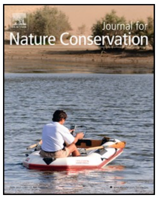
Journal for Nature Conservation 53 (2020) 125748

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc



Telecoupling analysis of the Patagonian Shelf: A new approach to study global seabird-fisheries interactions to achieve sustainability

Andrea Raya Rey[a,b,c,*,1], Falk Huettmann[d,1]

[a] Centro Austral de Investigaciones Científicas y Técnicas, Consejo Nacional de Investigaciones Científicas y Técnicas (CADIC-CONICET), Ushuaia, Tierra del Fuego, Argentina
[b] Instituto de Ciencias Polares, Ambiente y Recursos Naturales, Universidad Nacional de Tierra del Fuego, Ushuaia, Tierra del Fuego, Argentina
[c] Wildlife Conservation Society, Amenábar 1595, Office 19, C1426AKC CABA, Buenos Aires, Argentina
[d] EWHALE Lab- Institute of Arctic Biology, Biology & Wildlife Department, University of Alaska Fairbanks (UAF), Fairbanks, AK, USA

ARTICLE INFO

Keywords:
Biodiversity conservation
Coupled human and nature systems
CHANS
Fisheries bycatch
Fisheries governance
Patagonia
Seabird conservation

ABSTRACT

The Southwest Atlantic Ocean, particularly the extended Patagonian Shelf, constitutes a complex, globally-relevant ecosystem. It is a highly productive area, and it maintains a high diversity and abundance of seabird species. At the same time, the Patagonian Shelf experiences pressues, such as fisheries that have been identified as a main stressor for marine ecosystems worldwide, including being a principal cause of seabird population declines. Using the telecoupling framework - which incorporates natural and socioeconomic interactions over large distances - we present here a holistic look at the dynamics of threatened seabird- fisheries interactions for the Patagonian Shelf over space and time. Based on the best-available public data for seabird presence, we used machine learning and geographic information systems to model-predict the at-sea distribution of seabirds. Then, maps were overlaid with fisheries distributions to show spatial correlation and hotspots for co-occurrence between seabirds and fisheries. We found that even this remote corner of the Atlantic Ocean is globally connected to XXX nations and XXX other outside-stakeholders through fisheries. By identifying and characterizing the systems, flows, agents, causes and effects involved in this telecoupling process, we highlighted specific complexities, bottlenecks and sensitivities that must still be addressed to achieve both biodiversity conservation and management as well as fisheries sustainability not only in this study area, but worldwide.

1. Introduction

In the Anthropocene (Crutzen, 2002), global marine biodiversity is facing massive human-driven declines across many taxa (Butchart et al., 2010). Such biodiversity loss comes from a synergic effect of various anthropogenic impacts that include, but are not limited to, overfishing, global warming, biological invasions, shipping, and pollution (Sala et al., 2006). Marine top predators and their populations are no exception and have already suffered declines, and even extinctions, at local, regional, and global levels (Pauly, Christensen, Dalsgaard, Froese, & Torres, 1998). Seabirds, as relatively high trophic-level consumers, are among the most threatened groups of birds in the world (Croxall et al., 2012). Given their life history traits, pelagic seabirds have inherently long recovery response times, even after the removal of a threat (Owens & Bennett, 2000). Recent estimates are that seabird populations have declined by 70% over the past 60 years (Paleczny, Hammill, Karpouzi, & Pauly, 2015). Currently, humanity's dominance of global systems has extended well into the sea, where impacts due to fisheries harvests, including overfishing and bycatch, have been singled out as a major cause of seabird declines worldwide, but this effect operates via multiple mechanisms (Furness, 2003; Tasker et al., 2000; Tuck, Polacheck, Croxall, & Weimerskirch, 2001). On the other hand, some species benefit from food subsidies (e.g., discards, offal, Bugoni, McGill, & Furness, 2010), but there are also potential negative consequences at the broader community- and ecosystem-levels. Among the threats caused by fisheries, for example, bycatch has been identified as the principal problem for pelagic seabirds and has been by far the most-studied interaction (Brothers, Cooper, & Lokkeborg, 1999; Croxall et al., 2012; Melvin & Parrish, 2001).

Given these issues, we know that marine and coastal management benefit when human and natural systems are viewed not only as complex, but rather as coupled across multiple dimensions (Liu et al., 2015;

---

[*] Corresponding author at: Centro Austral de Investigaciones Científicas y Técnicas, Consejo Nacional de Investigaciones Científicas y Técnicas (CADIC-CONICET), Ushuaia, Tierra del Fuego, Argentina.

E-mail address: arayarey@cadic-conicet.gob.ar (A. Raya Rey).

[1] Authors contributed equally to this work.

https://doi.org/10.1016/j.jnc.2019.125748
Received 16 March 2018; Received in revised form 10 September 2019; Accepted 11 September 2019

Table 1
List of selected species that forage within the study area, including their IUCN status, Aves Argentinas AA status (López-Lanús et al., 2009) (T, threatened, V vulnerable, NT not threatened), population trends (I: increasing, D: decreasing, S: stable, U: unknown), global abundance (individuals), breeding places within the region (include Argentina, Falkland/Malvinas Islands and South Georgia, and threats (on land and at sea) data from BirdLife International (2015) for each species and commercial fishes consumed or interaction with a particular target species, fisheries fleet for those species and references data from BirdLife International (2015) and Seabird Maps and information for fisheries http://www.fisheryandseabird.info/. Threats on land and at sea, I: introduced species, C: increase numbers of predators or competitors (i.e. sea lions), P: pollution, N: natural events (i.e. volcanic eruptions), CC: climate change (i.e. reduced sea ice extension), H: harvest of species, HL: habitat loss, F: fisheries.

Species Common names	Scientific name	IUCN Status	AA Status	Pop trends	Global pop (ind)	Breeding Places (within region)	Breeding pairs (within the area)	Threats land /coastal	Threats at sea	Commercial fishes	Gear type Interaction	References
Diomedeidae												
Wandering Albatross	Diomedea exulans	Vulnerable	T	D	15,860	SG	1,552	I-P	F-P-CC	Dissostichus eleginoides	Longlines	Xavier, Croxall, Trathan, & Rodhouse, 2003; Xavier et al., 2004
Black-browed Albatross	Thalassarche melanophrIs	Near Threatened	V	D	1,820,000	F(M)-SG	591,000	I	F-P-CC	Loligo gahi Micromesistius australis, Dissostichus eleginoides	Trawlers and longlines	Thompson, 1992; Arata & Xavier, 2003; Reid & Sullivan, 2004
Procellaridae												
Southern Giant Petrel	Macronectes giganteus	Least concern	V	I	121,680	A-SG-F(M)	27,500	I-N-C	F-P	Illex argentinus Loligo gahi Macruronus magellanicus Merluccius hubbsi	Jiggers and trawlers	Copello, Quintana, & Pérez, 2008; Copello & Quintana, 2009
Southern Fulmar	Fulmarus glacialoides	Least concern	NT	S	4 million			N	CC	Dissostichus eleginoides	Longlines Trawlers (in low numbers)	Otley, Reid, & Pompert, 2007; da Silva and Petry, 2007
Cape (Pintado) Petrel	Daption capense	Least concern	NT	S	2 million	SG		CC	F-CC		Trawlers and Longlines (in low numbers)	Coria, Soave, & Montalti, 1997; Yorio & Caille,1999
Sooty Shearwater	Ardenna grisea (Puffinus griseus)	Near Threatened	NT	D	20 million	F(M)	10,000-20,000	H-I	F-CC	Dissostichus eleginoides	Longlines	Ashford, Croxall, Rubilar, & Moreno, 1995, Otley et al., 2007
White-chinned Petrel	Procellaria aequinoctialis	Vulnerable	V	D	3.12 million	F(M)-SG	23,650	HL	F	Dissostichus eleginoides Illex argentinus	Longlines Jiggers	Berrow, Wood, & Prince, 2000; Anderson et al., 2011
Great Shearwater	Ardenna gravis	Least concern	V	S	15 million	F(M)		H-I	F		Trawlers	Carboneras, 1992; Yorio & Caille, 1999; Anderson et al., 2011
Oceanitidae												
Wilson's Storm-petrel	Oceanites oceanicus	Least concern	NT	S	12-30 million			CC	CC	Euphausia superba	Longlines Trawlers (in low numbers)	Croxall, Hill, Lidstone Scott, O'Connell, & Prince, 1988; Yorio and Caille, 1999; Quillfeldt, 2002

White, Halpern, & Kappel, 2012). In particular, the understanding of seabird-fisheries interaction could be enhanced if it were studied under a more holistic framework. In this context, it is imperative to incorporate the dynamics of drivers that are frequently considered separated, such as socioeconomic and environmental interactions that can occur over greater spatial scales, which is increasingly inherent to the Anthropocene's global-scale causes and effects. Attaining such a multi-dimensional and multi-scale understanding of our oceans is crucial if we are to attain broader sustainability policies and management actions.

The telecoupling framework (Adger, Eakin, & Winkels, 2009; Eakin et al., 2014; Friis et al., 2016; Liu et al., 2013) offers specific tools to achieve this goal; it analyzes and characterizes system components and their interrelationships, feedbacks, and multidirectional flows (Eakin et al., 2014; Liu, 2014; Liu et al., 2013) to provide a greater understanding of how local biodiversity and ecosystems interact with planetary anthropogenic forces. Two approaches have been proposed that differ in their systems definition and in the causes that set telecoupling into motion (Eakin et al., 2014; Liu, 2014). The framework also allows for best management practices and governance to incorporate an international (cross-jurisdictional) perspective, no matter the approach that is used (for details and comparison between these two approaches, see Friis et al., 2016). In short, telecouplings are composed of systems, flows, agents, causes, and effects. Systems are defined as sending, receiving and spillover. Flows are movements of entities (e.g., money, people, materials, information) between sending systems and receiving systems. In turn, flows are facilitated by agents (e.g., individuals or groups of human and non-human species), driven by causes (e.g., socioeconomic and environmental reasons), and characterized by effects (e.g., socioeconomic and environmental impacts; Liu et al., 2013, 2015).

Fisheries are clearly complex coupled human and natural systems (CHANS) and have previously been analyzed under the telecoupling framework (i.e. Carlson, Taylor, Liu, & Orlic, 2017; Carlson et al., 2018; Lynch & Liu, 2014). Nonetheless, telecoupling is still a relatively new concept and has not yet been applied to seabird-fisheries interactions in the southern hemisphere; doing so will allow insights on international and interdisciplinary view of biodiversity conservation in times of globalization (Lambin & Meyfroidt, 2011). Also, it has been shown to help analyze the system components and their interrelationships, allowing for clarification and re-assignment of environmental responsibilities (see Liu et al., 2013 and studies within). Thus, telecoupling helps to identify and understand distant interactions and the effectiveness of policies for both socioeconomic and environmental sustainability from local to global levels (Liu & Yang, 2013; Liu et al., 2013, 2015). In addition, this approach to sustainability follows the basic notion of ecosystem carrying capacity (Daly & Farley, 2011) and of the relevance of an appropriate governance framework (Ostrom, 1990, 2009).

Our study focuses on the extended Patagonian Shelf in the Southwest Atlantic Ocean, an important foraging ground for more than 60 species of resident and visiting seabirds (Croxall & Wood, 2002; Favero & Silva Rodríguez, 2005; Otley, Munro, Clausen, & Ingham, 2008).

Fishery fleets have been identified as a major problem for the Patagonian Shelf seabird community (Seco Pon et al., 2015). The principle fishing fleets comprise ice-trawlers/demersal trawl-net for Argentine hake (Merluccius hubbsi) ice trawler/mid-water trawl-net for Argentine anchovy (Engraulis anchoita), freezer trawler/demersal trawl-net for Argentine hake, freezer longline/bottom demersal longline for Patagonian toothfish (Dissostichus eleginoides) and kingclip (Genypterus blacodes), and freezer longline/bottom-demersal longline for Patagonian toothfish, kingclip and skates. Together annual mortality account for more than 20,000 birds (capture rates range between 0.04-0.12 birds fishing day^{-1}) from 2003 to 2014, primarily due to bycatch, entanglement and collision (for more details see Table 2 in Seco Pon et al., 2015). Bycaught species included Ardenna shearwaters, Thalasarche melanophries, Diomedea epomorpha, Diomedea exulans, Daption capense, Procellaria aequinoctialis, Macronectes giganteus, Fulmarus glacialoides (all analyzed in this study), as well as smaller numbers of other species like Thalassarche crysostoma, Macronectes halli, Speheniscus magellanicus and Larus dominicanus (these last two species nearer to the coast). Favero et al. (2013) showed a reduction in the mortality rate towards 2010, attributed primarily to (1) a general drop in fishing effort, (2) the closure in 2008 of the yellow-nosed skate (Dipturus chilensis) fishery, and (3) the progressive conversion, starting in 2008, of part of the fishing effort in the Patagonian toothfish-kingclip fleet to move from standard longlines to the use of cachaloteras (…..) and pots. Currently, some seabird species seem to be recovering (i.e. increasing or stable population trends), but others continue to decline (Birdlife, 2015 see details in Table 1). This emphasizes the importance of fisheries governance to prevent seabird declines, apart from the implementation of mitigation methods.

Here, we investigated seabird-fisheries interactions on the Patagonian Shelf with the telecoupling framework. This approach allows us to capture and synergize a broad suite of CHANS relationships and highlight even those that occur at greater distances, and therefore may be unrecognized. Nonetheless, these telecoupled relationships can have strong implications for conservation actions to be implemented to mitigate the trends in declining seabird populations. To date, these long-distance relationships have not been considered in seabird management in this area and hardly anywhere else (Seco Pon et al., 2015). Therefore, we first analyzed the at-sea seabird distribution as part of the wider natural system in the Patagonian Shelf, and fisheries as a main component of the human system. Second, we overlaid and related seabird distribution with fisheries to identify and assess consistent dual seabird-fisheries hotspots in the region. Finally, for the first time, five major components of telecoupling were described for seabird-fisheries interactions in the study area: systems; flows; agents; causes; and, effects. This approach allows us: a) to provide a more complete understanding of this complex CHANS; b) to enhance the identification of priority areas and key stakeholders for conservation and management; and c) to recommend and design more effective conservation and development policies and practices.

2. Methods

2.1. Study site

The study's natural system focused on the Patagonian Shelf marine ecosystem and the seabirds found there (Croxall & Wood, 2002). To be ecologically meaningful, we extended the analysis of the Patagonian Shelf Large Marine Ecosystem (LME) (Sherman & Duda, 1999, http://lme.edc.uri.edu/) by 200 km to cover the shelf-break region, a critical frontal area for seabirds and ecological processes (Croxall & Wood, 2002). We used an encompassing square to bound this relevant study area and to build the predictive maps and overlaps with fisheries activity (see Fig. 1).

Regarding the human system, we focused on the fishing industry, because it has been identified as a major cause of seabird declines (Favero et al., 2013). The fisheries in the Patagonian Shelf have changed and developed over the last decades; today, they constitute a complex mixture of both human and natural systems, as is true for virtually all fisheries in a globalized world (Alder & Watson, 2007). An additional complexity in the study area is that it includes the Falkland/Malvinas Islands, a territory under international dispute between Argentina and the United Kingdom (UK) (Bologna, 2012). Although Argentina does not recognize the UK's sovereignty over the islands, there are currently two assigned Exclusive Economic Zones (EEZs) in the study area, as well as international waters (Churchill & Lowe, 1988). Our general workflow and methods to jointly analyze the human and natural dimensions of this system are shown in Fig. 2.

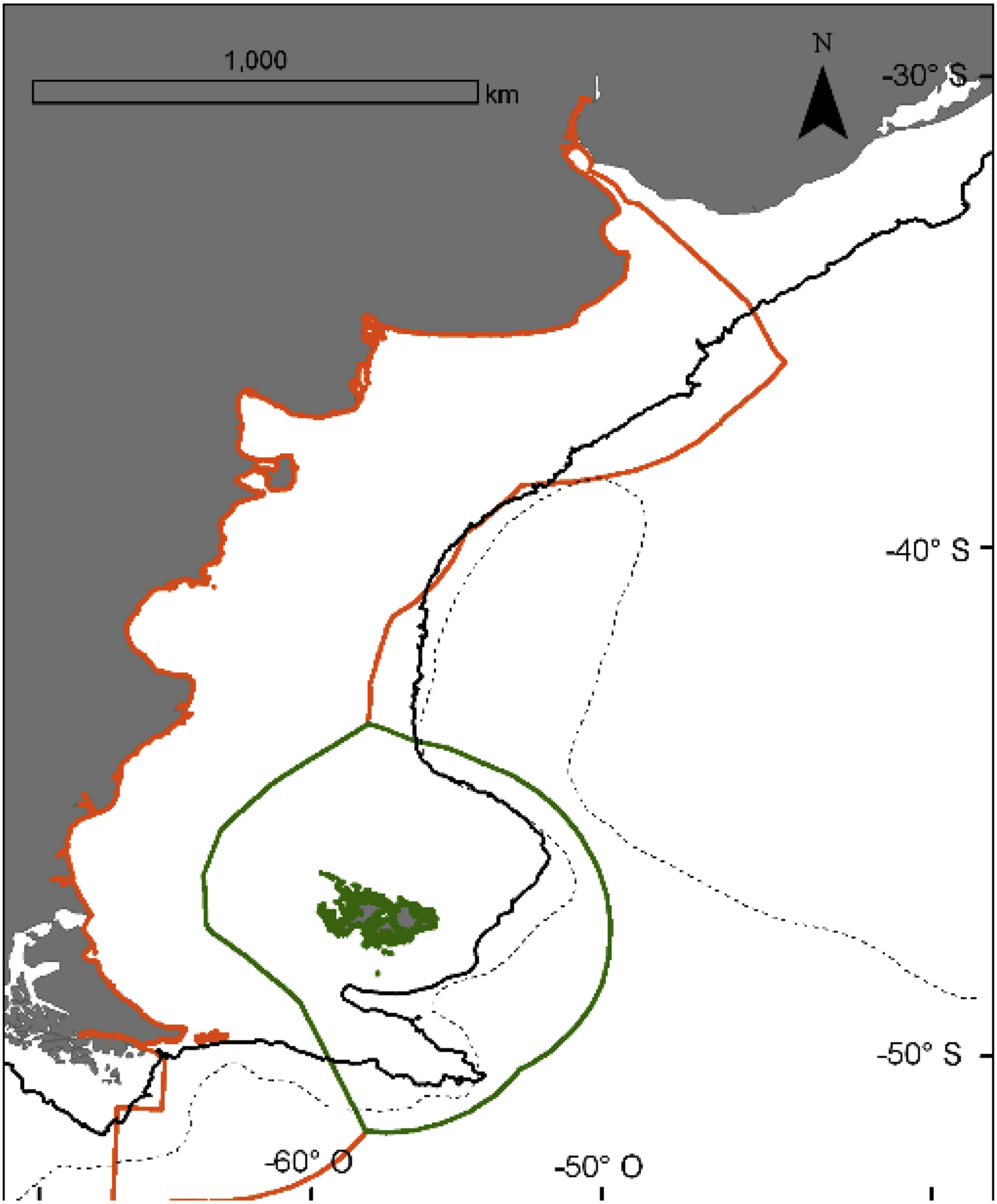


Fig. 1. Map of the study area. We delimited the analysis to include the Argentine Economic Exclusive Zone -EEZ (orange line) and the Falkland/Malvinas EEZ (green line). Black line: 1000 m contour bathymetry; dotted line: Sub-Antarctic Front.

2.2. Natural subsystem: seabirds of the Southwest Atlantic Ocean

Seabirds are well-studied ecosystem indicators (Croxall et al., 2012). We compiled publically available presence data for nine representative pelagic seabird species that forage in the Patagonian Shelf and that also are known to interact directly with fisheries. Most of them have been documented to be declining and thus are of conservation concern (Table 1, see also Seco Pon et al., 2015). We used the widely-employed, open-source Global Biodiversity Information Facility GBIF (http://www.gbif.org/), Ocean Biogeographic Information System OBIS (Halpin et al., 2009, http://seamap.env.duke. edu/), and the Scientific Committee on Antarctic Research-Marine Biodiversity Information Network (SCAR-MarBIN, http://data.biodiversity.aq/), which together host the vast majority of seabird-related open-access data (Huettmann, Artukhin, Gilg, & Humphries, 2011????). Further details of the seabird data for the Patagonian Shelf are available in Table A1, Appendix A. Details of presence surveys for each species within the study area, including the Patagonian Shelf, are provided in Table A1, as well. Plus, we used our own survey data for the study area to validate the seabird distribution model (Raya Rey, Scioscia, Dellabianca, & Torres, 2009).

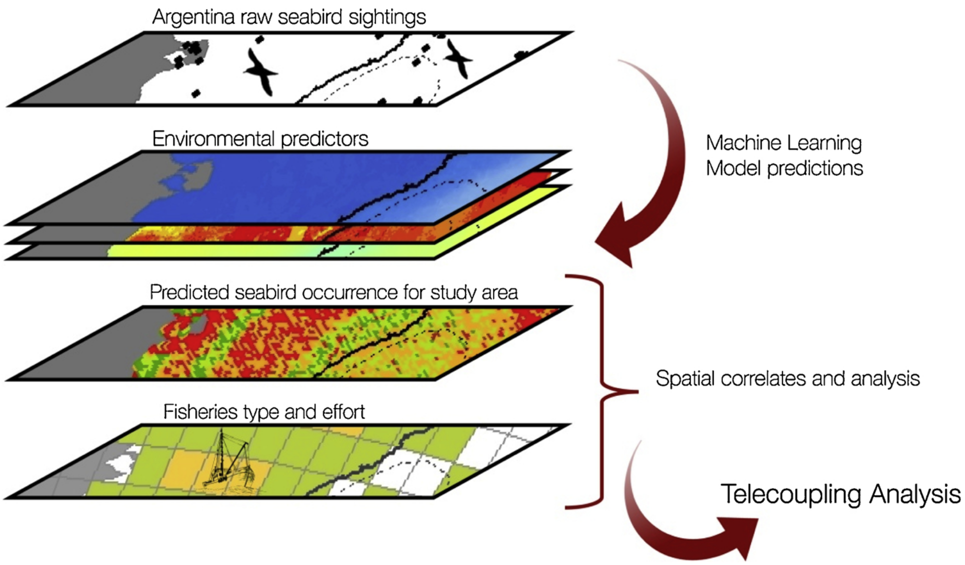


Fig. 2. Workflow and method steps of the analysis pursued in this study, building on raw data (seabirds and environment), predicted seabird distributions and subsequent telecoupling analysis.

2.3. Predictors for distribution modeling of seabirds

To model the distribution of the studied species, we selected ten socio-economic and environmental predictors for the Patagonian Shelf that are known to determine (sea surface temperature SST, oceanographic fronts, ports) or to affect (human and natural detrimental effects in the ocean, pollution, acidification, fisheries) seabird distributions worldwide (Huettmann & Schmid 2014a, 2014b) and that are also known to be acting specifically in this region (Copello, Dogliotti, Gagliardini, & Quintana, 2011; Raya Rey, Trathan, Pütz, & Schiavini, 2007). For further details on the predictors used for distribution modeling, see Table A2 in Appendix A.

2.4. Predictive relative index of occurrence (RIO) maps for seabirds

We followed an ecological niche modeling approach for seabirds to produce predictive maps for nine focal seabird species, identified as threatened by fisheries (Table 1). We used presence only data and then applied standard methods (Huettmann & Diamond, 2001, 2006; Huettmann, Riehl, & Meissner, 2016; Humphries, Huettmann, Nevitt, Deal, & Atkinson, 2012, 2018) to create predictions. The overall work flow for our predictive model and data compilation is presented in Fig. A1 in Appendix A (see also Appendix A3 for further details on seabird distribution modeling). We used high performance decision tree-based machine learning algorithms to provide a predicted RIO (Huettmann et al., 2011; Pearce & Ferrier, 2000) using SPM7 by Salford Systems (www.salford-systems.com/).

2.5. Human subsystem: Fisheries as a main threat for seabirds

Mortalities and serious injuries of albatrosses and petrels have been documented due to longline bycatch, strikes with vessels and cables, and entanglements with nets and other components of the fishing gear in the Patagonian Shelf (Seco Pon et al., 2015; Wienecke & Robertson, 2002, see Table 1). Spatial overlap was used as a proxy for and correlate with risks from these activities, as it is a necessary precondition for those interactions between seabird and fisheries (Seco Pon et al., 2015). Thus, we identified areas where direct impact can occur by overlaying GIS data layers for seabirds and linked to fisheries. For further details, see Appendix B in the fisheries operating in the Patagonian Shelf. Fig. 4 presents the catch per unit effort spatial distribution for fisheries on the study area.

2.6. Data analysis and spatial correlates between fisheries and seabirds

As shown in Fig. 2, to assess the degree of overlap for each pixel of the study area we then overlaid the RIO maps for each species with the marine regions (Argentine EEZ, Falkland/Malvinas Island EEZ and international waters, www.marineregions.org/downloads.php) and with fishing fleets effort maps.

For each point on the lattice/pixel, we obtained the corresponding RIO value for each species, the marine region and the category of the fishing effort (low, medium, high or none) per fleet (trawlers, jiggers, longlines). Then, we analyzed these data with their complexities in space and time. For further details on the methodology to determine hotspot of seabird-fisheries overlap in the Patagonian Shelf, see Appendix C.

2.7. Telecoupling components

We reviewed literature, public sources, and official websites (e.g., FAO websites, Argentine National Fisheries Secretariat reports, World Bank data, United Nations reports, etc.; for source details see references) to describe the human and natural systems (focused on fisheries) and to identify the major components of the Patagonian Shelf fisheries under the telecoupling framework (i.e. systems, flows, agents, causes, and effects). We followed Liu et al. (2013) for the definition of these components (see Introduction). In particular, to define systems as sending, receiving, and spillover, we took into account the commerce related to fisheries catches and the sending systems were identified as the countries where the fish, squid and shrimp were harvested, but also the countries that do the harvesting within the study ecosystem. Then, we present a generic template on how to better capture, study, and manage the ocean in a more holistic manner, as exemplified here with the broader seabird-fisheries interactions for the Patagonian Shelf.

3. Results

3.1. Human and natural systems

Using publically available data, we produced predictive distribution maps for each of the nine selected seabird species in the study area (Fig. 3a–i). The model assessments, based on Receiving Operating Characteristic (ROC) model accuracy, showed rather high values (> 0.9), as well as the percentage of correct presences for the new field

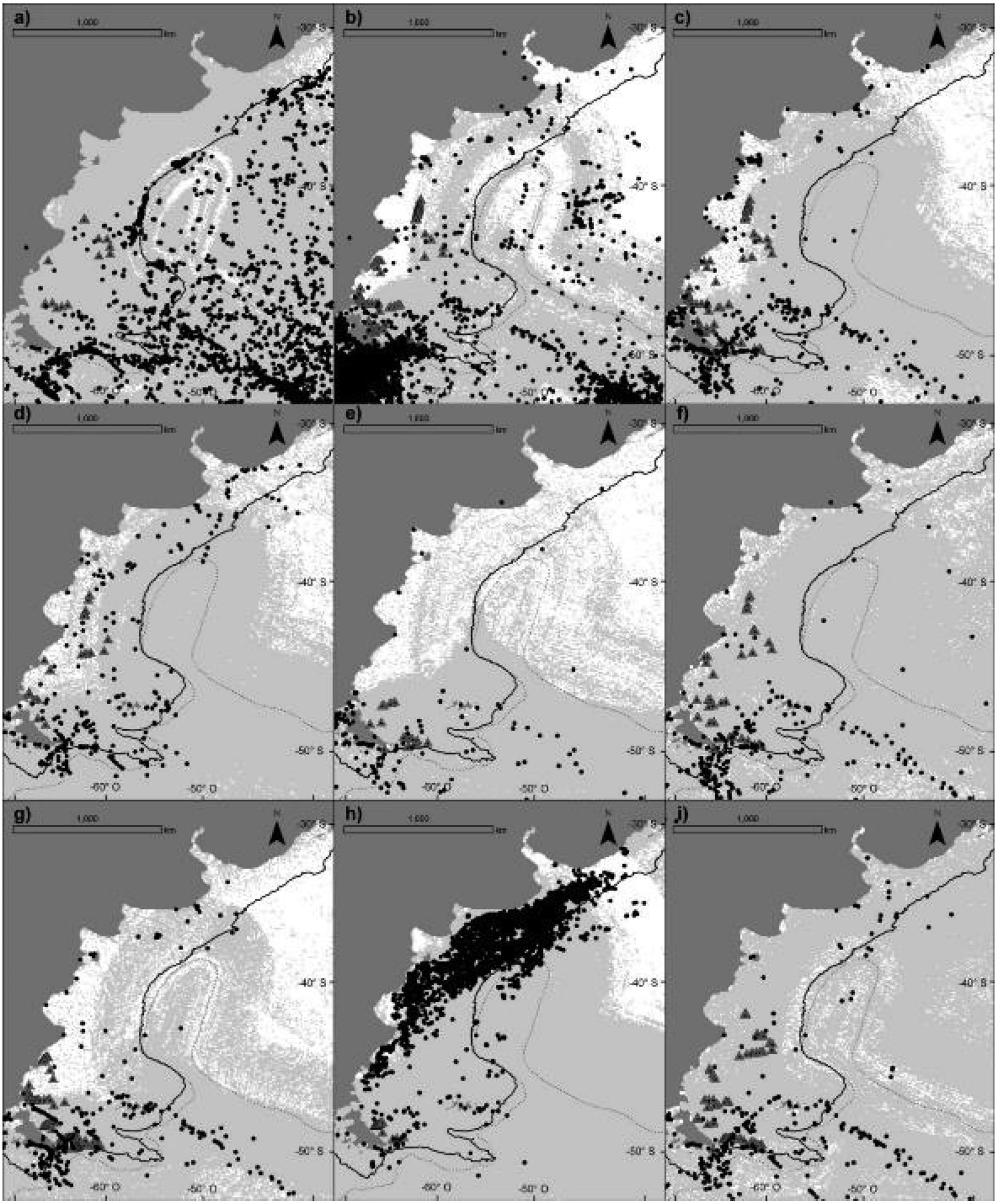


Fig. 3. Predicted distribution of nine pelagic species that forage on the Patagonian Shelf. Black dots: presence data for modeling; grey triangles: assessment new presence data. Each map represents the RIO greater than the 95% percentile of correct presence shown in grey for each species. Black line: 1000 m contour bathymetry; Dotted line: Sub-Antarctic Front. a) Diomedea exulans, b) Thalassarche melanophris, c) Macronectes giganteus, d) Procellaria aequinoctialis e) Fulmarus glacialoides, f) Daption capense, g) Ardenna grisea (Puffinus griseus), h) Ardenna gravis, i) Oceanites oceanicus.

data for all the models (Table A1 in Appendix A). The main drivers for pelagic seabird distribution in the Patagonian Shelf were i) distance to shelf break, ii) distance to the sub-Antarctic front, iii) distance to coast, iv) distance to ports, and v) bathymetry (Table D1 in Appendix D). All of these predictors were present in eight of the nine species models. Distance to ports was the only socioeconomic human predictor that influenced seabird distribution in all models, indicating that seabird numbers were driven partially by ports and their proximities, with RIO values being higher near ports. The species maps showed the southern region of the Patagonian Shelf (south of 48 °S) and the shelf itself are hotspots in terms of seabird RIO estimations.

Fisheries are known to be a major factor of seabird mortality in this area (Table 1, Seco Pon et al., 2015), including fishing fleets based on trawlers, jiggers, and longlines that operate throughout the region (Fig.

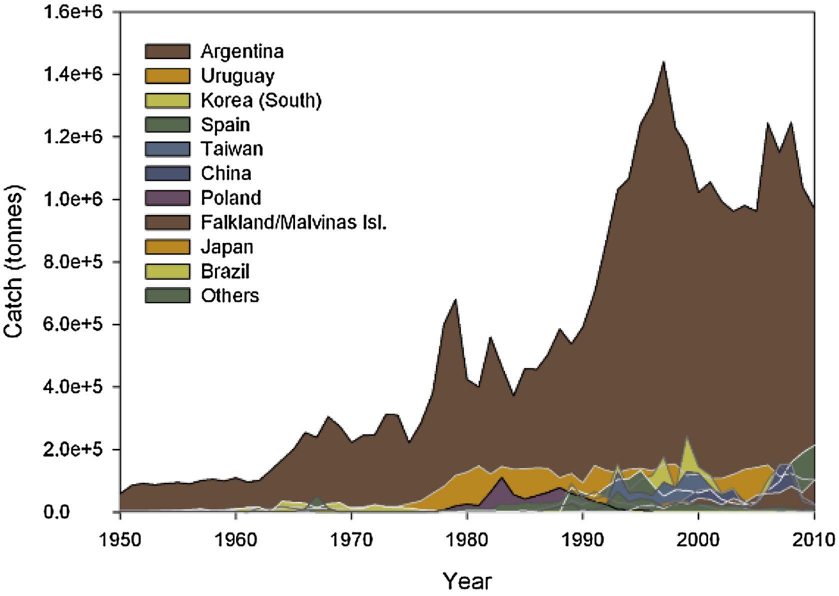


Fig. 4. Fisheries total captures (tones) in the waters of the Patagonian Shelf by country from 1950-2010 (data from Sea Around UsXXX).

B1 in Appendix B). Pauly and Zeller (2015) showed that total captures in the region have increased consistently since 1950 with specific ups and downs, depending on markets, financial crises, stock availability, demand, technology, fuel costs, and stochastic factors (Fig. 4). Moreover, the reconstructed catch was 55% higher than FAO reports, due to unreported landings and discards for the same period 1950–2010 (Villasante et al., 2015).

In our correlation analysis of seabirds versus fisheries, we found that median area-corrected RIO values for all species together were highest for the Falkland/Malvinas EEZ, followed by the Argentine EEZ, and then international waters for all fishing efforts within the three fishing fleets, except for high effort recorded for trawlers where data were only available for the Argentine EEZ (Fig. 5). In most cases, the same pattern held true for the mean RIO values. However, for some fisheries, values within the Argentine EEZ and international waters were similar, or even higher, in the case of international waters. The species-specific analysis showed the same pattern for most species with higher corrected RIO values within the Falkland/Malvinas EEZ fisheries area, followed by the Argentine EEZand international waters (Fig. D1 in Appendix D). Median area-corrected RIO values for the species overlapping with trawler, jigger, and longline fleet fishing areas were highest for Daption capense, Diomedea exulans, Oceanites oceanicus, *Puffinus griseus* and to a lesser extent Macronectes giganteus within the Falkland/Malvinas EEZ. Thus, from this analysis, we could infer that fisheries around the Falkland/Malvinas Islands posed the highest risk for seabirds, at least when judged from co-occurrence. Thirty-nine percent of the breeding seabird population of the Southwest Atlantic Ocean declined in a period of 60 years (Paleczny et al., 2015). In particular, the wandering albatross (Diomedea exulans) and black-browed albatross (Thalassarche melanophris), as well as the white-chinned petrel and sooty shearwater in our study area have exhibited dramatic population declines (i.e. 1.4% and 1.65% per year decline in the South Georgia Islands for wandering albatross and white chinned petrel, respectively, Birdlife, 2015 and reference in Table 1).

Regarding fisheries governance within the area, Argentina's management and conservation of fisheries resources is regulated by the Federal Fisheries Law #24922/97, promoting science, conservation, and management for the nation's entire fishery sector (for a review of laws related to wildlife and fisheries management, including closure and mitigation methods, see Seco Pon et al., 2015). The region shared by Argentina and Uruguay is currently managed by a joint committee (Comisión Mixta del Frente Maritimo, FAO, 2014-2016; FAO, -, 2016). Argentina has a regime of individual, transferable quotas for different species. Throughout its EEZ, it also has seasonal closures that differ for each target species and also some permanent closures (e.g., Marine Protected Area [MPA] Namuncurá-Burdwood Bank) along its EEZ. Argentina is also a member and signatory of several international agreements that link national policies and management of the Patagonian Shelf with international actors (see below). For those policies, they are similar to those described by Boardman (2006) and Huettmann et al. (2011) for polar regions in the northern hemisphere and include for instance the Bonn Convention of Migratory Species (CMS), the Convention for the International Trade in Endangered Species (CITES), Agreement on the Conservation of Albatross and Petrels (ACAP), International Union for the Conservation of Nature (IUCN), the International Polar Years (IPY) and Rio Convention (Biodiversity and Climate).

A performance assessment for marine ecosystem management in 53 maritime countries showed that Argentina performed poorly, although all countries performed rather poorly, and overall there was only a small difference between “the best” and “the worst” (Alder et al., 2010). This assessment was for the 2000–2004 period, and in response Argentina has since improved in most of the 14 indicators used in that study. Argentina also has recently implemented several National Plans of Action (NPAs) for reducing the interaction between fisheries and seabirds, and between fisheries and marine mammals (FAO, 2014-2018; FAO, 2014). Taken together, these efforts comprise various indicators used by Alder et al. (2010) to assess performance.

Meanwhile, the offshore fishery is not only the main commercial activity in the Falkland/Malvinas Islands, but it is also the primary source of government revenues through license fees. In this EEZ, fisheries management is essentially based on effort limitation (Barton, 2002; Palomares & Pauly, 2015).

3.2. Telecoupling components of the Patagonian Shelf

3.2.1. Sending and receiving systems

We found that the action of capturing fish and other sea products and the associated markets based on seafood extracted from the Patagonian Shelf comprise CHANS connected over vast distances and multiple dimensions. Indeed, both the human and natural subsystems are not merely local events and truly involve global dynamics (Figs. 5 and 6). Taking into account where the fish are caught for trade in the market (i.e. product per capital), the Patagonian Shelf Large Marine Ecosystem (LME) is the primary sending system. The nations involved

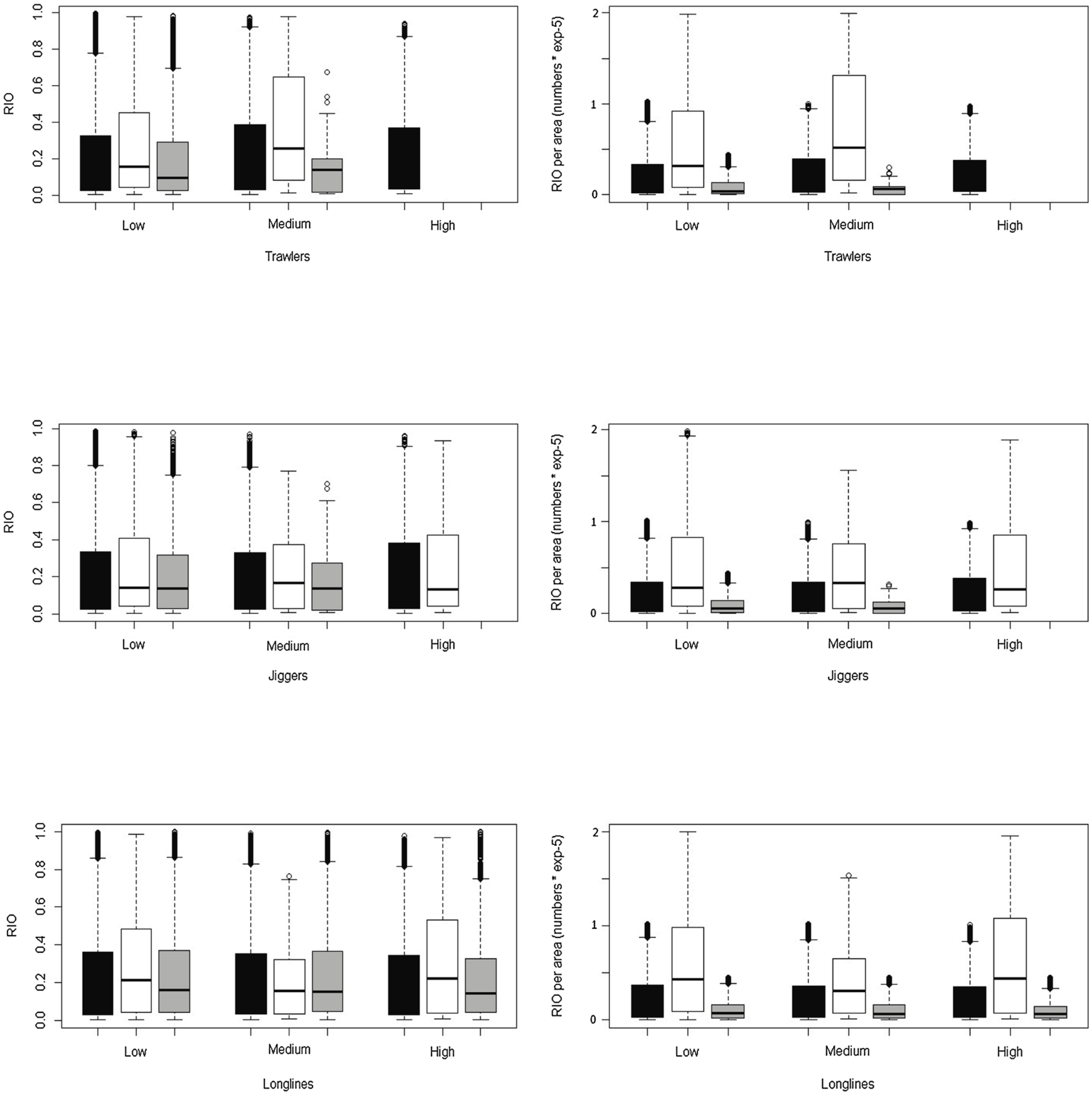


Fig. 5. Boxplots of mean and corrected (relative to the extension of each marine region, see text for details) Relative Index of Occurrence (RIO) values for all species combined within the area where each fishery fleet (trawlers, jiggers and longliners) occurred, taking into account the capture effort within each fishery fleet area. Black: Argentina, White: Falkland/Malvinas Islands, Grey: international waters. Boxplots: bottom and top of the box are the first and third quartiles, and the band inside the box represents the second quartile (the median), whiskers represent the minimum and maximum of all of the data, and outliers are represented by individual points.

in fisheries are numerous (poner el numero); Argentina is the main exporting nation, followed by Spain, Uruguay, the Falkland/Malvinas Islands, Brazil, Japan, China, Taiwan, and Korea. In 2010, most fisheries operating within the Argentine EEZ belonged to domestic companies (Ministerio de Agricultura, 2018). However, the Falkland/Malvinas Islands has a license regime within its EEZ that authorizes fee-based permits to fish within these waters, based on effort limitation (Barton, 2002). Spain is identified as the principal country in this EEZ's fishery (Figs. 6 and 7) but other nations like the UK, China and Japan also play an important role (Pauly & Zeller, 2015, Fig. 4).

The analysis revealed that receiving countries correspond mainly to the nations where Argentina exported its products during 2010 (Fig. 7). Fishing product exports for other countries (e.g., Spain, the UK, or China) are not categorized by region in the available national data sources and websites. Thus, it was not possible to discriminate what truly comes from the captures on the Patagonian Shelf versus other ecosystems, where these third party nations fish (i.e. in Fig. 7, there are no arrows between Spain and the countries to where they export their fishing products that are extracted from this study area). Data are still unavailabile, particularly georeferenced data, regarding catch-sharing and trading across regions, which is known to occur in international fleets. Consequently, our estimates should be taken to be at the low end (or minimum) of these processes. The principal markets (i.e. receiving systems) for seafood catches made by Argentina are Spain (responsible for purchasing 35% of the catch), Brazil (13%), Italy (11%), France (6%), Japan (5%), the USA and China (4% each); XXX other countries responsible for less than 4% of imports (see Fig. 7).

3.2.2. *Spillover systems*

In our study, spillover systems, defined as those countries and/or

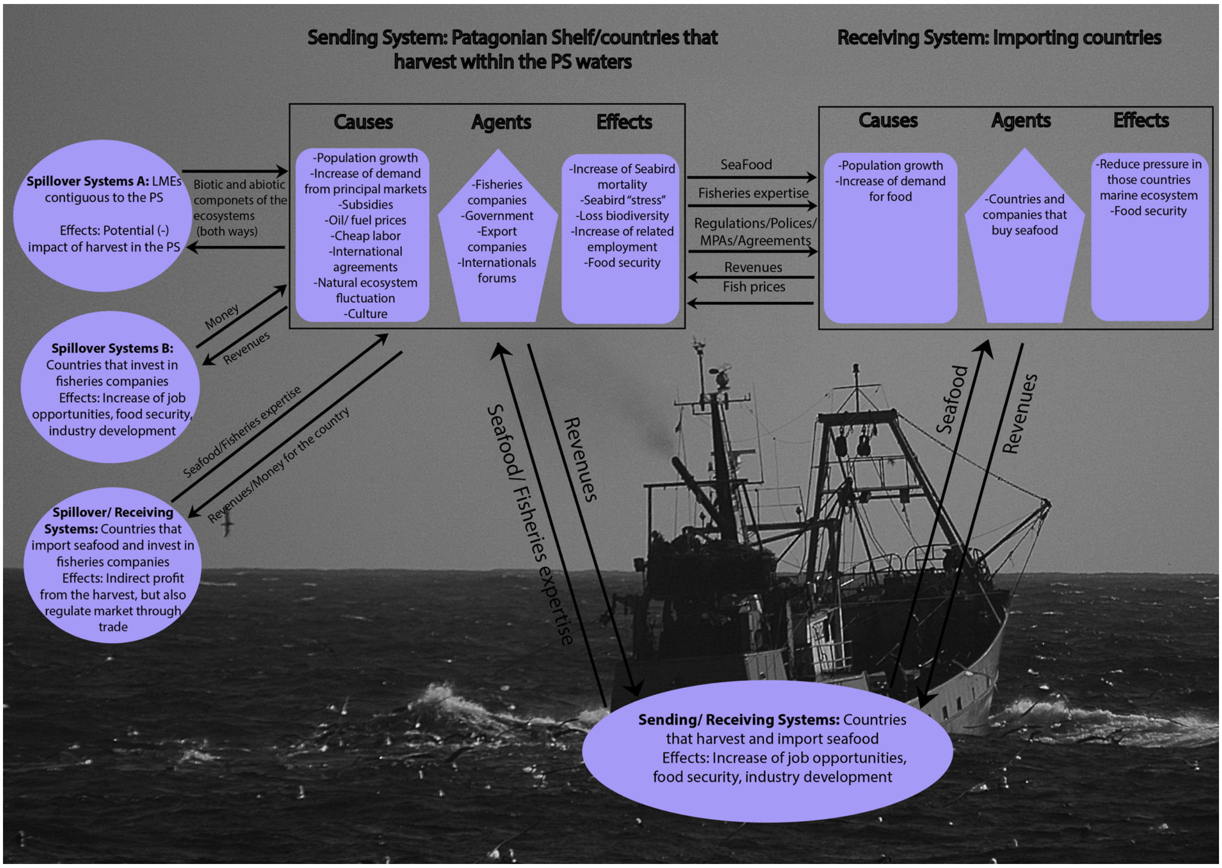


Fig. 6. A scheme of the five major and interrelated components of the telecoupling framework (Liu et al., 2013) for the fisheries in the Patagonian Shelf and their long-distance relationships to other parts of the continent and world. Photo: L Tamini.

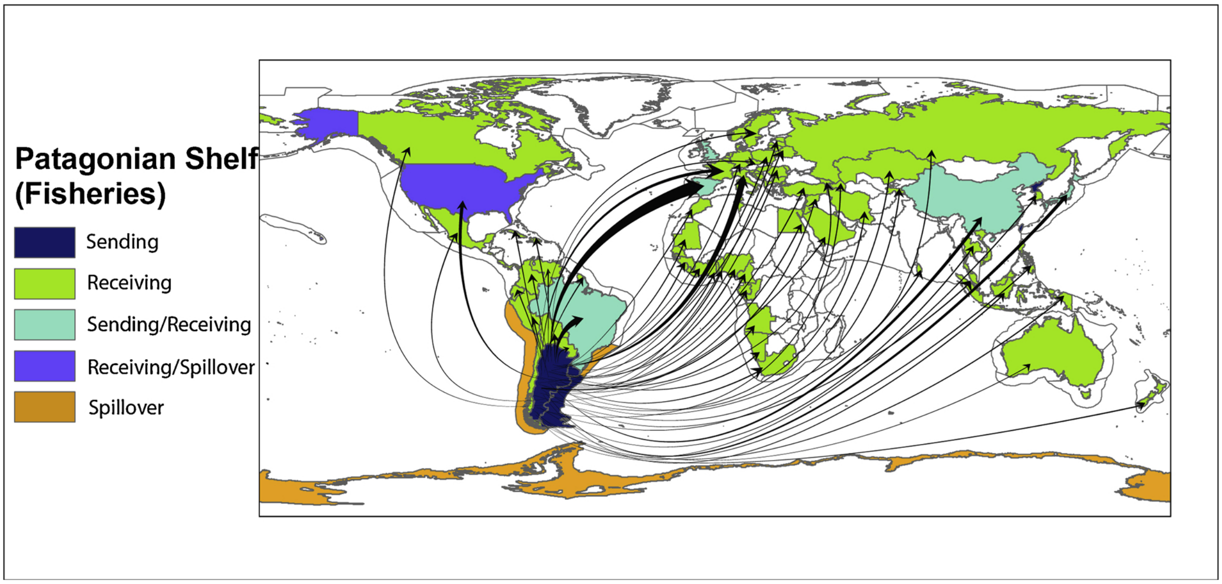


Fig. 7. Map of sending, receiving and spillover system as well as major flows under the telecoupling framework for the fisheries in the Patagonian Shelf. Black arrows indicate the relative size of fish products flows between sending (Argentina) and receiving countries (see details in Results). Flows from the Falkland/Malvinas fisheries and the countries that they sell license to fish (e.g., Spain) are not shown because information were not available in open access databases.

LMEs that are affected by or which affect fisheries on the Patagonian Shelf beyond sending and receiving (Figs. 6 and 7), included the Antarctic Shelf, Humboldt Current, and South Brazil Shelf LMEs, as well as those ecosystems that border and interact with the Patagonian Shelf LME (Figs. 6 and 7). These ecosystems are potentially affected by any detrimental effect on the Patagonian Shelf as a sending system, where fisheries of this study were located. We also found Japan and the USA (Figs. 6 and 7), as the two countries with capital/investment allocated in the Argentine fishing industry (according to fishing companies operating in Argentina, Sesar, 2015).

The system is made more complex because countries like Spain operate as both receiving and sending systems, and countries like the

USA operate as both, but in a different combination: receiving and spillover (Figs. 6 and 7). Even without having the full scenario (i.e. georeferenced data on imports and exports for some sending countries were not available), most of the world's countries are involved one way or another in fisheries taking place on the Patagonian Shelf (Ministerio de Agricultura, 2018). Countries that are not benefitting from this resource tend to be low income countries and/or land-locked and thus, disadvantaged economically.

3.2.3. Flows

The flows for this telecoupled system include seafood products (fish, cephalopods and crustaceans) caught in the study area by the sending countries and sold to the receiving countries (Ministerio de Agricultura, 2018). They also include the actual know-how and logistics of fishing in this remote region, which is difficult and expensive to conduct operations and often requires international investment. An important management flow through the main sending countries to the receiving ones contain policies and regulations, including MPA information and political agreements regarding seascape and biodiversity conservation, including non-target species. Lastly, revenues and seafood products from the receiving countries to the sending constitute the main counter flows (Fig. 6).

3.2.4. Agents

There are multiple agents involved in these fisheries (see Fig. 6). They belong to private (i.e. fishing companies, fleets) and government sectors, including the countries that own and determine the "sustainable" certifications and also the NGOs that promote these policies. We found that many of those agents are global. Among the international agents is the Convention on the Conservation of Migratory Species of Wild Animals (CMS Bonn Convention, www.cms.int/) and its signatory parties. Further, the Agreement for the Conservation of Albatross and Petrels (ACAP, http://acap.aq/) deals with the implementation of mitigation measures for reducing transboundary by-catch and improving the conservation status of listed seabird species at colonies as main conservation goals. Many agents have a direct effect through the provision of and support for funds (e.g., The World Bank Group, see section on 'Causes' below).

3.2.5. Causes for fishing in the Patagonian Shelf

Overexploitation and fisheries collapse in developed countries, as well as an increasing consumption (driven by increase in human population numbers, FAO, 2014, both in the sending but mostly in the receiving countries) are the main drivers of the increase in the fishing industry in the Patagonian Shelf (Onestini, 2003). The global economy and that of the European Union (EU), as a main market for the fisheries (receiving systems) operating in Patagonia (Onestini, 2003), disproportionately influence the dynamics of these fisheries. We found that the EU market established prices and made demands controlling much of the annual captures (Fig. 6); it determines what is profitable and had implications for operating costs and investments. It also determines what is worthwhile; for example, the market recovery of 2010 came after an economic crisis two years earlier, together with an increase in the products' prices, which benefitted Argentine fisheries (MINAGRI, 2018).

Domestic and foreign (mainly with the EU) subsidies affect the fisheries in the Argentine EEZ (Godio, 2014; Onestini, 2003). For instance, lending by the World Bank to the fishing sector has had considerable fluctuations (Milazzo, 1998), but these investments have led to the improvement of fishing gear and better technology and has fostered a higher catch per unit effort (CPUE) by fleets. Annual lending levels to the sector declined in recent decades, but indirect support (Milazzo, 1998), such as subsidized fuel costs, and relatively low-priced 'dirty' oil at a global scale (due to production levels maintained by the Organization of Petroleum Exporting Countries –OPEC- and refineries) should be taken into account here as well as causes enhancing fisheries in the study area. For our study area, the EU is currently one of the world's top four subsidizers, along with China, Korea, and Japan (Godio, 2014), while the USA provides a global governance scheme to operate under these guidelines. Subsidies available under this scheme to EU fishing fleets alone totaled € 3.3 billion in 2009, which is more than three times the publicly available figure referenced in the past (http://oceana.org/reports/european-union-and-fishing-subsidies). Sumaila et al. (2010) presented data on worldwide subsidies, including the countries fishing in the Patagonian Shelf in 2003 and found that Spain, one of the main operating fishing fleet within the area, is heavily supported by the EU subsidies. International agreements, such as ACAP, delineate and encourage conservation management that directly or indirectly affect fishing activity and include seabird conservation through the obligation to put into practice mitigation methods and promote certification processes (Seco Pon et al., 2015, 2018).

Fluctuations in stocks also influence the sustainability of the fisheries on the Patagonian Shelf. For example, although the prices of shrimp (Pleticus muelleri), hake (Merluccius merluccius hubbsi), and squid (Illex argentines) increased in 2010, the economic outcome of these three fisheries differed given the availability of those target species. While captures of shrimp maintained the annual average, values for squid were actually lower than in previous years (Ministerio de Agricultura, 2018).

3.2.6. Effects of catching fish on the Patagonian Shelf

Detrimental effects include annual seabird mortality that account for more than 19,000 birds including species analyzed in this study Puffinus shearwaters, Thalasarche melanophries, Diomedea epomorpha, Diomedea exulans, Daption capense, Procellaria aequinoctialis, Macronectes giganteus, Fulmarus glacialoides (Seco Pon et al., 2015). Mean capture rate fluctuates from 0.003 birds every thousand hooks in the freezer longliner fleet for Patagonian toothfish, kingclip and skates to 0.7 birds per fishing day in the ice trawler fleet for Argentine anchovy (see Table 2 in Seco Pon et al., 2015).

Recent declines in catch and the shift to species from lower trophic levels (i.e. crustaceans, squids, and scallops) indicate over exploitation of Argentine fisheries (Villasante et al., 2015). This, in turn, places stress on seabird foraging with a detrimental effect at the individual and population levels (Thompson & Hamer, 2000). Food from fisheries discards could be advantageous to some seabirds in the Patagonian Shelf (Blanco, Sánchez-Carnero, Pisoni, & Quintana, 2017); however, short-term advantages could be offset by potential long-term detrimental effects.

One benefit of fisheries is related to employment, and in Argentina the number of people involved in marine fisheries is around 20,000 (30% on fleet and 70% on land in fish processing plants, FAO, 2014-2018; FAO, 2014).

Fish and fishery products play a critical role in global food security, and supply has grown steadily in the last five decades (FAO, 2014). However, for Argentina in 2012, per capita consumption fell from 8.6 to 7.6 kg person^{-1} (FAO, 2014-2018; FAO, 2014). Also, the international fleets that use these waters reduced the exploitation of their own EEZ, thereby reducing damage in their own ecosystem.

4. Discussion

While several predictive models exist for the study area and region (Catry et al., 2013; Huettmann et al., 2016; Carman et al., 2016), this is the first study to move a step further and apply a multi-species analysis to global linkages and show hotspot areas for conservation, considering high spatial overlap between multiple seabird predictive distribution maps and fisheries. Secondly, we show overlaps and hotspots and employ for the first time a global telecoupling analysis for the Patagonian Shelf, which allows a more complete, holistic understanding of how this ecosystem is related to human and natural systems from the local to global levels. Third, we found that not only environmental variables influence seabird distribution patterns, but also ports affect this community and act as a potential source of food that can attract birds. This approach and workflow allows for a new insights and a better analytical platform that can become a standard in seabird and fisheries management and other related issues disciplines, as well.

Incidental mortality in fisheries is still the main cause of seabird population declines (Croxall et al., 2012; Seco Pon et al., 2015). So far, though, seabird conservation and management actions (Seco Pon et al., 2015) have not incorporated other cause and effect relationships that are related to distant actors. While the Patagonian Shelf contributes to the well-being of many countries, either as a food supply or as revenues from harvest (Figs. 4 and 7, Pauly & Zeller, 2015), this area is also of great relevance for seabird conservation, particularly its southern sector (Fig. 3). We also found that ports, in addition to fisheries (Blanco et al., 2017), were relevant to seabird distribution, probably due to greater food supply around ports. While this food subsidy might have a positive short-term effect on seabirds, its impacts are uncertain for the long-term seabird community health and ecosystem stability. In the following sections, we present several management recommendations based on our results related to this seabird-fisheries telecoupling analysis, including the harvest and trade of seafood.

4.1. *Governance and multinational agreements for the Patagonian Shelf*

Telecoupling analysis allowed us to identify and describe the many stakeholders (nation-states and others) involved in the harvest, trade and commerce of fish and seafood. Also, our predictive multispecies seabird distribution maps, when overlaid with different fisheries, emphasize the relevance of this conflicted region for making progress in seabird conservation (Fig. 3). Both should be fully taken into account for governance and management, for the sustainable exploitation of this marine ecosystem, and for the conservation of non-target species threatened by fisheries. For instance, flows (i.e. seafood, revenues), causes and effects (see Tonini & Liu, 2017; Millington, Xiong, Peterson, & Woods, 2017 for examples, models and tools) should be examined and quantified in more detail to better delineate policies and actions that promote a desired social-ecological balance, including seabird conservation.

Multilateral agreements for regional best practices and sustainable management are desirable, but are not easy to achieve under the current global governance scheme. In the absence of truly equal and fair agreements between all sending countries, and with a capitalist framework globally installed, shared marine resources are easily susceptible to enter what Hardin (1968) called “the tragedy of the commons” (see Ostrom, 1990), where each sending country will try to obtain as much as possible, and the resource gets destroyed (“race to the bottom,” Rudra, 2008). However, Ostrom’s work shows that except for the industrial period these tragedies can be and have been avoided by human communities for millennia. However, doing so entails coupling social and natural systems so that human actions occur within the biophysical limits of the ecosystem, which in the Anthropocene now requires understanding these dynamics at a global scale.

By 2050, the global human population is expected to reach at least 9.6 billion people, and one challenge is to feed our planet without further compromising the environment (FAO, 2014). Fisheries and aquaculture provide jobs to tens of millions of workers, and support the livelihoods of hundreds of millions of people (FAO, 2014). However, to date, ‘modern’ fisheries have proven to be far from sustainable (Pauly et al., 2002) and have not created equal wealth to all nations and people. FAO (2014) -as the mandated global authority - proposes the Blue Growth Initiative as a coherent framework for the sustainable and socioeconomic management of aquatic resources, reconciling and balancing priorities between growth and conservation and between industrial and artisanal fisheries. Beyond this, there are still other serious challenges for the sector, such as illegal, unreported and unregulated (IUU) fishing, harmful fishing practices, legacy damage, and poor governance (FAO, 2014). Entities like UNEP and FAO propose that these obstacles can all be overcome with greater political will, strategic partnerships, and fuller engagement with civil society and the private sector (FAO, 2014), and regulating fisheries subsidies (UNCTAD, 2016). Most of these suggestions are thought to be put into practice locally. They simply propose countries to improve national policies and processes for the management of fisheries and for the adoption of best practices with partners such as FAO, UN, World Bank, etc. Inspired by Ostrom (1990), our proposal, based on the telecoupling analysis, instead involves tackling the problem on a well-founded macro-level instead of just locally or nationally in a patchwork manner.

4.2. *Global concern and subsidies for the Patagonian Shelf*

As pointed out already by Nettleship (1991), if emphasis by governments is towards socioeconomic issues rather than environmental concerns, seabird researchers, NGOs and managers must develop management plans that are also politically attractive. Although written 30 years ago, Nettleship (1991) presciently noted three major axes at that time which are still valid to further improve seabird management: (i) legislation and education; (ii) global databases and monitoring; and, (iii) coordinated international research. Based on our results, we suggest adding global management to these base points in order to complete the proposed strategy. Likewise, subsidies might be evaluated with caution, as it is known that they can easily turn “perverse” (UNCTAD, 2016). They are also known to alter the relationship between shortage, market prices, and production costs which emphasize the ´toxic triad´ described by Pauly (2009) triggering successive tragedies of commons (Hardin, 1968). Our results show clearly an overlap of fisheries affecting seabirds, e.g. figures and appendices (Fig. 5 and Fig. D1 Appendix D). Although environmentally all countries could benefit from these practices, socioeconomically the scenario is more nuanced and in particular the sending nations could be damaged in the short term. Yet, other actors and international entities, such as the World Bank, will need to address other challenges, such as implementing meaningful ecosystem service payments for the people and countries whose livelihoods depend on the fisheries instead of plain subsidies for fisheries as identified in our study. As the World Bank’s mandate is to reduce poverty (www.worldbank.org/), it should be delivered in an effective fashion and through support for better fisheries and ocean practices.

4.3. *Marine protected areas (MPAs) for the Patagonian Shelf*

Currently, Argentina has 61 MPAs (including coastal areas), but only 26 of them include marine space. All are small (average 89 km^2), and they were created as isolated and independent units without much connectivity and synergies (MAyDS, 2016). Yet, MPA coverage in Argentina has improved during the last 8 years (2010–2018), reaching 7.9% of the EEZ and comprising 127,900 km^2 (MAyDS, 2016, V. Falabella unpublished data). This means that Argentina is now close to the 10% goal proposed by the Convention on Biological Diversity’s Aichi Target 11. Nonetheless, only a very few of these MPAs have relevant budgets, enforcement or “no take” zones. For most seabirds, MPAs are not large enough to cover breeding birds foraging range during most of their breeding cycle (Yorio, 2009) nor do they cover most of the offshore fishing areas. Our findings -seabird prediction maps, show exactly that. There are not just a few hotspots to be protected and preserved, and indeed, it is the wider ecosystem that needs our attention on the context of conservation. Based on our results, if more MPAs in the Patagonian Shelf are created, for effective measurements to be implemented and for good governance, not only the country that owns the resources but the wider ocean system including “users” (Ostrom, 2009) should be involved, at least partially in the management plans and considerations. Also, the seabird hotspots we identified could be a good start for the potential location of more MPAs as Target 11 pointed out those areas should be of particular importance for biodiversity and ecosystem services, being ecologically representative and well connected (www.cbd.int/sp/targets/default.shtml).

4.4. Multinational and interdisciplinary research for the Patagonian Shelf

In comparison with the ecological coupling that works on a local level, telecoupling presents the greater challenges for research and governance. Adding predictive data into such an analysis further helps to apply it in real world data situations. However, it is essential to consider realistic approaches -as complex as it is in real life for global sustainability (Liu et al., 2013). This challenge recalls for combined actions for economists, ecologists, oceanographers, managers, and social scientist and all of their institutions alike. All are to work together in a more integrated manner and with an appropriate reward system (i.e. sustainable ecosystem services payments) for the more holistic understanding and management of fisheries and the ocean ecosystem, globally. Seabird-fisheries interaction in the Patagonian Shelf and worldwide will benefit if telecoupling analysis becomes mandatory by law in local and international decision-making, and put forward as best professional practices in support of the implementation of global sustainability.

Acknowledgments

ARR would like to thank M Spangler, J Fochesatto and family, A Maspero and E Maspero, and Wildlife Conservation Society for their support during the study and writing of the manuscript and S Dodino for figure design and editing. FH acknowledges Salford Systems Ltd, D Steinberg, H Berrios, L Luna, C Cambu, H Hera, S Sparks and Antarctica XXI for support. We also acknowledge Christopher Anderson English-language edition and useful comments that greatly improve the manuscript. This is EWHALE lab publication # 199.

Funding

This research was possible due to a CONICET international travel grant for young researchers, which allow ARR to perform this study within the EWHALE lab at the University of Alaska Fairbanks, UAF.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jnc.2019.125748.

References

Adger, W. N., Eakin, H., & Winkels, A. (2009). Nested and teleconnected vulnerabilities to environmental change. *Frontiers in Ecology and the Environment, 7*, 150–157.

Alder, J., Cullis-Suzuki, S., Karpouzi, V., Kaschner, K., Mondoux, S., Swartz, W., et al. (2010). Aggregate performance in managing marine ecosystems of 53 maritime countries. *Marine Policy, 34*, 468–476.

Alder, J., & Watson, R. (2007). Fisheries globalization: Fair trade or piracy. Globalization: Effects on fisheries resources. In W. W. Taylor, M. G. Schechter, & L. G. Wolfson (Eds.). *Globalization: Effects on fisheries resources* (pp. 47–74). New York: Cambridge University Press.

Anderson, O. R. J., Small, C. J., Croxall, J. P., Dunn, E. K., Sullivan, B. J., Yates, O., et al. (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research, 14*, 91–106.

Arata, J., & Xavier, J. C. (2003). The diet of black-browed albatrosses at the Diego Ramirez Islands, Chile. *Polar Biology, 26*, 638–647.

Ashford, J. R., Croxall, J. P., Rubilar, P. S., & Moreno, C. A. (1995). Seabird interactions with longlining operations for *Dissostichus eleginoides* around South Georgia, April to May 1994. *CCAMLR Science, 2*, 111–121.

Boardman, R. (2006). *The international politics of bird conservation: Biodiversity, regionalism and global governance.* New York: E. Elgar Publisher.

Barton, J. (2002). Fisheries and fisheries management in Falkland Islands conservation zones. *Aquatic Conservation, 12*, 127–135.

Berrow, S. D., Wood, A. G., & Prince, P. A. (2000). Foraging location and range of White-chinned Petrels *Procellaria aequinoctialis* breeding in the South Atlantic. *Journal of Avian Biology, 31*, 303–311.

BirdLife International (2015). *IUCN red list for birds.* Available at: http://www.birdlife.org on 21/08/2015.

Blanco, G. S., Sánchez-Carnero, N., Pisoni, J. P., & Quintana, F. (2017). Seascape modeling of southern giant petrels from Patagonia during different life-cycles. *Marine Biology, 164*, 53.

Bologna, A. (2012). El tratamiento del conflicto de las Islas Malvinas, Georgias del Sur y Sándwich del Sur en la Unasur. Centro de Estudios en Relaciones Internacionales de Rosario CERIR. *Humania del Sur, 7*, 99–118.

Brothers, N. P., Cooper, J., & Lokkeborg, S. (1999). *The incidental catch of seabirds by longline fisheries: Worldwide review and technical guidelines and mitigation.* Available at:Food and Agriculture Organization of the United Nationshttp://afrilib.odinafrica.org/handle/0/16358.

Bugoni, L., McGill, R. A., & Furness, R. W. (2010). The importance of pelagic longline fishery discards for a seabird community determined through stable isotope analysis. *Journal of Experimental Marine Biology and Ecology, 391*, 190–200.

Butchart, S. H., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J. P., Almond, R. E., et al. (2010). Global biodiversity: Indicators of recent declines. *Science, 328*, 1164–1168.

Carboneras, C. (1992). Procellariidae (Petrels and Shearwaters). In J. del Hoyo, A. Elliott, & J. Sargatal (Eds.). *Handbook of the birds of the world* (pp. 216–257). Barcelona, Spain: Lynx Edicions.

Carlson, A. K., Taylor, W. W., Liu, J., & Orlic, I. (2017). The telecoupling framework: An integrative tool for enhancing fisheries management. *Fisheries, 42*, 395–397.

Carlson, A., Taylor, W., Liu, J., & Orlic, I. (2018). Peruvian anchoveta as a telecoupled fisheries system. *Ecology and Society, 23*(1).

Carman, V. G., Mandiola, A., Alemany, D., Dassis, M., Seco Pon, J. P., Prosdocimi, L., et al. (2016). Distribution of megafaunal species in the Southwestern Atlantic: Key ecological areas and opportunities for marine conservation. *ICES Journal of Marine Science, 73*(6), 1579–1588.

Catry, P. R. T., Lemos, P., Brickle, R. A., Phillips, R., Matiasa, J. P., & Granadeiro (2013). Predicting the distribution of a threatened albatross: The importance of competition, fisheries and annual variability. *Progress in Oceanography, 110*, 1–10.

Churchill, R. R., & Lowe, A. V. (1988). *The law of the sea.* Manchester, UK: Manchester University Press.

Copello, S., Dogliotti, A. I., Gagliardini, D. A., & Quintana, F. (2011). Oceanographic and biological landscapes used by the Southern Giant Petrel during the breeding season at the Patagonian Shelf. *Marine Biology, 158*, 1247–1257.

Copello, S., Quintana, F., & Pérez, F. (2008). The diet of the Southern Giant Petrel in Patagonia: Fishery-related items and natural prey. *Endangered Species Research, 6*, 15–23.

Copello, S., & Quintana, F. (2009). Spatio-temporal overlap between the at-sea distribution of Southern Giant Petrels and fisheries at the Patagonian Shelf. *Polar Biology, 32*, 1211–1220.

Coria, N. R., Soave, G. E., & Montalti, D. (1997). Diet of Cape petrel *Daption capense* during the post-hatching period at Laurie Island, South Orkney Islands, Antarctica. *Polar Biology, 18*, 236–239.

Croxall, J. P., Butchart, S. H., Lascelles, B., Stattersfield, A. J., Sullivan, B., Symes, A., et al. (2012). Seabird conservation status, threats and priority actions: A global assessment. *Bird Conservation International, 22*, 1–34.

Croxall, J. P., Hill, H. J., Lidstone Scott, R., O'Connell, M. J., & Prince, P. A. (1988). Food and feeding ecology of Wilson's storm petrel *Oceanites oceanicus* at South Georgia. *Journal of Zoology, 216*, 83–102.

Croxall, J. P., & Wood, A. G. (2002). The importance of the Patagonian Shelf for top predator species breeding at South Georgia. *Aquatic Conservation, 12*, 101–118.

Crutzen, P. J. (2002). Geology of mankind. *Nature, 415* 23–23.

da Silva Fonseca, V. S., & Petry, M. V. (2007). Evidence of food items used by Fulmarus glacialoides (Smith 1840) (Procellariiformes: Procellariidae) in Southern Brazil. *Polar Biology, 30*, 317–320.

Daly, H. E., & Farley, J. (2011). *Ecological economics: Principles and applications.* Washington DC, USA: Island press.

Eakin, H., DeFries, R., Kerr, S., Lambin, E. F., Liu, J., Marcotullio, P. J., et al. (2014). *Significance of telecoupling for exploration of land-use change.* Cambridge, Massachusetts: MIT Press.

FAO (2014). *The state of the world fisheries and aquaculture (SOFIA).* Available atRome, Italy: Food and Agriculture Organization. http://www.fao.org/fishery/sofia/en.

FAO (2014). *Perfiles de Pesca y Acuicultura por Países. Argentina Hojas de datos de perfiles de los países.* 2014- 2016. [March 10 2016]; 2014. Available at:Roma. Actualizado: Departamento de Pesca y Acuicultura de la FAO [online]. http://www.fao.org/fishery/facp/ARG/es#CountrySector-LegalFrameworkOverview.

Favero, M., Blanco, G., Copello, S., Seco Pon, J. P., Patterlini, C., Mariano-Jelicich, R., et al. (2013). Seabird bycatch in the Argentinean demersal longline fishery, 2001–2010. *Endang. Species Res. 19*, 187–199.

Favero, M., & Silva Rodríguez, M. P. (2005). Estado actual y conservación de aves pelágicas que utilizan la plataforma continental argentina como área de alimentación. *El Hornero, 20*, 95–110.

Friis, C., Nielsen, J.Ø., Otero, I., Haberl, H., Niewöhner, J., & Hostert, P. (2016). From teleconnection to telecoupling: Taking stock of an emerging framework in land system science. *Journal of Land Use Science, 11*, 131–153.

Furness, R. W. (2003). Impacts of fisheries on seabird communities. *Scientia Marina, 67*, 33–45.

Godio, L. M. (2014). Problemas actuales vinculados a la pesca marítima. La situación argentina. *Revista de Derecho Ambiental de la Universidad de Palermo, 3*, 75–130. Available at: http://www.palermo.edu/derecho/pdf/DA_N4_03.pdf.

Halpin, P. N., Read, A. J., Fujioka, E., Best, B. D., Donnelly, B., Hazen, L. J., et al. (2009). OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. *Oceanography, 2*, 104–115.

Hardin, G. (1968). The tragedy of the commons. *Science, 162*, 1243–1248.

Huettmann, F., Artukhin, Y., Gilg, O., & Humphries, G. (2011). Predictions of 27 Arctic pelagic seabird distributions using public environmental variables, assessed with colony data: A first digital IPY and GBIF open access synthesis platform. *Marine Biodiversity, 41*, 141–179.

Huettmann, F., & Diamond, A. W. (2001). Seabird colony locations and environmental determination of seabird distribution: A spatially explicit seabird breeding model in the Northwest Atlantic. *Ecological Modelling, 141*, 261–298.

Huettmann, F., & Diamond, A. W. (2006). Large-scale effects on the spatial distribution of seabirds in the Northwest Atlantic. *Landscape Ecology, 21*, 1089–1108.

Huettmann, F., Riehl, T., & Meissner, K. (2016). Paradise lost already? A naturalist interpretation of the pelagic avian and marine mammal detection database of the IceAGE cruise off Iceland and Faroe Islands in fall 2011. *Environment Systems and Decisions, 1–17* 10.1007/s10669-015-9583-0.

Huettmann, F., Schmid, M., et al. (2014a). Climate change and predictions of pelagic biodiversity components. In C. De Broyer, P. Koubbi, & B. Danis (Eds.). *Biogeographic atlas of the Southern Ocean* (pp. 390–396). Cambridge: Census of Antarctic Marine Life and SCAR Marine Biodiversity Network.

Huettmann, F., & Schmid, M. (2014b). Publicly available Open access data and machine learning model-predictions applied with Open source gis for the entire Antarctic Ocean: a first meta-analysis and synthesis from 53 charismatic species. In B. Veress, & J. Szigethy (Vol. Eds.), *Horizons in earth science research: Vol. 11*, (pp. 24–34). Chapter 3).

Humphries, G. R. W., Huettmann, F., Nevitt, G. A., Deal, C., & Atkinson, D. (2012). Species distribution modeling of storm-petrels (*Oceanodroma furcata* and *O. leucorhoa*) in the North Pacific and the role of dimethyl sulfide. *Polar Biology, 35*, 1669–1680.

Humphries, G. R. W., Magness, D., & Huettmann, F. (Eds.). (2018). *Machine learning for ecology and sustainable natural Resource management.* Switzerland: Springer.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 3465–3472.

Liu, J., Hull, V., Batistella, M., DeFries, R., Dietz, T., Fu, F., et al. (2013). Framing sustainability in a telecoupled world. *Ecology and Society, 18*, 26.

Liu, J., Hull, V., Luo, J., Yang, W., Liu, W., Viña, A., et al. (2015). Multiple telecouplings and their complex interrelationships. *Ecology and Society, 20*, 44.

Liu, J., & Yang, W. (2013). Integrated assessments of payments for ecosystem services programs. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 16297–16298.

Liu, J. (2014). Forest sustainability in China and implications for a telecoupled world. *Asia & the Pacific Policy Studies, 1*, 230–250.

López-Lanús, B., Unterkofler, D., Ornstein, U., del Sastre, V., Moller Jensen, R., & Herrera, P. (2009). *Diversidad y estado de conservación de las aves de los Bajos Submeridionales (AICA SF03): Informe de Aves Argentinas/AOP para la Fundación Vida Silvestre Argentina.* Buenos Aires, Argentina: Informe inédito1–56 Available at https://scholar.google.com/scholar?hl = es&as_sdt = 0%2C5&q = Diversidad + y + estado + de + conservaci%C3%B3n + de + las + aves + de + los + Bajos + Submeridionales + &btnG = .

Lynch, A. J., & Liu, J. (2014). Fisheries as coupled human and natural systems. In W. W. Taylor, A. J. Lynch, & N. J. Leonard (Eds.). *Future of fisheries: Perspectives for emerging professionals* (pp. 459–466). Bethesda, MD: AFS Press.

MAyDS (2016). *El Sistema Nacional de Áreas Marinas Protegidas. Bases para su puesta en funcionamiento.* Buenos Aires: Ministerio de Ambiente y Desarrollo Sustentable de la Nación. https://www.argentina.gob.ar/sites/default/files/ambiente-sistema-nacional-areas-marinas-protegidas.pdf.

Melvin, E. F., & Parrish, J. K. (2001). *Seabird Bycatch: Trends, roadblocks, and solutions.* Available at:Fairbanks: University of Alaska Sea Grant, AK-SG-01-01. http://nsgl.gso.uri.edu/aku/akuw99002.pdf.

Milazzo, M. (1998). *Subsidies in world fisheries: A reexamination, Vol. 23*. Washington DC, USA: The World Bank Publications.

Millington, J. D., Xiong, H., Peterson, S., & Woods, J. (2017). Integrating modelling approaches for understanding telecoupling: Global food trade and local land use. *Land, 6*, 56.

Ministerio de Agricultura (2018). *Ganadería y Pesca MINAGRI.* https://www.agroindustria.gob.ar/sitio/areas/pesca_maritima/.

Nettleship, D. N. (1991). Seabird management and future research. *Colonial Waterbirds, 14*, 77–84.

Onestini, M. (2003). *Fisheries subsidies and marine resources management: Lessons learned from studies in Argentina and Senegal.* Kenya: UNEP Publications.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action.* Cambridge, UK: Cambridge University Press.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*, 419–422.

Otley, H., Munro, G., Clausen, A., & Ingham, B. (2008). *Falkland Islands state of the environment report 2008*Stanley: Falkland Islands Government and Falklands Conservation.

Otley, H. M., Reid, T. A., & Pompert, J. (2007). Trends in seabird and Patagonian toothfish *Dissostichus eleginoides* longliner interactions in Falkland Island waters, 2002/03 and 2003/04. *Marine Ornithology, 35*, 47–55.

Owens, I. P., & Bennett, P. M. (2000). Ecological basis of extinction risk in birds: Habitat loss versus human persecution and introduced predators. *Proceedings of the National Academy of Sciences of the United States of America, 97*, 12144–12148.

Paleczny, M., Hammill, E., Karpouzi, V., & Pauly, D. (2015). Population trend of the world's monitored seabirds, 1950–2010. *PloS One, 10*, e0129342.

Palomares, M. L. D., & Pauly, D. (2015). Fisheries of the Falkland Islands and the South Georgia, South Sandwich and South Orkney Islands. In M. L. D. Palomares, & D. Pauly (Eds.). *Marine fisheries catches of Subantarctic Islands, 1950–2010* (pp. 1–20). USA: Fisheries Centre, University of British Columbia.

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

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., et al. (2002). Towards sustainability in world fisheries. *Nature, 418*, 689–695.

Pauly, D., & Zeller, D. (2015). *Sea around us concepts, design and data.* Available at:www.seaaroundus.org.

Pauly, D. (2009). Beyond duplicity and ignorance in global fisheries. *Scientia Marina, 73*, 215–224.

Pearce, J., & Ferrier, S. (2000). Evaluating the predictive performance of habitat models developed using logistic regression. *Ecological Modelling, 133*, 225–245.

Quillfeldt, P. (2002). Seasonal and annual variation in the diet of breeding and non-breeding Wilson's storm-petrels on King George Island, South Shetland Islands. *Polar Biology, 25*, 216–221.

Raya Rey, A., Scioscia, G., Dellabianca, N., & Torres, M. (2009). Censo de Aves y Mamíferos Marinos en la Plataforma Patagónica Austral. In G. Lovrich (Ed.). *Estudios biológicos en plataforma patagónica austral* (pp. 8–29). . Available at http://www.cadic-conicet.gob.ar/wp-content/uploads/2016/03/Informe-Campa%C3%B1a-Deseado-CADIC.pdf.

Raya Rey, A., Trathan, P., Pütz, K., & Schiavini, A. (2007). Effect of oceanographic conditions on the winter movements of rockhopper penguins *Eudyptes chrysocome chrysocome* from Staten Island, Argentina. *Marine Ecology Progress Series, 330*, 285–295.

Reid, T. A., & Sullivan, B. J. (2004). Longliners, black-browed albatross mortality and bait scavenging in Falkland Island waters: What is the relationship? *Polar Biology, 27*, 131–139.

Rudra, N. (2008). *Globalization and the race to the bottom in developing countries: Who really gets hurt?* Cambridge, UK: Cambridge University Press.

Sala, E., & Knowlton, N. (2006). Global marine biodiversity trends. *Annual Review of Environment and Resources, 31*, 93–122.

Seco Pon, J. P., Copello, S., Tamini, L., Mariano-Jelicich, R., Paz, J., Blanco, G., & Favero, M. (2015). Seabird conservation in fisheries: Current state of knowledge and conservation needs for Argentine high-seas fleets. In G. Mahala (Ed.). *Seabirds and songbirds: Habitat preferences, conservation and migratory behavior* (pp. 45–87). Nova Publishers.

Seco Pon, J. P., Paz, J. A., Mariano-Jelicich, R., García, G., Copello, S., Berón, M. P., et al. (2018). *Certification Schemes in Argentine Fisheries: Opportunities and Challenges for Seabird Conservation. In Seabirds. IntechOpen.Sesar, G.E. (2015). Estudio de mercado de la cadena de suministro del pescado blanco proveniente de la República Argentina.* Aavilable at:FVSAhttps://www.vidasilvestre.org.ar/?12620/Estudio-de-mercado-de-la-cadena-de-suministro-de-pescado-blanco-proveniente-de-la-Repblica-Argentina.

Sherman, K., & Duda, A. M. (1999). Large marine ecosystems: An emerging paradigm for fishery sustainability. *Fisheries, 24*, 15–26.

Sumaila, U. R., Khan, A. S., Dyck, A. J., Watson, R., Munro, G., Tydemers, P., et al. (2010). A bottom-up re-estimation of global fisheries subsidies. *Journal of Bioeconomics, 12*, 201–225.

Tasker, M. L., Camphuysen, C. J., Cooper, J., Garthe, S., Montevecchi, W. A., & Blaber, S. J. (2000). The impacts of fishing on marine birds. *ICES Journal of Marine Science, 57*, 531–547.

Thompson, K. R. (1992). Quantitative analysis of the use of discards from squid trawlers by Black-browed Albatrosses *Diomedea melanophris* in the vicinity of the Falkland Islands. *IBIS, 134*, 11–21.

Thompson, D. R., & Hamer, K. C. (2000). Stress in seabirds: Causes, consequences and diagnostic value. *Journal of Aquatic Ecosystem Stress and Recovery, 7*, 91–109.

Tonini, F., & Liu, J. (2017). Telecoupling Toolbox: Spatially explicit tools for studying telecoupled human and natural systems. *Ecology and Society, 22*(4).

Tuck, G. N., Polacheck, T., Croxall, J. P., & Weimerskirch, H. (2001). Modelling the impact of fishery by-catches on albatross populations. *The Journal of Applied Ecology, 38*, 1182–1196.

UNCTAD (2016). *NCTAD-FAO-UNEP joint statement on fisheries subsidies.* (Accessed 06.02.2018) http://unctad.org/en/pages/MeetingDetails.aspx?meetingid = 1170.

Villasante, S., Macho, G., de Isusu Rivero, J., Divovich, E., Zylich, K., Harper, S., et al. (2015). *Reconstruction of marine fisheries catches in Argentina (1950–2010). Working Paper 2015-50.* Vancouver: Fisheries Centre, University of British Columbia.

White, C., Halpern, B. S., & Kappel, C. V. (2012). Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses. *Proceedings of the National Academy of Sciences of the United States of America, 109*, 4696–4701.

Wienecke, B., & Robertson, G. (2002). Seabird and seal—Fisheries interactions in the Australian Patagonian toothfish *Dissostichus eleginoides* trawl fishery. *Fisheries Research, 54*, 253–265.

Xavier, J., Croxall, J. P., Trathan, P., & Rodhouse, P. (2003). Inter-annual variation in the cephalopod component of the diet of the wandering albatross, Diomedea exulans, breeding at Bird Island, South Georgia. *Marine Biology, 142*, 611–622.

Xavier, J. C., Trathan, P. N., Croxall, J. P., Wood, A. G., Podesta, G., & Rodhouse, P. G. (2004). Foraging ecology and interactions with fisheries of wandering albatrosses (Diomedea exulans) breeding at South Georgia. *Fisheries Oceanography, 13*, 324–344.

Yorio, P., & Caille, G. (1999). Seabird interactions with coastal fisheries in northern Patagonia: Use of discards and incidental captures in nets. *Waterbirds, 22*, 207–216.

Yorio, P. (2009). Marine protected areas, spatial scales, and governance: Implications for the conservation of breeding seabirds. *Conservation Letters, 2*, 171–178.