six breeding colonies accounted for 61 % of the total number of sea lions registered. The three main rookeries were Topocalma, Cobquecura, and Lobería, representing the most important breeding areas in the central coast of Chile. The total number of pups, after applying a 30 % correction factor, was estimated in 1868 (95 % CI = 1804-1932). Further applying daily and weekly correction factors, the mean total population size in the central Chilean coast was estimated to be 18179 (95 % CI = 17777-18581) sea lions. Pups represented around 10 % of the total estimated population size.

Population trend

Fig. 2 shows the historical census data for the South American sea lion, as well as the fish landing data of the last 40 years. Three historical counts have been performed for *O. flavescens* in the study area: (1) Aguayo & Maturana (1973) recorded 13702 sea lions in 1970; (2) Palma (1985) counted 18075 sea lions in 1985; and (3) Aguayo et al. (1998) estimated a population of 17256 animals in 1997. For comparative purposes we used the raw counts in the 2007 census, since no correction factors were applied for estimating population size in any of the previous surveys. From 1970 to 1985, South American sea lions showed a positive trend of nearly 2.1 % yr^{-1}, although the number of colonies registered in 1985 was lower. On the contrary, sea lions exhibited a slight decrease from 1985 to 1997, showing a negative trend (± SD) of 0.4 ± 0.1 % yr^{-1}, although sixteen new colonies were found. Finally, based on counts performed during the last ten years, sea lions showed a decrease of 0.5 ± 0.1 % yr^{-1}, although the number of colonies increased. The corresponding finite population growth rates (λ) obtained through historic abundance data in the zone of study are: $\lambda_{85\text{-}70}$ = 1.289; $\lambda_{97\text{-}85}$ = 0.996; and $\lambda_{07\text{-}97}$ = 0.925. Taking into account the number of pups counted in the 1997 and 2007 censuses (1259 and 1262, respectively), the population of *O. flavescens* did not change from 1997 to 2007.

Fig. 3 shows the abundance by categories for the censuses of 1997 and 2007, differentiated for each of the study areas. According to this figure, in both periods the maximum abundance was found in the Biobío region. However, there was a change in the abundance of the age and sex categories between the two studies. There was a decrease in the number of animals in the Valparaíso and La Araucanía Regions in 2007, especially of

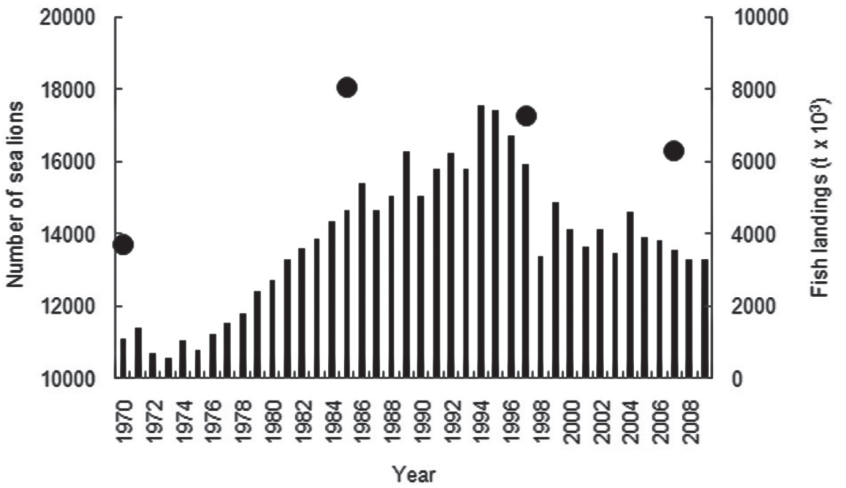


Fig. 2: Number of South American sea lions (*Otaria flavescens*) historically registered along the central coast of Chile between 1970 and 2007 (black dots), and fish landings data (columns) from 1970 to 2009 (Source: Servicio Nacional de Pesca 2009).

Abundancia de lobos marinos comunes (*Otaria flavescens*) registrados históricamente a lo largo de la costa central de Chile entre 1970 y 2007 (círculos negros), y datos de desembarques de peces (columnas) desde 1970 a 2009 (Fuente: Servicio Nacional de Pesca 2009).

adult males and females. The opposite situation was found in the Bernardo O'Higgins and El Maule Regions, in which there was an increase in some categories, especially females and juveniles.

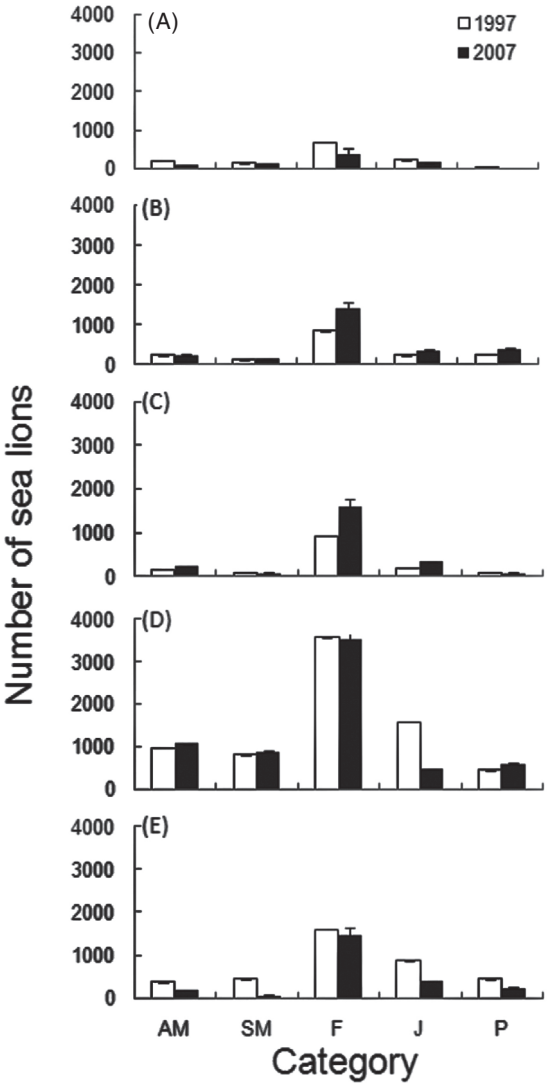


Fig. 3: Abundance by categories of the South American sea lion (*Otaria flavescens*) for the censuses of 1997 and 2007. Regions of: (A) Valparaíso; (B) Libertador Bernardo O'Higgins; (C) El Maule; (D) Concepción; and (E) La Araucanía. AM: adult males; SM: sub-adult males; F: females; J: juveniles; P: pups.

Comparación de las abundancias poblaciones por categoría de sexo y edad de lobos marinos comunes (*Otaria flavescens*) en los censos de 1997 y 2007. Regiones de: (A) Valparaíso; (B) Libertador Bernardo O'Higgins; (C) El Maule; (D) Concepción; y (E) La Araucanía. AM: machos adultos; SM: machos subadultos; F: hembras; J: juveniles; P: crías.

DISCUSSION

The objective of this study was to present the results of censuses carried out in the central coast of Chile. We discuss the historical changes in the distribution and abundance of sea lions, the trends for this population, and its relation with fish landings during this period. We then explore some other factors that could affect the sea lion population growth.

The number of sea lion colonies found in this study was the highest ever recorded in the study area. These were five new non-breeding colonies: Matanza Alejada, Muelle Talcahuano, Punta Liles, Punta Guapón, and La Isla. Four of these five colonies were found in the Biobío region and, according to fishermen, were occupied by sea lions only since 2005. In contrast, some areas which had colonies in 1997, such as Papudo, Las Salinas (Valparaíso region) and Punta Millonhué (La Araucanía region), were completely vacant in 2007. This adjustment in the distribution of sea lions has been demonstrated in other species of pinnipeds (e.g., harbor seals *Phoca vitulina* L., Brown & Mate 1983).

New sites may be explained by the response of some individuals to an increment in local food availability; which can take some advantage of a food source at a low energy cost. This is because the new haul-outs found in the present study are close to fishing ports. A similar situation was recorded by Oliva et al. (2008). These authors found a change in the distribution of sea lion colonies as a response to the presence of salmon farms in southern Chile. Some colonies near the salmon farms disappeared, while new haul-outs appeared in other sectors. By contrast, we found a decrease in the number of colonies in the Valparaíso and La Araucanía regions, coincident with the decrease in population abundance recorded for the different age classes from 1997 to 2007 in those regions (Fig. 3).

In the current study, as in the studies of Palma (1985) and Aguayo et al. (1998), the greatest abundance and number of colonies were recorded in the Biobío region, which account for nearly 50 % of the total abundance and 36 % of the colonies, including four of the five new colonies registered. This region also represents the most important area for sea lion

reproduction within the range of the study. Primary production reported for the upwelling system of the Biobío region is one of the highest ever reported for the open ocean (Daneri et al. 2000) and the fishery landings represent more than de 50 % of the total national landings. Since females rely on food resources adjacent to the rookery during the breeding season (Costa 1993), it is expected that females will select sites where prey resources are concentrated and predictable (Pitcher et al. 1998).

Pinnipeds of almost all the world were heavily exploited during the 19th and 20th centuries, resulting in significant reduction of their stocks (Gerber & Hilborn 2001). At present, the responses of the different populations and species are different; some are still decreasing, some are recovering slowly, and some are increasing (Gerber & Hilborn 2001). For *O. flavescens*, different scenarios are found over the distribution of the species. For example, in Uruguay the overall number of sea lions is decreasing (Túnez et al. 2008); in northern and central Patagonia (Argentina) and in northern and southern Chile populations are increasing (Dans et al. 2004, Bartheld et al. 2008, Oliva et al. 2008), and in the central coast of Chile the number of sea lions has remained relatively stable, with a slight decrease since 1985-2007.

An increase of the population in the north (Bartheld et al. 2008) and south (Oliva et al. 2008) of Chile may be explained, at least in part, by an emigration from areas with less abundance of prey, such as the central coast of Chile. If this is the case, it would be expected that the overall population in Chile is actually increasing, but the rates of increase observed in the north and south could be actually lower because part of their increase is based on a inmigration from the central region.

Variations in the abundance of South American sea lions over time are also recorded. For the study area there was an increase in abundance from 1970 to 1985, followed by a slight decrease since 1985 to 2007. The increase in animal abundance from 1970 to 1985 may be due to a recovery after a prolonged period of hunting, as has been reported recently for this species in the coast of Argentina (Dans et al. 2004). During this period fishery exploitation was in a growth phase, reaching its maximum in 1994 (Fig. 2). The decrease in population abundance which was recorded between 1997 and 2007 may be related to the decline of the main fishing industries in the central area of Chile. According to the national fisheries statistics, from 1995 to 2009 fish landings have shown a noticeable decrease, from about 7.5 million t in 1995 to 3.4 million t in 2009 (Servicio Nacional de Pesca 2009). This drastic decrease may be associated with the collapse of the jack mackerel (*Trachurus murphyi* Nichols, 1920) and the Chilean hake (*Merluccius gayi gayi* Guichenot, 1848) fisheries. Both species are common in the diet of *O. flavescens* (George-Nascimento et al. 1985, Hückstädt et al. 2007). Therefore it could be expected that prey shortage is having an impact on the abundance, distribution and population structure of this species as a result of commercial fish overexploitation.

Other factors, such as environmental variability and/or anthropogenic threats may also impact the abundance and distribution of *O. flavescens* and explain why the situation observed in this study differs from that found in other parts of its distribution. For example, physical perturbation is a factor that could explain the reduction in one of the principal colonies, Lobería. More than 4100 individuals were counted in 1997 (Aguayo et al. 1998), whereas only 2621 individuals were found during 2007 (this study). Frequent landslides have occurred in this colony during the last ten years (Pavés et al. 2005), effectively reducing the area available and perhaps causing a high mortality or an emigration to other sites.

Túnez et al. (2008) found that variables related to human disturbance (e.g., people, cities) were negatively associated with sea lion breeding colonies distribution, suggesting that human presence has a negative influence on sea lion distribution. The central Chilean coast has the highest human population density in the country, which implies a high level of perturbation of sea lion colonies by fishermen, local people and tourists. For this reason, it is likely that the abundance of sea lions in central Chile will not increase if the animals cannot find suitable sites for resting, breeding, and rearing their young (Dans et al. 2004). In fact, in the Region de Valparaíso the number of

females and the pup production decreased between 1997 and 2007, suggesting human disturbance. This situation contrasts with the north and south of Chile, where the main colonies are difficult to access by sea or land, which protects them from anthropogenic disturbances and probably favors population recovery.

Understanding of the causal factors of variation in the status of long-lived and slow-reproducing species such *O. flavescens* is especially difficult, since long-term data are needed. Thus it is necessary to establish long-term demographic studies to quantify life-history parameters and detect trends. Accurate size estimations, status and distribution of the South American sea lion population are an essential baseline for developing management and conservation strategies.

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