Title

Designing Marine Protected Areas for the South American Sea Lion (Otaria byronia) in the Argentine Patagonia

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Publication Date

2014

UNIVERSITY OF CALIFORNIA

SANTA CRUZ

Designing Marine Protected Areas for the South American Sea Lion (*Otaria byronia*) in the Argentine Patagonia

A thesis submitted in partial satisfaction
of the requirements for the degree of

MASTER OF ARTS

in

ECOLOGY AND EVOLUTIONARY BIOLOGY

by

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June 2014

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Abstract

Designing Marine Protected Areas for the South American Sea Lion (*Otaria byronia*) in the Argentine Patagonia

by

Cynthia Gabriela Padula

This work looks into the conservation of South American sea lions (SSL), *Otaria byronia*[1] by advancing a process of Marine Protected Area (MPA) design targeted for reproductive females during the first weeks of lactation. Focusing on protection of a single species may result in the establishment of a more comprehensive and ecologically functional system for management. SSL is distributed in the Atlantic and the Pacific coasts of South America. Along the coast of the Argentine Patagonian coast, 73 colonies were described, 42 % of which are reproductive. Breeding females give birth during the austral summer (January) and lactation lasts *ca*. one year. Critical to the annual cycle are the few weeks after birth, when mothers spend 2-3 days nursing and a similar or longer time at sea foraging, while pups remain alone on shore. Satellite tracking and dive recording instruments indicate that females are either coastal or pelagic in their feeding habits, but the latter travel relatively short distances from colony (mean 152 km). SSL are bottom foragers that dive to maximum depths of approximately 80 m. Optimizing travel and foraging time is critical for these animals, as pups left alone fast and are threatened by both starvation and being accidentally crushed by fighting adult males. Foraging areas overlap with fishing grounds, sea lions are caught in fishing gear and competition for food cannot be ignored. Yet, although 20 of the 31 existing breeding colonies are within coastal protected areas, none of the foraging areas have been considered for protection to minimize the consequences of interactions with fisheries. This work draws from very limited data to advance a process of design of Marine Protected Areas that is eminently practical, thus affordable to government wildlife administrators. I selected the most important colonies, based on location and abundance, integrated satellite locations at sea, analyzed potential associations with physical variables, and proposed criteria to decide important marine areas based on distribution at sea. Finally, I estimated the cost for fisheries to comply with the proposed conservation intervention scenarios. Foraging distribution did not follow a pattern consistent with physical oceanographic variables (sea surface temperature, productivity, bathymetry and seafloor composition) to guide conservation intervention. Bathymetry was the best proxy to help in the design of protected areas. Most of the conservation scenarios based on distribution at sea of lactating females did not strongly overlap with fisheries to justify conservation intervention. The colonies that did, however, involved the largest breeding colonies of Argentine Patagonia and Uruguay. In a context of closing the fisheries for the area of overlap and compensate for the loses during one month, I estimate a conservation cost of 2-3 million dollars, as the impact is on the most profitable of all Argentine Patagonian fisheries, targeting Argentine red shrimp, *Pleoticus muelleri*. I conclude that management that includes MPAs for this species requires *a priori* spatial planning considerations. Once a fishery is operational, the costs for conservation will not be affordable for the administrators.

I identified some areas where an *a priori* approach would be practical, effective and feasible.

Dedication and Acknowledgments

An immense THANKS to Dr. Claudio Campagna for his support, dedication, friendship and for always walking by my side, I could not have done this without you. An equally immense thanks to my husband Vicente for his unconditional support and to my daughters Lucia and Maia for putting up with me during those difficult days and long absences. Thank you Jim Estes for giving me the opportunity to embark on this journey and Mark Carr and Dan Costa for your invaluable input and support. A big thanks to the following people that at some point along the line provided me with ideas, monetary support or much needed data: Leo Ortiz, Federico Riet-Sapriza, Luis Hückstadt, Valeria Falabella, Alberto Piola and Tim Tinker. And last but not least, thank you Polita Glynn and the Pew Fellows for support provided to visit sites and facilitate personal contact and discussion.

Introduction

The goal of this study is to identify marine sites along the Argentine Patagonian coast that could function as protected areas for lactating females of the South American sea lion *(SSL,Otaria byronia).* An ancillary goal is to illustrate the application of the same rationale to one of the largest and best known breeding areas for the species outside Argentina, Isla de Lobos, in the Uruguayan coast. This is an exercise in Marine Protected Area (MPA) design using one species and one particular sex-age class, lactating females, as the target of the conservation effort. My rationale for this approach is that females in the earliest period of lactation are the most vulnerable category for the species, particularly susceptible to local threats and of formost importance to pup survival.

According to IUCN red listing criteria, the SSL is not threatened as a species in Argentina *(http://www.iucnredlist.org/details/41665/0)*. However, populations are declining in Chile (Venegas et al., 2002; Sepúlveda et al., 2011) and Uruguay (Páez, 2006; Dirección Nacional de Recursos Acuáticos, 2012; Riet-Sapriza et al., 2012). Conflict and threats arise from fisheries and aquaculture. Fisheries are known significant threats to marine mammals (e.g., Read et al., 2006; Read, 2008; Schipper et al., 2008). For the SSL, conflict and interaction commonly affect colonies in the proximity of the areas where fisheries operate (e.g., Aguayo and Maturana, 1973; George-Nascimiento et al., 1985; Sielfeld et al., 1997; Koen Alonso et al., 2000). Interactions between fisheries and the SSL involve incidental catch (Crespo et al., 1994, 1997; Dans et al., 2003; Huckstadt and Antezana, 2003; Arata and Hucke-

Gaete, 2005), entanglement (Ramirez et al., 1986; Crespo et al., 1997; Sepúlveda et al., 2007), competition for resources (Szteren et al., 2004; Riet-Sapriza et al., 2012) and direct killing of individuals by fishermen (Arias Schreiber, 1993a, 1993b; Seal Conservation Society, 2000). Despite the variety of ways by which fisheries might have negative impacts on sea lions, these interactions have not been identified as a major threat to the species, at least along the Buenos Aires (Corcuera et al., 1994; Crespo et al., 1994) and northern Patagonian (Río Negro and Chubut provinces) (Crespo et al, 1997; Romero et al, 2011) coasts of Argentina. The species has been harvested in the Argentine Patagonian coast for half a century, causing a significant decrease in population size (Crespo and Pedraza, 1991). Once the harvest ended, populations in Argentina's northern Patagonia expanded (Dans et al., 2004; Reyes et al., 2004). The impact of fisheries has been recorded but it is not halting the expansion of the population (Dans et al., 2010). Populations along southern Patagonia (Santa Cruz and Tierra del Fuego provinces) are data-deficient to estimate population trends, although Schiavini et al. (2004) showed that SSL abundance for this area in 1997 represented only 20% of the numbers found in 1940s. In Uruguay, some colonies have shown a high degree of spatial resource overlap between the SSL and fisheries, although it is yet unknown if fisheries operations are the main cause of population decline (Szteren et al, 2004; Riet Sapriza et al., 2012). Central Chile shows a high degree of interaction between the SSL and the purse seine fishery targeting jack mackerel (*Trachurus symmetricus*) (Huckstadt and Antezana, 2003) and bottom trawlers targeting the common hake (*Merluccius gayi*). For the latter, as many as 82 entanglements and 12 deaths have been reported as a minimum impact in the course of ten days (Reyes et al., 2012). If fisheries intereactions causing death affect females during early lactation, their pups will be affected, and population declines may soon follow. This rationale justifies understanding how to protect females from interactions with fisheries by advancing spatial planning near colonies.

Here, I propose criteria for the design of discrete spatio-temporal MPAs and discuss economic costs required for their implementation. This study is also aimed at solving interaction problems in ways that are practical and useful to managers.

The SSL may not be at risk in the study area and interactions with fisheries may not yet affect population numbers. However, the exercise is valuable as coastal fisheries in the Southwest Atlantic are ever expanding (Bertellotti et al., 2001; Lasta et al., 2001). Moreover, the inherent dynamic of local fisheries, continually redirecting their efforts to varying target species imply great variability and uncertainty with respect to the accidental mortality of top predators. Fishing in both coastal and pelagic waters will likely intensify the interactions between fisheries and marine mammal populations, in general, not only due to competition for resources but also to simple spatial overlap (Read, 2005; Read et al., 2006). Despite the recognition that top predators are in general decline throughout the world, knowledge about the impacts caused by fisheries to marine mammals is fragmentary and for most fisheries it is unknown, globally underscored and likely to have significant demographic effects on marine mammal populations (Read et al., 2006). Therefore, an *"a priori"* design of protected areas may be a useful tool for conservation in places where interactions with fisheries might not seem to be a direct threat at present but are likely to become a threat as human populations expand.

Rationale for this study

Sexually mature females of long-lived species are especially relevant in conservation planning because breeding individuals contribute disproportionately to sustaining populations (Heppell et al, 1999; Gerber et al., 2004; Maxwell et al, 2011). The necessity of female otariids to feed closer to the rookery during lactation links reproductive success with local abundance of food and population status to localized environmental disturbances (Costa et al., 2006). Availability of local resources during the early stages of maternal attendance is especially important for lactating otariid females to reduce the intervals between bouts of pup suckling (Trillmich, 1990; Boyd et al., 1998; Costa, 2008) and to keep mothers with their pups for longer periods, thus safeguarding pups from being injured during competition raids among males in the breeding colony (Campagna et al., 1988). Sepúlveda et al., 2012 (unpublished) suggested a positive relation between body condition of pups and fish landings, indicating that pup survival may be affected by spatial and temporal variation in marine productivity. Moreover, fisheries often operate close to the coast and within range of lactating female foraging sites (Wickens, 1995; Koen Alonso et al., 2000; Crespo et al., 2007; Riet Sapriza et al., 2012).

Approaches to MPA design (i.e.,, Sobel and Dahlgren, 2004; Claudet, 2011; Klein et al., 2013) rarely focus on threats affecting just one species, and much less address a subgroup with particular demands restricted in space and time. Moreover, the discrete spatio-temporal protected areas that I propose here will allow practical protection that is more feasible than in cases where protected areas are established year-round, or individuals are dispersed throughout an extensive range (Hyrenbach, 2000; Gerber, 2004; Maxwell et al, 2011).

The design of discrete spatio-temporal offshore MPAs for lactating female SSLs could have implications for the conservation of other species in the region. Some aspects of the ecology, life history and demography of the SSL may also apply to other species of high conservation value in the region, especially the Magellanic penguin (*Spheniscus magellanicus*). Both the SSL and Magellanic penguins reproduce seasonally, in large colonies along the coast; both travel to sea for short periods during attendance of the offspring; and both are susceptible to competition with fisheries. Moreover, offshore MPAs designed for the lactating females of SSL could offer indirect protection to the critically endangered marine turtles whose distributional range overlap with the northern, warmer regions were SSL reproduces.

Another important aspect of designing MPAs for this species is that top predators are often critical in ocean conservation planning to promote reserve designation (e.g., Reeves, 2000; Hooker et al, 2004; Sergio et al., 2008). Top predators are frequently seen as surrogates for the establishment of a more comprehensive and ecologically relevant system of management (Agardy, 1994; Campagna et al., 2007). They also serve as indicators of ecosystem health because of the significant impact they exert on the structure and function of the ecosystems they live in (Estes et al, 1974; Ray, 1981; Laws, 1984; Katona and Whitehead, 1988; Terborgh and Estes, 2010; Estes et al., 2011).

I also explore another important element to the approach and design of MPAs; their practicality for administrators. A rich body of theoretical, empirical, and methodological work exists to design networks of MPAs (e.g., Roberts, 1998; Hyrenbach et al., 2000; NRC, 2001; Sala et al., 2002; Airamé et al., 2003; Friedlander et al., 2003; Roberts et al., 2003; Sobel and Dahlgren, 2004; Nowlis, 2005; Claudet, 2011; Tulloch et al., 2013; Drew and Barber, 2012; McInerney et al., 2012; Guizien et al., 2012; Saarman et al., 2013). However, many of these approaches are sometimes beyond the capabilities of managers to apply in a practical and useful way because the methods require an expertise or finances that are not available to decision makers. It is an ancilliary aim of this study to provide decision makers with a simple innovative model that could be implemented as is or adjusted as stakeholders and science experts become involved.

I also explore design criteria that consider international policies that are less influenced by ecological considerations (e.g., population distributions) and more on recognizing political opportunities. For example, 80% of the SSL population along the Argentine coast occurs in the northern region (Chubut and Río Negro provinces) while only 7% of pup production occur in southern Patagonia (Santa Cruz and Tierra del Fuego provinces). Therefore, it would seem reasonable to assume that the maximum conservation benefit would be achieved by investing greater resources and effort in northern Patagonia. However, this strategy would leave out potential conservation opportunities in two of the main Argentine Patagonia provinces. Some SSL colonies in the latter are associated with bird colonies and are in proximity to foraging areas where fisheries operate. Therefore, if opportunity to take conservation action in Chubut and Río Negro fails, advancing in secondary priority sites would provide protection to several species in addition to SSL. Therefore, we include one of the low density colonies in southern Patagonia in our study.

General background

1. Marine Protected Areas

MPAs are one of the most essential tools in ocean conservation (Pauly et al., 2002; Hoyt, 2005; Roberts et al., 2005). They serve many purposes including : (a) maintaining a diversity of habitats and functions in an ecosystem (Castilla and Bustamante, 1989; Bennet and Attwood, 1991; Polunin and Roberts, 1993; Agardy, 1994; Roberts, 1995), (b) sustaining one, a few or a diversity of species (Buxton and Smale, 1989; Murray et al., 1999; Halpern, 2003), (c) limiting the impact of human use, particularly destructive fishing practices (Davis, 1989; Dugan and Davis, 1993; Carr et al., 1999; Lubchenco et al, 2003), (d) providing an opportunity for restoration in damaged, resilient systems (Almany et al., 2007; Russ et al, 2008), (e) becoming benchmarks to compare with altered ecosystems, assess human impact and improve management (Dayton et al., 2000; Davis et al., 2003), and (f) benefitting the overall welfare of the oceans and societies that depend on it (CBD, 2008; Toropova et al., 2010).

MPAs typically target many species (e.g., the Pelagos Sanctuary for Mediterranean Marine Mammals, the Gully Marine Protected Area in Canada, the Irish Whale and Dolphin Sanctuary, the Cabo Vírgenes Nature Reserve along the Brazilian coast, the network of MPAs along the coast of California, USA; see Hoyt, 2005 and *http://protectedplanet.net/*). MPAs could also be specific for a species (e.g., Bay of Fundy for Right Whale Conservation, Marine Tucuxi Envirnomental Protection Area of Paraty Bay in Brazil, Tortuguero National Park in Costa Rica; see Hoyt, 2005). MPAs are typically permanent, but could also be seasonal (e.g., Hutchings, 1995). They are mostly fixed in space, but could be dynamic (e.g., Aswani et al., 2006). Finally, they could range from preventing all extractive activities, as no-take marine reserves (Murray et al, 1999; Alcala et al, 2006) to conservation areas that allow select human uses (Saarman et al., 2013).

The global extent on ocean protected areas is approximately 2.85 million km^2 (*ca*. 5,000 MPAs). This figure equates to 2.8% of the world's marine area and represents 0.8% of the world's 361 million km^2 of ocean and 2.0% of the 147 million km^2 of ocean under national jurisdiction. Of the global marine area that is protected, only 10% are no-take MPAs *(www.protectedplanet.org)*. The global extent of MPAs has risen 150% since 2003, a year after the World Summit on Sustainable Development and the Convention on Biological Diversity, owing its increase to the recent designation of 11 very large MPAs larger than 100,000 km^2 which make up 60% of the worldwide total protected area (Spalding et al., 2010).

The global distribution of protected areas is both uneven and unrepresentative at multiple scales, and only half of the world's MPAs are part of a coherent system that considers diversity, function and use (Roff, 2005; Wood et al., 2008; Guarderas et al., 2008). Spatiotemporal and year-round, no-take marine reserves are one of the most successful management tools to reverse degradation trends of habitats and species while benefiting fisheries (Gell and Roberts, 2003; Balmord et al., 2004; Russ, 2004). Biomass and diversity can rapidly increase inside no-take MPAs, both in tropical and in temperate ecosystems (Sobel and Dahlgren, 2003; Halpern 2003; Abesamis et al., 2005; Lester and Halpern, 2009). No-take MPAs comprise a virtually negligible proportion of the global oceans, despite the overwhelming evidence from around the world on the sharp positive effect of no-take reserves on biomass, numerical density and size of organisms within their boundaries (Lester et al., 2009).

2. Marine mammals and Marine Protected Areas

Large marine predators have often been used as charismatic species attracting significant attention in ocean conservation planning to promote reserve designation (e.g., Ray, 1981; Gittleman, 2001; Hooker et al., 2004; Ray et al., 2005; Sergio et al., 2008). The benefits of approaching ocean protection targeting charismatic species are multifold. First, species protection can be seen as a starting point for the establishment of a more comprehensive system for management (Agardy, 1994). Second, the distribution and relative abundance of marine predators can be used as an indication of underlying prey and ecosystem processes (Tershy et al. 1991; Croll et al., 1998; Preen, 1998). Large carnivores are particularly vital to ecosystem function and thus reserves must be large enough to maintain viable populations of these animals. Without them, other species and ecological processes are lost (Soulé and Terborgh, 1999). Finally, even though the protection given to many top predator species is often minimal, it can be used to attract public and private funds, and encourage research (Reeves, 2000) to create infrastructure. An approach that has been suggested to advance conservation at the species level is the landscape species approach already applied to the Patagonian Sea (see Campagna et al., 2007).

Protected areas have been created more often and more regularly for some groups of marine mammals. The number of areas proposed and established for cetaceans has been rapidly increasing. According to the Whale and Dolphin Conservation Society, in 2004 there were 358 marine mammal protected areas with cetacean habitat worldwide, and the numbers climbed to 570 by June 2011, a 58% increase in seven years *(http://www.wdcs.org/)*. Cetacean marine protected area design has mostly focused on areas of high cetacean or biological diversity or in some cases on the protection of "critical habitat" or areas regularly used by individual species for feeding, breeding, migrating and raising calves (See Hoyt, 2005). Although most of the cetacean MPAs remain small, too small in fact to offer sufficient habitat protection for sometimes highly mobile marine species, the average size of MPAs for marine mammals is increasing. This is due in part to the designation in recent years of some very large sites that protect cetacean habitat, such as Papahānaumokuākea Marine National Monument (360,000 km^2), the Pelagos

Sanctuary for Marine Mammals of the Mediterranean sea (87,492 km^2), the Banco del Plata Whale Sanctuary in Dominican Republic (25,000 km^2) and other large new Pacific MPAs (Hoyt, 2005, 2012; Guarderas et al, 2008). Comparing the 15 existing largest MPAs for marine mammals from 2005 to 2011, for example, average size increased from just over 100,000 km^2 to 220,591 km^2 (Hoyt, 2011).

Almost no offshore protected areas (feeding grounds or migratory routes) exist for pinnipeds (Reeves, 2000). Some critically endangered pinnipeds, such as the Hawaiian and Mediterranean monk seals (*Monachus spp*.), have been given particular attention and protected from exploitation in protected areas such as the Hawaiian Islands National Wildlife Refuge, the Kure Atoll State Wildlife Refuge, the Midway Atoll National Wildlife Refuge, the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve and the Papahanaumokuakea Marine National Monument for the Hawaiian monk seal and Desertas Islands in the Madeira Archipelago and the northern Sporades Islands National Marine Park in Greece created specifically for the protection of Mediterranean monk seals (IUCN, 2013). The endangered Galapagos fur seal is also fully protected within the more encompassing Galapagos Marine Reserve (*www.pinnipeds.org*; IUCN, 2013).

Reserves created for cetaceans may offer indirect protection to pinnipeds as well. Some examples are: the Bay of Fundy Right Whale Conservation area in the NW Atlantic offering protection to the local harbor seal *(Phoca vitulina)* population, the Saguenay-St Lawrence Marine Park in Canada offering indirect protection to harbor, gray (*Halichoerus grypus)* and harp seals (*Pagophilus groenlandicus)*, and the

Kurilskiy Nature Reserve in Russia, established for the protection of cetaceans but also offering indirect protection to the local population of the endangered Steller sea lions (*Eumetopias jubatus)* and other pinniped rookeries such as that of Largha seals (*Phoca vitulina largha*) and *Phoca vitulina kurilensis*, a subspecies of the harbor seal (www.protectedplanet.net; Hoyt, 2005).

Protected areas for marine mammals worldwide have also been created for threatened or endangered species, such as the vaquita (*Phocoena sinus*) in Mexico, the dugong (*Dugong dugong*) throughout the Indo-Pacific, and the river dolphins in Asia and South America (Reeves, 2000).

3. The Patagonian Sea/SW Atlantic

The target species of this study, the SSL, is distributed along two major ocean basins, the SW Atlantic (here referred as the Patagonian Sea) and the SE Pacific (Dans et al., 2010). This work focuses on the former, as it is for the Atlantic coast sea lions that we have data on female behavior during lactation. Moreover, the Chilean and Peruvian coasts and offshore waters differ widely from the Atlantic ecosystems in oceanographic and use aspects, possibly requiring a different approach.

The Patagonian sea covers more than 1,000,000 km^2, including an extensive neritic region with one of the most productive and diverse oceanic areas of the southern hemisphere (Guerrero, 1998; Acha et al., 2004; Acha and Mianzan, 2006; Rivas, 2006; Romero et al., 2006; Acha et al., 2008; Acha and Mianzan, 2008; Piola, 2008). The concentration of phytoplankton in these waters is three times the world's ocean average (Rivas, 2006), supporting a wide array of wildlife, such as 47 of the 129 extant marine mammal species and 83 species of marine birds (Yorio et al., 1998; Campagna et al., 2007, Santos, 2010).

Many colonial marine birds and mammals reproduce along the coast of Argentine Patagonia (Yorio et al., 1998; Campagna et al., 2007). Some of these species are endangered, endemic or have restricted distributions (Foro para la Conservación del Mar Patagónico y Áreas de Influencia, 2008; *http://www.atlas-marpatagonico.org/;* Falabella et al, 2009). Others, such as the Magellanic penguin, are common but vulnerable (Gandini and Boersma., 1996; Gandini et al, 1999; García Borboroglu et al., 2006; García Borboroglu et al., 2008).

From the mid-1960 to the present, about 53 MPAs have been created on the Argentine Patagonian coast representing a surface area of 39,700 km^2, and covering approximately 2.4% of the Exclusive Economic Zone (Figure 1). The main targets of protection are reproductive colonies of birds and marine mammals (Tagliorette and Mansur, 2008). Most do not have a marine component, or the ocean area under protection is negligible, with a few recent exceptions (Yorio et al, 2007; Giaccardi and Tagliorette, 2007). The lack of open-ocean protected areas limit the effectiveness of conservation as all the species in coastal MPAs forage at sea where they are exposed to multiple threats.

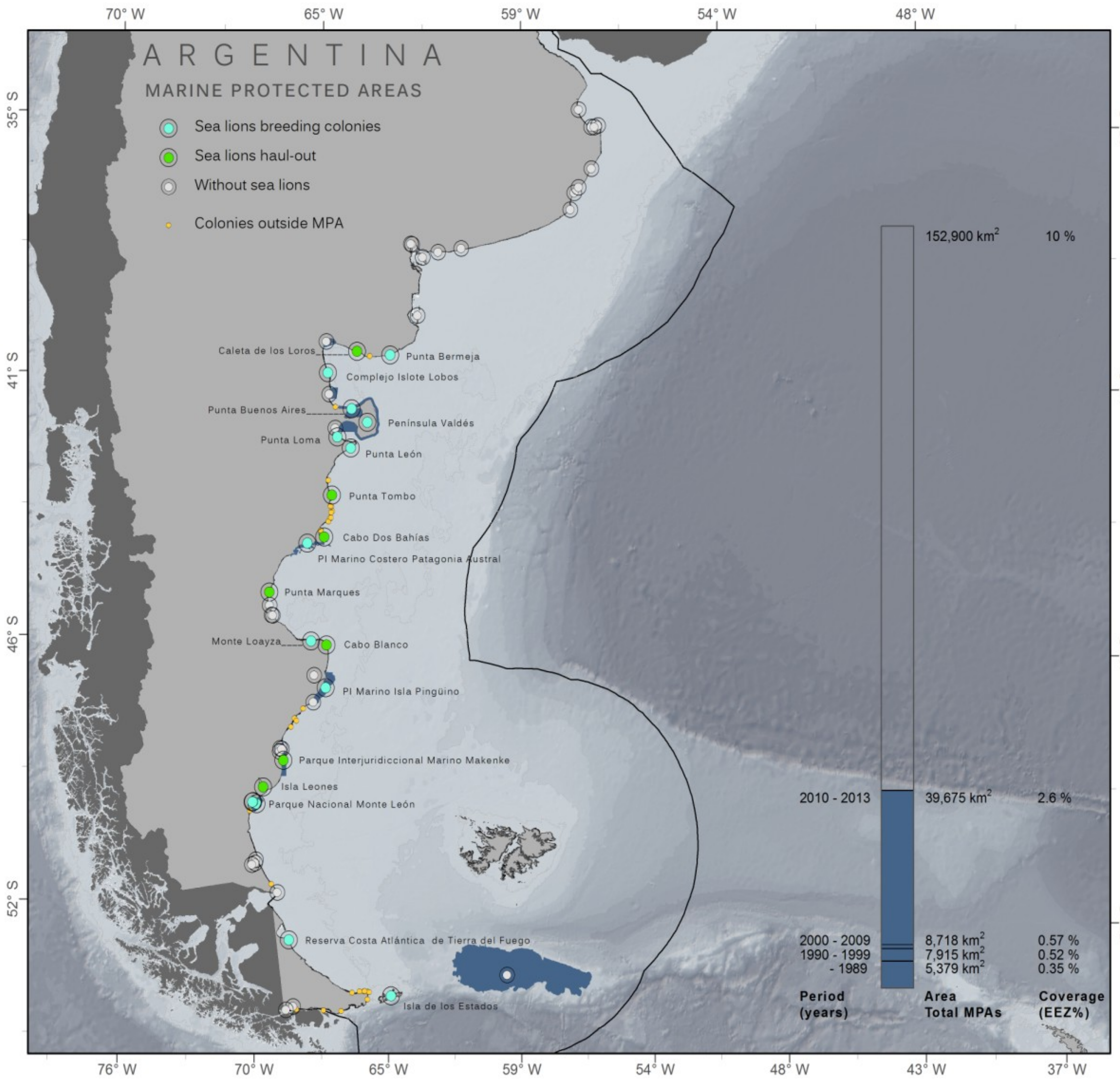


Figure 1: Fifty three coastal protected areas have been declared for the coast of Argentine Patagonia. Forty two include SSL colonies (twenty reproductive and twenty two haul out sites). Thirty one colonies are outside protected areas (35% are reproductive). From our study sites: Península Valdés colonies (Punta Buenos Aires and Punta Norte) are under the management of the UNESCO world heritage sites, Punta León and Monte Loayza are within protected areas and Isla de Lobos is protected under the natural reserve "Parque nacional de Islas costeras" of Uruguay. Map obtained from Valeria Falabella, WCS Marine Program, unpublished information.

The Patagonian sea is exposed to a number of threats such as oil and solid from pollution, human disturbance, wildlife diseases and the introduction of non-native species (Esteves, 2008; Tagliorette et al, 2008; Schwindt, 2008; Uhart et al., 2008; Orenzans et al., 2008, Foro para la Conservación del Mar Patagónico y Áreas de Influencia, 2008). Fisheries are the main threat affecting the region's top marine predators (e.g., Gandini et al, 1999; Domingo et al., 2006; González-Zeballos and Yorio, 2006; Crespo et al., 2007; Cappozzo et al., 2007; Rabuffetti et al., 2008; González-Carman et al., 2012).

The high productivity of the Patagonian sea supports intense fishing efforts, with fish landings reaching a maximum of 1,300,000 tons in 1997 and stabilizing to an average of 741,250 tons between 2009 and 2012 (Subsecretaría de Pesca y Acuicultura, 2013). More than 65% of all fish landings between 2009 and 2012 are for just four species: Common hake (*Merluccius hubbsi*) 37% , Patagonian greniadier (*Macruronus magellanicus*) 12 %, Argentine shortfin squid (*Illex argentinus*) 11% (except for 2011 constituting a 35% of total landings) and Argentine red shrimp (*Pleoticus muelleri*) with an annual landing average of 9% (Subsecretaria de Pesca y Acuicultura, 2013). Fisheries cause entanglement (Campagna et al., 2007; Lewis and Campagna, 2008), accidental catch and competition for food (Croxall et al, 1998; Hall et al., 2000; Gonzalez Zevallos and Yorio, 2006). Bycatch and overfishing are also critical threats for some taxa (Domingo et al, 2006; Gomez Laich et al, 2006; Crespo et al, 2007). The combined effect of fisheries and pollution may cause population declines, and this has been reported for some Magellanic penguin colonies

(Gandini et al, 1996; García Borboroglu et al. 2006), as well as for species like the black-browed albatross (*Thalassarche melanophrys*; Schiavini et al, 1998). Accidental catch, mainly in longline fisheries but also from trawling, affects at least four species of marine turtles, 20 species of marine birds and seven species of marine mammals, including the SSL (Gandini et al, 1999; Capozzo et al., 2004; Domingo et al., 2006; Tamini et al, 2006; Crespo et al., 2007; Rabuffetti et al, 2008).

4. The South American sea lion

The SSL is one of the most numerous marine mammals of the Patagonian sea/SW Atlantic (Vaz Ferreira, 1981; Crespo, 1988; Crespo and Pedraza, 1991; Reyes et al., 1999; Bastida and Rodriguez, 2003; Dans et al., 2004; Schiavini et al., 2004). Approximately 268,000 individuals are distributed in coastal and insular aggregations in South America, from the north of Peru to Brazil (IUCN 2013; Figure 2a). The species may be relatively common for an otariid but populations are recovering from a history of unsustainable use that slaughtered at least 500,000 animals in half a century. The species was hunted almost to local extinction for the exploitation of their skin and fat and to protect fisheries (Crespo and Pedraza, 1991).

The distribution of breeding colonies for the species covers the entire length of the Argentine Patagonian coast with a total of 73 breeding and haul-out colonies and a total population of approximately 100,000 individuals (Dans et al., 2010, Figure 2b). The geographic range of reproductive animals extends into the coasts of Uruguay, Chile and Peru (Majluf and Trillmich, 1981; Brieva et al., 1999,2000; Thompson et al., 2005; Bartheld et al., 2008; Sepulveda et al., 2011; Figure 2a). Forty two colonies along the Argentine Patagonian coast are already in coastal protected areas (Figure 1), but there is virtually no protection for the pelagic places where these otariids forage (Giaccardi and Tagliorette, 2006).

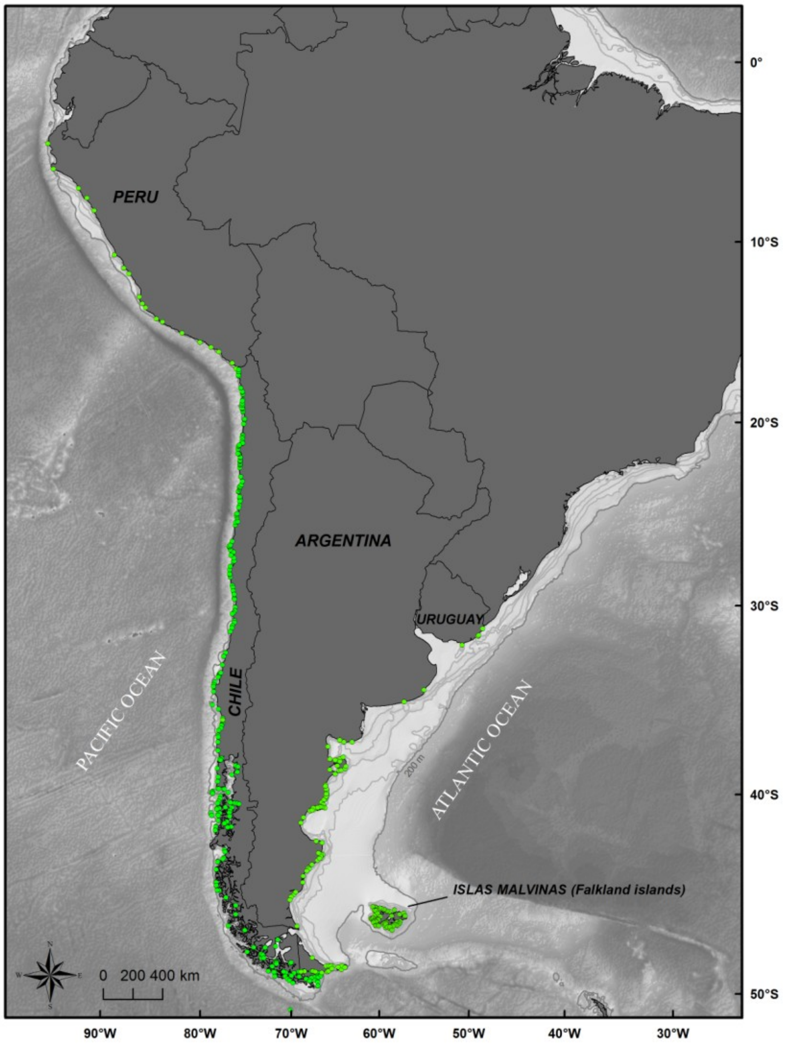


Figure 2a: South American sea lion breeding colonies (n = 266) and haul-outs (n = 221) along their distributional range. Estimated total population size is approximately 268,000 individuals (IUCN 2013). Fifty two percent of the total population is distributed in the Atlantic coast.

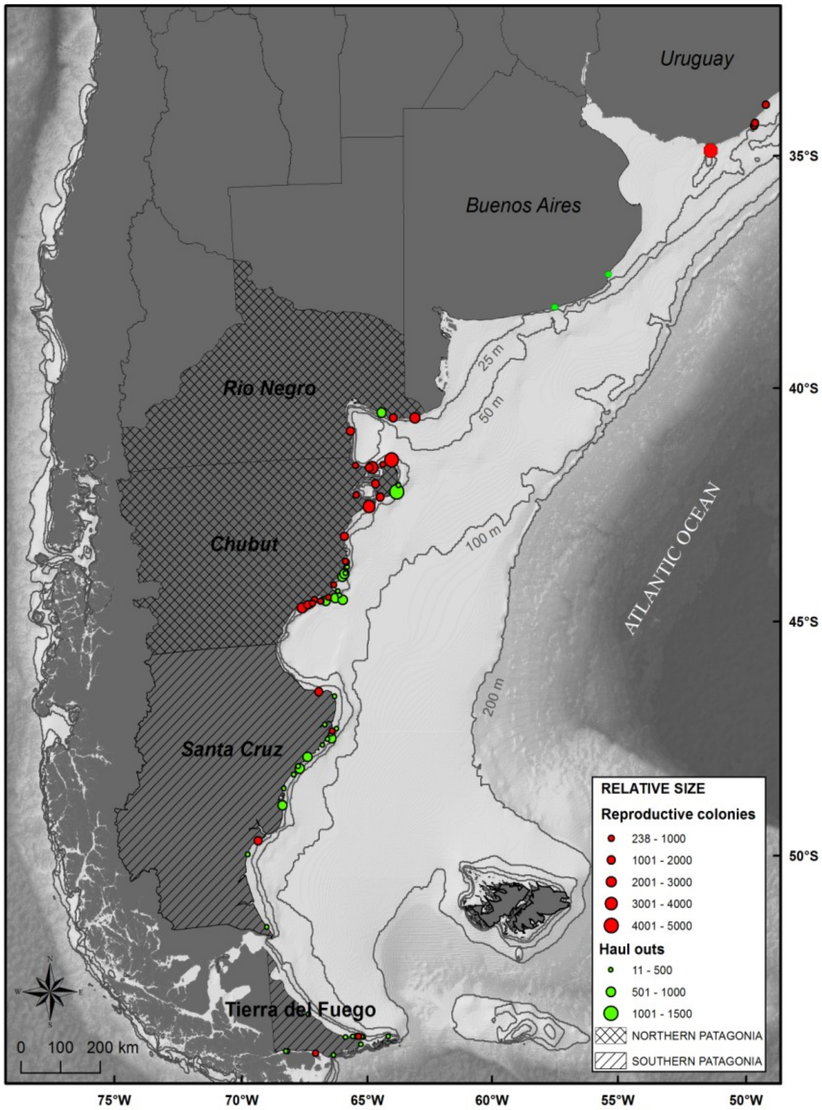


Figure 2b: Location and relative size of reproductive (red; n = 36) and haul-out (green; n = 42) colonies of the South American sea lion along the coast of Uruguay and Argentine Patagonia (Dans et al., 2004; Schiavinni et al., 2004; Reyes et al., 1999. Total population in this region is estimated at 100,000 individuals along the Argentinean coast (Dans et al., 2010) and 12,000 in Uruguay (IUCN 2013). Number of colonies is similar for northern (n = 41) and southern (n = 32) Patagonia. The northern region comprises 80% of total number of individuals and 93% of pups born in Argentina (See Appendix 1). The population of Uruguay represents 10% of the total SW Atlantic South American sea lion population.

4.1 Breeding cycle. Adult males and females breed during the Austral summer (Campagna and Le Boeuf, 1988). Reproduction starts the first half of December. During early December, most adult animals are foraging at sea. Males arrive at the colonies first and take up position on the beach anticipating the places where most females are going to be later in the season. Adult females give birth to one pup, copulate about one week later and remain with their newborn pups for nearly a week before making routine foraging trips of approximately 1-4 days with a similar period nursing on land. The initial period of lactation is particularly crucial for the pups as they strictly depend on their mothers for nutrition, growth and ultimately survival. By the first week of February, 90% of the adult males are back at sea.

4.2 Foraging distribution and diet. Distribution at sea has been studied for colonies in Chile (Huckstadt et al., in press) and Uruguay (Riet-Sapriza et al., 2012), it is unknown for Peru, and there are no data on the majority of continental and insular aggregations of the Argentine Patagonian coast. The distribution at sea of the SSL for the studied colonies is restricted to waters of the continental shelf and slope. Males travel further than females, reaching as far as the edge of the slope. Foraging lactating females from Argentine Patagonia perform short flat bottom dives with a median depth ranging between 19 to 62 meters and a maximum depth of 80 m, being mostly bottom as well as mid-water feeders and exploiting a wide range of prey species (Campagna et al., 2001). Prey species include a variety of teleost fishes and cephalopods ranging from benthic, demersal benthic, demersal pelagic to pelagic

(George-Nascimento et al., 1985; Thompson et al, 1998; Koen Alonso et al., 2000; Naya et al., 2000; Drago, 2009).

Lactating females differ in distance travelled from colony during the time they spend at sea. Satellite tracking data (Campagna et al., 2001 for Patagonia; Riet Sapriza et al., 2012 for Uruguay) show that females that feed close to the coast forage at an average maximum distance from colony of 59 km while off-shore females travel an average maximum distance of 144 km with a ratio of coastal to pelagic of 12:14 (n = 26). The distinction between maximum distance travelled for pelagic and coastal females can be used as a "proxy" to establish areas of conservation due to the existing similar ratio (ca. 50/50) between these two feeding strategies.

Foraging trips are restricted to areas close to their breeding grounds within the continental shelf, with almost no overlap between females of different colonies and with an average time spent away from colony of 4.4 days (Campagna et al., 2001; Riet Sapriza et al.,2012). The short distance trips and short trip duration indicate that availability of local resources for lactating females is imperative for the viability of the population via success of the reproductive individuals (Costa el al., 2006).

4.3 Threats to populations along their distributional range. During the first half of the twentieth century SSL were intensely exploited for their skin and oil, reducing the population in some areas by 80 – 90% (Bonner, 1982; Crespo and Pedraza, 1991). Commercial exploitation is currently banned throughout the species' range. Throughout this range the animals are affected by commercial fisheries (Corcuera et al., 1994; Crespo et al., 1994; Crespo et al, 1997; Huckstadt and Antezana, 2003; Szteren et al, 2004; Romero et al, 2011; Riet Sapriza et al., 2012; Reyes et al, 2012), salmonid fish farms (Chile), where animals become entangled on the nets and get shot by fishermen attempting to protect their stocks (Nash et al., 2000, Sepulveda and Oliva, 2005), small scale artisanal fisheries (Sepulveda et al., 2007) and El Niño events causing bottleneck effects further exacerbated by polygyny with a negative impact on the populations of the Pacific (Sielfeld et al., 2002). In the center and south of Chile (Venegas et al., 2002; Sepúlveda et al., 2011), Uruguay (Páez, 2006; Dirección Nacional de Recursos Acuáticos, 2012) and on the Malvinas-Falkland Islands (Thompson et al., 2005) the number of animals has shown a clear decline in recent decades. The population on the Malvinas-Falkland Islands appears to be recovering (Thompson et al., 2005). Nevertheless, the species is classified as of *least concern* (IUCN, 2008) due to its relative abundance in part of the distribution range.

4.4 Fisheries interactions with the SSL populations of Argentine Patagonia and Uruguay. Fisheries of the Patagonian sea are large-scale, industrial, commercial, international operations *(http://www.minagri.gob.ar)* that started to develop as such in the 1990s (Bertellotti et al., 2001). In the late 1990s, Argentine fisheries produced well over a billion dollars of exports, and landings of 1,341,000 tons (comparatively, beef exports generate a revenue of about 1.5 billion US$/year).

A main target species of Argentine fisheries, the Argentine common hake (*Merluccius hubbsi*), is also an important item in the diet of the SSL (Crespo et al., 1997; Koen Alonso et al., 2000; Drago et al., 2009). Hake catches alone for 1997 (including an estimate of bycatch and unreported data) were estimated at over 800,000 tons, 111% higher than the allowable catch for the species for that year. The overexploitation of common hake and the out of control explosion of the fishing industry immediately led to the declaration of common hake as a species at risk of collapse (Aubone et al., 2004).

Argentine red shrimp is also the base of a very profitable industry with a high discard rate of juvenile Argentine hake, the most important size in the diet of SSLs (Cañete, 1995; Cordo and Simonazzi, 2003). At least 100 trawlers and outrigger trawlers of the coastal and artisanal fishery were targeting shrimp in the 1990s and early 2000s.

Reported interactions between the SSL and fisheries operating in the coasts of Argentina are many. Along the Buenos Aires coast individuals of the SSL have been reported to interact with nets of demersal trawlers targeting a variety of coastal demersal species known locally as “variado costero”. These interactions, however, consisted of SSL preying on fish captured in the nets with no evidence of entanglement (Crespo et al., 1994; Corcuera et al., 1994).

Along the coast of Argentine Patagonia a decadal study on fisheries interactions between marine mammals and fisheries, reported SSL entanglement and mortality with all types of trawling gear (which constitutes 80% of the entire fleet operating in the Patagonian Sea). Highest entanglement and mortality rates were reported in diurnal demersal nets targeting hake and nocturnal outriggers targeting shrimp (Crespo et al., 1997, 2007; Dans et al., 2003).

Uruguay presents many types of interactions between the trawling and longliner artisanal fleet and its resident SSL population. Studies by Szteren and Páez (2003), Lezama and Szteren (2003) and Szteren and Lezama, (2006) showed operational interactions consisting in the stealing of captured fish by SSL, damages of fishing gear and stealing of bait with a mean number of one SSL per fishing event (fishing event: a fishing trip of a fleet using a particular fishing gear).

Materials and Methods

Decision-making process

The steps presented in Figure 14 show the rationale followed in our design of offshore protected areas for the lactating females of the SSL.

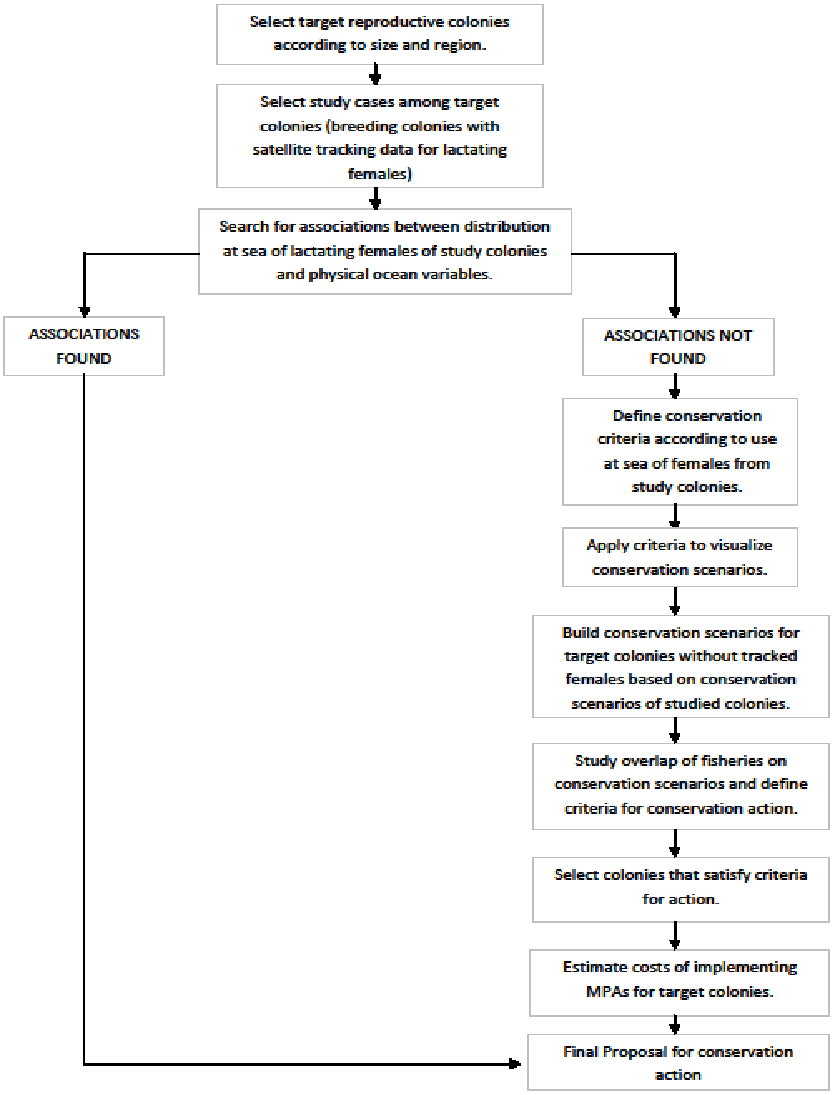


Figure 14: Decision-making process to arrive to conservation intervention scenarios for lactating, SSL females. Most of the effort in this work followed the path of conservation criteria not related to environmental variables, as limited data for locations at sea do not guide conservation implementation based on physical variables.

Selection of reproductive target colonies

The distribution, type (breeding vs. haul out) and size of SSL colonies along the Argentine Patagonian coast were obtained from Dans et al. (2004), for northern Patagonia (Río Negro Province and northern Chubut), Reyes et al. (1999), for south and central Chubut Province, and Schiavini et al. (2004) for southern Patagonia (Santa Cruz and Tierra del Fuego; Appendix 1, Figure 2b). An unpublished report updated information and controls for numbers of individuals at sea (Dans et al., 2010). I used data from this report to estimate relative size of the population for each individual province of the Argentine Patagonia and Uruguay. Distribution for Uruguay and the rest of South America was obtained from Bartheld et al., 2008; Sepulveda et al., 2011; Brieva et al., 1999,2000; Thompson et al., 2005 and Majluf and Trillmich, 1981; Figure 2a.

Colony sizes and distribution pattern on the Atlantic side of the species distribution differ widely. There are virtually no reproductive colonies between Isla de Lobos, in Uruguay, and the northern Patagonian rookeries (Figure 2b). This gap in the distribution is probably due to coastal development and to lack of breeding habitat. The coastal distribution and number of colonies is similar for northern (Río Negro and Chubut Provinces) and southern (Santa Cruz and Tierra del Fuego Provinces) Patagonia (41 versus 32 rookeries, respectively). However, the population density in each area differs. The northern Patagonia region comprises 80% of the total Patagonian population of SSL in Argentina (*ca*., 98,578 animals), while southern Patagonia has a total population estimated in 22,157 animals (Dans et al., 2010).

Northern Patagonia contributes 93% of all pups born in continental Argentina (Dans et al., 2004; Schiavinni et al., 2004; Reyes et al., 1999; Appendix 1). From the thirty two breeding colonies described for the SSL along the Argentine Patagonian coast, a sample of eight were chosen for my study of the design of protected areas. Isla de Lobos was also selected as target colony as a way to illustrate the same rationale to one of the best known breeding areas for the species outside Argentina. The goal was to encompass the largest number of lactating females in the smallest proportion of protected sites. Key places included colonies for which animals have been tracked and other significant breeding sites. Target breeding colonies are shown in Figure 3. Due to the differing abundance and pup natality per year at different latitudes of the distributional range, we chose as target colonies those with 1000 or more pups born per year for northern Patagonia and colonies with 100 or more pups born per year for southern Patagonia. The 100 "mark" for southern Patagonia was chosen by calculating the median value of pups born in each breeding southern Patagonian colony (n = 7) (See Appendix 1). Northern Patagonia had 23 SSL breeding colonies, twenty of which contained ≤ 900 pups born per rookery. With the goal of selecting the largest number of lactating females in the smallest proportion of protected sites, we selected the three largest breeding colonies in the region yielding 1,570 – 1,975 pups born per year respectively (see Appendix 1).

Although target colonies of southern Patagonia are small in abundance and pup production, and the allocation of effort and resources would seem more practical if applied to the more abundant colonies of the north, they play a significant role in terms of conservation strategy. A regional approach that includes priority as well as secondary areas is more desirable, since it includes a larger number of potential conservation sites, more decision makers involved, thus more opportunity for conservation action. Moreover, the smaller SSL colonies of the south are associated to other species that could indirectly benefit from SSL protection. With that in mind, we chose Monte Loayza as a case study and representative of the four remaining colonies of similar population and geographical profiles.

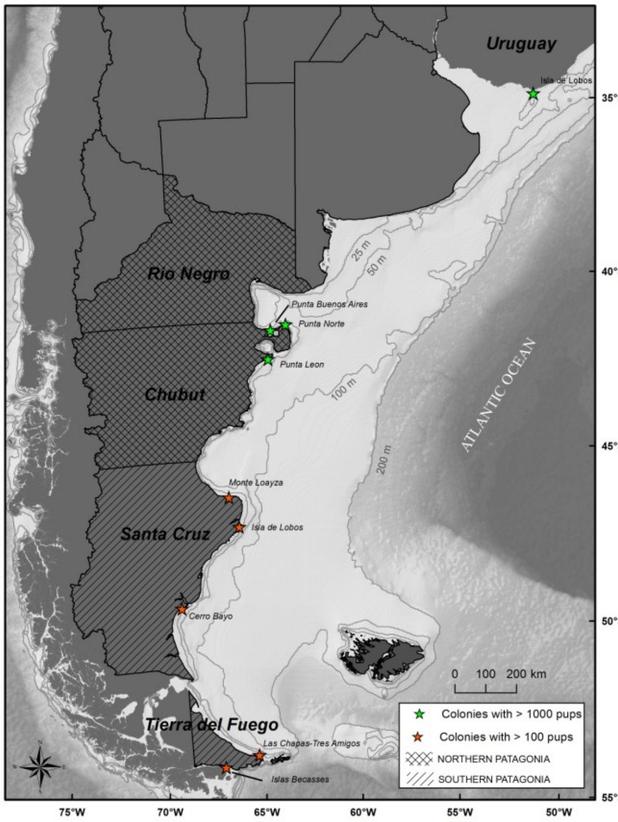


Figure 3: Target northern Patagonia colonies (Provinces of Río Negro and Chubut) include those with 1,000 or more pups born per season. For southern Patagonia (Provinces of Santa Cruz and Tierra del Fuego) colonies are much smaller. Target breeding places were selected based on 100 pups or more born per season.

Satellite tracking data for females were available for all target colonies of northern Patagonia and Uruguay. These colonies include Isla de Lobos (35o 01’S; 54o52’W; Figure 4b) and central Patagonian colonies located at Península Valdés and nearby areas (Punta Buenos Aires, Punta Norte and Punta León; Figure 4a; Dans et al., 2004). Punta Pirámide was not selected as a target colony (number of pups born per season < 1,000), but was used in this study because three lactating females of this colony were tagged with satellite data loggers, thus providing us with supplementary information that added to the limited data on female distribution at sea. Punta Norte (42° 4’S; 63° 47’W; Figure 4a) is one of the largest SSL colonies in central Patagonia, with 2,300 reproductive adults at peak season, and 1,900 pups born per year. Punta Buenos Aires (42° 14’S; 64 22’W; Figure 4a), located in the eastern side of the mouth of Golfo San José, concentrates about 2,300 adult males and females, with approximately 1,800 pups born each breeding season. Punta Pirámide (42° 35’S; 64° 17’W; Figure 4a) is the smallest of all studied rookeries, with approximately 525 adults and 700 annually born pups per year. It is also the only rookery located in an enclosed bay, Golfo Nuevo, rather than facing the open ocean. Punta León (43° 04’S; 64° 29’W; Figure 4a) is located south of Península Valdés. About 1,700 adults breed there, with 1,600 pups reported to be born each year.

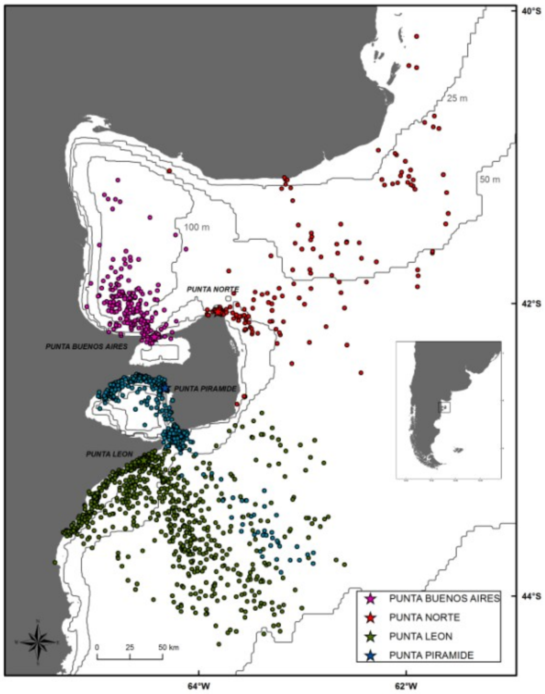


Figure 4a: Satellite locations of lactating females of the South American sea lion (n = 20) tagged at four northern Patagonian breeding rookeries (original data from Campagna et al., 2001).

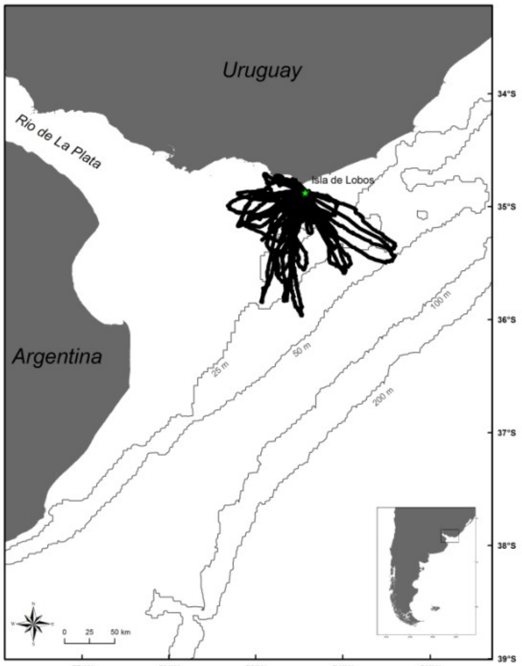


Figure 4b: Satellite locations of lactating females of the South American sea lion (n = 7) tagged at the Isla de Lobos rookery in Uruguay (original data from Riet-Sapriza et al., 2012).

Satellite data and tagging locations

Satellite locations for the species were reported in three studies, for colonies in Argentina (Campagna et al., 2001), Uruguay (Riet-Sapriza et al., 2012) and Chile (Hukstadt et al., in press). Only the former two were considered in this work because the Chilean study did not target lactating females. Moreover, as mentioned earlier, the Chilean coast has oceanographic, physical and ecological features that differ from the Argentine Patagonian and Uruguayan coasts.

Satellite locations of adult females at sea during pup attendance were drawn from Campagna et al. (2001) for Península Valdés and from Riet-Sapriza et al. (2012) for Isla de Lobos in Uruguay. The studies used similar approaches but took place a decade apart, with improved technology for the Uruguayan work resulting in more abundant information. Diving data available for Argentine Patagonian animals were obtained from a different study than the satellite tracking data (Werner and Campagna, 1995).

Península Valdés (Figure 4a): Twenty females were satellite tracked during January 1994-1998 at four different northern Patagonia rookeries: Punta Norte (n = 6; 168 locations), Punta Buenos Aires (n = 4; 68 locations), Punta Pirámide (n = 3; 337 locations) and Punta León (n = 5; 780 locations).

Sixteen of the twenty females from the Argentine Patagonian study where tagged with microprocessor-controlled, satellite linked, dive recorders (SDR-ST6 and SDR-ST10 – Wildlife Computers, Richmond, Washington). Instruments provided locations at sea and diving data (number of dives, dive duration and depth). All females from Punta Pirámide and female BA4 from Punta Buenos Aires were tagged with ST-10 (PTT's; Telonics, Mesa, Arizona, U.S.A.) transmitters that determined geographic location but did not sample diving data. Locations were determined using the Argos satellite system (Service Argos, Inc., Tolouse, France and Landover, Mayland, U.S.A). Raw data from Argos was filtered using the variable "quality" as proxy to select the most accurate satellite locations. A detailed description of materials and methods is reported by Campagna et al. 2001.

Isla de Lobos, Uruguay (Figure 4b): Ten females were satellite tracked in Uruguayan waters, all from the breeding rookery of Isla de Lobos (n = 10; 4,256 locations). Instruments were deployed from mid-January to late February, 2009.

Females for this study were fitted with smart position and transmitting (SPOT) Argos tags (SPOT5 model 32 g. Wildlife Computers, Redmond, WA, USA) and Rechargeable Fastloc GPS data loggers (F1G 238A model, 217 g. Sirtrack, Havelock North, New Zealand). Satellite locations were filtered by selecting all locations transmitted every hour. Data were published in Rietz-Sapriza et al., (2012). For this work, I had access to original satellite locations provided as a courtesy of Federico Riet-Sapriza, Daniel Costa, ValentinaFranco-Trecu, Yamandú Marín, Julio Chocca, Bernardo González, Gastón Beathyate, B. Louise Chilvers and Luis Huckstadt.

Physical variables

For this study, chlorophyll *a*, sea surface temperature (SST), bathymetry and sea floor composition were compared and contrasted with high-use areas of satellite tracked lactating females as a first step in looking for correlations that could help us determine important foraging areas for the lactating females while at sea.

Cholorphyll a: Primary productivity is known to be an important indicator affecting the abundance and distribution of pinnipeds at sea (Hindell et al. 1991, McConnell et al. 1992, Boyd et al.1998, Georges et al. 2000; Guinet et al., 2001). Some of the most conspicuous productivity fronts along the Argentine Patagonian shelf that could serve as foraging areas for the females of this study are: the Río de la Plata estuary, El Rincón, the Valdés front and Santa Cruz area fronts (Acha et al., 2004) (Figure 5). In this paper fronts are described in terms of chlorophyll *a* values as no primary productivity indexes have been deciphered for the Patagonian Sea.

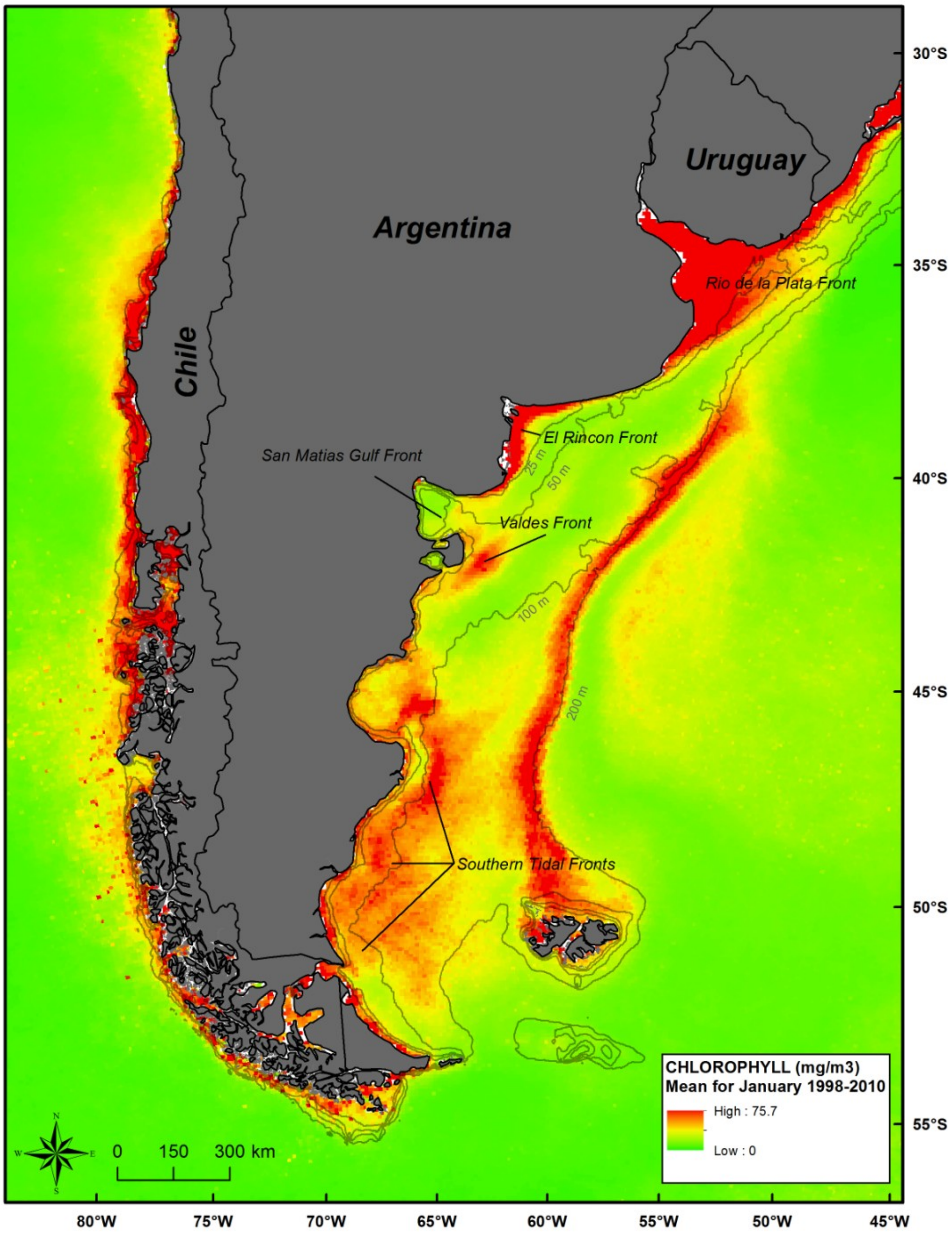


Figure 5: Ocean productivity fronts of the Southwest Atlantic with potential implications for lactating female distribution at sea. These include: the Valdés and southern tidal fronts formed by the mixing of stratified and well mixed tidal waters, the thermohaline front of the San Matías gulf and the haline fronts of Río de la Plata and El Rincón.

The Río de la Plata (35 – 36^{o} S) front is an extensive coastal shelf plain estuary characterized by vertical stratification formed by the convergence of fresh waters from the Río de la Plata river and the more salt dense waters of the continental shelf (Guerrero et al., 1997). This front persists throughout the year and is characterized by a strong vertical stratification (fresh waters flow seawards and denser waters intruding along the bottom) with higher chlorophyll *a* aggregations (≤ 15.5 mg m^{-3}) below the halocline and immediately offshore its turbidity front (Acha et al., 2008). El Rincón estuary (39^{o} S – 41^{o} S, depth < 40 m) with January average chlorophyll *a* values of ~ 2.3 mg m^{-3} show weak seasonality and is formed by the convergence of tidal forcing and a coastal front separating diluted waters coming from the Negro and Colorado rivers and shelf waters (Guerrero and Piola, 1997; Guerrero, 1998). Most prominent for the sea lion colonies of Peninsula Valdés is the Valdés front, a mesoscale (10-1,000 km) thermal front that forms during the austral spring (mean chlorophyll *a* values ~ 8.0 mg m^{-3}) and persists throughout the summer where it reaches average chlorophyll *a* concentrations of 2.62 mg m $^{-3}$. The Valdés front defines the boundary of stratified offshore water caused by surface warming and coastal mixed water forced by tidal currents (Carreto et al., 1986; Glorioso et al., 1987). The southernmost area of the coastal shelf is characterized by a series of less studied tidal fronts defined from barotropic models at 51^{o} S by Sabatini et al. (2000) and Glorioso and Flather (1995) reaching highest productivity from November through February and with January average chlorophyll *a* values between 2.0 – 3.64 8.0 mg m^{-3} (Rivas et al., 2006). Not so conspicuous is the existence of a front located in the mouth of Golfo San Matías and produced by the mixing of different thermohaline water masses located north and south within the gulf (Scasso and Piola, 1988).

Chlorophyll *a* data for this study were obtained from the SeaWiFs project as a monthly average for the month of January from 1998 through 2010, and mapped at 9-km, equal-angle grids (Giovanni - Ocean color radiometry online visualization an analysis *(http://gdata1.sci.gsfc.nasa.gov/daacbin/G3/gui.cgi?instance_id=ocean_month).*

Sea Surface Temperature and thermocline: Between 41° S and 44° S, the increased solar radiation on the ocean surface of the Patagonian shelf during the austral spring and summer creates a marked stratification of water layers (warm less dense waters of approximately 16 °C on the above layer and cooler dense waters of 11 °C in the deeper layers; Rivas, 2006; Acha and Mianzan, 2008; Piola, 2008). Thermoclines such as this one aggregate zooplankton and prey distributions potentially affecting areas were top predators prefer to eat (eg. Sabatini et al., 2000). The Patagonian thermocline reaches a maximum stratification of 40 m depth in mid February (defined by a Simpson parameter of mean value $\Phi = 50$ J m^{-3}; Bianchi et al., 2005) and forms a productivity front at approximately 30-40 km from shore where it meets the well mixed waters of 15 °C created by the tidal currents along the coast (Acha and Mianzan, 2008). A marked thermocline along the Argentine Patagonian coast is also prominent at southern latitudes (45° S – 54 ° S) as it appears closer to the coast due to less intense tidal force and the local dynamics of ocean currents (Palma et al, 2004; Bianchi et al., 2005) .

Enclosed systems, such as that of Golfo San Matías present their own local oceanographic features. In spring and summer, the gulf is characterized by two areas of distinct water masses: one north and east of the gulf, and characterized by high temperatures, high salinity and low nitrates, and another located in the south and southeast sector with cooler, low salinity waters and high nitrate concentration diluted and influenced by the water influx from the continental shelf (Lusquiños, 1971; Carreto et al., 1974; Gagliardini and Rivas, 2004). These two converging masses create a weak front caused by the difference in salt and temperature densities (Scasso and Piola, 1988). The Golfo Nuevo is characterized by atmospherically induced, well mixed waters during fall and winter and stratified waters during spring and summer, presenting a relatively homogeneous SST year-round across its range. No conspicuous thermal fronts have been detected in the area (Rivas and Ripa, 1989; Rivas and Beier, 1990).

SST data were obtained as day and night averages for the month of January 1994 – 1998, and mapped at 4.4 km equal angle grids from the Pathfinder version 5.0 project *(http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowserWW360.jsp*). In order to obtain an overall average for the five consecutive years, all SST raster datasets were added up and divided by four using the Arcgis 10.0 raster calculator tool. The Simpson Parameter (referred here as “thermocline”), used here to visualize the boundary between cooler (SST 15 ^{o}C) well mixed and warmer (SST ^{o}C 16) well stratified waters was defined by a mean value of $\Phi = 50$ J m^{-3}. The Simpson Parameter shapefile was created using the drawing tools in Arcgis 10.0 and information was obtained from Bianchi et al., 2005.

Seafloor composition: The ocean floor is composed of six major substrates: sand, gravel, medium and large rocks, silt and small shells. Lactating females at Peninsula Valdés feed largely on benthic species such as flounder (*Paralichthys isosceles*) found in sandy substrates, and rarely on mud (Díaz de Asterloa, 1998) , the red octopus (*Enteroctopus megalocyathus),* found in crevices of hard bottom, rocky habitats (Roper et al., 1984; Ré, 1998) and the Tehuelche octopus (*Octopus tehuelchus*) preferring hard rock substrates but also found in areas of sandy substrates, where they find shelter in crevices (Ottoman, 1967, Ré, 1998). A study by Szteren (2004) on the diet of the SSL in January 1998 at Isla de Lobos determined that 90% of the diet was comprised by three main species: stripped weakfish (*Cynoscion guatucupa*), cutlass fish (*Trichiurus lepturus*), both of which are benthopelagic and have no known association to bottom subrstrates, and anchovy (*Anchoa marinii*) a pelagic species distributed along the upper water layers *(www.fishbase.org; www.inidep.gob.ar/ayuda/)*. Due to the benthopelagic-pelagic nature of prey distribution of females of Isla de Lobos and the lack of apparent association with seafloor composition, no substrate-high-use area analysis was performed for this colony. Spatial data on seafloor composition was built into a shapefile using the polygon drawing tool in Arcgis 10.0. Data were obtained from Parker et al. (1997).

Bathymetry: Bathymetry data were obtained from ETOPO2v2 Global Gridded 2-minute Database (http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html) and drawn in Arcmap 10.0 using the "add data" tool. Females are mostly benthic feeders (Drago et al., 2010) diving to mean depths of 60 m and up to a recorded maximum of 80 m (Werner and Campagna, 1995; Campagna et al., 2001). We used these parameters (60m and 80m respectively) to analyze associations between bathymetry and high-use areas of lactating females during their trips at sea.

Methodological steps

We proceeded in three steps: 1) interpolation of raw Argos Satellite data to obtain a more complete set of at sea locations for each tagged female, 2) identification of putative foraging areas of each individual female for which tracking data was available, and 3) overlap of oceanographic variables (chlorophyll *a*, SST, bathymetry and sea floor composition) and foraging habitats of tracked females to find correlations that could guide us in offshore protected areas design.

The first step was to interpolate raw Argos data for each tagged female utilizing the particle filter methods described in Tremblay (2009). The program created pseudo, at-sea locations of two-hour intervals for each female, calculated based on the time and location of existing Argos raw data. Interpolated tracks excluded satellite locations of animals while on land.

The areas of high use while at sea for each individual tracked female were identified by performing a kernel density analysis utilizing the kde analysis tool from Spatial Analyst in Arcgis 10.0 and later converting the density units to percentage (raster calculator tool in Arcgis ((kde/total density)*100)) thus converting density values to more manageable units. Areas of 50% total density or more were selected as core areas of high use. Raster cell size and search radius were calculated using the default settings of the kernel density estimate tool – shorter of width or length distance of home range divided by 250 for raster cell size and 30 for search radius.

Each identified high-use area of 50% density or more was then visualized in Arcmap 10.0 against average Chlorophyll *a*, average SST values and type of sea floor composition.

Due to the varying degrees of chlorophyll *a* concentration along the Argentine Patagonian coast, and for better visualization purposes, the range of average chlorophyll *a* concentrations used to contrast high-use areas were different for the area surrounding the tracked females of Península Valdés and area surrounding the colony of Isla de Lobos in Uruguay. Range values for SST were the same for all colonies. Moreover, due to the high concentration of areas of high-use located within a radius of 1.8 km from the Isla de Lobos colony (average chlorophyll *a* value approximately 5.49 mg/m^3) the comparison between chlorophyll *a* and female use for this colony was done by looking at average chlorophyll *a* concentration and entire distribution of females at sea.

Conservation scenarios, criteria for conservation intervention and costs for proposed spatio-temporal MPAs

Conservation scenarios

I proposed several alternative conservation approaches (referred to as conservation scenarios), based on the behavioral distribution of satellite-tracked lactating females while at sea. These are, from largest to smallest:

a) Furthest distance from colony reached by any female (Scenario 6). This scenario provides a conservative estimate of use that integrates the home range at sea, as indicated by satellite data of females for each colony (Appendix 2). A polygon resulted from simply connecting the locations furthest from the colony. The rationale was that a protected area that covers a surface that results from integrating these points will necessarily cover the distribution of most females for the particular colony.

b) Mean, maximum distance reached by females of the same colony (Scenario 5). This scenario was defined by finding the mean of maximum distance reached by all females of each colony (Appendix 2). This scenario provides a more inclusive approach than the previous by skewing the maximum distance from colony to a more representative scenario defined by all studied females of a colony. This approach also reduces the size of the proposed protected area because each colony has a proportion of females foraging close to shore.

c) Maximum distance reached if females where to travel one way at the mean speed of all females for that colony (Scenario 4). This scenario was calculated by finding the mean travel speed of all tracked females of each colony and calculating the distance they would reach if they were to travel constantly and in a straight line away from colony at that speed for 1.5 days (Appendix 2). Trip duration of 3 days total (roundtrip) was determined by taking the average of mean trip duration of all tracked females. Eighty percent of all tracked females of northern Patagonia showed a mean trip duration in the range of 2.7 – 3.4 days while females of Uruguay showed a mean trip duration distance of 2 days. As a conservative measure 3 days roundtrip was applied to all focal colonies.

d) Maximum distance if 100% of "high-use" areas were to be protected (Scenario 3). High-use areas were determined by the kernel density analysis of tracked females of each colony thus potentially safeguarding important foraging sites while significantly reducing MPA size to a more feasible area for protection. This scenario was calculated by measuring distance from colony to the furthest high-use area as determined by tracked females in each colony.

e) Maximum distance if 80% and 50% of high-use areas were to be protected (Scenarios 2 and 1). The rationale here is similar to that of scenario 3, although it has the potential to draw a smaller area (more practical and feasible for conservation purposes against an expectation of resistance by fisheries) still protecting a considerable proportion of high-use sites including areas of high transit density to and from the colony. High-use areas were measured as units (not surface area) and distance to colony from each individual high-use area was also measured. To calculate 50% and 80% scenarios, I counted the total high-use area "units" for each colony and looked at the furthest distance within the desired percent total. High-use areas were those of kernel densities > 50% in an attempt to provide a more conservative scenario of use.

Each of the parameters used to define the above scenarios (calculated individually for each target colony of northern Patagonia and Uruguay; Appendix 2) were converted to polygons by using the multiple-ring buffers tool in Arcgis 10 (Analysis tools/proximity/multiple ring buffer) and then clipped to fit each colony's at sea home range (100% MCP). Surface area (km^2) for each scenario was also measured (see Appendix 2).

Due to the lack of satellite tracked females in southern Patagonia (Santa Cruz and Tierra del Fuego) that could help us determine behavioral scenario parameters for those colonies, we created scenarios 6, 3 and 1 based on the mean values of those colonies for which we had data. Maximum distance from colony (scenario 6) and 100% high-use areas (scenario 3) were determined by calculating the mean values of scenarios 6 and 1 respectively from the four northern Patagonia colonies and Uruguay. Scenario 1 (50% high-use areas) was calculated by taking the mean of all 50% high-use area scenarios from the northern Patagonian colonies only. These scenarios were only applied to Monte Loayza, as a case study. Its results are assumed applicable to the remaining southern Patagonian colonies of similar geographic location (eg., coastal colonies w/ access to open ocean, similar hydrography and coastal bathymetry) and population profile.

Criteria for conservation intervention

Conservation scenarios of northern Patagonia and Uruguay target colonies were overlaid with the fishing distribution of 11 fleet types (Table 1, Fig 13) operating along the coastal Patagonian shelf during the months of January to March, 2012.

Our goal was to estimate the degree of fishery overlap (measured here by calculating percentage overlap = surface area of overlapping fishery/surface area of MPA scenario x 100) within scenarios of each colony to define criteria for conservation intervention. Fisheries were considered "conflicting" and a "target for conservation intervention" if meeting the criteria based on the following mid-point approximations:

1. Fishery overlap is 50% or higher within any scenario.
2. Fishery overlap is 20% or higher within scenario 1 (50% of high-use areas)
3. Fishery overlap is 30% or higher within scenario 2 (80% of high-use areas).

Percent overlap estimations to determine conflict for conservation scenarios 1 and 2 were lower than 50% to compensate for reduced area size and proximity to colony (area of higher animal density determined by higher transit to and from colony).

Because in many instances different fleet types operate in the same areas only the most representative fishery, the one with the largest surface area overlap and encompassing smaller ones, was used in the initial assessment of the above criteria. Once the most representative fishery was identified as "conflicting", the area defined by the fishery overlap (area to be considered for the establishment of spatio-temporal MPA) was examined for a series of conservation intervention alternatives if females of the SSL were to be protected during the month of January. All fisheries operating within the MPA were considered in the analysis.

Costs for implementing proposed conservation intervention scenarios (MPAs)

To explore conservation intervention scenarios for the Punta León rookery we gathered the following data for the period of 2010-2012: fleet types operating within the proposed MPA, administrative and operational ports for these fleets, species targeted, declared annual landings (source: *http://organismos.chubut.gov.ar/pesca/*) and exported value of target species and fishing activity during the month of January obtained from *http://www.miniagri.gob.ar/site/pesca/index.php*. Similar fishing data were not available for Isla de Lobos. Punta León was used as a case study.

Rationale and methodology to estimate economic costs associated to implementing the proposed conservation intervention scenarios were as follows:

Conservation intervention 1 (CJRw_all). Economic cost (compensation) if all fleets operating from Puerto Rawson ceased their activities during the month of January. This scenario was calculated using the following formula:

[1] $\text{CJRw\_all} = \%\, L_j\, [(L_{sp1} * EV_{sp1}) + [(L_{sp2} * EV_{sp2})]$ Where:

CJRw_all = Cost of ceasing fishing activities in January from Puerto Rawson

$\% L_{j\,=}$ percent landings for January

$L_{sp1\,=}$ Mean annual landings (ton/year) of sp1 (Argentine hake, *Merluccius hubbsi)*

$EV_{sp1\,=}$ Economic value (U$S/ton) of sp1 (Argentine hake, *Merluccius hubbsi*)

$L_{sp2\,=}$ Mean Annual landings (ton/year) of sp2 (Argentine red shrimp, *Pleoticus muelleri*)

$EV_{sp2\,=}$ Economic value (U$S/ton) of sp2 (Argentine red shrimp, *Pleoticus muelleri*)

Conservation intervention 2 (CJRw_MPA). Close all activity within MPA during the month of January assuming only a conservative estimate of ± 10% of the declared landings come from the targeted area. To calculate this scenario we obtained the 10% of the compensation cost calculated in the conservation intervention scenario 1. This scenario was calculated using the following formula:

[2] $(\text{CJRw\_MPA}) = 0.10 * \text{CJRw\_all}$., where,

CJRw_MPA = Cost of ceasing fishing activities inside MPA in January.

Conservation intervention 3 (CJRw_MPA (Argentine hake not included)). The area defined by the MPA is mostly used by fleets targeting argentine red shrimp. Thus, if we cease all activity within the MPA to the fishing of Argentine red shrimp during January we could reduce the compensation costs by:

[3] CJRw_all *(A.hake not included)* = % L_j (L_{sp2} * EV_{sp2})

Then,

CJRw_MPA *(A.hake not included)* = 0.10 (CJRw_all (*A.hake not included*))

Where,

CJRw_all *(A.hake not included)*= Cost of ceasing fishing Argentine red shrimp activities in January

CJRw_MPA *(A.hake not included)*= Cost of ceasing fishing Argentine red shrimp activities in January inside MPA

% $L_{j\,=}$ percent landings for January

$L_{sp2\,=}$ Mean Annual landings of sp2 (Argentine red shrimp, *Pleoticus muelleri*)

$EV_{sp2\,=}$ Economic value of sp2 (Argentine red shrimp, *Pleoticus muelleri*) in tons/year

Conservation intervention 4 - Compensate 100 % reduction in landings (offsets) if area of MPA (assumed as "optimal") was closed and fisheries had to operate outside this area during the month of January. This scenario was calculated by:

[4] OFFSETS = CJRw_MPA – [landings declared by fleet for January of year of MPA implementation]

Conservation intervention 5 - This option considers the compensation of a set US$ amount to be negotiated by the involved parties (i.e., government and fisheries) if fisheries were to operate outside MPA during the month of January. This option can be implemented in the case in which the fishing sector understands and agrees that this measure can contribute to the conservation of biodiversity, ecological services and sustainable fishing practices favorable for the industry in the long run.

Fisheries

Fisheries data were obtained from the Secretaría de Agricultura, Ganadería, Pesca y Acuicultura (SAGPyA) de Argentina. Data included satellite positions from December 1st, 2011 through March 31st, 2012 reported to the MONPESAT system between 30° S and 50° S and within a distance of 200 km from the Argentine Patagonian coast. Positions were included for 10 different fleet types (Table 1).

Determination of fishing effort

Original fisheries data were filtered by time of day (as some fleets operate during day and others during night) and fleet speed to differentiate between "transit" vs. "fishing" activities.

Fishing effort locations for the different fleets were calculated as follows:

a. All pelagic, coastal and artisanal trawlers targeting Argentine hake *(Merluccius hubbsi)*, Argentine red shrimp *(Pleoticus muelleri)* and an assemblage of demersal coastal species (referred to as "variado costero") were filtered by selecting those satellite positions falling between 6:00 am and 9:00 pm and speeds between ≥ 1 and ≤ 4 knots.

b. Outriggers were filtered by selecting those satellite positions falling between 6:00 am and 9:00 pm (shrimp fishing forbidden between sunset and sunrise) and speeds between > 0 and ≤ 3.5 knots (the maximum speed allowed by law for these type of fishing fleets) (source: *http://www.inidep.gob.ar/wpcontent/uploads/Langostino.pdf)*.

c. Jiggers targeting argentine shortfin squid (*Illex argentinus*) were first filtered by time of year as fishing this species is only allowed after February 1st. Those positions falling between February 1st and March 31st 2012 were selected. I then proceeded to filter satellite positions falling between the hours of 8 pm and 6 am when fishing speed was 0 (zero).

d. Two types of longline fishing operate within the continental shelf: local artisanal longliners targeting Argentine hake and large commercial ice longliners targeting a larger variety of species. Commercial longliners operate exclusively along the outer edge of the continental shelf and are excluded from this study for that reason. Filtering for the artisanal longliners comprised those satellite positions between the hours of 6 am and 9 pm and traveling speeds of ≥ 1 and ≤ 4 knots.

Once fishing areas were selected I proceeded with a kernel density analysis with the goal of visualizing overall distribution and percentage of effort of each fleet. Search radius (*h*) for the kernel density analysis was 5 km for artisanal fleets, 50 km for coastal fleets and 150 km for all high seas ice and freezer trawlers. Resolution or cell size for artisanal and coastal fishing fleets was established as 1/10 of the search radius (or *h* parameter) corresponding to 0.5 km and 5 km respectively. Ice and freezer trawlers were not calculated as 1/10 of the original search radius but rather 5 km providing a better visualization of these fleets' distributions. Density grids were later normalized to sum 100 % and categorized in Arcmap as areas of > 10%, > 25%, > 50% and > 75% density use. (raster calculator (kde/value of cell w/max kde value) * 100).

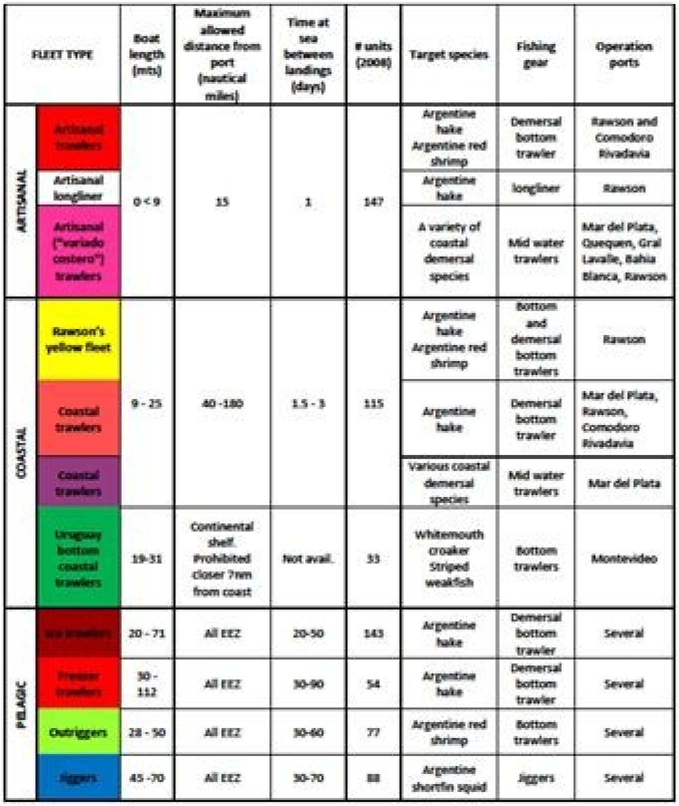
The pelagic ice-trawler fishery distribution within Golfo San Matías was treated as an individual unit because of its importance as fishing grounds of the demographic unit of the Patagonian Argentine hake population (*Merluccius hubbsi*) residing exclusively in the San Matías gulf (Romero et al., 2011) and because of its low representativeness when run under the kernel density analysis for the entire pelagic ice-trawler fleet distribution. To achieve this I selected all locations pertaining to the pelagic ice trawler fishery within Golfo San Matías and performed a kde (search radius 5 km and cell size 0.5 km) on the selected points.

The distribution of the Uruguayan coastal bottom trawl fishery targeting whitemouth croaker *(Micropogonias furnieri)* and striped weakfish *(Cynoscion striatus)* was digitized manually using the drawing tools from Arcgis 10.0. Data were obtained from Riet-Sapriza et al., 2012.

Jurisdictions

I also overlaid each colony with provincial and federal jurisdictions in an attempt to define the government bodies in charge of marine protected area implementation and management. Provincial jurisdiction for the Patagonian Sea was drawn by creating a 12 nautical mile buffer along the coast utilizing the buffer tool in Arcgis 10.0. Exclusive Economic Zone boundaries were downloaded from http://www.marineregions.org website version World EEZ v7 (2012-11-20, 67 MB). Data on fishery management jurisdictions were obtained from the Consejo Federal Pesquero (www.cfp.gov.ar) and drawn using the drawing tools in Arcmap 10.0.

Table 1: Description of fisheries operating during the months of January-March 2012 between 30^{o}S and 50^{o}S and within 200 km from the Patagonian coast (source: Secretaría de Agricultura, Ganadería, Pesca y Acuicultura de Argentina). Data for coastal bottom trawler fleet of Uruguay was obtained from…Artisanal "variado costero" fleets operating from Puerto Rawson strictly target Argentine hake and Argentine red shrimp. Cientific names for Argentine hake: *Merluccius hubbsi*, Argentine red shrimp: *Pleoticus muelleri,* Argentine shortfin squid: *Illex argentinus*, Whitemouth croaker: *Micropogonias furnieri* and Stiped weakfish: *Cynoscion striatus.*



FLEET TYPE		Boat length (mts)	Maximum allowed distance from port (nautical miles)	Time at sea between landings (days)	# units (2008)	Target species	Fishing gear	Operation ports
ARTISANAL	Artisanal trawlers	0 < 9	15	1	147	Argentine hake Argentine red shrimp	Demersal bottom trawler	Rawson and Comodoro Rivadavia
	Artisanal longliner					Argentine hake	longliner	Rawson
	Artisanal ("variado costero") trawlers					A variety of coastal demersal species	Mid water trawlers	Mar del Plata, Quequen, Gral Lavalle, Bahia Blanca, Rawson
COASTAL	Rawson's yellow fleet	9 - 25	40 -180	1.5 - 3	115	Argentine hake Argentine red shrimp	Bottom and demersal bottom trawlers	Rawson
	Coastal trawlers					Argentine hake	Demersal bottom trawler	Mar del Plata, Rawson, Comodoro Rivadavia
	Coastal trawlers					Various coastal demersal species	Mid water trawlers	Mar del Plata
	Uruguay bottom coastal trawlers	19-31	Continental shelf. Prohibited closer 7nm from coast	Not avail.	33	Whitemouth croaker Striped weakfish	Bottom trawlers	Montevideo
PELAGIC	Ice trawlers	20 - 71	All EEZ	20-50	143	Argentine hake	Demersal bottom trawler	Several
	Freezer trawlers	30 - 112	All EEZ	30-90	54	Argentine hake	Demersal bottom trawler	Several
	Outriggers	28 - 50	All EEZ	30-60	77	Argentine red shrimp	Bottom trawlers	Several
	Jiggers	45 -70	All EEZ	30-70	88	Argentine shortfin squid	Jiggers	Several

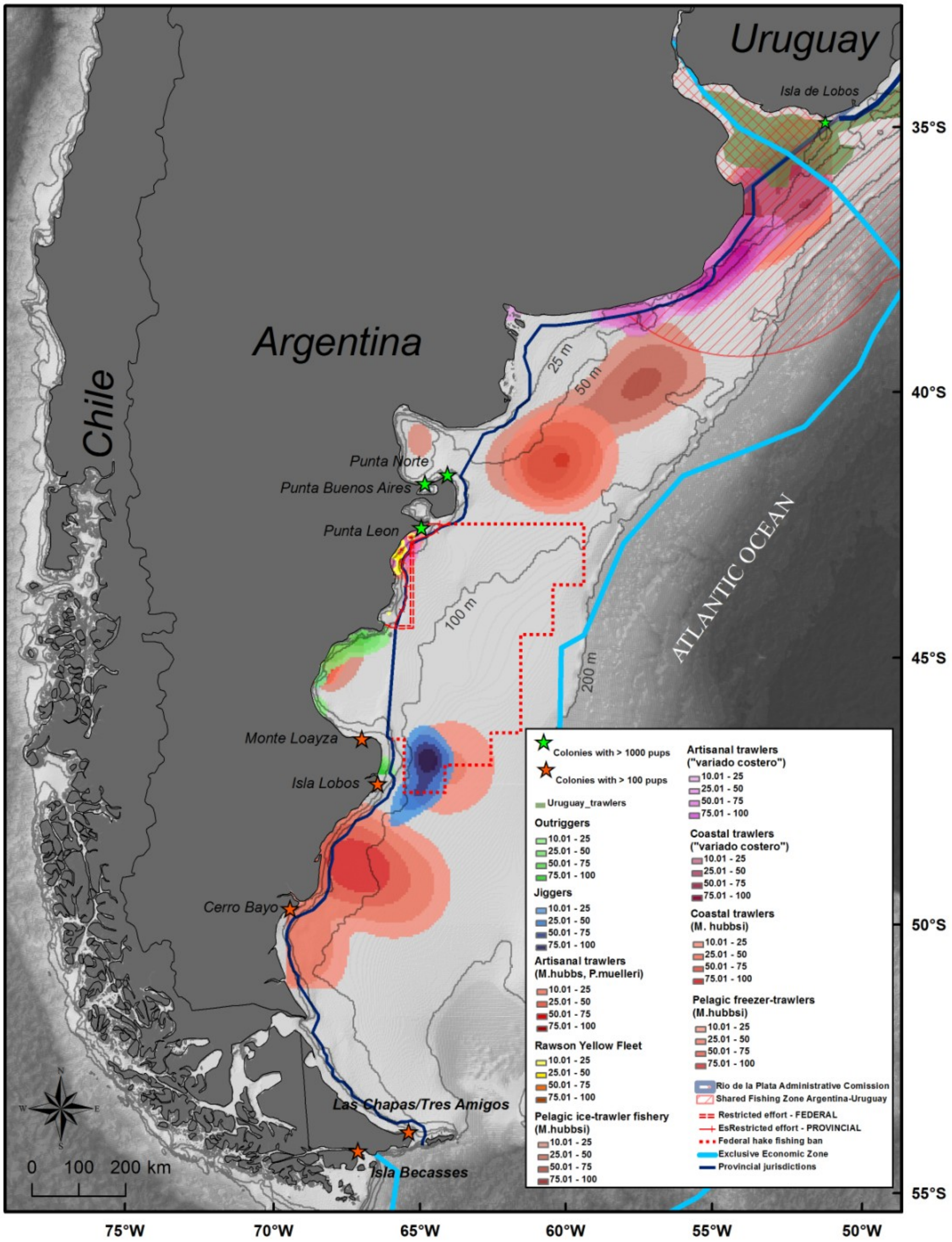


Figure 13: Effort distribution of 9 fleet types (Table 3) operating between 30^{o} S and 50^{o} S and within 200 km from the patagonian coast between January and March 2012 (source: Secretaría de Agricultura, Ganaderia, Pesca y Acuicultura of Argentina). Distribution effort of the coastal bottom trawler fishery operating along the coast of Uruguay is also included. For clarity purposes (and due to its lack of conflict with the SSL, the artisanal longliner fishery has been excluded.

Results

Target colonies

Three of the 31 breeding colonies reported for Argentine Patagonia along 4,989 km of coastline fit the requisite of producing ≥ 1,000 SSL pups per season: Punta León (1,570 pups), Punta Norte (1,975 pups) and Punta Buenos Aires (1,778 pups), all located in Península Valdés and nearby areas (Appendix 1, Figure 3). About 2,600 SSL (needs update) pups were born at Isla Lobos Uruguay, the largest of the Uruguayan SSL colonies. For southern Patagonia, we identified five colonies with ≥ 100 pups born per season, three located in the Santa Cruz province (Cerro Bayo: 135 pups, Isla Lobos: 175 pups, and Monte Loayza: 245 pups) and two in Tierra del Fuego (Isla Becasses and Las Chapas-Tres Amigos with 179 and 111 pups, respectively) (Appendix 1, Figure 3). These colonies represent five of seven breeding colonies for southern Patagonia.

Physical variables (chlorophyll *a*, sea surface temperature, bathymetry, seafloor composition) and high-use areas of satellite tracked lactating females of study colonies.

We not detect a significant association of foraging females with any of the physical variables we examined, suggesting that these variables could not be used as proxies to design MPAs. The one possible exception is bathymetry.

Chloropyll a:

No clear association was found between female movements, preferred putative foraging areas and ocean productivity as indicated by the concentration of chlorophyll *a* in remote, satellite images. The distribution at sea of the SSL females (n = 20) from the four northern Patagonia breeding colonies comprised an area of 33,000 km^2 Within their range, there were two frontal zones, El Rincón and Valdés, both with chlorophyll *a* levels about twice the value of preferred putative foraging places. Even when frontal areas were located close to a colony (eg.,Figure 5b for Valdés and El Rincón fronts), females did not use them predictably (Figures 5a and 5b). Comparisons among colonies indicated that individuals foraged in the proximity of highly productive frontal areas (eg., Figure 5b) while others travelled and spent most of their time in relatively low productivity waters (eg., Figure 5a).

Females from Isla de Lobos travelled mostly S, SE and SW from the island, in chlorophyll *a* concentrations ranging between 1.56 – 7 mg/m^3. No preference was shown for the Río de la Plata front with chlorophyll *a* values ranging 10-12 mg/m^3, doubling those of the preferred waters. Of the seven tagged females from Isla de Lobos, three consistently travelled W and SW from colony and dispersed at average chlorophyll *a* values ranging between 2.5 – 7 mg/m^3. The other four, travelled SE from colony with two remaining almost exclusively within chlorophyll *a* values between 2.5 mg/m^3 - 5.6 mg/m^3 (when closest to colony) and two in areas with values ranging between 5.6 mg/m^3 (when closest to colony) and 1.56 mg/m^3 when furthest from colony (Fig. 5a).

Individuals from Punta Buenos Aires and Punta Pirámide showed no association to any conspicuous area of high productivity (Figure 5b). All three females tracked at Punta Buenos Aires foraged and travelled in low productivity areas of chlorophyll *a* concentrations ranging between 0.5-1.0 mg/m^3 showing no particular pattern or preference for a "weak" front described for San Matías (see Methods). Two of the three lactating females of Punta Pirámide foraged and travelled close to the coast in areas with chlorophyll *a* concentrations ranging between 0.5-1.0 mg/m^3. One of the instrumented females (Figure 5b, high-use areas inside polygon) travelled towards the continental shelf, from medium levels of productivity into lower chlorophyll *a* values ranging between 1-2 mg/m^3. Females from Punta Pirámide would have to travel approximately 100 km to reach the Valdés front. Yet, some of them travelled 108 km to spend time in low productivity waters.

Lactating females of Punta León travelled SE from their colony, concentrating at sea time around chlorophyll *a* values ranging from 1-2 mg/m^3 while avoiding the front of Valdés, which was located well within reach of travel distance 86 km recorded for females from that colony (furthest high use area located at 158 km from colony) (Figure 5b).

Of the four females sampled from the Punta Norte rookery two showed areas of high use at close proximity to colony with chlorophyll *a* values ranging between 1-1.5 mg/m^3 while a third animal travelled further, mostly to areas of average chlorophyll *a* concentrations ranging between 1-1.5 mg/m^3 with high use areas at close proximity (12 km) to the edge of El Rincón front (average cholorphyll value 2.3

mg/m^3; Figure 5b). The fourth female also travelled and foraged in waters with chlorophyll *a* concentrations ranging between 1-1.5 mg/m^3, and in proximity (approx. 7 km) to the northwest boundaries of the Valdés front (average chlorophyll *a* value 2.62 mg/m^3; Figure 5b).

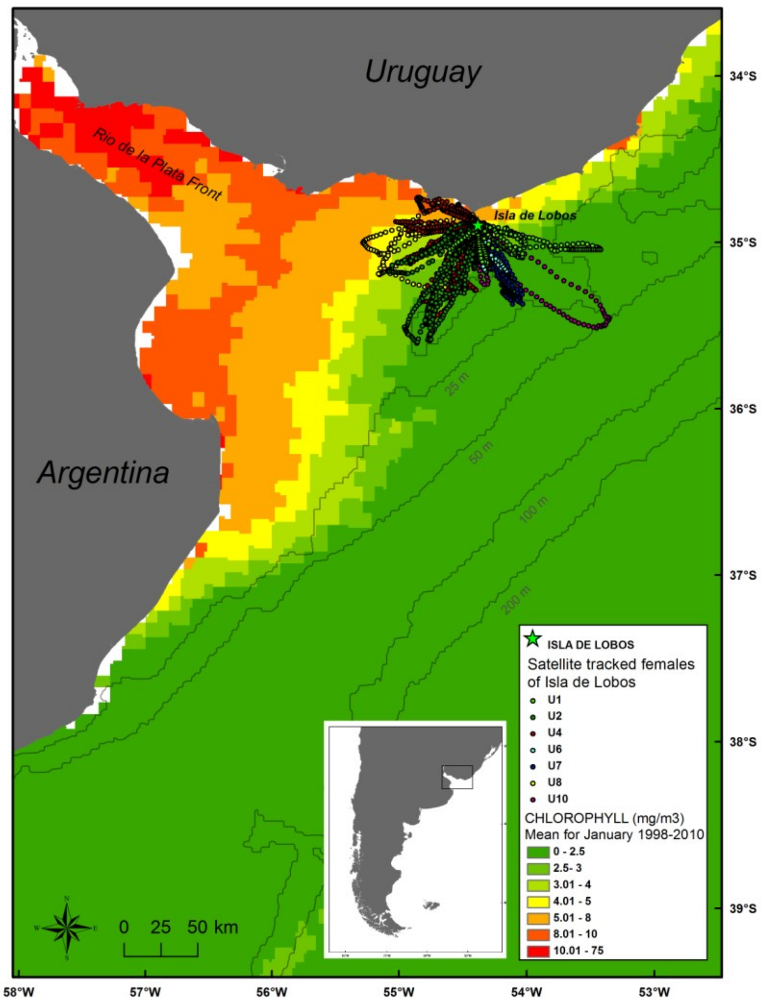


Figure 5a: Distribution at sea of lactating females (n = 7) tagged at Isla de Lobos, Uruguay (Riet-Sapriza et al., 2012) and its association with mean chlorophyll values (mg/m^3) obtained for January 1998 – 2010 (source: Giovanni - Ocean color radiometry online visualization and analysis). Females remained in proximity to the colony and the productive waters of the La Plata river front were not targeted by the sampled individuals.

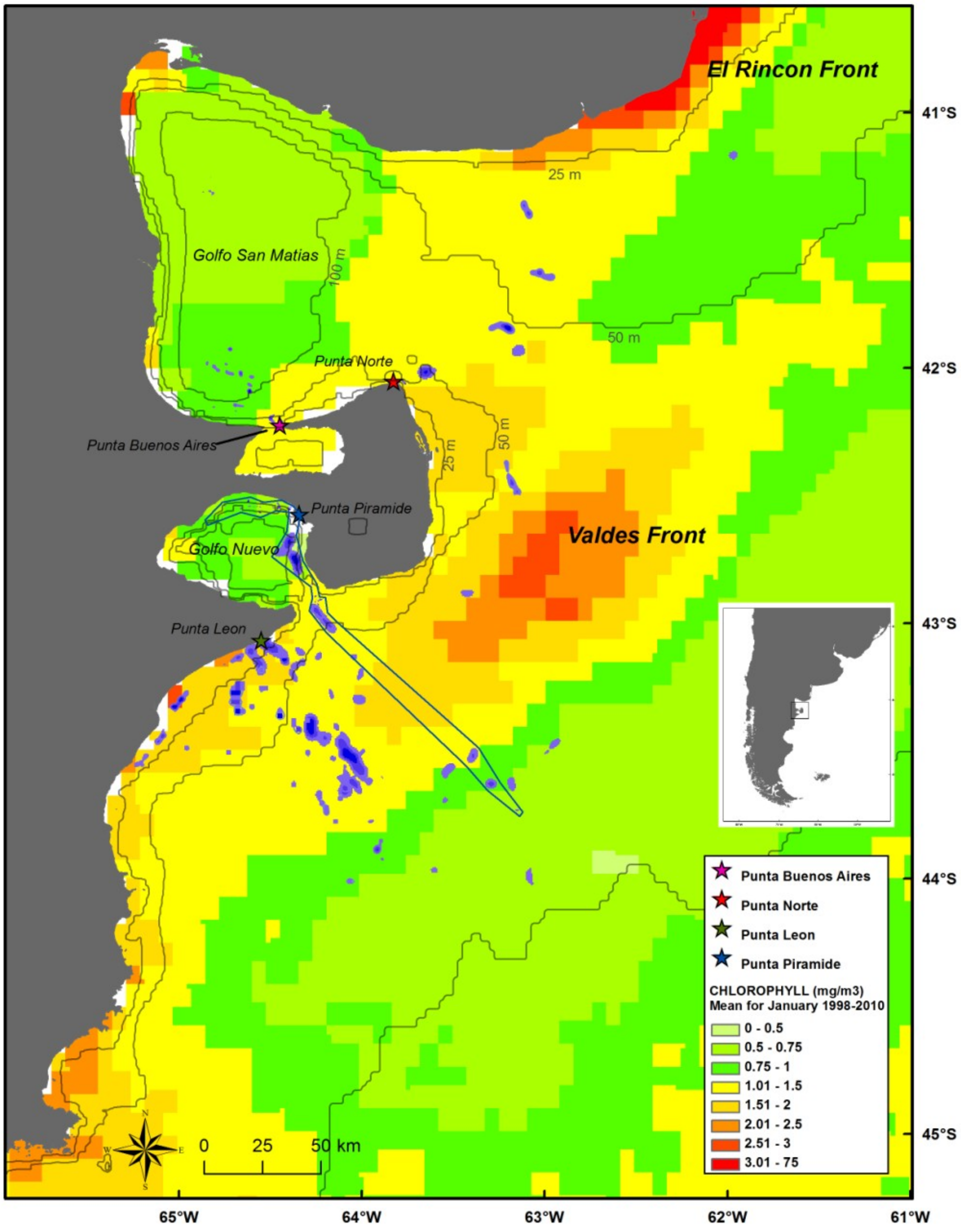


Figure 5b: Mean chorophyll values (mg/m^3) for January 1998-2010 (Giovanni - Ocean color radiometry online visualization and analysis) and areas of high use (see Methods) for satellite tracked lactating females tagged in the four northern Patagonia studied colonies. For clarity purposes, high use areas pertaining to females of Punta Pirámide were enclosed in a polygon to separate them from high use areas of females of Punta León. Females do not show preference for productivity fronts in the range of their travel distance.

Sea surface temperature and thermocline

Females from four of the five studied colonies did not show a clear association between SST and female foraging area preferences. Females form Isla de Lobos travelled and foraged in waters of 21 ^{o}C (Fig. 6a) while females from northern Patagonia, ranged over areas with SST ranging between 15 to 18 ^{o}C (Fig. 6b). Females from the Punta Pirámide, Punta Norte and Punta León rookeries occured at sea within the range of stratified, offshore waters (Fig. 6b, dotted line), E of the mixed coastal waters (stratified waters may represent areas of high-prey densities; see Methods). The thermocline was closest (36 km to closest point) to the Punta León colony. Four of the five females from this colony crossed the thermocline with 50-70 % of high-use areas in stratified waters. One of the three females from Punta Pirámide also showed 50 % of its high-use areas in stratified waters (Fig. 6b).

Females of Punta Buenos Aires ranged across SST between 15-17 ^{o}C, although 95% of their high-use locations were in the southern cooler water with temperatures of 15-16 ^{o}C and in close proximity to the colony where salinity is lower and phytoplankton more abundant (Figure 6b).

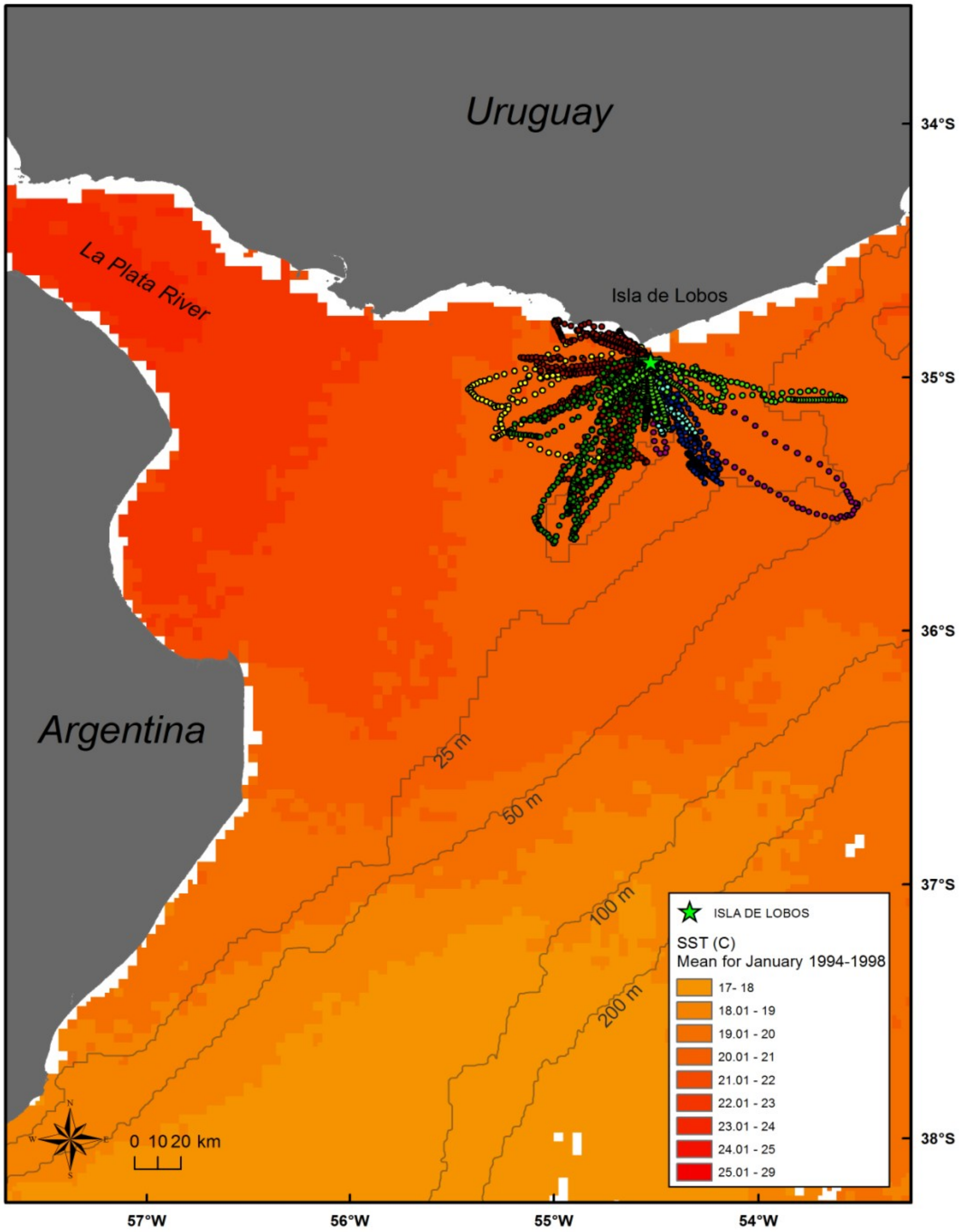


Figure 6a: Sea surface temperature (SST) and distribution at sea of lactating females from Isla de Lobos, Uruguay. SST data was obtained as day and night averages for the month of January 1994 – 1998 *(http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowserWW360.jsp)*. Females of this colony foraged at SST of 21^{o} C. Little temperature gradation is found within the female's travel range.

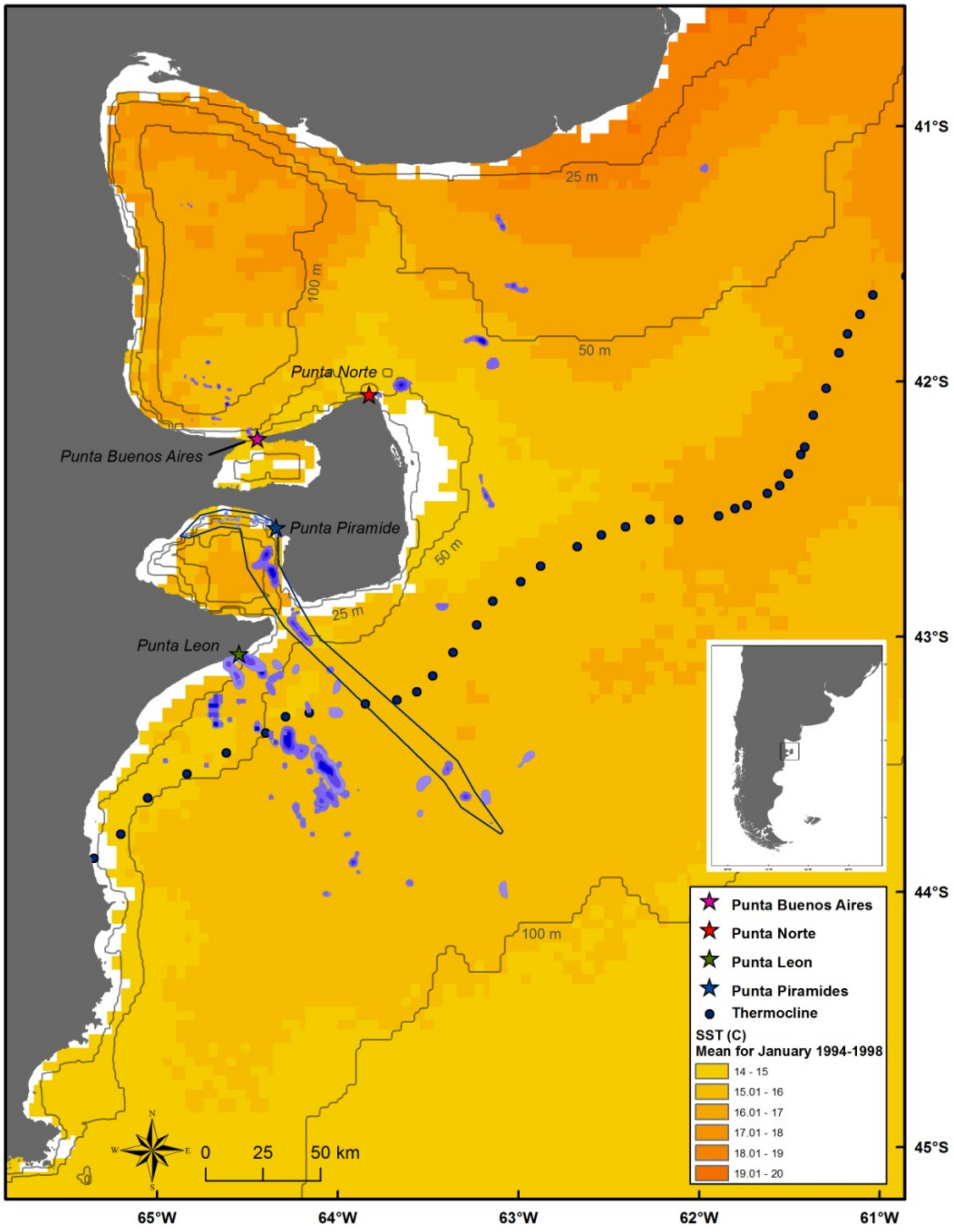


Figure 6b: Sea surface temperature (SST) and high use areas (see Methods) of lactating females of the four tagged northern Patagonia colonies. SST data was obtained as day and night averages for the month of January 1994 – 1998 *(http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowserWW360.jsp)*. No clear association was observed between SST values and female preference.

Seafloor composition

Seafloor composition varied greatly in areas surrounding the studied colonies and females did not show preference for a particular seafloor substrate and therefore for a distinctive benthic habitat. While Golfo San Matías and Golfo Nuevo were predominantly composed of silt at depths of approximately >100 and sand at the shallower edges, the waters of the continental shelf surrounding the colonies of Punta Norte and Punta León were composed of a similar proportion of gravel, sand and sea shells for Punta Norte and gravel and sand for Punta León (Fig. 7).

High-use areas of females from Punta Buenos Aires were associated with silt substrates ranging from <75 m when closer to colony to > 100 m as they travelled offshore. Of the three tagged females from Punta Pirámides, one foraged exclusively in sandy coastal waters at depths of <75 m, a second frequented areas in sandy and gravel substrates at depths between 50-80 m, and a third was found exclusively in gravel substrates at 50 m of depth. Females of Punta Norte were found in a variety of sea floor substrates ranging from medium rocks to gravel, while high-use areas pertaining to the females from Punta León were equally distributed along seafloor substrates composed of gravel and sand (Fig. 7).

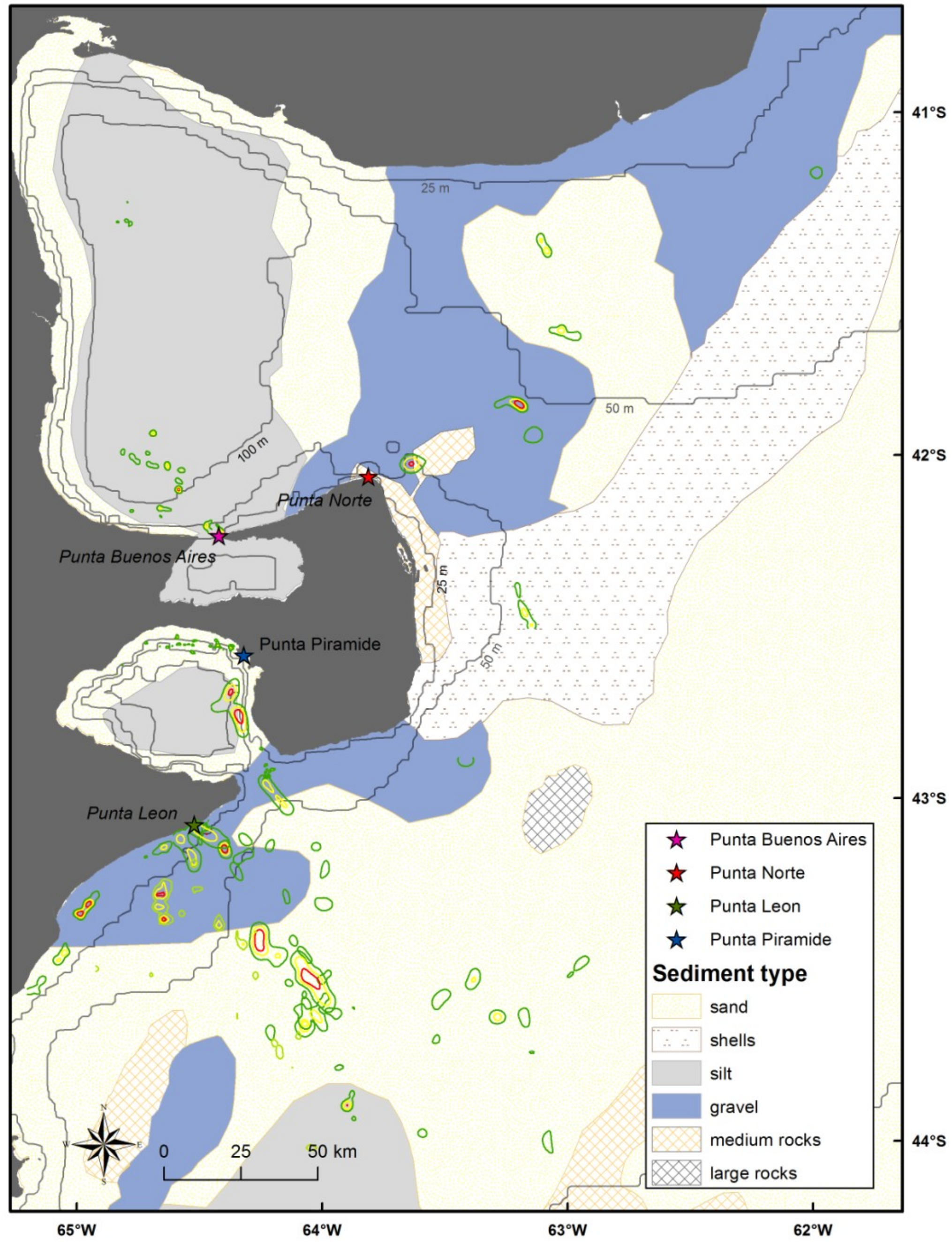


Figure 7: Sea floor composition and areas of high use for tagged lactating females from four breeding rookeries in Península Valdés. Substrate data was obtained from Parker et al. (1997). No clear association was observed between seafloor substrate and female high use areas.

Bathymetry

Consistent with reported mean and maximum depths and benthic habits, most tracked animals remained within the 60 – 80 m bathymetric contours. Figure 8b shows results from northern Patagonia and Figure 8a shows results for Isla de Lobos. Females from Punta Buenos Aires foraged in the deep waters of Golfo San Matías, with most high-use areas beyond the 80m depth contour. Individuals from Punta Norte remained within the 60 m depth line and the coast. The Punta Pirámide rookery is in close proximity to the deep waters of Golfo Nuevo. However, females from this colony remained in coastal areas < 80 m deep or travelled toward the continental shelf in waters no deeper than 80 m. Females from Punta León rarely incurred into deep waters, being either coastal or travelling offshore to areas 80 m deep or less. Females form Isla de Lobos rarely reached the 50 m depth limit and mostly remained within the 25 m bathymetric line.

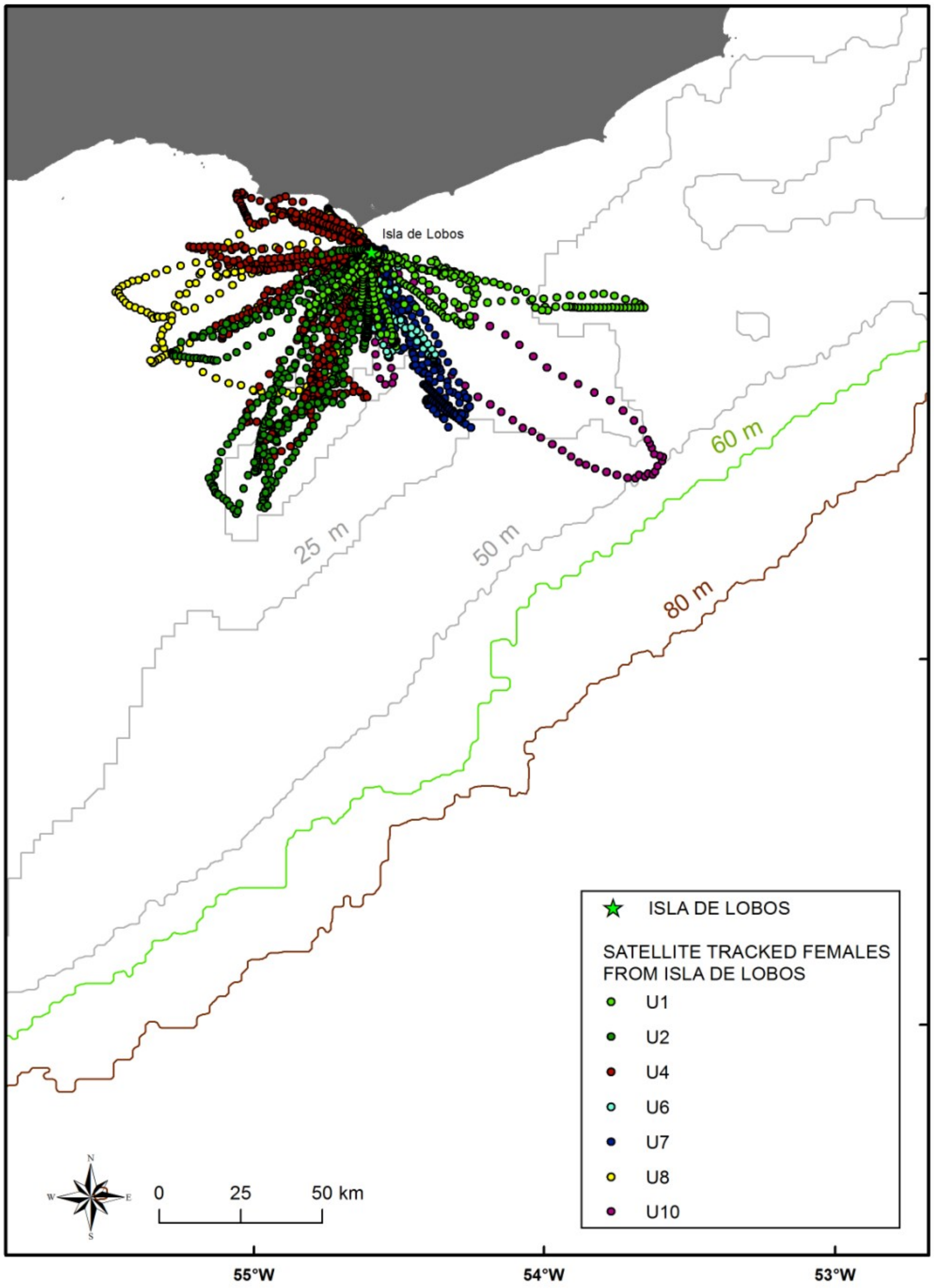


Figure 8a: Bathymetry and areas of high use for tagged lactating females (n = 7) from Isla de Lobos. Bathymetry data was obtained from ETOPO2v2 Global Gridded 2-minute Database (http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html). Lactating females at sea were almost exclusively distributed within areas of 25 m in depth.

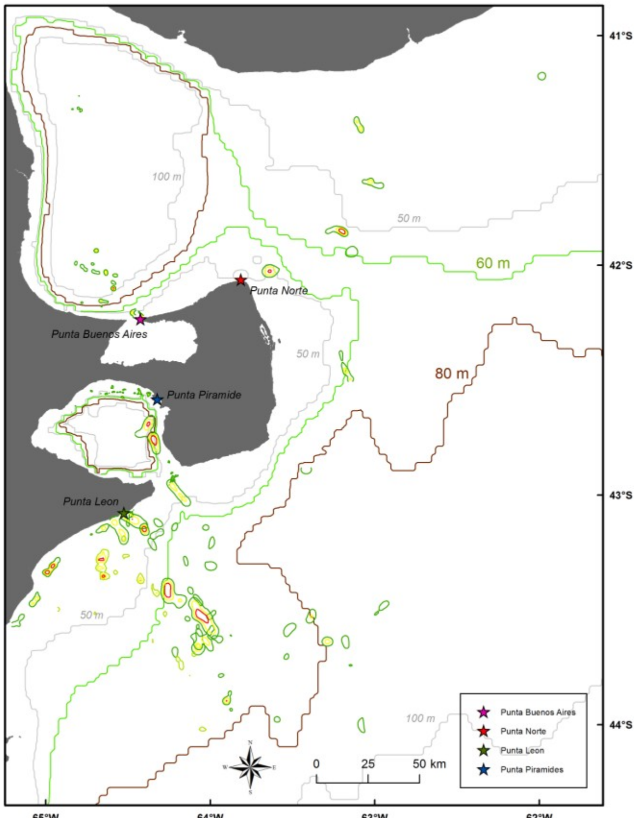


Figure 8b: Bathymetry and areas of high use for lactating females (n = 20) pertaining to the four northern Patagonia studied rookeries. Bathymetry data was obtained from ETOPO2v2 Global Gridded 2-minute Database (http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html). Females showed preference for the 60 m and 80 m waters with the exception of females from Punta Buenos Aires foraging in coastal waters and areas of > 80 m in depth.

Conservation scenarios, criteria for conservation intervention and costs of proposed protected areas

Conservation scenarios

Table 2 summarizes the surface areas and maximum distance parameters (used to define scenario boundaries) that corresponded to the six different conservation scenarios defined for each colony to guide implementation of potential MPAs.

Table 2: Surface areas and maximum distance parameters corresponding to conservation scenarios of target colonies.

Target colonies	Conservation scenarios	Distance to colony (km)	Surface Area (km^2)
PUNTA BUENOS AIRES	(1) 50% high-use areas	10	164
	(2) 80% high-use areas	28	977
	(3) 100% high-use areas	39	2,587
	(4) 1.5 day travel at mean speed	100	6,266
	(5) Mean max. distance all females	51	3,348
	(6) Max. distance reached by any female of colony	112	6,656
PUNTA NORTE	(1) 50% high-use areas	20	724
	(2) 80% high-use areas	80	10,324
	(3&5) 100% high-use areas/Mean max. distance all females	95	12,468
	(4) 1.5 day travel at mean speed	104	15,954
	(6) Max. distance reached by any female of colony	213	28,873
PUNTA LEON	(1) 50% high-use areas	47	3,554
	(2) 80% high-use areas	63	6,151
	(3) 100% high-use areas	75	8,493
	(4) 1.5 day travel at mean speed	106	15,842
	(5) Mean max. distance all females	128	20,203
	(6) Max. distance reached by any female of colony	166	25,611
ISLA DE LOBOS	(3) 100% high-use areas	1.8	10
	(5) Mean max. distance all females	76	8,876
	(6) Max. distance reached by any female of colony	110	14,217
MONTE LOAYZA	(1) 50% high-use areas	26	800
	(3) 100% high-use areas	69	7,900
	(6) Max. distance reached by any female of colony	150	40,000

Maximum distance reached by any female in colony (home range) (scenario 6). The smallest area that resulted from creating a Minimum Convex Polygon (MCP) of satellite locations for females of each colony at sea was that of the Punta Buenos Aires rookery with a surface area of 6,656 km^2. MCP for Punta Norte females was the largest of all studied colonies and resulted in a polygon 4.3 times larger than that of Punta Buenos Aires.

Mean maximum distance reached by females of the same colony (scenario 5)

For the Punta Norte rookery, the size of the polygon that comprised the mean, maximum distance of the tracked females was equivalent to the scenario that resulted in the encompassment of 100% of the high-use areas. In all other colonies, scenario 5 was much larger than that resulting in protecting 100% high-use areas, resulting in areas up to 2 times larger and suggesting a less effective MPA strategy based on this parameter.

Maximum distance reached if females where to travel one way (1.5 days) at the mean speed of all females for that colony (scenario 4)

For Punta Buenos Aires, the polygon that resulted in implementing this scenario was similar to that defined by scenario 6 (maximum distance from colony reached by any female). This suggests that females were reaching the furthest distance if this parameter were to hold true.

Maximum distance if 100% of high-use areas were to be protected (scenario 3)

Due to the extreme coastal habits of females from Isla de Lobos, an area of 10 km ^{2} included all high-use areas of studied females from that colony. Conversely, the broad dispersal of females from Punta Norte resulted in the largest polygon encompassing 100% high-use areas with a surface area of 12,468 km^2.

Maximum distance if 80% of high-use areas were to be protected (scenario 2)

This criteria could be useful for some colonies, such as Punta Buenos Aires, with a decrease in surface area of almost 40% compared to the previous scenario (100% high-use areas), for only a 20% reduction in high-use cover.

Maximum distance if 50% of high-use areas were to be protected (scenario 1)

This resulted in the smallest surface area for colonies with high dispersal of coastal and pelagic individuals with area sizes ranging from 164 - 3,554 km^2.

Monte Loayza

The application of conservation scenarios for this breeding site of southern Patagonia suggest that maximum distance polygon were too large to be practical and only scenario one (50% high-use areas) yielded polygons of comparable size to other Patagonia rookeries.

Overlap of selected fisheries (see Methods) and conservation scenarios of target colonies

Most relevant fisheries operating within the limits of conservation scenarios for each target colony are summarized in Appendix 3. The analysis of overlap between conservation scenarios and fisheries effort indicate that conservation intervention is justified for scenarios 1 and 2 of Punta León and all scenarios of Isla de Lobos.

Punta Buenos Aires

The overlap of fishing activity on conservation scenarios of females from this colony fell below the criteria for conservation action (Figure 9; Table 3a).

The only fishery operating in an area adjacent to this colony was the pelagic, ice-trawler fleet specializing in a demographic unit of the Patagonian, Argentine hake population resident of the San Matías gulf. Percent overlap of the pelagic, ice-trawler fishery within conservation scenarios ranged from 0-15%, with a maximum overlapping area of 809 km^2 (Table 3a).

The full distribution of lactating females of Punta Buenos Aires while at sea falls entirely within the Golfo San Matías, a jurisdiction of Rio Negro and Chubut provinces. Fishery distribution falls strictly within the boundaries of Río Negro province.

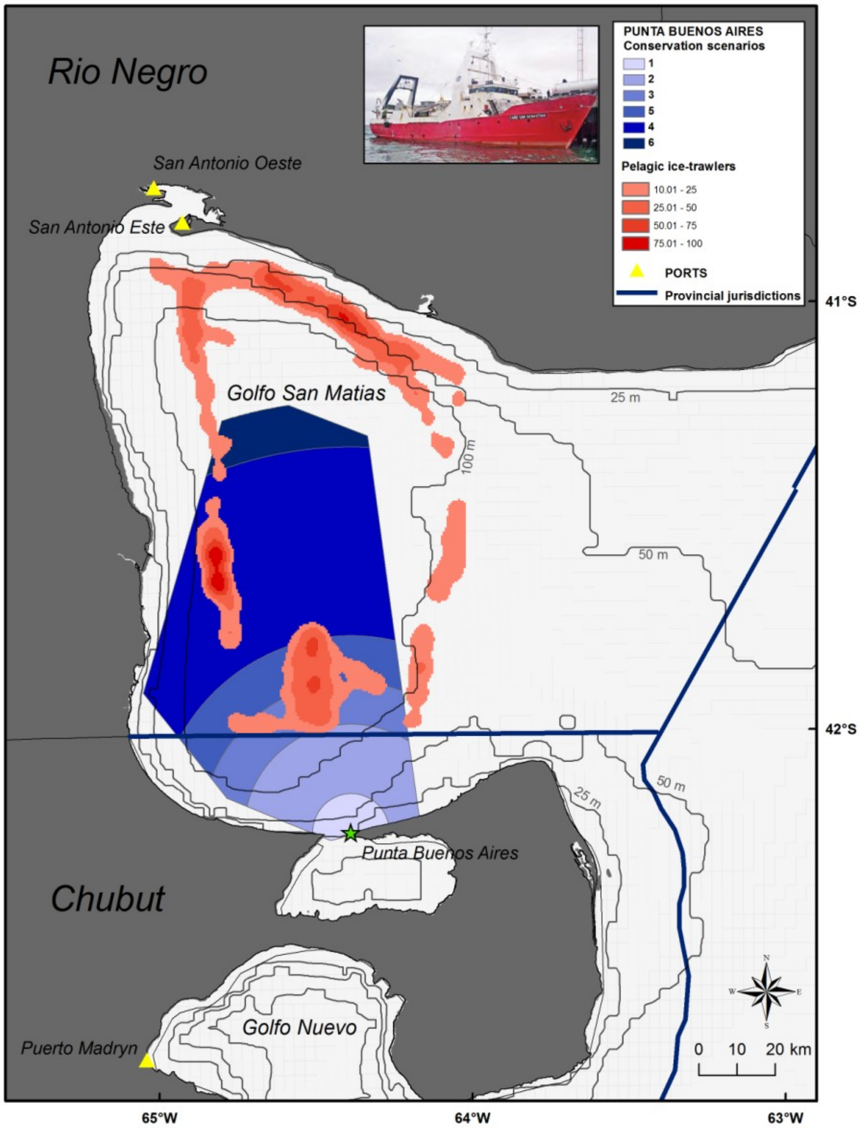


Figure 9: Kernel density estimate of fishing effort (Jan.-Mar.2012) for the pelagic ice-trawler fishery targeting Argentine hake, *Merluccius hubbsi* operating within the Golfo San Matías and overlaying with conservation scenarios for the Punta Buenos Aires rookery (fishery data from Secretaría de Agricultura, Ganadería, Pesca y Acuicultura de Argentina)

Table 3a: Original data for Fig. 9b, including surface area of overlap of the pelagic ice-trawler fishery overlaying with conservation scenarios for Punta Buenos Aires. See also Fig. 9a (see Methods for a description of each conservation scenario).

Conservation scenarios	Scenario surface area (km^2)	Surface Area of overlap with fishery (km^2)	% Overlap with fishery
(1) 50% high-use areas	164	0	0
(2) 80% high-use areas	977	0	0
(3) 100% high-use areas	2,587	229	8
(4) 1.5 day of travel at mean speed	6,266	782	12
(5) Mean max. distance all females from colony	3,348	495	15
(6) Max. distance reached by any female in the colony	6,656	809	12

Punta Norte

There were two fishing operations overlapping with conservation scenarios of the lactating females of Punta Norte: the pelagic, ice and freezer trawler fisheries, both targeting Argentine hake (Figure 10). Overlap of the pelagic, ice-trawler fleet with conservation scenario 6 (home range) amounted for 9,200 km^2 or 31 % overlap (Table 3b) while overlap of the pelagic, freezer-trawler fishery with the same conservation scenario was approximately 13%. Overlaps did not include the most intensely fished areas, as indicated by the kernel density analysis of fisheries shown in Figure 10.

The at-sea distribution of females from Punta Norte fell within the 12 nm provincial jurisdictions of Río Negro and Chubut provinces and the EEZ under jurisdiction of the federal government. Overlapping fisheries operate only in areas managed by the federal government.

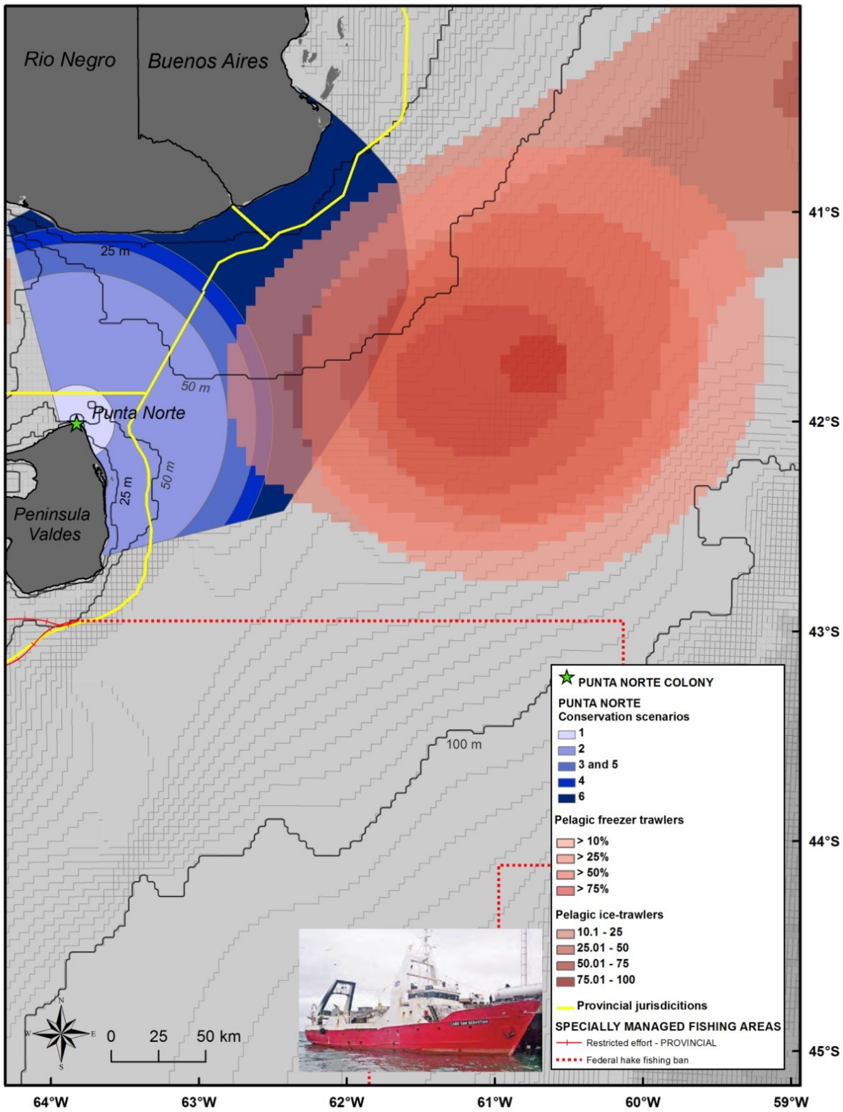


Figure 10: Kernel density estimate of fishing effort (Jan-Mar. 2012) for the pelagic, ice and freezer trawlers targeting Argentine hake, *Merluccius hubbsi,* and overlapping with conservation scenarios for the Punta Norte rookery (fisheries data from Secretaría de Agricultura, Ganaderia, Pesca y Acuicultura de Argentina).

Table 3b : Original data for Fig. 10b, including surface area of overlap of the pelagic ice-trawler fishery overlaying with conservation scenarios for Punta Norte. See also Fig. 10a (see Methods for a description of each conservation scenario).

Conservation scenarios	**Scenario surface area (km^2)**	**Surface Area of overlap with fishery (km^2)**	**% Overlap with fishery**
(1) 50% high-use areas	724	0	0
(2) 80% high-use areas	10,324	0	0
(3) 100% high-use areas	12,468	651	5
(4) 1.5 day of travel at mean speed *(see Methods)*	15,954	1,331	8
(5) Mean max. distance all females from colony	12,468	651	5
(6) Max. distance reached by any female in the colony	28,873	9,200	31

Punta León

Punta León is one of two target colonies meeting conservation criteria for the implementation of MPAs aimed at decreasing potential detrimental interactions between lactating, foraging females and coastal fisheries.

Four fisheries operated within the 12 nm jurisdiction of the Chubut province in waters surrounding the Punta León rookery. These fisheries were: the coastal Rawson's yellow fleet, the artisanal ("variado costero") trawling fishery, the artisanal trawlers (all targeting Argentine hake and Argentine red shrimp) and the artisanal longliner fishery targeting Argentine hake (Figure 11). The artisanal longliner fishery was not considered because operational interactions with the SSL were unlikely.

A federal fishing ban, established in 1997 specifically for the protection of juvenile Argentine hake, and in force year round, limits potential overlaps with foraging SSLs. Fishing is almost completely excluded in this area except for occasional jiggers.

The artisanal ("variado costero") fishery was selected as proxy to determine if conservation criteria were met to support the establishment of MPAs. This fishery met the conservation criteria for action, as it exceeded the 20% and 30% overlap with conservation scenarios 1 and 2. These overlaps constituted surface areas of 1,000 – 2,000 km^2 respectively (Table 3c).

The Rawson's yellow fleet and the artisanal trawler fishery showed a high proportion of their fishing distribution (87-100%) within the three largest scenarios (home range, 1.5 day of travel and mean maximum distance from colony) and 15-62% of their distribution within high-use areas. However, the total percentage overlap of these fisheries within conservation scenarios ranged between 1% - 9%, thus not meeting the criteria for conservation intervention.

Even though many fleet types operate in this area, fishing activity concentrates in a small portion SW of the entire female home range, restricted to 9**%** of the complete female distribution and within the 12nm jurisdiction of the Chubut province. Moreover, areas of fishing effort pertaining to all operating fleets are located at a distance > 23 km from colony thus not intercepting the area closest to colony were transit of individuals leaving and arriving to colony is more eminent.

The at-sea distribution of females of Punta León fell within the provincial jurisdiction of the Chubut province, encompassing the first 12 nm from coast, and federal jurisdiction managing the offshore area, beyond.

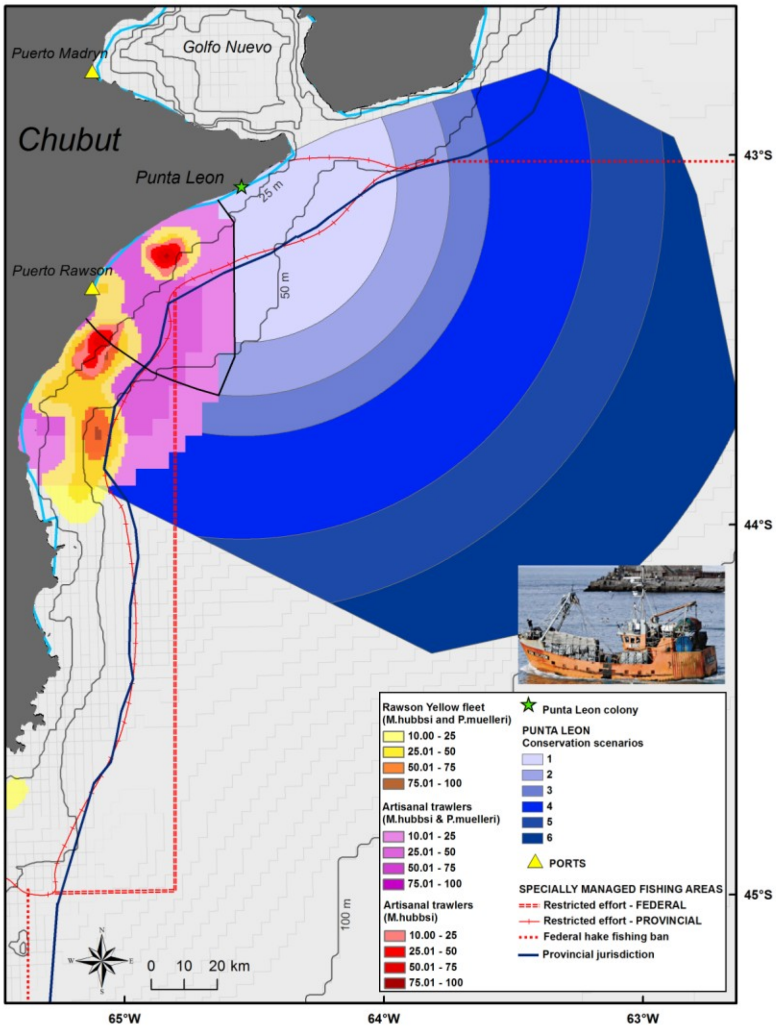


Figure 11: Kernel density estimate of fishing effort (Jan-Mar. 2012) for the three fleets (two artisanal trawlers and the coastal Rawson's yellow fleet) overlapping with conservation scenarios for the Punta León rookery (fisheries data from Secretaría de Agricultura, Ganadería, Pesca y Acuicultura de Argentina). All fleets target Argentine hake, *Merluccius hubbsi*, and Argentine red shrimp, *Pleoticus muelleri,* and have their operational and administrative base in the fishing harbor of Rawson. Proposed MPA delineated in solid black line.

Table 3c: Original data for Fig. 11b, including surface area of overlap of the "variado costero" artisanal trawlers overlaying with conservation scenarios for the Punta León rookery. See also Fig. 11a. (see Methods for a description of each conservation scenario).

Conservation scenarios	**Scenario surface area (km^2)**	**Surface area of overlap with fishery (km^2)**	**% overlap with fishery**
(1) 50% high-use areas	3,554	1,000	28
(2) 80% high-use areas	6,151	2,000	33
(3) 100% high-use areas	8,493	2,400	28
(4) 1.5 day of travel at mean speed *(see Methods)*	15,842	3,510	22
(5) Mean max. distance all females from colony	20,203	3,510	17
(6) Max. distance reached by any female in the colony	25,611	3,510	14

Isla de Lobos

Three conservation scenarios were feasible for this colony: maximum distance reached by any female from colony (scenario 6), mean maximum distance of all females (scenario 5) and 100% high-use areas (scenario 3).

Four fishery fleets overlapped with the distribution at sea of females at Isla de Lobos: the Uruguayan bottom coastal trawlers targeting Whitemouth croaker, *Micropogonias furnieri,* and Striped weakfish, *Cynoscion striatus*, the pelagic, ice and freezer trawler fleets, targeting Argentine hake, and the coastal ("variado costero") fleet targeting a variety of costal demersal species (Figure 12).

The fishing grounds of the Uruguayan, coastal, bottom trawl fishery integrated all other fisheries and was thus selected as the most representative in the conservation intervention analysis. This fishery showed an overlap of 80% with scenarios 5 and 6 and no overlap with scenario 1 (100% high-use areas) (Table 3d). The next fishery with the largest overlap was the pelagic, freezer trawler fishery, with 57% overlap with scenario 6 and 64% with scenario 5. All other fisheries fell below the criteria for conservation intervention. Fishery overlap within conservation scenarios 5 and 6 were in the order of 7,000 – 11,000 km^2 . Yet, these animals showed extreme coastal habits. An area of only 10 km^2 was of differential relevance for females and was not used as target fishing grounds for any fishing operation.

The at sea distribution of females of Isla de Lobos falls within the jurisdiction of a bilateral fishing zone shared by Argentina and Uruguay and the Río de la Plata jurisdiction under the Comisión Administradora del Río de la Plata.

Table 3d: Original data for Fig. 12b, including surface area of overlap of the Uruguayan coastal, bottom trawl fishery overlaying with conservation scenarios for the Isla de Lobos rookery. See also Fig. 12a (see Methods for a description of each conservation scenario).

Conservation scenarios	**Scenario surface area (km^2)**	**Surface Area of overlap with fishery (km^2)**	**% Overlap with fishery**
(3) 100% high-use areas	10	0	0
(5) Mean max. distance all females from colony	8,876	7,159	80
(6) Max. distance reached by any female in the colony	14,217	11,224	80

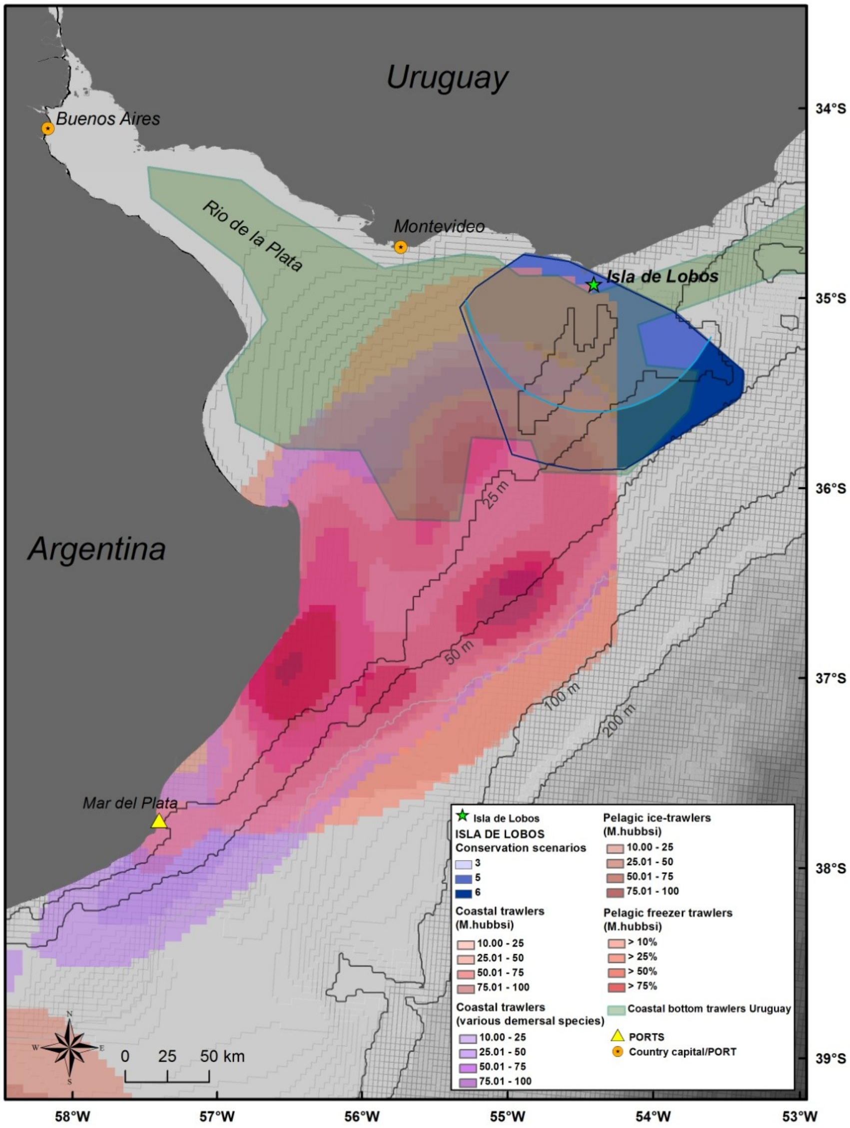


Figure 12: Kernel density estimate of fishing effort (Jan-Mar. 2012) for one coastal and two pelagic trawler fleets targeting Argentine hake, *Merluccius hubbsi*, and the coastal "variado costero" fleet (targeting a variety of demersal species) overlapping with conservation scenarios for the Isla de Lobos rookery (fisheries data from Secretaría de Agricultura, Ganadería, Pesca y Acuicultura de Argentina). Distribution of coastal bottom trawler fishery of Uruguay targeting Whitemouth croaker,*Micropogonias furnieri,* and Striped weakfish, *Cynoscion striatus,* was obtained from Riet-Sapriza et al. (2012).

Monte Loayza

This colony did not present one larger fishery encompassing the distribution of smaller ones, but rather four different fleet types operating throughout the area (Figure 13).

Conservation criteria for intervention were not met as fisheries operating during the month of January-March did not distribute differentially in the same areas expected to be relevant for SSL females (Table 3e). This result held true even for the home-range scenario that resulted in a very large area for this particular colony as specific locations at sea were not available to optimize conservation scenario size.

Table 3e: Original data for Fig. 13b, including surface area of overlap of fisheries overlaying with conservation scenarios for the Monte Loayza rookery. See also Fig. 13a (see Methods for a description of each conservation scenario)

Conservation scenarios	**Scenario surface area (km^2)**	**Surface Area of overlap with fishery (km^2)**	**% Overlap with fisheries**
(1) 50% high-use areas	800	0	0
(3) 100% high use areas	7,900	207	2
(6) Max. distance reached by any female in colony	40,000	8,135	20

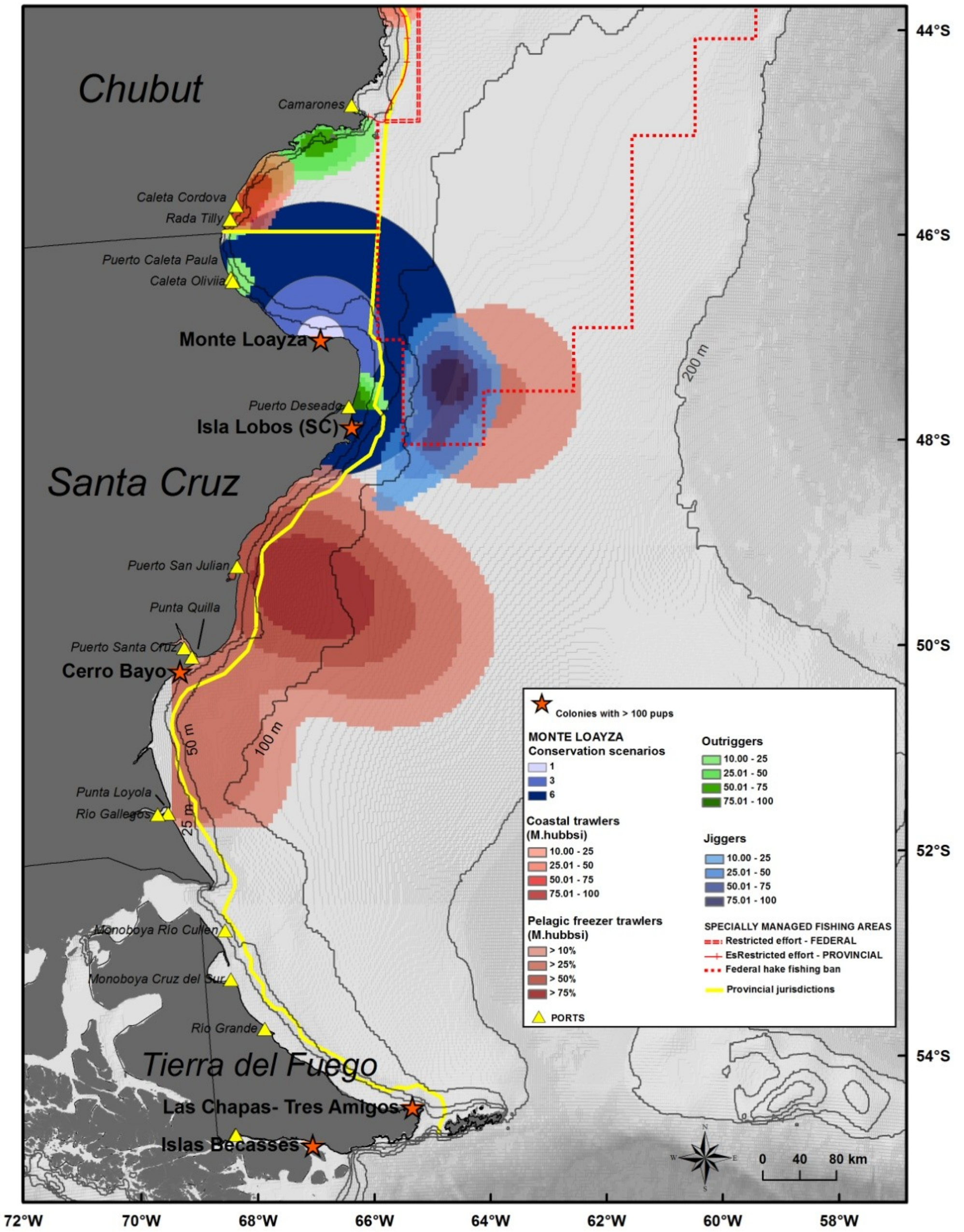


Figure 13: Kernel density estimate of fishing effort (Jan-Mar. 2012) for fleets overlapping with conservation scenarios for the Monte Loayza rookery (fisheries data from Secretaría de Agricultura, Ganadería, Pesca y Acuicultura de Argentina).

Compensation costs for the implementation of proposed MPAs

Two of the five target colonies satisfied the criteria for conservation intervention: Punta León and Isla de Lobos. The Punta León rookery was selected as case study (see Methods). We selected as target area (spatio-temporal MPA to be implemented during January) the conservation scenario that included 80% of high-use areas (conservation scenario 2), of largest surface area and ecompassing scenario 1 (50% high-use areas) (Fig. 11a). Table 4 contains a summary of fishing data relevant for estimating costs for the Punta León proposed MPA.

Table 4: Summary of economic and landing data for the fisheries overlapping with conservation scenarios of Punta León. These fisheries are: the Rawson's Yellow Fleet, the Artisanal trawlers fishery and the Artisanal ("variado costero") trawlers all targeting Argentine hake, *Merluccius hubbsi* and Argentine red shrimp, *Pleoticus muelleri* and with operational and administrative base in Rawson's port. Landing data was obtained from *http://organismos.chubut.gov.ar/pesca/,* and economic data from *http://www.miniagri.gob.ar/site/pesca/index.php*.

Target species	**Declared landings tons/year**	**Exported value U$S/ton**
Argentine red shrimp, *Pleoticus muelleri*	Mean: 15,700 ± 3,055 (range: 12,000-18,000)	Mean: 6,274 ± 308 (range 6,096 - 6,630)
Argentine hake, *Merluccius hubbsi*	Mean: 3,700 ± 1,154 (range: 3,000-5,000)	Mean: 2,598 ± 237 (range: 2,361 - 2,834)

Fishing activity during January

The highest fishing activity for fleets operating from Puerto Rawson began in Spring (October) of each year, and reached its peak in November – December, and declined by the end of March. Argentine hake and Argentine red shrimp landings for January represented 25% total annual landings for 2010-2012. The number of fleets operating from Puerto Rawson increased in the last 20 years, with approximately 1,400 departures/year in 1992 to 5,000 – 6,000 departures/year in 2005. The period of November - January contained 60% of all departures from port, while January alone represented about 17% of total annual departures.

Economic costs of proposed conservation interventions

Conservation intervention 1: To compensate fishing sectors for economic losses incurred by ceasing fishing completely during January would cost 27 x 10^{6}, estimated as follows (see Methods for rationale):

[1] CJRw_all = 0.25 [(3,700 t/y * 2,598 U$S/t) + (15,700 t/y * 6,274 U$S/t)] = 27,028,600 U$S

Conservation intervention 2: To compensate fisheries for the partial economic loss incurred by not operating in the target area during January would cost 2.7 x 10^{6}, estimated as follows (see Methods for rationale):

[2] CJRw_MPA = 0.10 * CJRw_all = 0.10 * 27,028,600 = 2,702,860 U$S

Conservation intervention 3: This option represented a compensation to fisheries slightly smaller than option 2 by excluding losses related to Argentine hake fisheries, considered economically negligible when compared to Argentine red shrimp fisheries. This option resulted in 2.4 x 10^6 U$S and was estimated as follows (see Methods for rationale):

[3] If
CJRw_all (*A.hake not included*) = 0.25 (15,700 t/y * 6,274 U$S) = 24,625,450 U$S
then,
CJRw_MPA (*A.hake not included*) = 0.10 * CJRw_all (without hake) = 2,462,545 U$S

Conservation intervention 4: This option does not offer an *"a priori"* scenario for conservation intervention, but opens for fisheries the opportunity to operate in areas outside the MPA and be fully compensated for the economic loss of a potential decrease in landings. It is presented as an option with no associated cost, and may range from 0 to 2.7 x 10^6 U$S.

[4] OFFSETS = CJRw_MPA – [landings declared by fleet for January of year of MPA implementation]

Conservation intervention scenario 5: This option represents an offset negotiated between fisheries and government for operating outside MPA and may vary according to the negotiated agreement. It is implied that the U$S amount resulting from this negotiation will result in a compensation cost lower than that estimated in option 2.

Table 5: Fisheries' compensation costs (in 10^6 U$S) for implementing conservation intervention scenarios during January in Punta León.

Conservation intervention scenarios	**Cost (U$S)**
Cease all fishing activity from Puerto Rawson during January.	27.03 ± 3
Close MPA during January assuming fishing in area accounts for 10% of total catch	2.7 ± 0.3
Cease fishing of the Argentine red shrimp from MPA assuming fishing in area accounts for 10% of total catch.	2.5 ± 0.3
Compensate fisheries for 100% of reduction of landings if operating outside MPA (assumed as optimal for fishing)	$<$ 2.7 ± 0.3
Compensate a portion of landings (set amount agreed with government) if fisheries were to operate outside area of interest.	$<$ 2.7 ± 0.3

DISCUSSION

Putative foraging places for lactating females could not be predicted by physical oceanographic variables, thus these features were not critical in the proposed conservation scenarios. Females apparently did not restrict their distribution to particular SST, stratified or mixed waters, seafloor composition or productivity fronts, as indicated by chlorophyll *a.* Female SSLs in northern Patagonia are predominantly coastal foragers, concentrating their effort on benthic prey (Koen Alonso 1993) and foraging on the continental shelf at maximum depths of 80 m (Werner and Campagna, 1995; Campagna et al., 2001). For the Uruguayan population, dives were much shallower, with a mean of 25 m (Riet-Sapriza et al., 2012). The bathymetric contour off the colony could then represent a physical limitation in the distribution at-sea of foraging individuals. Results are compatible with the proposition that the depth contour around a colony may help delineate potential protected spaces for lactating females.

Conservation scenarios, depicted here as potential discrete spatio-temporal MPAs, were based on behavioral features related to distribution at sea as determined by satellite tracking data. Overlap between fisheries and these scenarios guide what could be useful conservation interventions. I found that for most target colonies, interventions were not required based on a set of operational conservative criteria, as overlap with fisheries either did not occur or affected a small proportion of the areas defined by the conservation scenarios. However, two of the main target colonies, Punta León (Argentina) and Isla de Lobos (Uruguay), showed an overlap with important commercial operations that might warrant the creation of MPAs to decrease potential interactions. As fisheries are already established in both places, restricting fishing would have an economic cost. My best estimate for Punta León was *ca.* 2.5 million $US to compensate the fishery targeting Argentine red shrimp, *Pleoticus muelleri*, if this operation were to be halted within a hypothetical protected area during the month of January. These figures indicate the high costs of implementing closures *a posteriori* of an established operation, and suggest that *a priori* interventions may be the only feasible option if areas are to be set aside for the protection of lactating females of SSL in the region.

A. Methodological discussion

1. Limited available satellite tracking data for lactating females of the SSL

Although satellite tracking data were essential for the process of suggesting conservation scenarios, information regarding all Patagonian colonies was scarce even for those target colonies where tracking work had been accomplished.

Distribution at sea of lactating females of the SSL was based on satellite track studies conducted at four northern Patagonia rookeries during 1994-1998 (Campagna et al., 2001). More recent information was available on lactating female distribution at sea for Isla de Lobos (Riet-Sapriza et al., 2012).

The total sample was 27 females from five of the 36 reproductive colonies, representing less than 0.1 % of the estimated number of lactating females for the Patagonian coast and Uruguay (Reyes et al., 1999; Dans et al., 2004; Schiavinni et al., 2004; Dans et al., 2010) (see Figures 4 a & b).

Many studies using satellite tracking data to understand distribution at sea of sea lions are based on limited sample sizes (e.g., Feldenkamp et al., 1989; Thompson et al., 1998; Costa and Gales, 2003; Fadely et al., 2005; Chilvers et al., 2005; Sinclair et al., 2005; Gende and Sigler, 2006; Villegas-Amtmann et al., 2008; Leung et al., 2013). In all cases, the distribution and preference patterns need to be inferred from a few animals and a few places. Some representation is assumed and some expected coherent pattern is justified, due, among other reasons, to physiological constraints (Kooyman and Ponganis, 1998; Costa et al., 2000; Costa and Gales, 2003).

Females utilized virtually the entire area around the colony (clearly depicted by females from Isla de Lobos) and distance travelled was restricted by the time they spent away from their pups. Thus, these characteristics and depth were more critical for estimating the distribution at sea than other variables. More individuals added to the sample size would improve and expand the details of use within their distribution, but would not change the general dependency to resources located close to the colony. Distribution at sea had some relative similarities for both study sites, despite difference in the year of study, location and quality of the instruments deployed. Females from both northern Patagonia and Isla de Lobos were coastal and pelagic, travelled at similar speeds and to similar maximum distances from their colonies, and remained within depth contours predicted by the diving pattern (Werner and Campagna, 1995; Campagna et al., 2001, Riet-Sapriza et al., 2012).

Results from lactating females of the SSL from other areas showed similar patterns. For example, a study on the at-sea behavior of lactating females from the Malvinas-Falklands (Thompson et al., 1998) showed that individuals were benthic feeders that remained in close proximity to colony and dove to maximum depths *ca*. 40 m. Our findings for SSL were broadly similar to those reported for other sea lion species. The diving patterns varied among species, although lactating females of the Australian sea lion (*Neophoca cinerea*, Costa & Gales 2000, 2003) were also benthic foragers and dove at mean dive depths similar to those found for SSL along the Argentine Patagonian coast. Lactating New Zealand sea lion females, *Phocarctos hookeri,* travelled at similar speeds and to similar mean maximum distances from their colonies, (Chilvers et al. 2005). However, New Zealand sea lions dove much deeper than SSL females would have been capable of diving on shallow continental shelf of Patagonia. Galápagos sea lion, *Zalophus wollebaeki*, also behaved similarly but were not preferentially benthic foragers (Villegas-Amtmann et al., 2008). Lactating California sea lions, *Zalophus californianus,* also fed at similar depths (Feldkamp et al., 1989) and distances from their rookeries (Antonelis et al., 1990). These findings from other sea lion species lend support for the use of data from our analyses to select potential conservation areas for SSL.

2. Physical oceanographic variables and distribution of lactating females at sea

Bathymetry emerged as the physical variable that best predicted distribution at sea. Females travelled to distances of up to 200 km offshore, exposing themselves to a wide variety of temperatures, primary productivity conditions, bathymetry and benthic habitats. Females from the northern Patagonian colonies were confined to the continental shelf, within depths of up to 80 m. Depth would impose a limit in travel distances for preferred benthic foragers in a shallow shelf such as that off the coast of Patagonia. However, the shallowness of the continental shelf would make it complex to use only depth to design MPAs of manageable sizes.

Poor location data, but also ecological and behavioral factors related to the distribution of prey, could explain the lack of association between water temperature, productivity and substrate with female distribution. Females may forage on a large variety of prey species available throughout their distribution and prey distribution may not directly be linked to the immediate effects of average surface productivity (Drago, 2010).

To my knowledge, the association of oceanographic variables and the distribution at sea of SSL lactating females has not been reported in previous studies. Tunez et al. (2008) suggested some environmental variables that affected locations of breeding colonies along coastal Argentina and Uruguay. Breeding colonies are established in areas of small tidal amplitude and beaches of sandy substrates. Regarding ocean variables, I did not find a correlation between location of colony and primary productivity, sea surface temperature, seafloor composition or bathymetry.

However, I did not have data at finer spatial scales to examine possible finer scale associations between oceanographic variables and individuals from the breeding colonies during their trips at sea.

Data on other species show that some populations of sea lions respond to physical variables such as fish aggregations (Gende and Sigler., 2006) and bathymetry (Fadely et al., 2005; Sinclair et al., 2005; Leung et al., 2013) although most studies focus on the effects of environmental variability caused by El Niño conditions for species in the Pacific Ocean (Trimlich et al., 1985 and 1991; DeLong et al., 1991; Aurioles et al., 1991; Heath et al., 1991; Soto et al., 2004; Weise et al., 2006). In fur seals and elephant seals, associations have been shown between oceanographic features such as bathymetry, SST and chlorophyll *a* and distribution at sea (e.g., McConnell et al. 1992; Boyd et al., 1998; Georges et al. 2000; Bradshaw et al., 2004; Campagna et al., 2006; Arnould and Kirkwood, 2007).

3. Conservation scenarios

I proposed six different conservation scenarios based on behavioral features affecting distribution at sea of tagged lactating females. These were: furthest distance from colony reached by any female (Scenario 6), mean, maximum distance reached by females of the same colony (Scenario 5), maximum distance reached if females where to travel one way at the mean speed of all females for that colony (Scenario 4) and maximum distance if 100%, 80% and 50% of "high-use" areas were to be protected (scenarios 3, 2 and 1 respectively). For each colony, each scenario resulted in different sized areas. The rationale for creating several scenarios was to explore alternative conservation strategies applicable to the target colony that could be viable from a practical perspective, assuming that smaller areas would be more feasible for establishment, particularly in the light of potential conflict with fisheries. Smallest conservation scenarios, specifically those encompassing high-use areas, are of differential importance because they contain a higher density of "presence" per surface area unit. These areas converge movements to and from colony and the distribution at sea of those females with coastal foraging habits. Coastal females represented half of the satellite-tracked females of Argentine Patagonia and Uruguay.

Home ranges (scenario 6) encompassed much larger areas than any of the other scenarios. Surface areas for all colonies and scenarios ranged from only 10 km^2 to up to 29,000 km^2. According to the manual of protected areas compiled by Tagliorette and Mansur, (2008) the mean size of protected areas offering some kind of protection to sea lions in Argentina was 400 km^2 with ranges from 0.023 km^2 to 600 km^2. Of the 53 coastal protected areas in Patagonia (see Figure 1) 42 include a sea lion colony. The only two MPAs that exceeded 600 km^2 included the three mile zone around Peninsula Valdes Nature Reserve, and Isla Pingüino inter-jurisdictional park, with area sizes of 2,500 km^2 and 1,860 km^2 respectively *(www.cetaceanhabitat.org)*.

Although the proposed conservation scenarios are disproportionally larger than the average MPA for coastal Patagonia, the sizes here suggested are comparable and coherent with similar protected areas in other parts of the world. Virtually all proposed conservation scenarios for our target colonies exceeded the mean area size observed for established protected areas in Argentina by a factor of 2-70. However, compared to the mean surface area of the ten largest MPAs in the world (*ca*. 300,000 km^2) (http://www.protectplanetocean.org/collections/introduction/introbox/globalmpas/introduction-item.html) the largest of our conservation scenarios was quite small. According to www.cetaceanhabitat.org, comparable MPAs worldwide (not including Argentina) that provided protection to sea lion species had a mean size of 15,300 km^2 with a range from 2 to 158,000 km^2 (the latter pertaining to the Galapagos Marine resources reserve of Ecuador) *(http://www.cetaceanhabitat.org/)*. The sizes of 17 of our 20 hypothetical conservation scenarios fell below the *ca.*15,000 km^2 represented by protected areas that offered indirect protection to sea lion species worldwide.

The conservation scenario encompassing 100% high-use area for Isla de Lobos contrasted with high-use areas scenarios for the northern Patagonian colonies. It was the smallest scenario with a radius of 2 km and surface area of only 10 km^2, indicating that lactating females from Isla de Lobos basically forage around the colony. Only a very productive ocean in high proximity to a breeding area could explain this pattern, a conclusion supported by the presence of the most relevant fishing grounds in the area (Acha et al., 1999 and 2006; Mianzan et al., 2001).

The extrapolation of “distance from colony” parameters from tagged colonies to create conservation scenarios for the Monte Loayza rookery (with no satellite tracking data) resulted in unrealistically large areas, particularly for scenario 6 (home range), which resulted in an area twice as large as the largest scenario obtained from the colonies for which we had satellite data. The surface area for the smallest conservation area (50% high-use areas) of this colony was still twice the size of the current average size of marine protected areas in Argentina. These scenarios were the result of an experiment that assumed females from Monte Loayza behaved and distributed in the same manner as their counterparts in the northern region, although, we are aware that more research is needed to support this assumption. The implementation of such large protected areas would be beneficial, not only to the lactating females from the Monte Loayza rookery, but to the many species that live or use the Golfo San Jorge as foraging grounds. However, due to the lack of feasibility for proposing protected areas of such large size in an area of differential commercial relevance for fisheries, we incursioned in designing smaller protected areas using a different set of parameters which we describe in detail in section C of this discussion.

4. Criteria for deciding conservation interventions

My approach employed a decision-making process with potential to advance conservation whenever the threat of fisheries would impact at least half the area of each conservation scenario. This was an arbitrary operational definition that attempted to be conservative. Decision criteria for protected areas are often qualitative (Moffett and Sarkar, 2006; Home et al., 2009, Roberts et al., 2003; Hansen et al., 2011). My criteria are more quantitatively based but define MPAs as the mid-point between conservative and liberal scenarios.

Fisheries that overlapped with the smallest conservation scenarios, 50% and 80% high-use areas respectively, were considered to be potentially in conflict with SSLs if the overlap involved 20% and 30% of the high-use areas, respectively. The reason for this adjustment was the differential importance of smaller conservation areas in closer proximity to the colony. Animals must move through non-foraging areas as they traverse between rookeries and foraging areas. For conservation purposes, these corridors of movement are just as important as putative foraging areas.

I generated conservation scenarios and derived conservation interventions based on criteria that, in practice, would require discussion and involvement of stakeholders for effective conservation decisions (Klein et al., 2008, Sumaila & Charles 2002; Moore et al. 2004; Richardson, 2006; Mwaipopo, 2008; McClanahan et al., 2005; Lundqvist et al., 2005). The rationale to build these scenarios is transparent, simple and adaptive, so I would expect that they could be constructive in a planning process involving decision makers.

A new tool developed by Teh et al., 2012 offers the opportunity to go a step further in defining intervention for our proposed conservation scenarios. The Protected Area Suitability Index (PASI) is a spatial planning tool that uses fuzzy logic (Kusko, 1993; Montero, 2009) to assess the suitability of a site for protection based on fisheries preferences and the conservation value of the site. Fisheries' preference measures how desirable a site is for fishing and is determined by spatial attributes such as fish catch (kg trip^{-1}) and net revenue (MYR trip^{-1}), while input variables to the conservation preference component include occurrence of species to be protected (e.g., lactating females of the SSL) and can include other variables such as biodiversity and fish abundance. This tool could further refine priority areas by weighing both conservation and fisheries interests.

5. Fisheries data

Data on catch, location of vessels and economic value of some fisheries were essential in this work. Fisheries information is often qualitative and inaccurate. An error in location of fishing grounds would negatively impact conclusions of this thesis. Therefore, it is important to consider the kind of data that I had access to and its practical application. The systematization of fisheries data in Argentina started in 1989 (Santos et al., 2010). Official data by month, species, port and fleet type is provided by the Ministerio de Agricultura, Ganadería y Pesca *(www.minagri.gob.ar)* and data for this study were obtained from that Office. Fishing vessel locations were filtered by month of operation, time of the day in which specific fisheries types operate (e.g., jiggers operated during night hours while trawlers operate during the day), and fishing speed under which different fleet types operate. These filters resulted in a better and more accurate identification of putative fishing areas.

Most fisheries of relevance for this study operated either in internal waters or within the 12 mile jurisdiction of provinces, particularly Chubut and Santa Cruz (Figure 14). A legal provision implemented by the Subsecretaría de Pesca y Acuicultura de Argentina in September of 2002 require all vessels to report their location via a satellite system (MONPESAT - Monitoreo Satelital de la Flota Pesquera Argentina). Failure to use this system forbids the responsible party from operating until the system is fully functional *(http://www.minagri.gob.ar/)*.

Information on fish landings and income of commercial operations from the Port of Rawson, required to estimate the costs of compensating the industry for the establishment of a protected area around Punta León, was obtained as official data from the Subsecretaría de Pesca of the Chubut Province (*http://organismos.chubut.gov.ar/pesca/)*. This Government agency also offers data to supplement and compare that provided by the Federal Government. Some of the data were gathered by an on-board observer program, established in 2001 with the main objective of permanently monitoring fisheries operating within 12 nm of the coast of Chubut and recording real time information on vessel type, fishing gear, number of hauls, time of fishing effort, species caught, and species bycatch, among others *(http://organismos.chubut.gov.ar/pesca/2009/12/04/programa-de-observadores-a-bordo-de-chubut/)*.

B. MPAs targeting lactating females

1. Need for MPAs for the SSL. Fisheries interactions and conflict.

The SSL is not a threatened species (*http://www.iucnredlist.org/details/41665/0*). Some populations are affected by the interaction with fisheries and aquaculture (e.g., Venegas et al., 2002; Páez, 2006; Sepúlveda et al., 2011; Riet-Sapriza et al., 2012). Interactions with fisheries are common (Aguayo & Maturana, 1973; George-Nascimiento et al., 1985; Ramirez et al., 1986; Crespo et al., 1994, 1997; Crespo et al., 1997; Sielfeld et al., 1997; Koen Alonso et al., 2000; Dans et al., 2003; Huckstadt & Antezana, 2003; Szteren et al., 2004; Arata & Hucke-Gaete, 2005; Sepúlveda et al., 2007; Riet-Sapriza et al., 2012). These interactions involve incidental catch (Crespo et al., 1994, 1997; Dans et al., 2003; Huckstadt and Antezana, 2003; Arata and Hucke-Gaete, 2005), entanglement (Ramirez et al., 1986; Crespo et al., 1997; Sepúlveda et al., 2007), competition for resources (Szteren et al., 2004; Riet-Sapriza et al., 2012) and direct killing of individuals by fishermen (Arias Schreiber, 1993a, 1993b; Seal Conservation Society, 2000). In addition, SSL have been commercially killed throughout their range. The population of northern Patagonia, for example, declined from an estimated 137,500 individuals in 1938 (Godoy, 1963) to 5,000 by 1960 (Koen Alonso and Yodiz, 2005; Grandini, 2010). The current population in Argentine Patagonia (*ca.* 100,000) is thought to be a small proportion of its earlier abundance (Capozzo, 2002) particularly in the Malvinas-Falkland Islands (Thompson et al., 2005). Therefore, although the species is not legally threatened, I found justification in thinking proactively, as fisheries and aquaculture activities are expanding throughout its range (Sanchez et al., 2012; Niklitschek et al., 2013; FAO, 2014). It is based on this rationale that I suggest that conservation interventions should be supported as precautionary pragmatic measures.

Fisheries that occur within foraging areas of lactating females are of particular concern as these animals contribute disproportionally to sustaining populations (Heppel et al., 1999; Gerber et al., 2004; Maxwell et al., 2011). These females, which are under a particular demanding cycle of lactation on land and foraging at sea, must be as efficient as possible in their behavioral expenditures (Costa, 1993; Jönsson, 1997). The need of lactating females to remain relatively close to the rookery links reproductive success and population status with local abundance of food and environmental conditions (Costa et al., 2006).

Fisheries of the Patagonian sea have been expanding since the onset of the fishing industry in 1920, when estimated landings of 16,000 tons supplied only local markets (Perrota et al., 2007). Beginning in about 1960, landing grew exponentially because of domestic and international economic crises, thus resulting in overfishing of traditional coastal and demersal targets (Bertolotti et al., 2011).

Argentine hake is important to both fisheries and the SSL (Crespo et al., 1997; Koen Alonso et al., 2000; Drago, 2010). Hake consumed by the SSL overlap in size with those caught by the commercial fishery (Crespo et al., 1997). In 1997, Argentine fisheries landed over a million tons with an ex vessel value of more than 1 billion dollars US. Argentine hake catches alone for 1997 (including an estimate of bycatch and unreported data) were estimated at over 800,000 tons, or 111% higher than the allowable catch for the species for that year. Excess fishing capacity encouraged overfishing and is pushed the species towards collapse (Aubone et al., 2004). Total reported landings of Argentine hake for 2013 were 275,000 tons, 91% of which were from the region south of 41° S *(www.miniagri.gob.ar)* were most of the breeding colonies and largest rookeries of SSL are located. Banned and special management areas have since been established by fisheries managers. But, as juvenile Argentine hake often overlap with the distribution of Argentine red shrimp, the shrimp fishery has been bycatching hundreds of thousands of tons of juvenile hake of the same sizes consumed by the sea lions (Crespo et al., 1997; Bertolotti et al, 2003). Argentine red shrimp is the base of a very profitable industry. At least 100 trawlers and outrigger trawlers of the coastal and artisanal fishery were targeting shrimp in the 1990s and early 2000s (Bertolotti et al., 2001).

The EEZ of Argentina has been managed almost as an open access regime. Five Argentine provinces have an ocean coast, from North to South: Buenos Aires, Río Negro, Chubut, Santa Cruz and Tierra del Fuego. Sea lion rookeries occur in all these provinces (Reyes et al., 1999; Dans et al., 2004; Schiavinni et al., 2004). Most of the coast of the Buenos Aires province sustains a strong fishing pressure by the artisanal and coastal fisheries targeting Argentine hake and a variety of coastal demersal species denominated “variado costero”. The golfo San Matias, home to a number of SSL rookeries (Grandi et al., 2008) and under the jurisdiction of the Río Negro province, is the main fishing ground for another demographic unit of

Argentine hake (Di Giácomo et al.,1993; Sardella & Timi, 2004; González et al., 2007). The Chubut province, home to the largest rookeries in Argentine Patagonian (Reyes et al., 1999; Dans et al., 2004; Schiavinni et al., 2004) provides critical fishing grounds for Argentine red shrimp and Argentine hake fisheries. The Chubut and Santa Cruz provinces share jurisdiction of the San Jorge Gulf (*ca.* 27,000 km^2), a large area of the shallow continental shelf where most of the Argentine red shrimp, the most valuable of the Argentine target species, is caught. The coast of the San Jorge Gulf is home to a number of SSL rookeries including Monte Loayza, the largest rookery of southern Patagonia (Santa Cruz and Tierra del Fuego provinces) (Schiavinni et al., 2004). Not only are fisheries expanding, but the inherent dynamic of local fisheries, continually redirecting efforts to varying target species, imply great variability and uncertainty with respect to the mortality rates of the top predators affected by these operations.

Fisheries are prominent in other countries with SLLs. For example, the total annual fish landings in Chile ranks 6th in the world (Servicio Nacional de Pesca, 2005). South-central Chile is home to Chile's and Latin America's most important fishery, which targets jack mackerel *(Trachurus symmetricus),* anchoveta (*Engraulis ringens*), Patagonian grenadier (*Macruronus magellanicus*) and sardine (Aguero et al., 2005). Chilean jack mackerel is the 8th most exploited fish species in the world, accounting for landings of 1.8 million tons per year (FAO). Purse-seine fisheries for jack mackerel do interact with the SSL population of central Chile and incidental mortality and competition for resources have been identified (Huckstadt and

Antezana, 2003). Uruguay also has large fishing operations along the Río de la Plata and within 700 km of the country's coast. Main target species of Uruguayan fisheries (comprising 2/3 of total captures) are: Argentine hake (*Merluccius hubbsi), Whitemouth croaker (Micropogonias furniery) and Stripped weakfish (Cynoscion guatacupa)*, two of which are important dietary components of lactating SSL females from Isla de Lobos (Riet-Sapriza et al., 2012).

Of the remaining five sea lions species, three (Galapagos, Steller and Australian) are listed as endangered with primary threats resulting from direct or indirect interactions with fisheries (Lowry *et al*., 1989; Loughlin and York., 2000; Shaughnessy *et al.,* 2003, Page *et al.,* 2004; Goldsworthy and Page., 2007; Aurioles and Trillmich, 2008; Kovacs et al., 2012). This threat is further exacerbated by climate variability (e.g., El Niño) for populations in the Pacific (IUCN, 2014). The California sea lion is listed as of least concern, although high rates of mortality occur through direct and indirect conflicts with fisheries (Stewart and Yochem 1987; Aurioles-Gamboa *et al*. 2003) and climate variability caused by El Niño effects (Francis and Heath 1991). The New Zeland sea lion population is listed as vulnerable with high mortality caused by the squid fishery operating within their distributional range (Wilkinson *et al*. 2003, Chilvers 2008).

2. Diet of SSL females in the context of potential overlap/competition

Lactating SSL females forage on several cephalopod and teleost species (Thompson et al, 1998; Drago, 2010; Riet Sapriza et al., 2012). Lactating females of

Argentine Patagonia, in particular, forage on a variety of benthic and demersal species (Drago, 2010) among which is Argentine hake. Pups of females that rely on pelagic offshore species such as Argentine hake grow faster than those of females relying on benthic prey (Drago, 2010). Argentine hake is a main prey species targeted by fisheries operating in the Patagonian sea and its target size overlap with those consumed by SSL females (Crespo et al., 1997). Juvenile Argentine hake are bycaught in the Argentine red shrimp fisheries operating in Golfo San Jorge, the most important breeding area for Argentine hake in the region. A study by Bertolotti et al (2003) showed that bycatch of Argentine hake for 2003 was approximately 40,000 tons, exceeding the "acceptable" bycatch quota by 15%. Juvenile Argentine hake discarded by the shrimp fishery ranged in size from 10-15 cm, a size also consumed by females SSLs (Crespo et al., 1997).

The Argentine red shrimp fishery also discards other prey species consumed by lactating females. A study by Bovcon et al. (2013) on the Argentine red shrimp fisheries operating north and center of Golfo San Jorge, showed that species such as the Argentine shortfin squid *(Illex argentinus)* and Patagonian squid *(Loligo gahi)* were caught in 40% of the hauls. These two species, in addition to Argentine hake also caught by the shrimp fishery, make up 40 % of all species consumed by the lactating females of the SSL (Drago, 2010).

Spatial food resource overlap between industrial fisheries targeting Argentine hake and Argentine red shrimp and distribution at sea of lactating females of the SSL from the largest northern Patagonian rookeries is shown in this study and has also been reported for lactating females of the Malvinas-Falkland Islands, where they overlap with the *Loligo* trawl fisheries (Thompson et al., 1998). A study by Romero et al., (2006) looked at resource competition between SSL and the Argentine hake fishery in Golfo San Matías and suggested a minimal effect due to the different sizes targeted by both “consumers”. Another study by Riet-Sapriza et al. (2012), showed a high degree of overlap between the lactating females from Isla de Lobos and the coastal bottom trawler fishery targeting Whitemouth croaker and Stripped weakfish, both important components of the lactating females of SSL diet. This study also showed a high degree of spatial overlap with the artisanal fishery (targeting the same species as the coastal trawler fishery) although overlap in prey size was minimal.

3. *A special case of spatio-temporal MPAs targeting lactating females – reducing area and costs.*

Offshore protected areas safeguarding feeding grounds or migratory routes for pinnipeds are rare (Reeves, 2000). Some critically endangered pinnipeds, such as the Hawaiian and Mediterranean monk seals (*Monachus spp*.), have been given particular attention and are protected (Lowry et al., 2008; Aguilar and Lowry, 2013).

The marine mammal taxa with the largest number of protected areas are cetaceans *(http://www.wdcs.org/)*. The design of cetacean MPAs has mostly focused on areas of “critical habitat” regularly used by individual species for feeding, breeding, migrating and raising their calves. Most of these provide year round protection (see Hoyt, 2005). This approach to conservation can be complex and difficult to implement as most marine mammals span across large areas and at times entire ocean basins. MPAs for cetaceans target many species (e.g., the Pelagos Sanctuary for Mediterranean Marine Mammals, the Gully Marine Protected Area in Canada, the Irish Whale and Dolphin Sanctuary, the Cabo Vírgenes Nature Reserve along the Brazilian coast; see Hoyt, 2005 and *http://protectedplanet.net/*). Examples exists of MPA for a specific species (e.g., Bay of Fundy for Right Whale Conservation, Marine Tucuxi Envirnomental Protection Area of Paraty Bay in Brazil, Tortuguero National Park in Costa Rica; see Hoyt, 2005). Many MPAs established for cetaceans offer indirect protection to sea lions (*www.cetaceanhabitat.org)* and some MPAs have been strictly created for the protection of sea lion rookeries while on land (e.g., Tagliorette and Mansur, 2008).

My approach attempts to more expeditiously identify critical areas and thus reduce the size of MPAs by focusing on lactating females, the sex-age group that contributes most to sustaining populations (Gerber et al., 2004; Heppell et al, 1999; Maxwell et al, 2011). This approach may also apply to lactating females across sea lion species, all of which display similar patterns during their trips at sea (see section A.1 of discussion). Diving behavior, however, differs among these species (Feldkamp et al., 1989; Werner and Campagna, 1995; Costa & Gales 2000, 2003; Chilvers et al. 2005; Villegas-Amtmann et al., 2008) and should be taken into consideration when designing potential conservation scenarios for particular species. This approach further reduces cost and time of implementation as it proposes the establishment of an MPA during the peak month of pup natality (January in the case of the SSL;

Campagna, 1985) and during the perinatal period, the most critical time when the pup is most dependent on the mother for survival (Trillmich, 1990; Boyd et al., 1998; Costa, 2008).

C. Strategic issues regarding conservation scenarios

1. Proactive vs. reactive conservation interventions

Target colonies requiring conservation intervention were those where fisheries presence and targeting of highly valuable species were significant. Reactive conservation interventions, such as establishing spatio-temporal MPAs for these target colonies with high fishery overlap would be costly and do not secure entire home ranges. However, there are important benefits from *a posteriori* planning with established economically valuable, fishing operations. For example, females would less likely be caught in trawling fishing nets, an occurrence that has been reported (Ramirez et al., 1986; Crespo et al., 1994, 1997; Crespo et al., 1997; Dans et al., 2003; Huckstadt and Antezana, 2003; Arata and Hucke-Gaete, 2005; Sepúlveda et al., 2007). Likewise, fisheries could be direct competitors for prey items of same sizes as those targeted by female sea lions (Crespo et al., 1997; Romero et al., 2011; Riet-Sapriza et al., 2012) a situation known to be affecting Magellanic Penguins, *Spheniscus magellanicus,* by the presence of the Argentine red shrimp fishery in proximity to their colonies. (Gandini et al., 1999). Therefore, if fisheries are kept out of important foraging areas for SSL females during the critical times of early lactation, females will directly benefit, a situation particularly relevant for the Punta León rookery, the second largest colony of the Argentine Patagonian coast (Dans et al., 2004).

A different approach to MPA implementation is that of proactive action, that is, to set aside protected areas before the establishment of fisheries. Much of the at-sea distribution of females from seven of the nine target colonies showed little overlap with existing fisheries (see Figs 9a, 10a and 13a). Therefore, there is opportunity to act by increasing protection at no or little cost for present fisheries, as a precautionary approach. It has been recently suggested that MPAs are being created in places of "residual value" (Devillers et al., 2014) as they represent areas not targeted by fisheries because they are either remote or have no high commercial worth. Our proactive approach targeting areas where fisheries have not yet developed would not be an example of residual value places. Fisheries target prey present in fishing grounds not yet completely exploited throughout their distribution (Cousseau and Perrotta, 2000). New proposals are introduced for expanding the fishing effort on species of present secondary relevance (Skewgar et al., 2007). The fact that fisheries are not operating in areas suitable for conservation under the precautionary scenario is mostly due to the ease of access to still productive fishing grounds. We could expect this situation to change if resources are depleted in priority areas. Table 6 and Figures 16 and 17 summarize the vision in terms of colonies and criteria for *a priori* MPAs and identify the most effective scenario for areas where fisheries have developed and overlap significantly, according to our conservation criteria.

Punta León was the colony that fit our conservation intervention criteria for a reactive approach, that is, compensating fisheries for not operating during the most critical month to females. The cost for removing the Argentine red shrimp fishery, for example, was high. However, the proposal of compensating fisheries for 100% of reduction of landings if operating outside MPA (assumed as optimal for fishing) (conservation intervention 4 of this study) or compensating a portion of landings (set amount agreed with government) if fisheries were to operate outside the area of interest (conservation intervention 5 of this study) may prove feasible. A viable scenario for Uruguay requires fisheries data not available to us at the time of this analysis.

For Punta Buenos Aires and Punta Norte rookeries we propose to apply conservation scenario 3 (100% high use areas) during January. This would cover females of coastal foraging habits, putative foraging areas as indicated by locations of tagged females of each colony and areas of transit as females migrate to and from the colony. Fisheries´overlap with this scenario was low for Punta Norte (Figure 16) although it encompassed 26% of the total area for Punta Buenos Aires.

Punta Pirámide is the only medium-size breeding aggregation (800 pups born per year, Dans et al., 2004) located inside a semi-closed gulf (Golfo Nuevo). It was included in this analysis as a way to incorporate breeding grounds in proximity to areas where commercial fishing had not yet developed. The rookery was not included in our study because the number of pups born per season fell below our criteria for selecting target colonies.

MPAs encompassing 100% high-use areas for Punta Norte and Punta Pirámide fell within the 80 m contour line known to impose a distribution limit based on the physiology and diving behavior of females (Costa, 1993, Werner and Campagna, 1995). Proposed protected areas for these two colonies may be further reduced by protecting the area within provincial jurisdiction, thus simplifying the implementation and administrative process. For Punta Norte, this will result in the inclusion of conservation scenario 1 (50% high-use areas) and approximately 50% of the MPA proposed under proactive action. Punta Pirámide would result in approximately 75% of the proposed area.

Protected areas for all southern Patagonian target colonies were defined by the implementation of two criteria: Provincial jurisdictions (12 nm) to the E and mean travel distance estimated from satellite tracked coastal individuals from northern Patagonia to define N-S boundaries.

Establishing MPAs within provincial boundaries has benefits. First, the entire area is administrated by one government, making the implementation and administrative process simpler. Second, this boundary is in close proximity to the 80 m dive depth recorded for the females of this species (Werner and Campagna, 1995). Third, it would give a high degree of protection to coastal females of each rookery (which was the preferred foraging habit of half the females tagged in our study) and fourth, it would integrate areas of high density as females travel to and from colony during their foraging trips.

Due to the particular location of the Monte Loayza rookery located within the coasts of Golfo San Jorge, an area of high fisheries operations, and at a considerable distance of provincial jurisdictional boundaries, we defined protected area boundaries by the 80 m contour line, the known dive depth limit of these benthic predators (Werner and Campagna, 1995). Monte Loayza and Cerro Bayo converged when the N-S parameter based on mean maximum travelled distance of females from studied colonies was established.

The *a priori* protection zone for Isla Becasses, the southernmost target colony located in Tierra del Fuego within the Beagle channel, was delineated to the S by a line reaching the middle of the Channel, and to the E-W by applying the 56 km parameter as obtained from the mean maximum distance from colony of tagged females of this study.

Based on the lack of satellite tracking data for the southern Patagonia target colonies, we suggest that further research must be done to understand the degree of protection offered by the proposed MPAs.

In summary, spatial MPA scenarios for *a priori* conservation based on our best available data is in theory possible for females of one species and at a critical time of the annual life cycle. SSLs are one of the most common of the charismatic species on the Patagonian shelf. They reproduce close to colonies of many species of marine birds, also threatened by the direct and indirect impact of fisheries (Boersma and Rebstock, 2009). Thus, setting aside areas for their protection would have benefits that overflow to other species. Ideally, conservation planning should include all of these species as well as the input and participation of human stakeholders. However, the approach of this study may serve as a template for future thinking, more integrated and sophisticated procedures to achieve effective coastal management and conservation in Argentine Patagonia.

Table 6: Reactive and proactive MPA implementation approaches for target colonies

Conservation intervention	**Target colony**	**Spatial planning criteria**	**Surface area of best scenario (km^2)**
Reactive approach with data to show overlap	Punta León	Scenario 2 (80% high-use areas)	2,200
	Isla de Lobos	Not included in this study	n/a
Proactive with data on female distribution	Punta Buenos Aires	MPA delineated by scenario 3 (100% high-use areas). Low or no cost to fisheries	2,600
	Punta Norte		12,468
	Punta Pirámide		3,500
Proactive without data on female distribution	Monte Loayza	80 m bathymetry line within provincial waters	9,000
	Cerro Bayo	Up the limit of the provincial jurisdiction (12 nm) to the E, integrated with mean travel distance from colony of coastal females to define N-S boundaries	Joined with Monte Loayza
	Isla Lobos		2,700
	Las Chapas-Tres Amigos		2,600
	Isla Becassess	Only Argentine side of Beagle channel included. Integrated with mean travel distance from colony of coastal females to define E-W boundaries	600

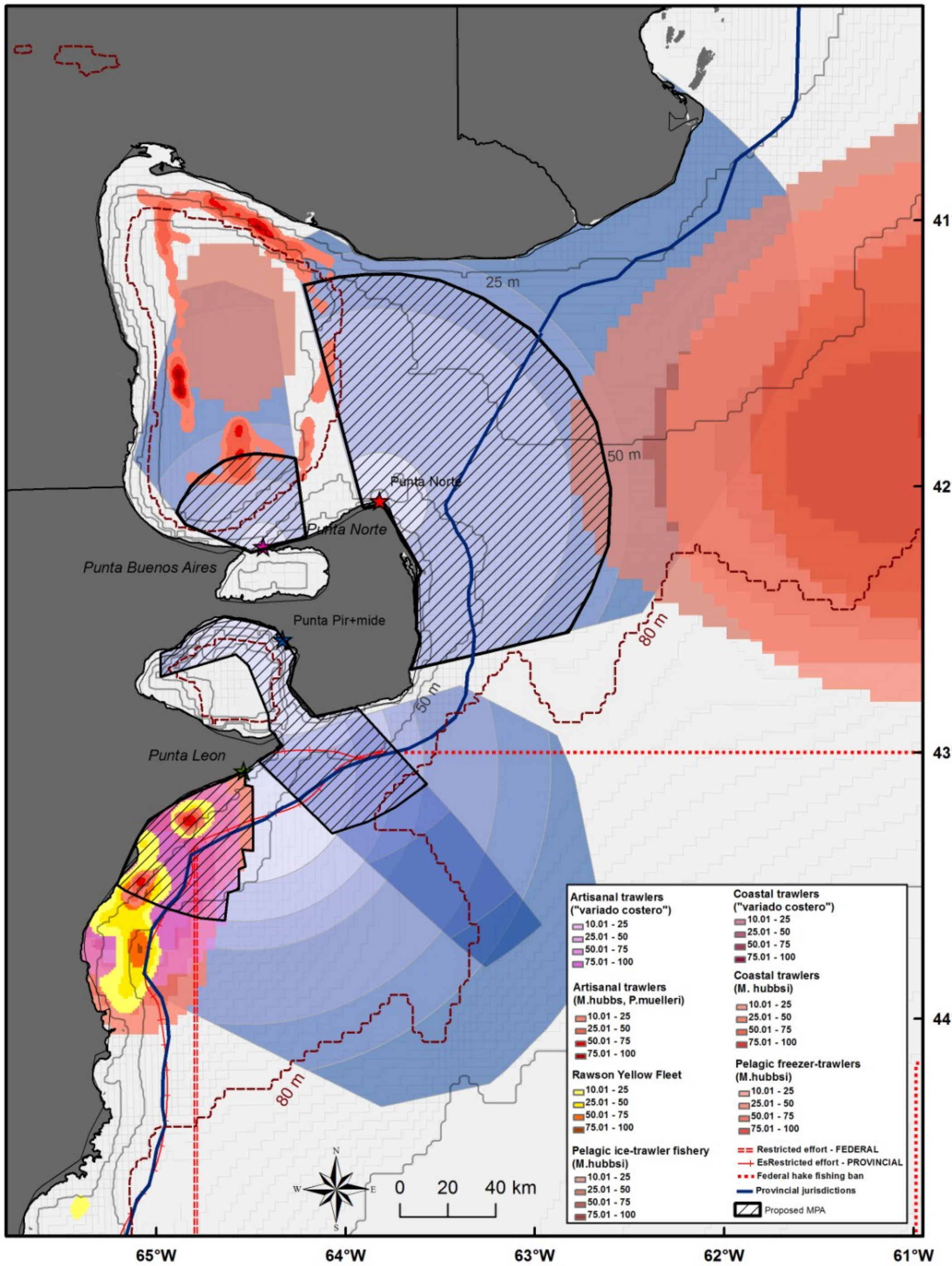


Figure 16: Proposed MPAs for the northern Patagonian target colonies.

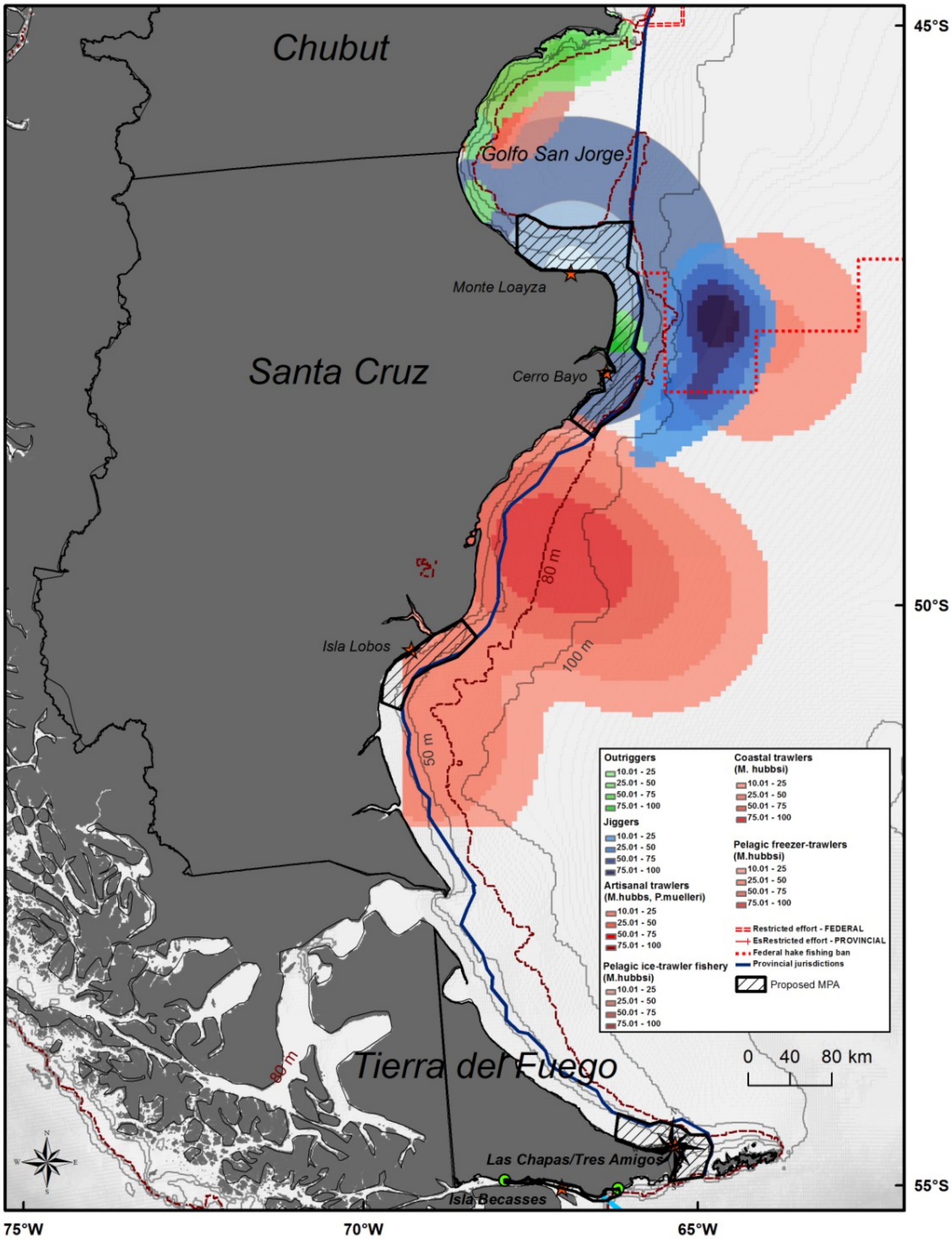


Figure 17: Proposed MPAs for the southern Patagonian target colonies

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APPENDIX

Appendix 1: List of colonies of the South American sealion along the coast of Patagonia in Argentina. These data were extracted from Dans et al., 2004; Schiavinni et al., 2004 and Reyes et al., 1999. Numbers represent animals in the rookery recorded during terrestrial counts. Additional up to date reports exists that updates counts (generalized by province) and extrapolates estimated animals at sea (see Dans et al., 2010). As a result, population numbers resulted in approximately 120,000. Figure 2b represents the distribution and size of colonies as reported in Dans et al., 2004; Schiavinni et al., 2004 and Reyes et al., 1999.

ROOKERY	PROVINCE	LONGITUDE	LATITUDE	Reproductive (R) haul out (H)	# OF PUPS	Total (incl pups & nonpups)
Caleta de los Loros	Rio Negro	-64.072221	-41.03194	H	16	530
Islote Lobos (RN)	Rio Negro	-65.022222	-41.419444	R	693	1164
Punta Belen	Rio Negro	-63.71667	-41.15	R	160	1009
Punta Bermeja	Rio Negro	-63.072222	-41.147222	R	480	2836
Barrancas Blancas	Chubut	-64.888886	-42.17917	R	509	985
Cabo Raso	Chubut	-65.22667	-44.38028	H	0	35
Isla Acertada	Chubut	-65.31667	-44.53333	R	205	617
Isla Arce	Chubut	-65.48333	-45.00417	H	4	288
Isla Blanca Este	Chubut	-65.64167	-44.77222	H	0	107
Isla Blanca Mayor	Chubut	-65.64027	-44.76944	H	0	90
Isla Blanca Oeste	Chubut	-65.65694	-44.76944	R	355	989
Isla Ceballos	Chubut	-66.36083	-45.15361	R	319	798
Isla Cumbre	Chubut	-65.38055	-44.59444	H	0	795
Isla Escondida	Chubut	-65.28333	-43.72167	R	729	1315
Isla Este	Chubut	-65.93333	-45.11666	H	0	528
Isla Gran Robredo	Chubut	-66.05695	-45.13334	H	8	271
Isla Lobos	Chubut	-66.29694	-45.07806	R	269	876
Isla Lobos Marinos	Chubut	-65.23889	-44.28333	R	369	871
Isla Moreno	Chubut	-65.53778	-44.90861	H	1	348
Isla Pequeño Robredo	Chubut	-66.09861	-45.11945	R	369	917
Isla Piedras	Chubut	-65.26667	-44.26111	R	297	689
Isla Quintano	Chubut	-66.70028	-45.24805	R	826	2303
Isla Rasa	Chubut	-65.39167	-45.10833	H	42	610

ROOKERY	PROVINCE	LONGITUDE	LATITUDE	Reproductive (R) haul out (H)	# OF PUPS	Total (incl pups & nonpups)
Isla Sudoeste	Chubut	-65.62334	-45.06333	H	0	775
Isla Vernacci Sudoeste	Chubut	-66.51444	-45.18222	R	596	1163
Isla Viana Sur	Chubut	-66.40583	-45.20028	H	0	176
Islote Puente	Chubut	-65.83833	-45.04	R	100	319
Morro Nuevo	Chubut	-64.1436	-42.872	R	895	1546
Playa La Armonia I	Chubut	-64.05	-42.16667	R	510	875
Punta Aristizabal	Chubut	-66.52084	-45.22222	H	0	11
Punta Betbeder	Chubut	-65.28333	-44.51667	H	0	127
Punta Buenos Aires	Chubut	-64.374991	-42.233325	R	1778	3049
Punta Delgada	Chubut	-63.63334	-42.76667	H	0	1031
Punta Gutierrez	Chubut	-65.26694	-44.40611	H	0	106
Punta Hercules	Chubut	-63.58333	-42.61666	H	0	122
Punta Le=n	Chubut	-64.49167	-43.075	R	1570	3212
Punta Loberia (norte)	Chubut	-65.26667	-44.27778	H	0	72
Punta Loma	Chubut	-64.891674	-42.816668	R	52	488
Punta Norte	Chubut	-63.783329	-42.066683	R	1975	4218
Punta Pir+mide	Chubut	-64.283333	-42.583333	R	824	1349
Punta Quiroga	Chubut	-64.46667	-42.23333	R	462	1029
Cabo Blanco	Santa Cruz	-65.75	-47.2	H	0	36
Cerro Bayo	Santa Cruz	-68.62801	-50.249988	R	135	898
Isla Lobos (SC)	Santa Cruz	-65.873331	-47.95917	R	175	944
Isla Pinguino	Santa Cruz	-65.721668	-47.91	H	0	207
Isla Shag	Santa Cruz	-65.89833	-48.115	H	0	744
Islote al N de Islote Chato	Santa Cruz	-67.083323	-48.686002	H	0	31
Islote Chato	Santa Cruz	-67.033342	-48.742825	H	0	509
Islote del Cabo	Santa Cruz	-66.222328	-48.252488	H	0	52
Islote frente a Cerro Ordoñez	Santa Cruz	-66.752828	-48.497505	R	51	673
Islote frente a Punta Medano Negro	Santa Cruz	-65.91666	-48.01667	H	4	34

ROOKERY	PROVINCE	LONGITUDE	LATITUDE	Reproductive (R) haul out (H)	# OF PUPS	Total (incl pups & nonpups)
Islote Lobos	Santa Cruz	-66.11667	-47.808333	H	0	25
Islote Puntudo	Santa Cruz	-66.036986	-48.126981	H	0	302
Islote S del Cabo Dañoso	Santa Cruz	-67.248	-48.857829	H	0	147
La Mina	Santa Cruz	-67.60833	-49.155	H	1	73
Maquenque	Santa Cruz	-67.6945	-49.5207	H	0	626
Monte Loayza	Santa Cruz	-66.271674	-47.088326	R	245	1972
Punta Cuevas o N de Cerro Observatorio	Santa Cruz	-69.042742	-50.526155	H	0	461
Cañadon Gapp	Santa Cruz	-68.55	-52.138333	H	0	60
Caleta Chica Oeste	Tierra del Fuego	-65.1781	-54.648897	H	3	130
Caleta Policarpo Oeste	Tierra del Fuego	-65.813644	-54.641238	H	17	240
Cabo San Diego 1	Tierra del Fuego	-65.1217	-54.6567	H	19	133
Cabo Santa Ines	Tierra del Fuego	-67.1922	-54.0948	H	0	221
Islas Becasses	Tierra del Fuego	-67.0133	-54.9583	R	179	238
Islote al NE de Isla Despard	Tierra del Fuego	-68.165	-54.8683	H	0	32
Islote Les Eclaireurs Este	Tierra del Fuego	-68.1	-54.8733	H	5	155
Islote San Martin de Tours	Tierra del Fuego	-66.3003	-55.0133	H	0	50
Laguna Centenario	Tierra del Fuego	-65.34	-54.6367	R	85	302
Punta E Bahia Policarpo	Tierra del Fuego	-65.514941	-54.631252	H	0	116
Las Chapas-Tres Amigos	Tierra del Fuego	-65.3	-54.6333	R	111	289
Bahia Buen Suceso Sur	Tierra del Fuego	-65.217287	-54.810255	H	0	100
Isla Observatorio	Isla de los Estados	-64.13333	-54.655	H	0	100
Bahia Flinders	Isla de los Estados			R	20	

Appendix 2: Satellite tracking information for the studied lactating females of Peninsula Valdes (Campagna et al., 2001) and Isla de Lobos (Riet-Sapriza et al., 2012). Numbers in bold indicate values selected as parameters to calculate conservation secenario's boundaries (black: averages, red: values from individual females). Numbers in green indicate conservation scenario surface area resulting from drawing the boundary from each selected parameter, and n/a means "not applicable".

COLONY	Satellite tracked females	(6) Max. distance reached from colony (km)	Scenario Surface Area (sq km)	(5) Max mean distance from colony (km)	Scenario Surface Area (sq km)	(4) Distance if females travelled at constant speed for 1.5 days each way	Scenario Surface Area (sq km)	(3) Max. dist. If 100% of all high use areas protected	(2) Max distance if 80% of foraging areas protected (km)	Scenario Surface Area (sq km)	(1) Max distance if 50% of foraging areas protected (km)	Scenario Surface Area (sq km)
PUNTA LEON	L1	115		115		2.8		41	n/a		n/a	
	L2	**166**	**25,611**	166		3.2		63	n/a		n/a	
	L3	133		133		3.2		**103.8 (8,493)**	n/a		n/a	
	L4	149		149		3.8		75	n/a		n/a	
	L5	77		77		1.8		62	n/a		n/a	
	LEON ALL	n/a		**128**	**20,203**	**106** (2.96 km/h)	**15,842**	n/a	**63**	**6,151**	**47**	**3,554**
PUNTA BUENOS AIRES	BA1	19		19		n/a		n/a	n/a		n/a	
	BA2	**112**	**6,656**	112		3.9		1.94	n/a		n/a	
	BA3	12		12		1.9		5	n/a		n/a	
	BA4	62		62		2.7		**39 (2,587)**	n/a		n/a	
	BA ALL	n/a		**51**	**3,348**	**100** (2.8 km/h)	**6,266**	n/a	**28**	**977**	**10**	164
PUNTA NORTE	N1	66		66		2.3		n/a	n/a		n/a	
	N2	41		41		n/a		3.01	n/a		n/a	
	N3	113		113		n/a		n/a	n/a		n/a	
	N4	97		97		4.1		**94 (12,468)**	n/a		n/a	
	N5	**213**	**28,873**	213		2.8		14	n/a		n/a	
	N6	41		41		2.4		1.9	n/a		n/a	
	NORTE ALL	n/a		**95**	**12,468**	**104** (2.9 km/h)	**15,954**	n/a	**80**	**10,324**	**20**	724
ISLA DE LOBOS	U1	85		85		n/a		**1.8 (10)**				
	U2	90		90		n/a		0.38				
	U3	n/a		n/a		n/a		n/a				
	U4	72		72		n/a		0.38				
	U5	n/a		n/a		n/a		n/a				
	U6	37		37		n/a		0.35				
	U7	62		62		n/a		0.42				
	U8	79		79		n/a		0.32				
	U10	**110**	**14,217**	110		n/a		0.37				
	ISLA DE LOBOS ALL	n/a		**76**	**8,876**	n/a	**n/a**	n/a				

Appendix 3: Fishing fleets operating along the coastal Argentine Patagonian shelf (see Methods) and their surface area and percent of overlap with conservation scenarios (from largest to smallest) of target colonies. All fleet types are color coded based on colors used in Figure 14 and Table 1.

				FLEETS																				
FISHERY TYPE				**ARTISANAL**						**COASTAL**								**PELAGIC**						
FISHERIES				**ARTISANAL TRAWLERS**		**ARTISANAL LONGLINERS**		**ARTISANAL TRAWLERS**		**RAWSON YELLOW FLEET**		**COASTAL TRAWLERS**		**COASTAL TRAWLERS**		**Uruguayan Coastal Bottom Trawlers**		**ICE TRAWLERS**		**FREEZER TRAWLERS**		**OUTRIGGERS**		**JIGGERS**
FISHERY TARGET				**Argentine hake** *(Merluccius hubbsi)* and **Argentine red shrimp** *(Pleoticus muelleri)*		**Argentine hake** (*Merluccius hubbsi*)		Many coastal demersal species		**Argentine hake** *(Merluccius hubbsi)* and **Argentine red shrimp** *(Pleoticus muelleri)*		**Argentine hake** (*Merluccius hubbsi*)		Several coastal demersal species		**Whitemouth croaker** *(Micropogonias furnieri)* and **Striped weakfish** *(Cynoscion striatus)*		**Argentine hake** (*Merluccius hubbsi*)		**Argentine hake** (*Merluccius hubbsi*)		**Argentine red shrimp** *(Pleoticus muelleri)*		**Argentine shortfin squid** *(Illex argentinus)*
COLONY	**CONSERRVATION SCENARIOS**	**Distance to colony (km)**	**Surface Area (s.a) (km^2)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km^2)**	**Overlap (%)**	**Overlap s.a (km2)**	**Overlap (%)**	**Overlap s.a (km2)**	**Overlap (%)**	**Overlap s.a (km2)**
PUNTA BUENOS AIRES	(6) Max. distance reached by any female of colony	112	6,656															809	12					
	(5) Mean max. distance all females	51	3348															495	15					
	(4) 1.5 day travel at mean speed	100	6266															782	12					
	(3) 100% high-use areas	39	2587															229	8					
	(2) 80% high-use areas	28	977															0	0					
	(1) 50% high-use areas	10	164															0	0					
PUNTA NORTE	(6) Max. distance reached by any female of colony	213	28873															9,200	31%	3,900	13%			
	(4) 1.5 day travel at mean speed	104	15954															1,331	8%	0	0%			
	(3&5) 100% high-use areas/Mean max. distance all females	95	12468															651	5%	0	0%			
	(2) 80% high-use areas	80	10324															0	0%	0	0%			
	(1) 50% high-use areas	20	724															0	0%	0	0%			
PUNTA LEON	(6) Max. distance reached by any female of colony	166	25,611	230	1	561	2	3,510	14	1,365	5	3,900	15	1,590	6									
	(5) Mean max. distance all females	128	20,203	230	1	561	3	3,510	17	1,365	7	3,900	19	1,590	8									
	(4) 1.5 day travel at mean speed	106	15,842	230	1	561	4	3,510	22	1,365	9	3,900	24	1,590	10									
	(3) 100% high-use areas	75	8,493	230	3	285	3	2,400	28	738	9	2,500	29	972	11									
	(2) 80% high-use areas	63	6,151	143	2	181	3	2,000	33	500	8	1,940	31	578	9									
	(1) 50% high-use areas	47	3,554	100	3	100	3	1,000	28	238	7	1,300	36	142	4									
ISLA DE LOBOS	(6) Max. distance reached by any female of colony	110	14,217									2,700	19	4,200	30%	11,244	80	4,500	32%	8,146	57%			
	(5) Mean max. distance all females	76	8,876									400	5	1,700	19%	7,159	80	1,900	21%	5,700	64%			
	(3) 100% high-use areas	1.8	10									0	0	0	0%	0	0	0	0%	0	0%			
MONTE LOAYZA	(6) Max. distance reached by any female of colony	150	40,000									608	2							5,527	13	2,000	5	6,620
	(3) 100% high-use areas	69	7,900									0	0							0	0	207	2	0
	(1) 50% high-use areas	26	800									0	0							0	0	0	0	0