Journal of the Marine Biological Association of the United Kingdom, 2013, 93(2), 489–494.
doi:10.1017/S0025315412001282

First observations of operational interactions between bottom-trawling fisheries and South American sea lion, *Otaria flavescens* in south-central Chile

PABLO REYES[1], RODRIGO HUCKE-GAETE[2,3,4] AND JUAN PABLO TORRES-FLOREZ[3,5]

[1]Endesa, Grupo Líneas Base, Especialidad Ingeniería Ambiental, Gerencia Ingeniería Latam, Santa Rosa 79, Piso 9, Santiago, Chile, [2]Instituto de Ciencias Marinas y Limnologicas, Universidad Austral de Chile, Casilla 567, Valdivia, Chile, [3]Centro Ballena Azul, Carlos Anwandter 624, Casa 4, Valdivia, Chile, [4]Centro de Investigación en Ecosistemas de la Patagonia (CIEP), Portales 73, Coyhaique, Chile, [5]Instituto de Ciencias Ambientales y Evolutivas, Universidad Austral de Chile, Casilla 567, Valdivia, Chile

This paper presents results of a study conducted on the trawling industrial fishery fleet of Merluccius gayi *in south-central Chile, and the resulting interactions with the South American sea lion* (Otaria flavescens). *This study is based on observations made during September 2004, when incidental sea lion catch in the trawls was 6.3 sea lions/working day (1.2 sea lions/trawl^{-1}). A total of 82 animals were incidentally caught, of which 12 were found dead, and the 70 remaining suffered from internal bleeding and/or fractures as a result of their capture. 83.3% of the fatalities occurred during nocturnal trawls, which comprise 30% of all observed trawls. Possible mechanisms of sea lion take are discussed. This note presents the first records of sea lions incidental by-catch by the trawler fleet along the south-east Pacific coast of Chile.*

Keywords: by-catch, marine mammal, *Merluccius gayi*, fishing mortality

Submitted 4 July 2012; accepted 29 July 2012; first published online 21 September 2012

INTRODUCTION

Interactions between marine mammals and fisheries can take several forms, which are divided principally into operational interactions in which the marine mammals have physical contact with fishing gear (Beverton, 1985), and interactions through trophic pathways (Shima *et al.*, 2000). Operational interactions can lead to the incidental catch of marine mammals; this is also referred to as incidental take or by-catch, and occurs when any unwanted, live or dead marine mammal is caught during fishing operations (Waring *et al.*, 1990; Alverson *et al.*, 1994). With an increasing global human population and the corresponding need for fish resources, fishing in both coastal and pelagic waters will likely increase, intensifying the interactions between fisheries and marine mammal populations due not only to competition for resources but also to simple spatial overlap (Read, 2005; Read *et al.*, 2006). In this sense, fisheries by-catch has been identified as a primary driver of population declines in several species of marine megafauna (e.g. elasmobranchs, mammals, seabirds and turtles) (Lewison *et al.*, 2004). These by-catches not only affect the survival of specific populations but also the trophic structure, species assemblages, and pathways of energy flow in the ecosystems (Pauly *et al.*, 1998; Myers & Worm, 2003).

Corresponding author:
J.P. Torres-Florez
Email: jptorresflorez@uach.cl

Despite the recognition of the marine top predator by-catch problem, the knowledge about the impact caused by fisheries to marine mammals is fragmentary, and in most of the world fisheries it is unknown and globally underscored (Read *et al.*, 2006) highlighting the need for by-catch reduction strategies to recover depleted populations (Cox *et al.*, 2007; Wallace *et al.*, 2010). Although marine mammals by-catch is a common event in fisheries worldwide this is not necessarily unsustainable, especially in those large population species that exhibit high rates of potential population growth, as is the case of some pinnipeds (Read, 2008). Although there is a large population size exhibited by some pinniped species, little knowledge exists about the impact these species are facing and there is even less knowledge about the sources responsible for this by-catch.

In this context, Chile being one of the major fishing countries worldwide (FAO, 2010) it is necessary to evaluate the different kinds of interactions between fisheries and marine mammals on the Chilean coast, as well as to understand what can be the possible effects of these interactions on the survival of marine mammals in this region. Although a number of studies have reported interactions between marine mammals and humans in Chile (Northridge, 1984, 1991; Hückstädt & Antezana, 2003; Moreno *et al.*, 2003; Hückstädt & Krautz, 2004; Sepúlveda *et al.*, 2007a; Goetz *et al.*, 2008), none of them report any interaction between trawling fisheries operations and marine mammals.

The South American sea lion (*Otaria flavescens*) is one of the most frequently encountered and abundant marine mammals on the Chilean coast, reaching approximately

140,000 individuals (Aguayo-Lobo *et al.,* 1998; Venegas *et al.,* 2002; Sepúlveda *et al.*, 2007b, 2011; Bartheld *et al.*, 2008; Oliva *et al.*, 2008). Due to its large population size and the proximity of fishing grounds to the coast, interactions with artisanal and industrial fisheries have been documented in Chile (e.g. Torres, 1979; Sielfeld, 1999; Hückstädt & Antezana, 2003; Sepúlveda *et al.,* 2007a; Goetz *et al.,* 2008). Research conducted in central Chile on purse seining ships fishing for jack mackerel (*Trachurus symmetricus*) has shown that an important relationship exists between the ships and *O. flavescens*, sometimes resulting in fatalities (Hückstädt & Antezana, 2003). Other studies carried out in southern Chile, indicate that the fisheries targeting Chilean anchovy (*Engraulis ringens*) and Chilean herring (*Strangomera bentincki*) can cause sea lion mortality, since *O. flavescens* individuals trapped within the nets are crushed by the hydraulic winches lifting the nets from the ocean and onto the ship (Arata & Hucke-Gaete, 2005). Finally, studies performed on long-line fleets targeting the Patagonian toothfish (*Dissostichus eleginoides*) have provided evidence that this activity does not cause sea lion mortality, except in cases when high-calibre firearms are used to frighten or kill approaching sea lions while hauling the catch (Moreno *et al.,* 2003; Arata & Hucke-Gaete, 2005). This practice, however, is isolated due to the lower presence of *O. flavescens* on these fishing grounds, which are generally far from the coast.

Globally, little published information exists about the number of marine mammals caught in trawl nets (Fertl & Leatherwood, 1997). Incidental take of marine mammals (pinnipeds) during trawl operations has received attention in several countries, including Australia (Shaughnessy & Davenport, 1996), South Africa (Shaughnessy & Payne, 1979), USA (Alaska) (Perez & Loughlin, 1991), Canada (Pemberton *et al.,* 1994) and Argentina (Romero *et al.,* 2011). However, no previous information exists about the interaction between trawling fisheries and *O. flavescens* along the South Pacific. In Chile the trawl fishery fleet is the second largest, after the pelagic purse-seine fishery, with a total of 213 to 226 ships (SERNAPESCA, 2010). The levels of interaction between industrial trawling fisheries and marine mammals that approach the vessels in search of discarded fish have not yet been assessed in Chile. In this sense, and considering the high importance of this fishery along south-central Chile, this short note aims to make a preliminary description and set the first record of *O. flavescens* mortality caused by interactions with the trawling fleet in this area and explore its possible relationship with different fisheries variables (e.g. time of setting and hauling of the trawl, depth of the trawls, target species biomass and geographical position).

MATERIALS AND METHODS

Study area and sampling procedure

Between 19 and 28 September 2004 (austral spring), direct observations on incidental catch of South American sea lion (*Otaria flavescens*) were made by a scientific observer on-board of an industrial trawler. Fishing effort was concentrated along the continental shelf in south-central Chile (37–40°S) in the South Pacific common hake (*Merluccius gayi*) main fishery ground. The trawling vessel was 48 m long and the net used measured 30 m wide and 8 m high across the mouth with an 11-mm mesh. A total of 69 trawls were performed on or immediately above the sea floor at a speed of 3.7 knots/h^{-1}. All trawls except one occurred between five and twenty-five nautical miles from the coast. 70% of the trawls were completed during daylight hours and the remaining 30% at night. The observation effort was made from the fishing bridge and accounted for ~95% of time during each trawl. Each trawl observation was made to calculate the number of sea lion captures as well as the state of the animals (dead or alive). Additional observations were performed via visual inspection of the net after each trawl and within the ship's hold.

Variables such as time of setting and hauling of the trawl, depth of the trawls, target species biomass, geographical position and distance to the nearest rookery were obtained with the aim to evaluate their relationship with the caught sea lions (Table 1).

Data analyses

Sea lions' mortality difference between day and night trawls was evaluated taking into account the time of setting and hauling of the net. The difference of mortality between both periods was evaluated using a contingency table in which it was assumed that the number of dead animals between day and night trawls would be equal. This last was evaluated with a correction by the number of trawls during each period.

With the aim to evaluate the potential predictors of caught sea lions and in particular dead sea lions, we used the variables described before (target species biomass (kg), duration time of the trawl (minutes), depth of the trawl and Beaufort state measured during the hauling of the net, and distance to the closest rookery). Dead sea lions' response to the predictors was assessed through multiple regression analyses, using a mixed multiple regression model of continuous and discrete variables. None of the predictors were strongly correlated ($R^2 < 25\%$). Analyses were run on Statistica 7.0 (StatSoft, 2004).

Total discarded fish by-catch biomass was estimated through direct evaluation of total catch volume aided by markings on the net, minus the actual retained catch that was of legal length (≥30 cm).

RESULTS

A total of 82 sea lions were observed entangled in the nets and subsequently hauled onto the ship's deck during this study. Twelve of these individuals were found dead (Table 1). Out of the 82 total caught sea lions, 33% were caught in a single trawl that caught 27 individuals (26 September 2004), two of which were found dead (Figure 1).

During the 10 days of the study, incidental sea lion capture in the trawling nets was 6.3 sea lions/working day^{-1} (1.2 sea lions/trawl^{-1}) ranging from zero to 27 caught per trawl. The sea lions that were alive when released onto the ship's deck were returned to the ocean. The total mortality resulted in an average of 0.92 sea lion fatalities each working day, ranging from 0 mortalities to 3 dead animals per day.

Eighty-three per cent of observed sea lion mortalities occurred during nocturnal trawls. Total sea lion mortality rate per ton of catch during the observation period (including

Table 1. Summary of *Otaria flavescens* mortality during bottom-trawling operations in southern Chile, as observed during September 2004.

Date	Setting time	Hauling time	Depth (m)	Wind/ Beaufort	Setting coordinates	Hauling coordinates	*Merluccius gayi* catch (kg)	Distance to nearest rookery (nm)	Sea lion mortality
09/19/04	23:00	1:30	100	S-4	39°10′13″ S 73°35′95″W	39°01′85S 73°42′39″W	1.35	25.22	1
09/20/04	2:10	4:50	147	SW-4	39°02′22″S 73°44′18″W	39°11′58″S 73°44′84″W	4.5	24.63	3
09/22/04	11:50	14:40	146	SW-2	39°10′54″S 73°46′18″W	39°02′01″S 73°42′79″W	4.59	25.32	2
09/23/04	0:40	2:45	112	SW-2	39°04′67″S 73°39′92″W	39°11′14″S 73°35′64″W	18.75	17.98	1
09/23/04	19:30	22:05	116	SW-2	39°06′20″S 73°39′76″W	39°14′61″S 73°35′49″W	2.1	16.90	1
09/26/04	23:40	2:40	116	S-2	39°03′36″S 73°40′66″W	39°02′34″S 73°74′72″W	7.44	38.95	2
09/28/04	20:15	23:00	110	S-2	39°16′49″S 73°38′34″W	39°05′72″S 73°37′86″W	14.34	22.24	2

Fig. 1. South American sea lions caught in a single trawl along the continental shelf in south-central Chile during September 2004.

diurnal and nocturnal trawls) was 0.012 mortalities/ton^{-1}. The diurnal mortality rate was 0.002 mortalities/ton^{-1}, and the nocturnal mortality rate rose to 0.033 mortalities/ton^{-1}. Upon completion of the study, the total average sea lion mortality rate out of all 69 trawls was 0.17 mortalities/trawl^{-1} ranging from 0 to 3 mortalities per trawl. The daytime mortality rate was 0.041 mortalities/trawl^{-1} and the night-time mortality increased to 0.476 mortalities/trawl^{-1}. These data indicate that a difference exists between the mortality rate during nocturnal tows and diurnal tows ($\chi^2_{0.05.1} = 0.6274$ ($P = 0.5717$)) possibly due to the sea lions' poor night-time vision that facilitates their entanglement in the nets.

This occurred mainly because of the rapid discard of by-catch and target species under legal extraction size (which accounted for 57.8% of the total catch during the sampling period; 575,082 kg of discarded hake). A large number of sea lions followed the ships during operations with the aim to take advantage of this situation.

https://doi.org/10.1017/S0025315412001282 Published online by Cambridge University Press

A multiple regression model did not suggest any positive association between dead sea lions and the predictor variables, nor interaction between all of them and the response variable ($P = 0.07$).

DISCUSSION

Considering that thirty-nine industrial trawlers are currently operating in southern central Chile, it is thought that each ship would be capturing the same amount of sea lions that were found in this study. However, the extrapolation of the sea lion mortality results presented here is not straightforward since some of these ships operate far from the coast, and therefore far from South American sea lion rookeries, such as those fishing for orange roughy (*Hoplostethus atlanticus*) more than 600 nautical miles into the open ocean (Lillo *et al.,* 2003; Niklitschek *et al.,* 2005). Although sea lions are capable of travelling hundreds of kilometres, it is uncommon to observe them beyond the continental shelf (Campagna *et al.*, 2001) where orange roughy and other trawling fisheries operate. Although there was no relationship between the dead animals and the proximity to a rookery, it should be highlighted that there are 33 rookeries in the fishing area of the south Pacific common hake. It must also be considered that the study occurred during September, at the end of winter and beginning of spring in the Southern Hemisphere, when the number of sea lion individuals at sea would be higher than in summer because they have not yet formed reproductive colonies (Aguayo & Maturana, 1973). Despite these records it is incorrect to extrapolate them to other situations because of the variability of the fishery and also of the sea lion foraging activity.

Based on field observations, two plausible explanations for elucidating how sea lions are trapped in trawl nets are stated below, both of which are related to the sea lions' positioning at the ship's stern as they follow the vessel during the fishing operations. The first explanation involves the setting of the trawl net. Sea lions often follow the ship alongside the stern, the location from which the net is launched. When the net is deployed, it can fall over a sea lion, entangling the animal and causing it to sink to the sea floor (90 and 250 m deep) where the net will operate. The remaining sea lions approach the net as it is drawn across the sea surface away from the ship prior to being submerged to the sea floor. They attempt to consume fish remains that have accumulated within the net from previous operations, since it is not cleaned between trawls. When the net is far enough away from the ship and ready to be submerged, the sea lions that have become entangled during their feeding attempts sink below the surface along with the net. All sea lions caught in the nets during the setting process are either killed by asphyxiation from remaining underwater for 45 minutes to three hours (an average of $1.3\ h^{-1}$) or by the physical stress of being crushed by the tons of catch entering the net during the trawl (between 1.3 and 18.7 tons during the study).

The second explanation (of what could cause the death of sea lions) is related to the hauling process and is directly affected by the ship's speed during the procedure. The ship reaches a maximum cruising speed of ten knots, but only in the trajectory between the home port (in this case, San Vicente: 37°S) and the trawling grounds (39°S). Once the boat has arrived at the trawling grounds, it decreases its operation speed to 5 knots/h^{-1}. This speed allows sea lions to swim alongside the ship without falling behind. Upon setting the net and beginning the trawl, the ship further decreases its speed to 3.7 knots/h^{-1}, enabling the sea lions to continue following the ship. The net, after completing the trawl and capturing the catch, is brought to the surface. Upon reaching the surface, the net is generally 200 or 300 m away from the trawler and is drawn toward the ship with the help of powerful auxiliary motors. This moment is crucial for the sea lions as they approach the net to feed on the fish dropping from it. Some sea lions even take advantage of an easy feeding opportunity and increase their catch by extracting fish from the net's partially open mouth; these are the individuals that enter the net and get trapped.

An important piece of information not available from the fisheries agencies is the amount of discarded fish, which could serve as a principal attractor for sea lions to ships. According to personal communications with workers at the Fisheries Department of the Chilean Subsecretary of Fisheries, the amount of discarded fish during the year of the study was unusually high, which could have caused an increase in the number of sea lions around ships, thereby increasing fatalities. This situation, similar to those previously described, is based on too many assumptions to address with certainty sea lion mortality caused by interactions with trawling ships. Although there was no interaction between the predictor variables and the dead sea lions, it must be recognized that a potentially severe problem does exist, along with a scarcity of studies focused on this topic.

At present by-catch mitigation has to been tackled mainly on a species-by-species or at best a gear specific basis. This is, in part, a reflection of the need for different approaches to manage the individual environmental issues found in each fishery and with each species.

In light of the records presented, we recommend that competent agencies support long-term and geographically broad studies specifically addressing the problem described in order to define it fully and explore possible solutions. Similar studies have already been completed assessing impacts on marine mammals in south-central Chile caused by long-line fishing (Moreno *et al.,* 2003; Hucke-Gaete *et al.,* 2004), purse seining and the development of salmon aquaculture (Oliva *et al.,* 2003).

Thus, having in mind human dependence on goods and services from the oceans, as well as the increasing human population, further studies have to be carried out in order to establish a framework of trade-offs between different human uses and the least possible ecological impact to the ecosystem (Halpern *et al.,* 2008).

ACKNOWLEDGEMENTS

We acknowledge the outstanding cooperation provided by the captain of the vessel, Captain Enrique Quiero and his crew. We are also indebted to the Fishery Research Institute (INPESCA) for providing logistic assistance.

REFERENCES

Aguayo A. and Maturana R. (1973) Presencia del lobo marino común (*Otaria flavescens*) en el litoral chileno. *Biología Pesquera Chile* 6, 45–75.

https://doi.org/10.1017/S0025315412001282 Published online by Cambridge University Press

Aguayo-Lobo A., Díaz H., Yánez J., Palma F. and Sepúlveda M. (1998) Censo poblacional del lobo marino común en el litoral de la V a la IX Regiones. *Informe Final, Proyecto FIP* 96/51, 1–214.

Alverson D., Freeburg M., Murawski S. and Pope J. (1994) A global assessment of fisheries by-catch and discards. *FAO Fisheries Technical Paper* 339, 1–233.

Arata J. and Hucke-Gaete R. (2005) Muerte silenciosa en el mar: la pesca incidental de aves y mamíferos marinos en Chile. *Oceana* 10, 1–86.

Bartheld J.L., Pavés H., Vera C., Manque C. and Miranda D. (2008) *Cuantificación poblacional de lobos marinos en el litoral de la I a IV Región*. Informe Técnico Fondo de Investigación Pesquera IT/2006-50.

Beverton R. (1985) Analysis of marine mammal–fisheries interactions. In Beddington J.R., Beverton R.J.H. and Lavigne D. (eds) *Marine mammals and fisheries*. London: George Allen & Unwin, pp. 3–33.

Campagna C., Werner R., Karesh W., Marin M., Koontz F., Cook R. and Koontz C. (2001) Movements and location at sea of South American sea lions (*Otaria flavescens*). *Journal of Zoology* 257, 205–220.

Cox T, Lewison R., Zydelis R., Crowder L., Safina C. and Read A. (2007) Comparing effectiveness of experimental and implemented by-catch reduction measures: the ideal and the real. *Conservation Biology* 21, 1155–1164.

FAO (2010) *The state of world fisheries and aquaculture 2010*. Rome: FAO Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, 218 pp.

Fertl D. and Leatherwood S. (1997) Cetacean interactions with trawls: a preliminary review. *Journal of Northwest Atlantic Fishery Science* 22, 219–248.

Goetz S., Wolff M., Stotz W. and Villegas M. (2008) Interactions between the South American sea lion (*Otaria flavescens*) and the artisanal fishery off Coquimbo, northern Chile. *ICES Journal of Marine Science* 65, 1739–1746.

Halpern B., Walbridge S., Selkoe K., Kappel C., Micheli F., D'Agrosa C., Bruno J., Casey K., Ebert C., Fox H., Fujita R., Heinemann D., Lenihan H., Madin E., Perry M., Selig E., Spalding M., Steneck R. and Watson R. (2008) A global map of human impact on marine ecosystems. *Science* 319, 948–952.

Hucke-Gaete R., Moreno C. and Arata J. (2004) Operational interactions between cetaceans and the Patagonian toothfish (*Dissostichus eleginoides*) industrial fishery off southern Chile. *CCAMLR Science* 11, 127–140.

Hückstädt L. and Antezana T. (2003) Behaviour of the southern sea lion (*Otaria flavescens*) and consumption of the catch during purse-seining for jack mackerel (*Trachurus symmetricus*) off central Chile. *ICES Journal of Marine Science* 60, 1003–1011.

Hückstädt L. and Krautz M. (2004) Interaction between southern sea lions *Otaria flavescens* and jack mackerel *Trachurus symmetricus* commercial fishery off Central Chile: a geostatistical approach. *Marine Ecology Progress Series* 282, 285–294.

Lewison R., Crowder L., Read A. and Freeman S. (2004) Understanding impacts of fisheries by-catch on marine megafauna. *Trends in Ecology and Evolution* 19, 598–604.

Lillo S., Rojas R., Tascheri R., Ojeda V., Olivares J., Balbontín F., Bravo R., Nuñez S., Braun M., Ortiz J., Torres P., Véjar P., Cubillos F. and Saavedra A. (2003) Evaluación hidroacústica del recurso merluza común en la zona centro-sur, 2002. *Informe Final, Proyecto FIP* 02/03, 1–648.

Moreno C., Hucke-Gaete R. and Arata J. (2003) Interacción de la pesquería del bacalao de profundidad con mamíferos y aves marinas. *Informe Final, Proyecto FIP* 01/31, 1–211.

Myers R.A. and Worm B. (2003) Rapid worldwide depletion of predatory fish communities. *Nature* 423, 280–283.

Niklitschek E., Boyer D., Merino R., Hampton I., Soule M., Nelson J., Cornejo J., Lafon A., Oyarzún C., Roa R. and Melo T. (2005) Estimación de la biomasa reproductiva de orange roughy en sus principales zonas de concentración, 2004. *Informe Final Proyecto FIP* 04/13, 1–159.

Northridge S. (1984) World review of interactions between marine mammals and fisheries. *FAO Fisheries Technical Paper* 251, 1–190.

Northridge S. (1991) An updated world review of interactions between marine mammals and fisheries. *FAO Fisheries Technical Paper* 734, 1–58.

Oliva D., Sielfeld W., Durán L., Sepúlveda M., Pérez M., Rodríguez L., Stotz W. and Araos V. (2003) Interferencia de mamíferos con actividades pesqueras y de acuicultura. *Informe Final, Proyecto FIP* 03/32, 1–227.

Oliva D., Sielfeld W., Buscaglia M., Matamala M., Pavés H., José Pérez M., Schrader D., Sepúlveda M., Urra A., Farias F., Inostroza P. and Melo A. (2008) *Plan de acción para disminuir y mitigar los efectos de las interacciones del lobo marino común (*Otaria flavescens*) con las actividades de pesca y acuicultura*. Informe Técnico Fondo de Investigación Pesquera IP-IT/2006–34.

Pauly D., Christensen V., Dalsgaard J., Froese R. and Torres F. Jr (1998) Fishing down the marine food webs. *Science* 279, 860–863.

Pemberton D., Merdsoy B., Gales R. and Renouf D. (1994) The interaction between offshore cod trawlers and Harp *Phoca groenlandica* and Hooded *Cystophora cristata* seals off Newfoundland, Canada. *Biological Conservation* 68, 123–127.

Perez M.A. and Loughlin T.R. (1991) Incidental catch of marine mammals by foreign and join venture trawl vessels in the U.S. EEZ of the North Pacific. *NOAA Technical Report NMFS* 104, 1–57.

Read A. (2005) By-catch and depredation. In Reynolds J., Perrin W., Reeves R., Montgomery S and Ragen T. (eds) *Marine mammal research, conservation beyond crisis*. Baltimore, MD: Johns Hopkins University Press, pp. 5–17.

Read A. (2008) The looming crisis: interactions between marine mammals and fisheries. *Journal of Mammalogy* 89, 541–548.

Read A., Drinker P. and Northridge S. (2006) By-catch of marine mammals in US and global fisheries. *Conservation Biology* 20, 163–169.

Romero M.A., Dans S., González R., Svendsen G., García N. and Crespo E. (2011) Solapamiento trófico entre el lobo marino de un pelo *Otaria flavescens* y la pesquería de arrastre demersal del golfo San Matías, Patagonia, Argentina. *Latin American Journal of Aquatic Research* 39, 344–358.

Sepúlveda M., Pérez M.J., Oliva D., Durán L.R., Sielfeld W., Araos V. and Buscaglia M. (2007a) Operational interaction between South American sea lions *Otaria flavescens* and artisanal (small-scale) fishing in Chile: results from interview surveys and on-board observations. *Fisheries Research* 83, 332–340.

Sepúlveda M., Oliva D., Pérez M.J., Moraga R., Urra A., Schrader D., Pavés H. and Buscaglia M. (2007b) *Censo poblacional de lobos marinos en el litoral de la V a IX Región*. Informe Técnico Fondo de Investigación Pesquera.

Sepúlveda M., Oliva D., Urra A., Pérez-Álvarez M.J., Moraga R., Schrader D., Inostroza P., Melo A., Díaz H. and Sielfeld W. (2011) Distribution and abundance of the South American sea lion *Otaria flavescens* (Carnivora: Otariidae) along the central coast off Chile. *Revista Chilena de Historia Natural* 84, 97–106.

SERNAPESCA (2010) *Anuario estadístico de pesca*. Valparaíso, Chile: Servicio Nacional de Pesca, Valparaíso. Available at: http://www.sernapesca.cl (accessed 1 July 2012).

Shaughnnesy A. and Payne I. (1979) Incidental mortality of Cape fur seals during trawl fishing activities in South African waters. *Fisheries Bulletin, South Africa* 12, 20–25.

Shaughnessy P. and Davenport S. (1996) Underwater videographic observations and incidental mortality of fur seals around fishing equipment in south-eastern Australia. *Marine and Freshwater Research* 47, 553–556.

Shima M., Hollowed A. and VanBlaricom G. (2000) Response of pinniped populations to direct harvest, climate variability, and commercial fishery activity: a comparative analysis. *Reviews in Fisheries Science* 8, 89–124.

Sielfeld W. (1999) Estado del conocimiento sobre conservación y preservación de *Otaria flavescens* (Shaw, 1800) y *Arctocephalus australis* (Zimmermann, 1783) en las costas de Chile. *Estudios Oceanológicos* 18, 81–96.

StatSoft, Inc (2004) *STATISTICA (data analysis software system), version 7*. Available at: www.statsoft.com (accessed 1 July 2012).

Torres D. (1979) Mamíferos marinos de Chile: antecedentes y situación actual. *Biología Pesquera, Chile* 11, 49–81.

Venegas C., Gibbons J., Aguayo A., Sielfeld W., Acevedo J., Amado N., Capella J., Guzmán G. and Valenzuela C. (2002) Distribución y abundancia de lobos marinos (Pinnipedia: Otariidae) en la Región de Magallanes. *Anales del Instituto de la Patagonia (Chile)* 30, 67–82.

Wallace B.P., Lewison R.L., McDonald S.L., McDonald R.K., Kot C.Y., Kelez S., Bjorkland R.K., Finkbeiner E.M., Helmbrecht S. and Crowder L.B. (2010) Global patterns of marine turtle by-catch. *Conservation Letters* 3, 131–142.

and

Waring G., Gerrior P., Payne P., Parry B. and Nicolas J. (1990) Incidental take of marine mammals off the Northeast United States, 1977–88. *Fishery Bulletin* 88, 347–360.

Correspondence should be addressed to:
J.P. Torres-Florez
Instituto de Ciencias Ambientales y Evolutivas
Universidad Austral de Chile, Casilla 567, Valdivia, Chile
email: jptorresflorez@uach.cl

https://doi.org/10.1017/S0025315412001282 Published online by Cambridge University Press