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ARTICLE

Operational interactions between the South American sea lion *Otaria flavescens* and purse seine fishing activities in northern Chile

Interacciones operacionales entre lobo marino común *Otaria flavescens* y actividades de pesca de cerco en el norte de Chile

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Resumen.- Se analizan variables temporales, espaciales, ambientales, ecológicas y pesqueras que contribuyen a la variación del número de lobos marinos comunes (*Otaria flavescens*) que interactúan con las faenas de pesca de cerco industrial de la flota que opera en el norte de Chile (18°21′-24°00′S). Observadores científicos fueron embarcados en buques cerqueros entre febrero 2010 y diciembre 2011. Los datos fueron modelados usando modelos lineales generalizados (MLG) y modelos lineales generalizados mixtos (MLGM). Los resultados muestran que la variabilidad en el número de lobos marinos atraídos por las operaciones de pesca para alimentarse o intentar hacerlo, se explica por las variables: Hora del lance, Distancia a las colonias de lobos más cercanas, Temperatura superficial del mar, Especie objetivo del lance, Latitud y Número de aves marinas en torno a la embarcación. Luego del análisis detallado de las variables significativas, se puede concluir que los principales mecanismos que estarían actuando sobre la interacción entre lobos marinos y la operación de pesca serían: 1) una estrategia utilizada por los otáridos para disminuir el estrés por calor en el período reproductivo (verano), saliendo al mar en horas de máxima radiación solar (al mediodía), lo que incrementa notablemente su presencia dentro del cerco en lances realizados a menos de 20 millas náuticas de las colonias y 2) durante períodos cálidos, la presencia de ondas Kelvin descendentes disminuiría la disponibilidad de anchoveta (*Engraulis ringens*) en la zona, lo que provoca que la flota reoriente sus operaciones hacia el jurel (*Trachurus murphyi*), recurso que generalmente se captura a mayores distancias de la costa y de las colonias, disminuyendo significativamente la interacción con los lobos marinos.

Palabras clave: Lobo marino común, *Engraulis ringens*, Índice ENSO Multivariado, Pesca de cerco

Abstract.- This study analyzes temporal, spatial, environmental, ecological and fishing variables that contributed to variations in the number of South American sea lions (*Otaria flavescens*) that interacted with the industrial purse seine fishing operations in the north of Chile (18°21′-24°00′S). Scientific observers were placed onboard purse seiners vessels between February 2010 and December 2011. Data were modeled using generalized linear models (GLM) and generalized linear mixed models (GLMM). The results show that the variations in the number of sea lions attracted to fishing operations for feeding or attempting to feed on catches, depends on the following variables: Time of haul, Distance to the closest sea lion colony, Sea surface temperature, Target species of the haul, Latitude, and Number of seabirds circling the vessel. After detailed analysis of the significant variables, it can be concluded that the main mechanisms involved in the interaction between the sea lions and the fishing operations were: 1) a strategy used by the sea lions to decrease heat stress during the breeding period (summer) by entering the water when solar radiation is at its peak (around midday), thus notably increasing their presence within the nets during sets that are less than 20 nautical miles from the colonies; and 2) during warm periods the presence of downwelling Kelvin waves decreases the availability of anchovies (*Engraulis ringens*) in the area. This causes the fleet to change target species and focus on jack mackerel (*Trachurus murphyi*), which is generally captured further from the coast and the colonies, significantly decreasing the interaction with local sea lions.

Key words: South American sea lion, *Engraulis ringens*, Multivariate ENSO Index, Purse seine

INTRODUCTION

In areas where the coast is intensively utilized for harvesting and farming marine resources, there is a potential for interactions between fish-related industries and marine mammals (Bjørge *et al*. 2002). In this context interactions between pinnipeds and fishing operations have been widely documented in the international

literature (Ainley *et al.* 1982, Bonner 1982, Northridge 1985, Hückstädt & Antezana 2003, Goetz *et al.* 2008, Reyes *et al.* 2013). It is known that such interactions will occur in any place in the world where the distributions between pinnipeds and fishing activities overlap (Riedman 1990, Wickens 1995).

Purse seine fishing operations conducted in the north of Chile are denominated as Fishing Units XV, I and II for Chilean Administrative Regions for anchovy SUBPESCA 2011a)[1] and jack mackerel (SUBPESCA 2011b)[2]. In the last decade, landings of these fisheries have represented on average 23% of fish landings in Chile (SERNAPESCA 2002-2011)[3]. In the Administrative Regions mentioned, both species are caught by the same fleet, which comprises 66 purse seine fishing vessels, averaging 34 m of length (range between 22 and 44 m), and 400 m³ of hold capacity (range between 140 and 670 m³; Bernal *et al.* 2010)[4]. The operations of this fleet cover an extensive area from the port of Arica in the north (18°21'S; 70°19'W) to Antofagasta in the south (23°38'S; 70°24'W), and reaching 90 nautical miles from the coast (SUBPESCA 2011a). This area sustains a large population of South American sea lions (*Otaria flavescens*), with population reaching 59,657 individuals distributed over 44 breeding and haul-out colonies, thus representing 43.6% of the total population of this species in Chile (Bartheld *et al.* 2008).

Though sea lions are considered generalist predators, located on the upper levels of the food web (Beverton 1985), in the study area the South American sea lion feeds mainly on anchovy (Sielfeld *et al.* 1997, Sielfeld 1999, Arias-Schreiber 2003), which might lead to its interaction with the purse seine fishing fleet that targets this species.

Two types of interaction can be defined between marine mammals with fishing activities: a biological (indirect) interaction due to competition for food, and an operational (direct) interaction due to predation, where the animals enter the purse seine nets to feed, occasionally leading to their capture in the net. In general, operational interactions negatively affect the fishers by disturbing the fishing operation (increased work time), reducing catches and in some cases damaging fishing gear (Beverton 1985, Wickens 1995, Read 2008). The operational interactions can also be negative for marine top predators due to the possibility of the animals coming into direct contact with the fishing system, leading to injury and even death (Oliva *et al.* 2003, Read 2008, Fertl 2009, Reyes *et al.* 2013).

The effects of the interaction on the pinnipeds (seals, sea lions and walrus) can be positive, due to the obvious advantages of preying on a concentrated food source that is easy to access (Hückstädt & Antezana 2003). The fishing operations concentrate the food source; leading to a reduction in the amount of energy the sea lions spend in feeding (Fertl 2009).

The main operational interactions between sea lions and fisheries reported in Chile are predation of catch, bycatch and incidental mortality of sea lions (Hückstädt & Antezana 2003, Sepúlveda *et al.* 2007, Reyes *et al.* 2013), while the damage to fishing gear is important in artisanal fisheries (Sepúlveda *et al.* 2007). Hückstädt & Antezana (2003) reported an average interaction of 21 sea lions per set while Reyes *et al.* (2013), working with the trawling industrial fleet that operates in the south-central Chile indicates a catch rate of 1.2 sea lion/trawl⁻¹ and a mortality of 14.6%.

Bycatch records are used to determine the extent (temporal, spatial, by species) and magnitude (number of individuals per species) of these events, while studying the interactions, abundance of species that interact with fisheries, environmental and operational data are used to understand the nature of these interactions, and the importance of the factors that influence the level of these interactions. This is important for identifying specific mitigation solutions for the particular fishery (ACAP 2012).

Considering the importance of understanding the main mechanisms underlying the interaction processes between non-target species and fishing operations in the context of an ecosystem approach to fisheries management (FAO 2003), the current study aims to analyze different factors

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[1]SUBPESCA. 2011a. Cuota global anual de captura para las unidades de pesquería de anchoveta y sardina española, regiones XV, I y II, año 2012. Informe Técnico (R Pesq), 108 pp. Subsecretaría de Pesca y Acuicultura, Valparaíso.

[2]SUBPESCA. 2011b. Cuota global anual de captura de jurel, para las unidades de pesquería de la XV-II, III-IV, V-IX y XIV-X regiones, año 2012. Informe Técnico (R Pesq), 129 pp. Subsecretaría de Pesca y Acuicultura, Valparaíso.

[3]SERNAPESCA. 2002-2011. Anuarios estadísticos de pesca. Servicio Nacional de Pesca, Ministerio de Economía, Fomento y Reconstrucción, Chile. <http://www.sernapesca.cl/>

[4]Bernal C, A González, J Azócar, V Escobar, JC Saavedra, Z Young, O Guzmán, C Vera & M González. 2010. Programa de Seguimiento de las Principales Pesquerías Nacionales. Informe Final Proyecto: Investigación Programa Observadores Científicos, 2010. Instituto de Fomento Pesquero, 121 pp.

(temporal, environmental, spatial, ecological and fishing) which may contribute to variations in the number of South American sea lions that interact with the industrial purse seine fleet operating in the north of Chile.

MATERIALS AND METHODS

DATA COLLECTION

The study area comprises the waters of the Chilean Exclusive Economic Zone from the port of Arica (18°21'S; 70°19'W) to the south of the region of Antofagasta (23°38'S; 70°24'W). The data used were obtained by scientific observers (SO) from the Instituto de Fomento Pesquero (IFOP; Fisheries Development Institute), as part of the North Zone Pelagic Fishing Situation Research Program. Information was collected by observers aboard vessels from 258 hauls over 166 trips performed between February 2010 and December 2011. This observation effort (166 trips) represented 1% of the total effort applied by the fleet in the study period (Gabriela Böhm, pers. comm.). All the observations recording by SO were made during daylight sets. The SO recorded the date, time, and geographic position of all sets, as well as sea surface temperature (SST), target species and catch per species (in tons). A proxy of ship size, the storage capacity (ton) was also taken. During each haul, the SO counted the number of sea lions attracted by fishing operations for feeding or attempting to feed on catches. The number of other purse seine fishing vessels operating nearby was also recorded, where distance of observation is depending of sighting conditions (radius between 5 and 10 nautic miles). In order to count the sea lions, the protocol used was developed for the IFOP scientific observer program (Bernal et al. 2012)[5], which stipulates that the counting should be conducted on daylight sets, on the winch side (starboard), maintaining a fixed counting location at the moment the net is pulled onto the vessel, and in a 250 m hemisphere centered alongside the vessel (Melvin et al. 2009, Bernal et al. 2012). The time of the haul was used to estimate the intensity of the solar radiation, assuming that the level of intensity increases from dawn and reaches a maximum around midday, and then decreasing until sunset (Campagna & LeBoeuf 1988). Abundance and geographic positions of sea lions colonies data recorded on February 2007 by Bartheld et al. (2008) was used to calculate size and geographic position of the sea lion colony centers (Fig. 1). A sea lion colony center was defined as a group of colonies within a radius of 10 nautical miles around the biggest colony of the group, where the geographic position of the biggest colony was chosen as the location of the center, and the size of the center was defined as the sum of the individual groups of colonies. The computer software packages PBSmapping, RODBC and R language RColorBrewer (R Development Core Team 2006) were used to calculate the distance in nautical miles (nm) from the position at the start of the set and the position to the closest colony center. Finally, the Multivariate ENSO (El Niño Southern Oscillation) Index (MEI) was also included in the analysis. This index describes the atmospheric and oceanic conditions in the tropical Pacific Ocean (30°S-30°N), adjusted seasonally with regard to the reference period 1950-1993 (Wolter & Timlin 1998)[6]. Negative values of the standardized MEI represent cold conditions, while positive values represent warm conditions). All the aforementioned factors were input into the model as independent variables. The response variable of the model was defined as the number of South American sea lion feeding or attempting to feed on the catch from each haul (Table 1).

STATISTICAL ANALYSIS

Regression analysis was performed using generalized linear models (GLM) and generalized linear mixed models (GLMM). The response variable, the number of sea lions interacting with fishing operations, was given by counting data that was therefore discrete and non-negative. The GLM and GLMM allowed increased flexibility in the assumptions compared with traditional regression techniques, allowing direct specification of the error distribution (Gill 2001) and integration of continuous and categorical data into one single setting. The GLMM cover the dependence between the observations, incorporating two types of effects: direct effects (fixed effects), which are the explanatory variables; and the indirect effects (random effects), which include a set number of observations (hauls). The first represent the mean or 'typical' level of the response variable and the second represent the specific deviations by grouped

[5]Bernal C, J Azócar, A González, L Ossa, V Escobar, M San Martín, JC Saavedra, C Villouta, R Bello & J Castillo. 2012. Programa de Seguimiento de las Principales Pesquerías Nacionales. Informe Final Proyecto: Investigación Programa Observadores Científicos, 2012. Instituto de Fomento Pesquero, Valparaíso, 169 pp.
[6]<www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.html>

Figure 1. Overlap between the South American sea lion colony centers and the centers of upwelling and fishing activity in the study zone / Sobreposición entre los focos de colonias de lobos marinos comunes, respecto de los focos de surgencias y actividad pesquera en la zona de estudio
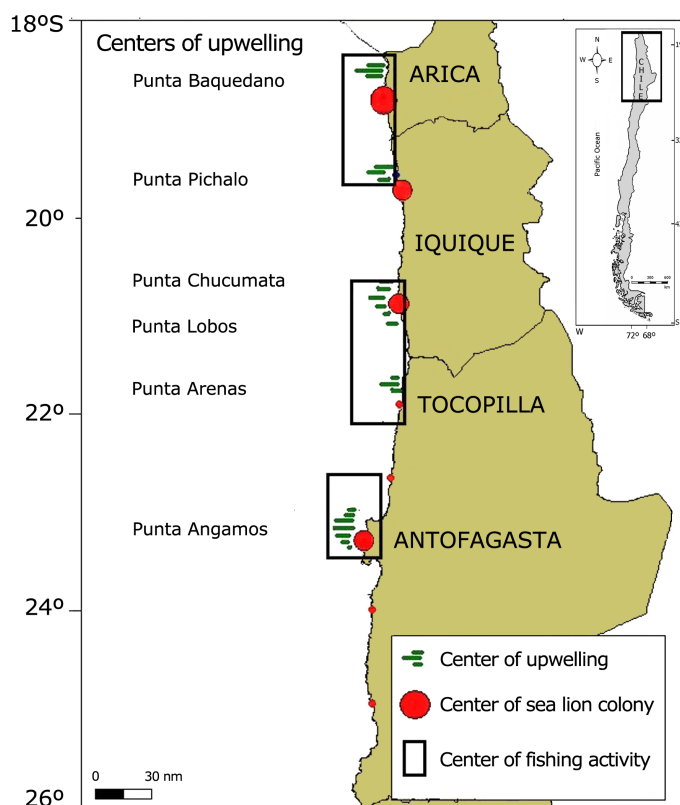
Table 1. Temporal, spatial, environmental, ecological and fishing variables included in the analysis / Variables temporales, espaciales, ecológicas y pesqueras incluidas en los análisis

Independent variables	Classes	Description
Temporal		
Year (annual)	2010-2011	Each year as category
Season (seasonal)	Summer-Autumn-Winter-Spring	Each season as category
Spatial		
Latitude (lat)	Continuous variable	Decimal degrees
Longitude (lon)	Continuous variable	Decimal degrees
Environmental		
Sea surface temperature (sst)	Continuous variable	Centigrade
Time of haul (time)	Continuous variable	Decimal number
MEI (mei)	Llnmf-Tt-Eenmf*	Each condition as category
Ecological		
Presence of seabirds (paves)	Yes-No	Discrete factor with two categories
Number of seabirds (naves)	Continuous	Whole number
Number of species of seabirds (nsps)	Continuous	Whole number
Size of colony centers (abund)	A-M-B**	Discrete factor with three categories
Distance to closest colony center (discol)	Continuous variable	Nautical miles
Reproduction period (reprod)	Inside-Outside***	Discrete factor with two categories
Fishing		
Number of vessels (nbuques)	Continuous variable	Whole number
Storage capacity (cbod)	Continuous variable	Cubic meters
Target species (spobj)	Anchovy-Jack mackerel	Discrete factor with two categories

The code for each variable is shown in brackets
* Lnmf=La Niña moderate to strong; T=transition; Enmf= El Niño moderate to strong
** A= high (> 8,000 individuals); M= medium (2,000-8,000 individuals); B= low (< 2,000 individuals)
*** Inside= during the reproduction period; Outside= outside the reproduction period

level, which are incorporated into the marginal distribution (Bates 2010). In addition to the GLM and GLMM analyses, generalized additive models (GAM) were also fit in order to allow the exploration of non-linear functional relations between the response variable and the independent variables. The GAM replaces the linear predictor of the GLM with an additive predictor allowing the combination of linear with non-linear and non-parametric relations (Hastie & Tibshirani 1990). Before adding the independent variables into the model, the absence of co-linearity was checked and the co-variables were put onto the same measurement scale by a process of standardization, in order to be able to compare their respective estimated coefficients. Poisson and negative binomial distributions were used to model the number of sea lions interacting with fishing operations as a function of the explanatory variables, because they are the best discrete probability distributions for describing count data (Crawley 2013). The models were first built with a Poisson distribution. After checking and confirming overdispersion, negative binomial distribution was used instead (Passadore et al. 2015). To choose the best-fitting model, explanatory variables were selected manually by deletion from a complex initial model (backward). Analysis of variance (ANOVA) was used to compare the resulting model with the previous model of the simplication procedure. When the removal of a variable produced a significant increase in model's deviance, that variable was considered statistically significant and, thus, returned and retained in the model. When the removal produced nonsignificant change in deviance, the variable was left out of the model (Passadore et al. 2015). Variables were sequentially removed until the model contained only significant terms; that model was considered as the minimum adequate model (Crawley 2013).

The following statistics packages were used for these analyses: lme4 (GLMM; Bates 2010), mgcv (GAM; Wood 2008), and MASS (GLM; Venables & Ripley 2002), available in R language (R Development Core Team 2011). The Akaike Information Criterion (AIC) was used to select the best model. AIC is a measure of the goodness of fit including parsimony. The model determined by parsimony is defined as a model that fits data and so it includes few parameters needed (Burnham & Anderson 2002).

RESULTS

The average number (± S.D.) of sea lions that were seen to interact over a total of 258 fishing sets was 55 (± 56) per haul, in a range of 0 to 290. A preliminary analysis of

the data allowed the exclusion of some variables, such as Longitude and Distance from the set to the coastline, since both were highly correlated with the variable Distance to closest colony center.

The final model showing the best fit was the GLMM that included the random effect of Fishing trip (IdViaje), within the random effect Fishing vessel (IdBuque). Due to the nested structure of the data, mixed modeling techniques were applied to allow the inclusion of correlation between observations of the same grouping level (Zuur et al. 2009). In our case, the hauls conducted during the same fishing trip are probably more related to each other than to hauls from other trips, and fishing trips of the same vessel are also more connected to one another than to trips of other ships.

When analyzing the abundance of sea lions interacting with the purse seiners in relation to explanatory variables, the model indicated the significant effect of Distance to closest colony center, SST, Latitude, Number of vessels operating in the area, Number of seabirds and Time of haul (Table 2). The number of sea lions interacting with the purse seiners tends to decrease when the number of vessels increased (Fig. 2a), and when fishing operations were performed further from the centers of the colonies (Fig. 2b). Moreover, sea lions showed a major level of interactions in the northern part of the study area and then decrease their number as we move south to finally present a secondary peak in the southern part of the area (Fig. 2c). Higher levels of abundance of sea lions attending

Table 2. Result of the fit of the GLMM model for the number of South American sea lions interacting with purse seine fishing operations in northern Chile / Resultado del ajuste del MLGM para el número de lobos marinos comunes interactuando con las operaciones de pesca de cerco en el norte de Chile

| Co-variable	D.F.	χ^2-value	P-value
Year	1	2.94	0.0864
Season	3	1.01	0.7998
Reproduction period	1	0.12	0.7310
Time of haul	2	309.39	<2.2e-16***
Distance to closest colony center	1	86.23	<2.2e-16***
Latitude	1	29.48	5.8e-08***
Number of vessels	1	0.08	0.7839
Storage capacity	1	1.58	0.2076
Sea surface temperature	1	57.36	3.6e-14***
Number of seabirds	1	14.33	1.5e-04***
Presence of seabirds	1	1.28	0.2579
Number of seabird species	1	3.64	0.0565
Target species	1	44.31	2.7e-11***
MEI	2	0.06	0.9683
Size of colony center	2	0.32	0.8502
Number of vessels:MEI	3	238.16	<2.2e-16***
Distance to colony center:Time of haul	2	173.38	<2.2e-16***
Target species:MEI	2	71.70	1.2e-15***

D.F.: degrees of freedom
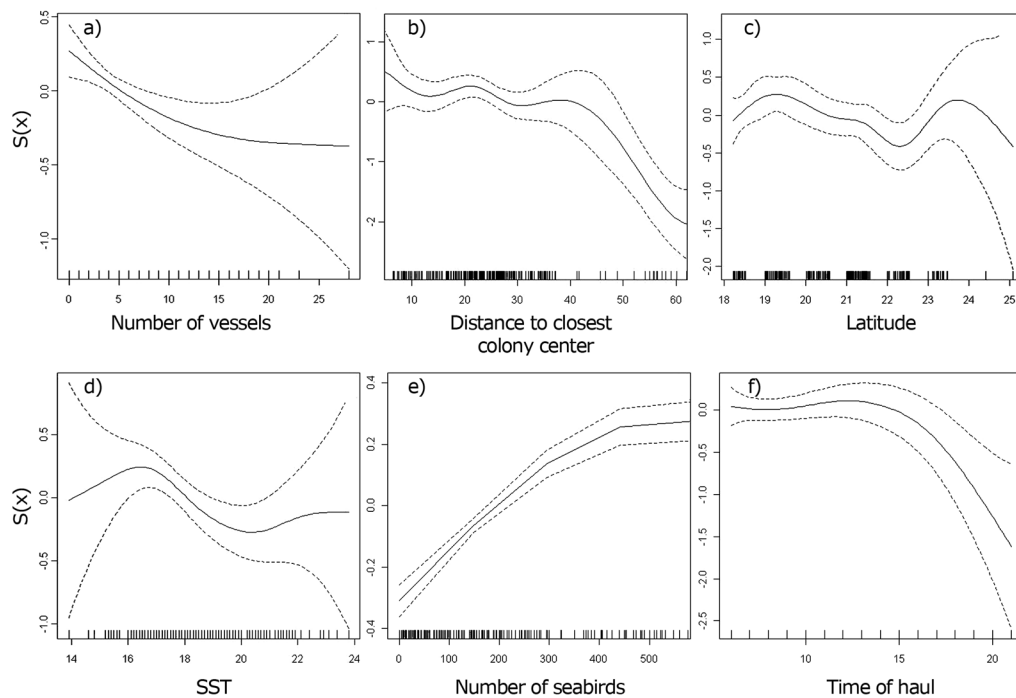
Figure 2. Graphs of the GAM fit. a) Number of vessels, b) Distance to closest colony center, c) Latitude, d) SST, e) Number of seabirds, f) Time of haul; S(x) represents the smoothed spline function of the predictor variable / Representaciones gráficas del ajuste del MAG. a) Número de buques, b) Distancia al centro de colonias más cercana, c) Latitud, d) Temperatura superficial del mar, e) Número de aves marinas, f) Hora del lance; S(x) representa la función spline suavizada de la variable predictora indicada

the fishing operations were observed between 16 to 17°C of SST, and tends to decrease when the SST increased (Fig. 2d). Furthermore, the number of sea lions interacting increases according as seabird abundance attending purse seine vessels increases (Fig. 2e). Time of haul showed higher values of sea lion interaction around midday and early afternoon (Fig. 2f). Finally, the level of interaction of sea lions was significantly higher (Wilcoxon rank sum test; P-value < 0.001; Fig. 3) when the fleet was capturing anchovy (mean 59 sea lions per set), regarding fishing operations on jack mackerel (mean 29 sea lions per set). The operation over anchovy was more coastal (mean 20 nm from coast), that over jack mackerel (mean 34 nm from coast).

High significance was found in the interaction of the variables Distance from haul to the closest colony center and Time of haul, where an important increase in the number of sea lions was observed around midday during sets that took place less than 20 nm from a colony center during the breeding period, from mid-December to mid-March (Fig. 4a). This effect disappears in non-reproductive period, where were observed similar levels
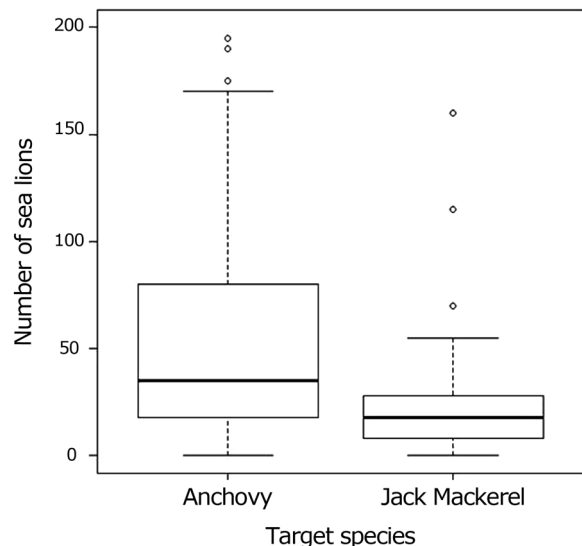

Figure 3. Boxplot of the number of sea lions interacting with fishing differentiated by target species / Box plot del número de lobos marinos comunes interactuando según especie objetivo
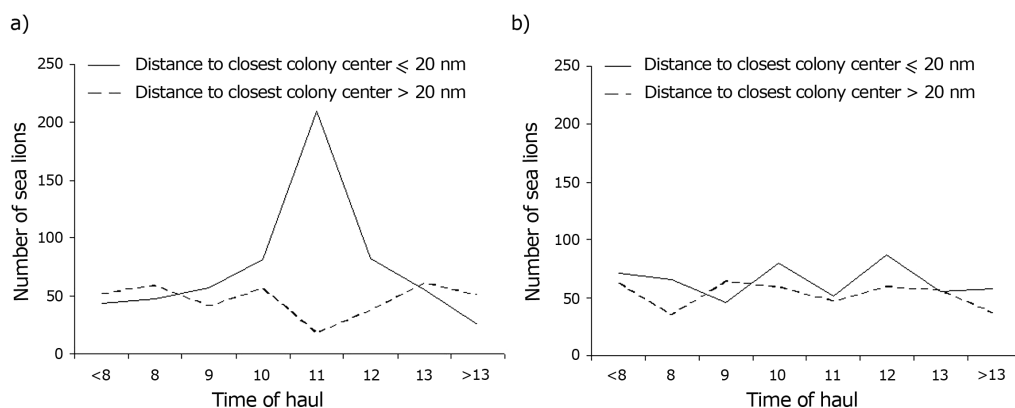
Figure 4. Graphs of the interaction between the Distance to the closest colony center and Time of haul: a) During breeding season, b) During non-breeding season / Representación gráfica de la interacción entre Distancia al foco de colonias más cercana y Hora del lance. a) Periodo reproductivo, b) Periodo no reproductivo
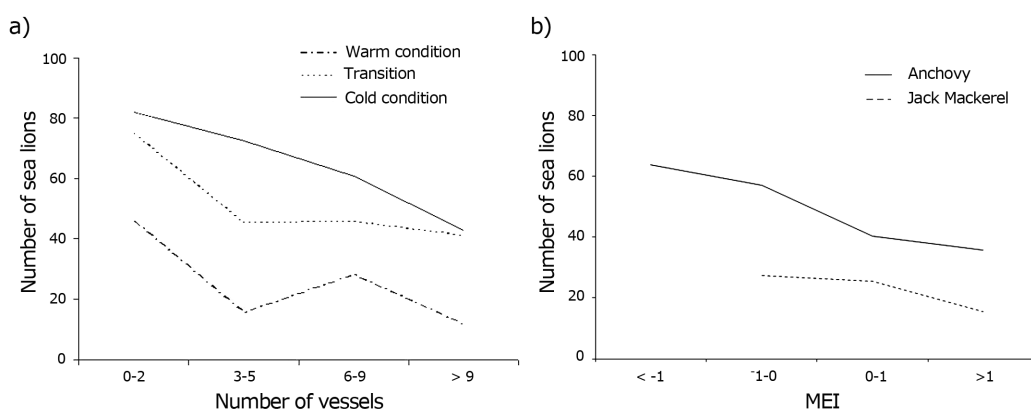

Figure 5. Graphs of interactions based on the GLMM fit. a) Number of vessels-MEI, b) Target species-MEI / Representaciones gráficas del ajuste del MLGM. a) Número de buques-MEI, b) Especie objetivo-MEI

in the abundance of sea lions during sets that took place to less and more than 20 nm from a colony center (Fig. 4b).

The individual contribution of the Number of vessels operating in the area and MEI was not significant since a large part of its effect is already considered in the interaction between these variables, which was highly significant, showing an escalated effect on the response variable for different levels of MEI (Table 2; Fig. 5a). The interaction between target species and MEI showed that the abundance of sea lions decreased as we move from cold conditions (negative values of the standardized MEI), to warm conditions (positive values of the standardized MEI), for both target species (Fig. 5b).

DISCUSSION

The association of the sea lions with coastal fisheries has been recorded previously in virtually all areas where breeding and non-breeding colonies occur (Bastida *et al.* 2007). Feeding of marine mammals in association with fishing operations is a learned behavior leading to the increase of the number of individuals seeking out fishing systems to find food easily. According to Königson *et al.* (2006), a prior feeding experience may encourage sea lions to return to feeding areas where they have been successful. It has been suggested that this type of feeding behavior is transferred from generation to generation by observation and participation (Fertl & Leatherwood 1997).

In our study, the average number of sea lions interacting with purse seine operations was 55 per haul, which is more than the figure reported by Hückstädt & Antezana

(2003) for the purse seine fleet targeting jack mackerel in the VIII region of Chile (36°00′S-38°30′S), which reported an average of 21 individuals per haul (range: 0-50). This difference may be explained in part by the difference in the size of sea lion populations in each zone. For the area from Arica to Antofagasta the population has been estimated at 59,657 individuals (Bartheld *et al.* 2008), while in the area from Cobquecura to Mocha Island in the VIII region, this value is only 8,189 individuals (Sepúlveda *et al.* 2011). In fact, in the former area there are colonies (Punta Lobos, Punta Piojo and Bandurrias del sur) with populations that exceed the total estimated population for the entire VIII region (Bartheld *et al.* 2008). Another factor that can explain the observed differences is the fact that sea lion in the south-central area of Chile interact mainly with coastal purse seine fleet of small pelagic, in fact Muñoz *et al.* (2013) found Chilean herring (*Strangomera bentincki*) as the main food items of sea lions in this area.

The result of the variable Distance to the closest colony center is in agreement with the findings of other studies (Szteren & Páez 2002, Smith & Baird 2005, Sepúlveda *et al.* 2007). This inverse correlation is partly explained by the fact that the feeding areas of the sea lions are fundamentally shallow-coastal waters (Hevia 2013, Hückstädt *et al.* 2014), and also the females need to remain close to their offspring (Smith & Baird 2005). The distance from the set to the colony center also interacted significantly with the variable Time of haul, which is an indicator of sunlight intensity, showing an increased number of sea lions in sets conducted around midday and at least 20 nm from the colony centers during breeding period. This effect disappears in non-reproductive period, where were observed similar levels in the abundance of sea lions during sets that took place to less and more than 20 nm from a colony center. This can be understood as part of a strategy used by the animals to reduce heat stress during breeding periods by entering the sea before the sun reaches its highest point in the sky (midday) and returning to land in the late afternoon, thus decreasing their exposure to heat during the hours around midday (Soto *et al.* 2006). According to Campagna & LeBoeuf (1988), this strategy is a behavioral adaptation seen in otariids living in tropical and subtropical areas, which are exposed to intense solar radiation and high air temperatures during the breeding period. This behavior has been observed in females in Peru (Soto *et al.* 2006) and young individuals in Chile (Sepúlveda *et al.* 2012).

One of the main sources of variation in the Humboldt Current System derives from coastally trapped Kelvin Waves (KW) which are originates by wind variations in the central and western equatorial Pacific (Pizarro *et al.* 2001), where the type of wind (eastern or western winds) determines whether an equatorial KW will upwell or downwell the thermocline often tens of meters (Bertrand *et al.* 2008). The KW are coastally trapped by the force of the rotation of the earth (Coriolis) along the continental platform or shelf (Clarke 1983, 1992). During a warm period the KW are in downwelling conditions, while during a cold period the KW are in upwelling conditions (Chavez *et al.* 2008).

The behavior of the co-variable MEI (one month delayed) showed that the number of sea lions interacting with purse seine fishing operations tends to decrease when the environment moves from cold (negative standardized values) to warm condition (positive values). According to Barber & Chavez (1983), during warm condition the anchovy tends to move to greater depths, below the warmer and less productive surface waters (Arntz & Fahrbach 1996), thus decreasing their availability to purse seine fishing nets (Ñiquen & Bouchon 2002, Bertrand *et al.* 2004). This causes the fleet to alter the focus of the operations to the jack mackerel, which is generally sought further from the coast and the sea lion colonies.

It has also been observed that during warm condition the abundance of the anchovy decreases and they move to greater depths, which means that the sea lions must expend more energy per unit of prey consumed, which would explain why the anchovy become less relevant to their diets during this period, where they are replaced by demersal species (Soto *et al.* 2006). The variation in the availability of anchovy induced by warm condition effects, affects higher predators such as fishing vessels and sea lions, which modify their target species in adverse conditions. Sets targeting anchovy went from 97% during cold condition to 48% during warm condition. This causes a decrease in the interaction with sea lions, though this can also be explained by the high significance of interaction between variables such as target species and MEI, or between number of vessels and MEI, where in the latter case the number of vessels has a clear mitigating effect on intraspecific competition of sea lions during cold condition, by decreasing the presence of the animals with the increase in the number of vessels operating in the zone. This effect disappears during warm condition due to the decrease in the number of sea lions interacting with the fishing operations.

The co-variable SST showed an inverse relation with the number of sea lions indicating that the foraging activities of these marine mammals is related to coastal upwelling, more than to oceanic factors, which is explained by the distribution of their main prey, the anchovy, a species that is associated with coastal upwelling (Swartzman *et al.* 2008). In fact, 84% of the catches of anchovy are obtained less than 20 nautical miles from the coast (Böhm *et al.* 2012)[7].

The number of seabirds present in the fishing operations was also highly significant, with an increase in the number of sea lions along with the increase in the number of marine birds. This correlation can be explained in two ways; firstly, most seabirds registered during the study are coastal species (mainly seagulls, pelicans, boobies and cormorants), whose numbers tend to decrease as the fishing activities move further from the coast, and secondly, it is known that pinnipeds are predators with highly developed cognitive abilities (Gentry 2002), meaning that they are able to associate a higher number of seabirds around a fishing vessel with easier access to a large amount of potential prey concentrated in a small area (Hückstädt & Antezana 2003).

The behavior seen in the response variable respecting to the co-variable Latitude is related to the pattern shown by the colony sizes measured by Bartheld *et al.* (2008), *i.e.,* larger colonies present in the northern part of the study area (19°S) with a continual decrease as we move further south, reaching minimum values around the port of Tocopilla (22°04'S; 70°12'W), and then resurging around the Mejillones peninsula (23°06'S; 70°27'W).

Further information of this type regarding the artisanal and industrial purse seiners that operate in the south-central part of Chile should also be gathered, and actions necessary to free animals captures must also be studied and defined.

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