Guidelines for Managing and Monitoring Seabirds in the Arvoredo Marine Biological Reserve, Southern Brazil

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ABSTRACT – Seabirds usually need productive waters and respond differently to environmental changes according to the oceanographic domain where they occur. The Arvoredo Marine Biological Reserve protects part of an important ecological region in Brazil and shelters substantial marine biodiversity. Here we studied seabird richness and abundance at this protected area to verify what kind of monitoring and managing protocols are needed for future conservation actions. We surveyed the Reserve's islands and surrounding sea from the autumn 2010 to the autumn 2012. We also considered historical data from literature on seabird colonies to access specific issues related to management actions. Most of 14 surveyed species were migratory, rare, and recorded during winter. The Kelp Gull (*Larus dominicanus*) was dominant and its abundance pattern alternated with those of the other species along seasons. Deserta Island is an important breeding site and Galé Islets is an important stopover site at the Reserve. Few places along the Brazilian coastline support breeding colonies such as the ones in the Arvoredo Marine Biological Reserve. However, the Reserve needs seabird active management to fulfill its purpose of protecting marine biodiversity. Breeding success must be considered as an indicator for intervention and control of predators in the Reserve. The effects of climate changes and overfishing near the Reserve affect the seabirds therefore managers should join a large-scale integrated coastal management and marine spatial planning. A long-term monitoring protocol at-sea and in the colonies using new technologies also can help in this process.

Keywords: breeding site; community; marine birds;protected area; tropical islands.

RESUMO – Aves marinhas se beneficiam de águas produtivas e respondem diferenciadamente a mudanças ambientais conforme diferentes domínios oceanográficos. A Reserva Biológica Marinha do Arvoredo é uma importante região ecológica no Brasil e abriga grande biodiversidade marinha. Neste trabalho, apresentamos a riqueza e abundância de aves marinhas presentes na Reserva Biológica Marinha do Arvoredo, sul do Brasil, como forma de verificar a necessidade de manejo ativo das aves na área para garantir seu papel de conservação e propomos protocolos de monitoramento da efetividade desta unidade de conservação para a conservação do grupo, com subsídios para o manejo. Foram amostradas todas as ilhas do arquipélago e mar do entorno entre o outono de 2010 e o outono de 2012. Também foram considerados dados da literatura para determinar fatores importantes na gestão das colônias das aves marinhas. A maioria das 14 espécies investigadas são migratórias, raras e registradas durante o inverno. O gaivotão (*Larus dominicanus*)

Afiliação

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foi dominante e sua abundância se alternou com a das outras espécies conforme a estação do ano. A Ilha Deserta e as ilhotas de Galé são locais importantes como sítios de reprodução e descanso, respectivamente. Poucos lugares na costa brasileira suportam colônias reprodutivas como as encontradas na Reserva Biológica Marinha do Arvoredo. Contudo, os resultados sugerem que a Reserva necessita de manejo ativo das espécies para garantir sua conservação. O uso territorial pelas aves em mar aberto e as colônias reprodutivas devem ser constantemente monitorados e algumas tecnologias sugeridas podem ajudar no processo. O sucesso reprodutivo deve ser considerado como indicador de necessidade de intervenção e controle dos predadores presentes na Reserva. Os efeitos das mudanças climáticas e da sobrepesca no entorno afetam as colônias presentes na Ilha Deserta e, portanto, os gestores desta área protegida devem tomar iniciativa e participar de planejamentos em larga escala da gestão integrada marinha e costeira.

Palavras-chave: aves marinhas; comunidade; área reprodutiva; ilhas tropicais; unidade de conservação.

RESUMEN – Las aves marinas beneficianse de aguas productivas y responden de manera diferente a los cambios ambientales según los dominios oceanográficos. La Reserva Biológica Marina del Arvoredo es una importante región ecológica en Brasil, y alberga gran biodiversidad marina. En este artículo se presenta la riqueza y abundancia de aves marinas de la Reserva Biológica Marina del Arvoredo, sur de Brasil, como forma de verificar la necesidad de manejo activo de las aves para garantizar su conservación y establecer protocolos de monitoreo de la efectividad de conservación de la biodiversidad en esta área protegida. Se tomaron muestras de todas las islas del archipiélago y el mar circundante entre el otoño de 2010 y el otoño de 2012. También si consideró la literatura acerca de las colonias en la Reserva para establecer medidas de manejo. La mayoría de las 14 especies investigadas son migratorias, raras y fueran registradas durante el invierno. La gaviota cocinera (Larus dominicanus) fue dominante y su abundancia fue alternada con las de otras especies de acuerdo con la estación del año. La Isla Deserta y los islotes de Galés son importantes sitios de cría y reposo, respectivamente. Pocos son los lugares en la costa brasileña son viables para colonias como los que se encuentran en la Reserva Biológica Marina do Arvoredo. Sin embargo, los resultados muestran que la Reserva necesita una gestión activa de las aves marinas. Las colonias deben ser monitoreadas constantemente y algunas tecnologías pueden ayudar en el proceso. El éxito reproductivo de las aves debe ser considerado como indicador para la necesidad de intervención y control de los predadores en la Reserva. El cambio climático y la sobrepesca cerca de la Reserva afectan a las aves marinas y por tanto los gerentes de esta área protegida deben unirse a una planificación espacial marina y gestión costera integrada en gran escala.

Palabras clave: área protegida; aves marinas; comunidad; islas tropicales; sítios reproductivos.

Introduction

Seabirds differ from other aquatic birds by dependence only on sea waters (Croxall *et al.* 1984) though in this study we also consider as seabirds gulls and some terns that breed in coastal islands and may be found also in marshes and inland seas during non-breeding season. Seabirds act in almost every level of animal marine food webs but mostly as predators and scavengers (Croxall 1987, Furness 1978, Furness & Camphuysen 1997). Most of the species need productive waters (Camphuysen *et al.* 2004) and respond to environmental changes differentially depending on their oceanographic domain (Sydeman *et al.* 2001). Some biological aspects in this group compromise their capacity of handling human pressures and not only 40% of them are globally threatened but also populations have plummeted by 69.7% in just 60 years (Croxall *et al.* 2012, Paleczny *et al.* 2015). Brazil is one of the twenty priority areas for marine conservation actions (Croxall *et al.* 2012). The Brazilian sea includes 4.4 million km^2 of potential habitat to seabirds and islands from São Pedro and São Paulo (00º 55'N, 29º 20'W) to Moleques do Sul (27º 51'S, 48º 26'W) are extensively used as resting and breeding sites (Branco 2004).

Around 50 species are found along the Brazilian state of Santa Catarina coastline (Rosário 1996) and 15 of them are nationally threatened (MMA 2014). The conservation of seabirds and important marine habitats in Brazil depends also on monitoring populations and understanding interactions within and between species (Schreiber & Burger 2001, Croxall *et al.* 2012). Most studies

on seabirds in Brazilian waters are related to breeding, new records of rare or vagrant species, or bycatch rates in fishery. However, little is known about seabird assemblage in marine protected areas. Arvoredo is a strategic archipelago in southern Brazil where a considerable number of marine birds occurs (Vieira *et al.* 2015). The archipelago and surrounding sea compose the protected area of Arvoredo Marine Biological Reserve which receives Laridae, Stercorariidae, Sternidae, Procellariidae, Diomedeidae, and Spheniscidae for resting, feeding and breeding every year (Vieira *et al.* 2015). The Deserta Island is located inside the Reserve and shelters colonies mainly of gulls and terns. Branco (2004) and Hogan *et al.* (2010) concluded that Kelp Gulls (*Larus dominicanus*) are the major impact factor on breeding success of terns in Deserta Island and this species needs specific control yet Prellvitz *et al.* (2009) concluded that Kelp Gull colonies are declining and need long term attention and protection. Though several studies have been conducted along Santa Catarina coastline, as well as in the Reserve (e.g. Escalante *et al.* 1988, Bege & Pauli 1988, Soares & Schiefler 1995, Villanueva *et al.* 1996, Efe *et al.* 2000, Branco 2003a, 2003b, 2004, Branco *et al.* 2004, 2005, 2007, 2010a, Branco & Fracasso 2005, Neves *et al.* 2006, Prellvitz *et al.* 2009, Cremer & Grose 2010, Hogan *et al.* 2010, Vieira *et al.* 2014, 2015), these focused specifically on islands, marshes and inland seas. Nonetheless, available data on the Reserve and other Brazilian marine protected areas are not enough to ensure management actions concerning seabirds. Here we use abundance and richness of seabirds at the Arvoredo Marine Biological Reserve to verify key features for managing and monitoring protocols. Furthermore, to verify predatory interactions between species that could affect breeding success as suggested by Branco (2004) and Hogan *et al.* (2010) and to delineate management actions specific to seabird colonies at Deserta Island, we analysed spatial and temporal overlap of breeding phenology of seabirds and abundance of potential predators.

Material and methods

Study area

The Arvoredo Marine Biological Reserve aims to protect the marine biodiversity at the Arvoredo Archipelago and surrounding sea (Brazilian Federal Decree 99.142/1990). The protected area is around 10 km away from mainland and has 17,600 ha (Figure 1). It includes the islands of Arvoredo, Galé, and Deserta as well as the São Pedro Rock and 17,146 ha of surrounding sea (Figure 1). The area is influenced by the South Atlantic Central Water (SACW), which is formed by mixing Brazilian Current and Subantarctic Mode Water originated in Patagonic Platform (Odebrecht & Castello 2000). Waters in this region are also influenced by nutrients from La Plata River and resurgences (Odebrecht & Castello 2000).

Data collection

Four sectors with continuous census (Branco *et al.* 2010b) were performed monthly between May 2010 and March 2012 on a motorboat cruising at 10 knots around each island. Strip-transects were performed (Camphuysen *et al.* 2004) in the same days as the sector sampling. These were carried on motorboat cruising at up to 15 knots along each of the four routes between islands. Both transect and sector varied in area and orientation according to the island length and position therefore comparisons were limited by the use of relative indexes. Sampling occurred from 8:00 to 14:00, with a total effort of 144 hours. We used software Bioestat 5.0 (Ayres *et al.* 2007) to perform statistical analysis. Estimator Jackknife I was used to compare raw richness and infer about survey sufficiency. Relative abundance (Bibby *et al.* 2000) was used for each season to compare islands and surrounding sea. Numbers were approximated to whole values. The relative frequency of occurrence (Bibby *et al.* 2000, Vielliard *et al.* 2010) was split in classes of rare (1% to 30%), occasional (31% to 60%), and frequent (61% to 100%). Names and resident status follow the Brazilian Ornithological Records Committee (CBRO 2014).

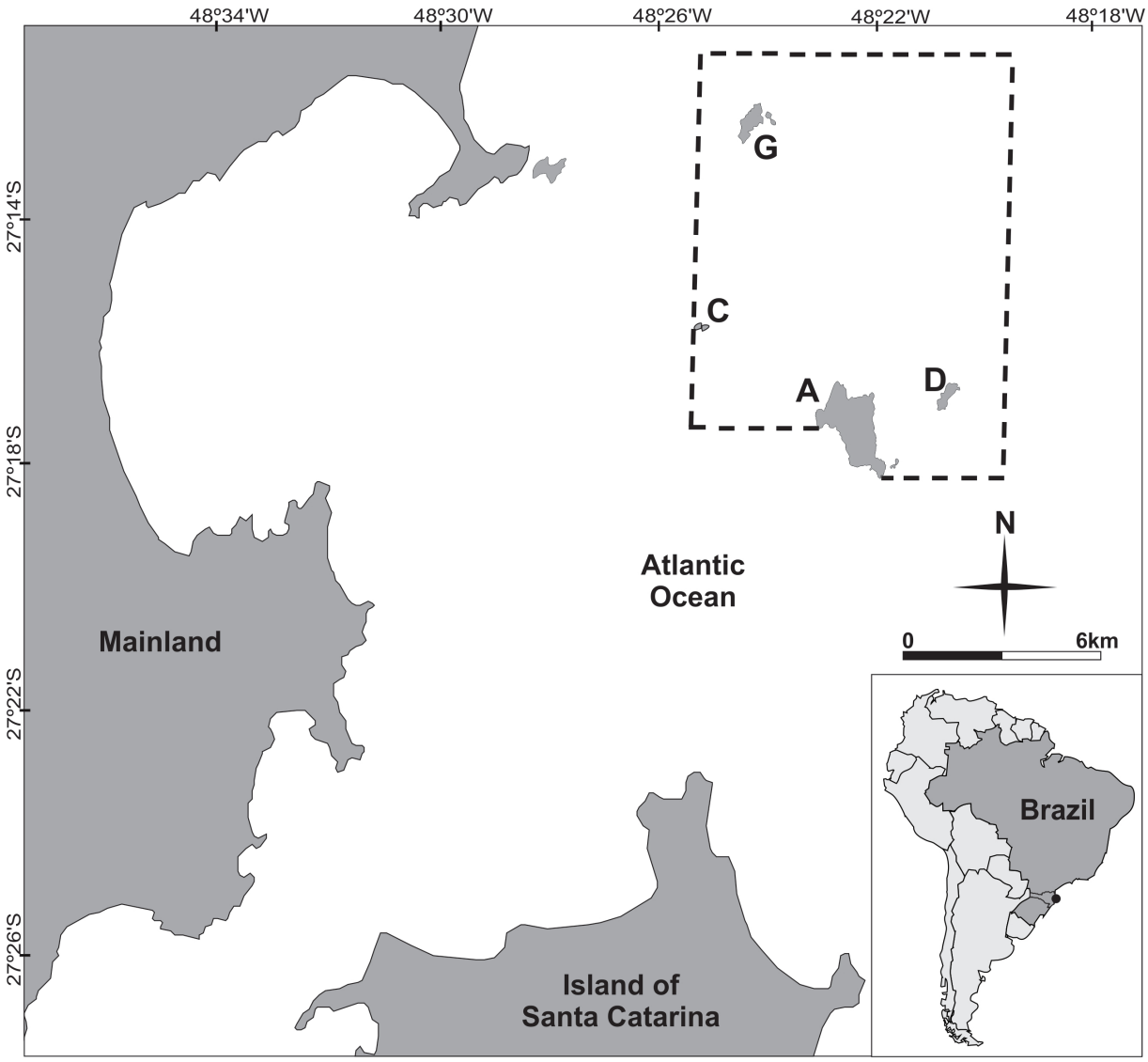

Figure 1 – The Arvoredo Marine Biological Reserve (dotted line) is located 10 km away from mainland and includes the islands of Arvoredo (A), Deserta (D), and Galé (G), as well as the São Pedro Rock (C), and surrounding sea (white), southern Brazil. Author: BPV.

Literature review

We considered data of seabirds breeding in the Arvoredo Marine Biological Reserve only therefore including Branco (2003a, 2004), Prellvitz *et al.* (2009), and Hogan *et al.* (2010). Although the richness of seabirds in the Reserve includes more species (see Results and Vieira *et al.* 2015), only Kelp Gulls, South American Terns (*Sterna hirundinacea*), Cabot's Terns (*Thalasseus acuflavidus*) and Brown Boobies (*Sula leucogaster*) were found breeding there. We noticed around half hundred nests of Kelp Gulls in Galés Islets (B. Vieira *pers. obs.*) but this location was not used to compare data because no other seabird seems to have nests there. Colonies at Deserta Island were georeferenced and compared to the literature to verify spatial overlaps implying a competition for structural resources. Despite no correspondence of surveying years, breeding phenology in literature was compared to a field survey of raptors to verify seasonal overlap patterns and possible impacts of greater abundance of predators during breeding season of seabird species. The Kelp Gull was the only species with enough data available to compare effectiveness of different surveying methods from motorboat cruising (our study) or counting at the colonies (literature).

Results

Richness and abundance

We found 14 species during surveys (Table 1) which is in accordance with the Jackknife I estimation (N = 15.8; IC = 11.7 to 19.8; p = 0.01). Six species were recorded only at sea. Most of the species were rare and only Magnificent Frigatebirds (*Fregata magnificens*), Brown Boobies and Kelp Gulls were frequent and dominated the assemblage throughout the year (Figure 2). Some rare and occasional migratory species such as South American and Cabot's terns were abundant and dominant during their breeding season (Table 1, Figure 2).

Table 1 – List of seabirds recorded in the islands and surrounding sea at the Arvoredo Marine Biological Reserve, southern Brazil. **Legend**: Resident status: national residence status according to CBRO (2014): resident (R), south visitor (SV) or north visitor (NV). Frequency of occurrence: rare (R), occasional (O) and frequent (F).

Species	English common name	Portuguese common name	Resident status	Frequency of occurrence	Relative abundance	
					Islands	Sea
Spheniscus magellanicus	Magellanic Penguin	pinguim-de-magalhães	SV	R	4	24
Thalassarche chlororhynchos	Atlantic Yellow-Nosed Albatross	albatroz-de-nariz-amarelo	SV	R	0	4
Thalassarche melanophris	Black-Browed Albatross	albatroz-de-sobrancelha	SV	R	0	4
Puffinus griseus	Sooty Shearwater	bobo-escuro	SV	R	0	1
Puffinus puffinus	Manx Shearwater	bobo-pequeno	NV	R	0	5
Fregata magnificens	Magnificent Frigatebird	tesourão	R	F	1,427	36
Sula leucogaster	Brown Booby	atobá-marrom	R	F	569	71
Stercorarius parasiticus	Parasitic Jaeger	mandrião-parasítico	NV	R	0	3
Larus dominicanus	Kelp Gull	gaivotão	R	F	4,666	68
Sterna hirundo	Common Tern	trinta-réis-boreal	NV	R	1	0
Sterna hirundinacea	South American Tern	trinta-réis-bico-de-vermelho	R	O	787	86
Sterna trudeaui	Snowy-Crowed Tern	trinta-réis-de-coroa-branca	R	R	290	19
Thalasseus acuflavidus	Cabot's Tern	trinta-réis-de-bando	R	O	388	102
Thalasseus maximus	Royal Tern	trinta-réis-real	R	R	0	9

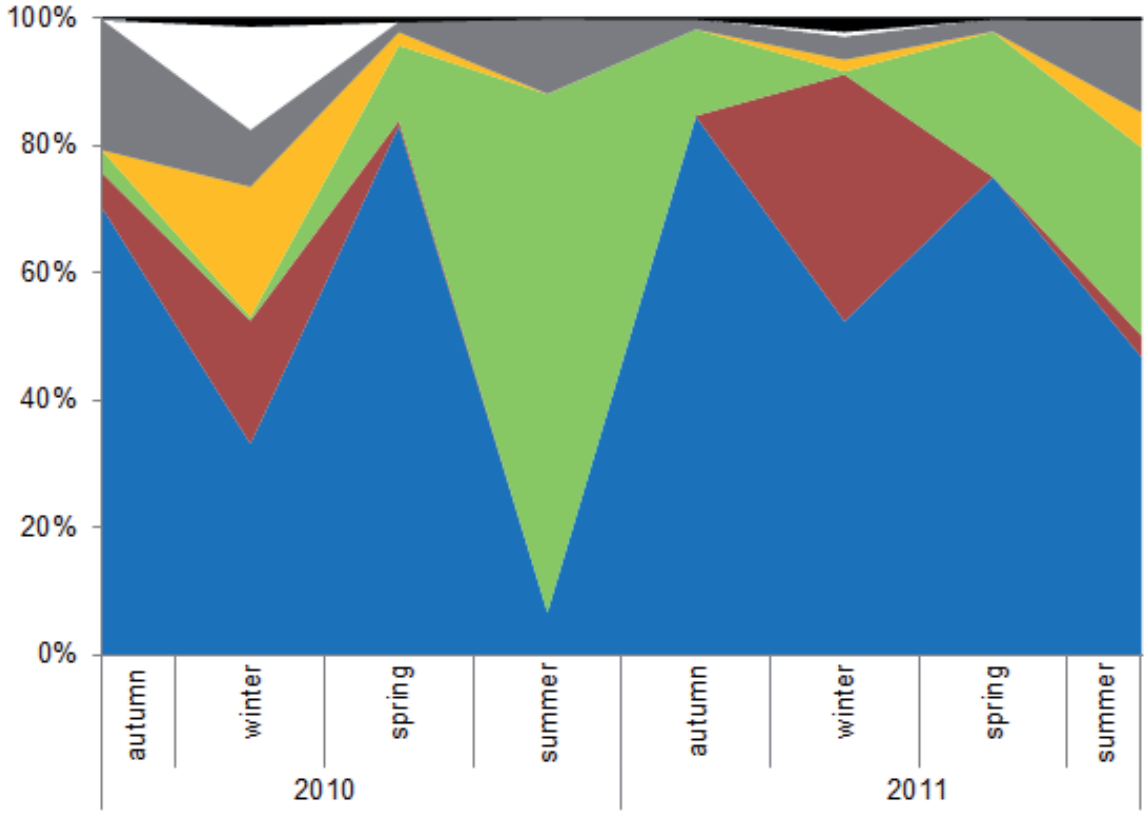

Figure 2 – Percentage of dominance considering relative abundance of seabirds recorded during two years at the Arvoredo Marine Biological Reserve, southern Brazil. **Legend**: blue – *Larus dominicanus*, red – *Sterna hirundinacea*; green – *Fregata magnificens*; orange – *Thalasseus acuflavidus*; grey – *Sula leucogaster*; white – *Sterna trudeaui*; black – others.

Some rare species were recorded only once. Three Sooty Shearwaters (*Puffinus griseus*) appeared only during winter and spring 2011. Ten Parasitic Jaegers (*Stercorarius parasiticus*) were seen on summer 2011. A Common Tern (*Sterna hirundo*) was seen on autumn 2010. Albatrosses were six juveniles of each species (*Thalassarche chlororhynchos* and *Thalassarche melanophris*) recorded during autumn and winter of both studied years. As rare species recorded once, most seabirds had higher abundance during autumn and winter (Figure 3). Among residents, Brown Booby was clearly less abundant when Kelp Gulls had a population increase during the springtime (Figure 3).

Breeding populations

Placement of colonies did not change from 1999 to 2012 (Figure 4). However, nests of Brown Booby were only detected after 2010. Eight nests of Brown Booby with one to two chicks were recorded in rocky slopes at both east and west sides of Deserta Island (Figure 4). Most of juveniles and some young with primaries were found between November 2011 and January 2012. Competition for space to establish colonies does not seen to be an impact factor because Brown Booby prefers to nest in cliffs with bushes while Kelp Gulls use 70° slopes, and South American and Cabot's terns prefer 50° slopes dominated by *Paspalum vaginatum* and *Dyckia encholirioides* (Figure 4). These different microhabitats are spatially away from each other (Figure 4).

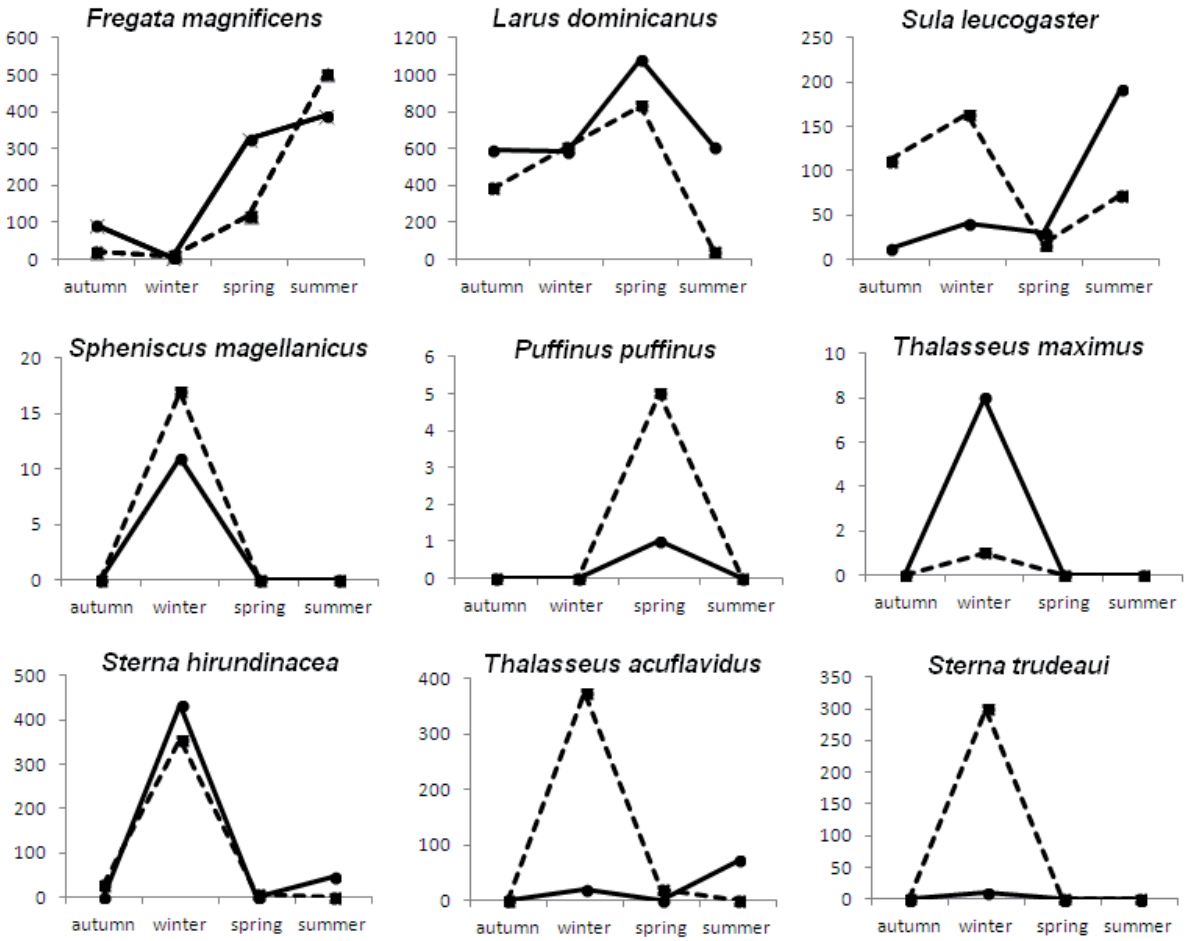

Figure 3 – Relative abundance of seabirds recorded between 2010-2011 (dotted line) and 2011-2012 (full line) at the Arvoredo Marine Biological Reserve, southern Brazil.

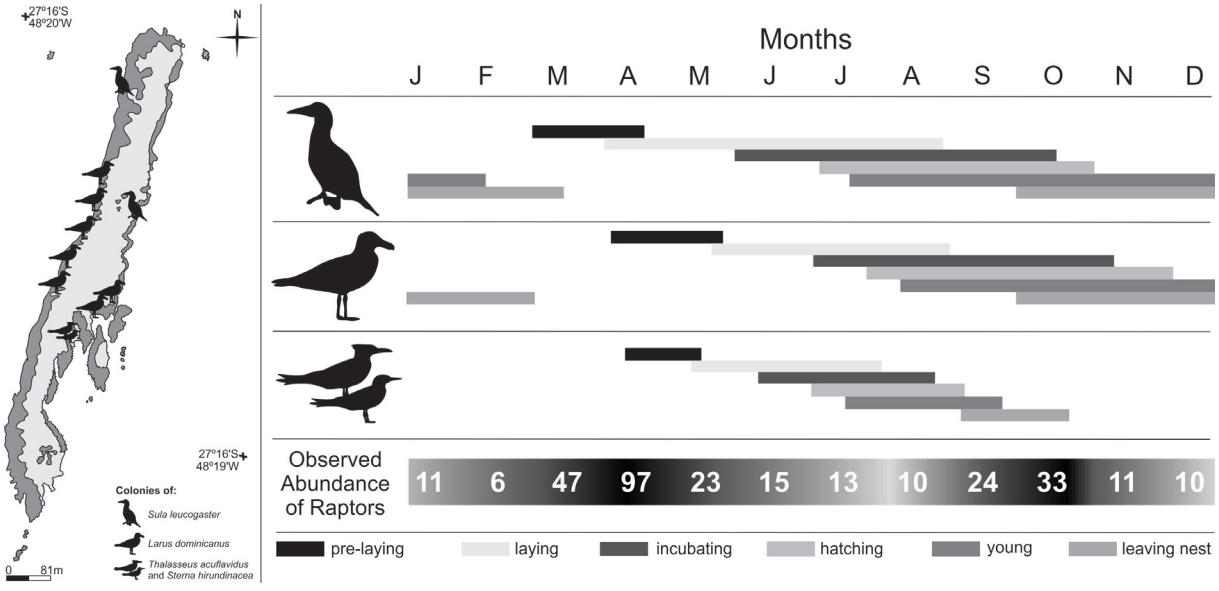

Figure 4 – Colonies of *Sula leucogaster*, *Larus dominicanus*, *Sterna hirundinacea* and *Thalasseus acuflavidus* located according habitat dominated by rocky slopes (dark grey) or low vegetation (light grey), and breeding phenology as well as the observed abundance of raptors at Deserta Island, Arvoredo Marine Biological Reserve, southern Brazil.

Breeding phenology overlapped between Brown Booby and Kelp Gull (Figure 4). Both terns breed in the same period with some couples of the South American Tern starting the season earlier than others (Figure 4). For all species, only adults stay in Deserta Island from laying period onwards. We observed raptors (*Caracara plancus*, *Milvago chimango*, *M. chimachima* and *Coragyps atratus*) near and inside the colonies mostly during vulnerable periods to chicks and juveniles (Figure 4). These moments were after hatching and when juveniles left the colony for the first long flights to others islands and mainland.

Available data in literature only allowed comparing the variation of abundance for Kelp Gulls at Deserta Island (Figure 5). Despite absence of year correspondence, censuses from motorboats were efficient to identify the abundance of adult gulls at Deserta Island only before and in the end of the breeding season (Figure 5). All censuses methods could detect juveniles yet direct counts in the colonies allowed achieving a higher number of individuals (Figure 5). Highest abundance in the colonies seemed to vary from 800 to 1,200 adults between 1999 and 2011. Numbers of juveniles were the same along the years with around 400 individuals if considering breeding data only (Figure 5).

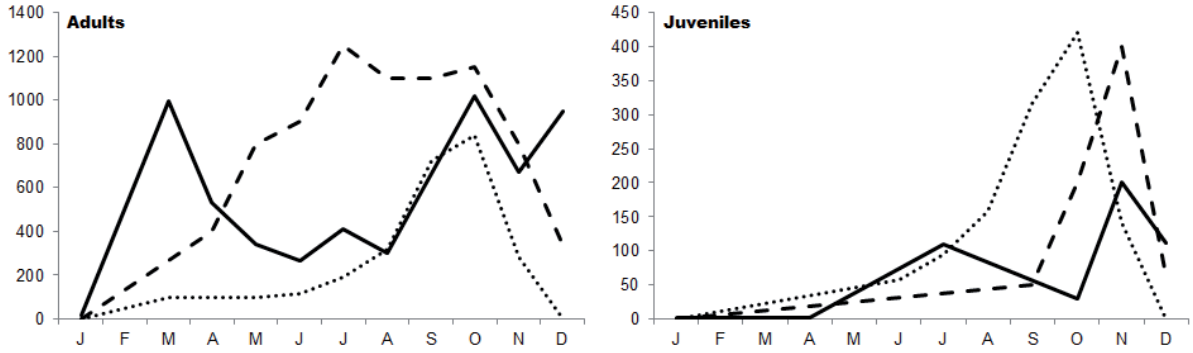

Figure 5 – Relative abundance per month of adults (left) and juveniles (right) Kelp Gulls according to counting in colonies during 1999 (dashed line, Branco 2004) and 2006 (point line, Prellvitz *et al.* 2009), and according to counting from a motorboat in 2011 (full line) at Deserta Island, Arvoredo Marine Biological Reserve, southern Brazil.

Discussion

Seasonality and dominance

The richness observed comprises half of the 32 seabirds listed to the Arvoredo Marine Biological Reserve reported in Vieira *et al.* (2015), which included extra random searches at sea and some pelagic species recorded in literature few kilometers away from the Reserve. Most species listed in this study were migratory and occasionally visiting Brazilian waters. When migratory terns were present they had high abundance similar to resident species. Winter is the usual period of migratory seabirds' presence. This season is characterized by southern winds and cold waters with the arrival of large shoals to the region (Vieira 2014). Most migratory species breeding in the Reserve's islands stays according to fish availability as well as safety and isolation from human disturbance (Martin 1987, Forbes & Kaiser 1994, Schreiber & Burger 2001). Few individuals of Magnificent Frigatebirds were still present during breeding season which could be related to immatures not ready to breed at the near Moleques do Sul Archipelago.

All pelagic seabirds recorded in the Reserve were juveniles or immatures recognized by plumage or commissure. Immature seabirds have limited navigation capabilities (Weimerskirch *et*

al. 2000, Péron & Grémillet 2013, Riotte-Lambert & Weimerskirch 2013) and tend to have first migration influenced by winds (Weimerskirch *et al.* 2000, Riotte-Lambert & Weimerskirch 2013) which explains why juveniles of the recorded species were found in the Reserve and near the coast. Though the Reserve is not a key spot for pelagic seabird abundance, it is a strategic stopover since juveniles tend to stay more time re-fulling during migration (Péron & Grémillet 2013, Riotte-Lambert & Weimerskirch 2013, Vieira 2014).

The Kelp Gull was the dominant species as noticed by other studies all over southern Brazil (e.g. Bege & Pauli 1988, Vooren & Chiaradia 1990, Schiefler & Soares 1994, Moraes & Krul 1995, Branco 2000, Branco & Ebert 2002, Branco 2004, Ebert & Branco 2009). Branco (2003a, 2004) listed the Kelp Gull colony at Deserta Island as the greatest in all Santa Catarina islands. Only the Magnificent Frigatebird surpassed dominance of Kelp gulls during summer time when Kelp Gulls families left the Reserve. Both parents leave the colonies together with their juveniles in the end of the breeding season to beaches across the mainland and the Island of Santa Catarina (Vieira 2014, B. Vieira *pers. obs.*). Terns also show this behavior (Vieira 2014, B. Vieira *pers. obs.*). Breeding phenology of Brown Booby and Kelp Gull overlapped but general abundance at sea for Brown Boobies decreased when gulls increased, which is related to a movement of Brown Boobies heading to Moleques do Sul Archipelago to stablish colonies and start breeding.

We observed raptors mostly during vulnerable periods after hatching and when juveniles left the colony for the first long flights to other islands and mainland. Prellvitz *et al.* (2009) also recorded that breeding season of the vulture *Coragyps atratus* at Deserta Island coincides with Kelp Gulls'. The vulture *C. atratus* raise chicks until January which become juvenile vultures and are able to fly, justifying the higher number of predators we found from March to May. Branco (2004) concluded that terns' breeding failure in 1999 happened due to disturbance and predation of chicks by Kelp Gulls. However, the complete failure of 1999 seems to be punctual and the colony continued successfully breeding after that (Hogan *et al.* 2010). Branco (2003) described that Kelp Gulls would decrease predatory activities during period from laying to feeding chicks, which overlaps with terns correspondent periods; therefore, the lowest predation rates by gulls would coincide with hatching and young periods for terns and gulls would not be the only impact factor for terns' failure after hatching. However, our results on matching phenology show an increase on raptors abundance in the island exactly during mortality peaks of both terns and gulls. Kelp Gulls do predate terns but mostly during territorial fights as terns and many other Lari species do within the colonies (Burger & Gochfeld 1990, Quintana & Yorio 1998, Yorio *et al.* 1998, B. Vieira *pers. obs.*). Nonetheless, starvation is an important factor that could explain the decrease of all seabird colonies observed in Prellvitz *et al.* (2009) and Hogan *et al.* (2010). According to Langham (1972) and Schreiber & Burger (2001), vulnerability of chicks on food availability and quality would be responsible for massive mortality in colonies. Hogan *et al.* (2010) indeed noticed significant changes in chicks' mass related to climate. When predicting climate change impacts on seabirds it is apparent that no single factor acts alone on populations, all factors (such as food availability, warming oceans or nest desertion rates) are interconnected (Heath *et al.* 2009). This is a fundamental clue for future actions in the Reserve because the current anthropogenic global change allied with overfishing is already proved to be the greatest risk ever faced by seabirds and specific management protocols need to be implemented to ensure their conservation (Furness 2003, Furness *et al.* 2007, Barbraud *et al.* 2012, Croxall *et al.* 2012, Sandvik *et al.* 2012, Sydeman *et al.* 2012).

Monitoring protocols

Due to the undeniable importance of the Arvoredo Marine Biological Reserve for seabirds, well-conceived and well-executed long term monitoring protocols must be implemented. First of all we strongly recommend following Lindenmayer & Likens (2009) guidelines to develop questions and a sampling design for long term monitoring.

Protocols on seabird conservation in this Reserve do not need to be restricted to but at least they should cover censuses of both colonies and birds at sea. We recommend to follow Camphuysen *et al.* (2004) and use strip-transects for censuses at sea. Transects should have same length, orientation and cruising must maintain speed lower than 15 knots with at least two observers to allow comparisons within islands (B. Vieira *pers. obs.*). In general, protocols should also cover aspects that can surely detect effects of population changes due to overfishing, climate change, human disturbance and other. Data must include not only on abundance and richness of birds but also on waters productivity, human presence, behaviour and specially interactions between species, environmental variables (ex. temperature, precipitation, wind) and coordinates of relevant flocks and colonies. Newson *et al.* (2009) selected some important indicators to look at concerning birds and climate changes. In this case, researches should look for changes (1) in timing of relative abundance of migrant birds on their breeding grounds; (2) in numbers of pairs in the colonies; (3) in both abundance and timing of migrants according to resources availability in the stopover sites; and maybe the most important is to look for (4) changes in numbers of chicks fledged per breeding attempt (Newson *et al.* 2009).

The predation rates of terns in Branco (2003a, 2004) and Hogan *et al.* (2010) could also be related to disturbance caused by investigators (Rodway *et al.* 1996, Blackmer *et al.* 2004, Carey 2009). Therefore, our guidelines to monitoring protocols consider special care when approaching colonies. We recommend researchers not to camp near the colonies due to the effects of human disturbance (Brown & Morris 1994, Rodway *et al.* 1996, Blackmer *et al.* 2004, Carey 2009). If the work cannot be performed in one day, researchers should have a base station at Arvoredo Island and use a motorboat to get to Deserta Island in a daily basis. When in Deserta Island, we strongly recommend researchers to stay out of the colonies to perform counting and approach only when gathering direct data. Colonial seabirds usually panic when humans approach and this can lead to chicks being impaled on sharp vegetation (Anderson & Keith 1980, Burger & Gochfeld 1990) or running away from safe areas where they become prey or are killed for invading territories (Burger & Gochfeld 1990, Quintana & Yorio 1998, Schreiber & Burger 2001). Further, when measuring and marking are necessary, we strongly recommend the use of low impact technologies to investigate the colonies, mainly if research aims include predation, behaviour and regular counting. The use of camera traps to film the colonies during the breeding season can give a much better view on predation and behaviour than human direct observation. Also, drones are efficient sampling tools with low disturbance effects even during breeding season (Martin *et al.* 2012, Hillman *et al.* 2015, Vas *et al.* 2015).

An important variable is the time staying inside the colony to take measures and mark eggs, chicks and adults. There is no international recommendation but experience in seabird colonies worldwide shows that depending on the researcher expertise, measures could take from 10 minutes to 1 hour per individual (B. Vieira *pers. obs.*). We recommend the period of 30 minutes for taking data on nests, eggs and chicks and intervals of one hour between each shift. However, this schedule has to change accordingly to the period of the breeding season and also to the air temperature, since without their parents chicks could have hypo- or hyperthermia with air temperatures respectively much lower or higher than 20°C (Nelson 1980). Eggs are most susceptible to changes in air temperature during incubating time. Seabirds can stay away from eggs a longer time during laying period because eggs' temperature is maintained yet eggs would still be exposed to predators (B. Vieira *pers. obs.*). On the other hand, the incubating period is critical and even 15 minutes away could effect eggs' temperature and survival (B. Vieira *pers. obs.*). Also, chicks are usually most susceptible to hypothermia in their first three to four weeks after hatching (Nelson 1980). Usually seabirds take from 2 to 15 minutes to come back to their nest (B. Vieira *pers. obs.*). To adults, we recommend taking only one parent to perform activities for each time. This individual should be taken out of the colony which would allow the other parent to come back and look for the nest, egg or chick. These precautions contribute to reduce the permanence of researchers within the colony and allow parents laying, incubating and protecting eggs and chicks (Carey 2009).

Survival rates, defection, colonization of other islands, and inter-annual shifts in colonies could be better monitored with tracking devices (Burger & Shaffer 2008). Tracking technologies have evolved in a plenty of options. Each seabird species respond differently to the size and shape of the tag as well as the method to fix it (Burger & Shaffer 2008, Bridge *et al.* 2011, Thomas *et al.* 2011, Vandenabeele *et al.* 2012, 2014). We strongly recommend following Vandenabeele *et al.* (2012) to model the right type of tag for the studied seabird. We also recommend following Thomas *et al.* (2011) to choose the right model in terms of battery, rate of points, and methods for collecting and downloading points due to difficulties in recapturing individuals and limitations in the satellite and GSM cover around the Arvoredo Marine Biological Reserve.

Management

Together with monitoring some managing actions must be implemented to enable populations' success on recruitment and survival. Fortunately the Deserta Island does not have invasive species that could threat seabirds yet the nearest Arvoredo Island already have records of House mouse (*Mus musculus*) which raises serious concerns on the safety of seabird colonies in Deserta Island (B. Vieira *pers. obs.*). The exotic House mouse must be exterminated from Arvoredo Island as a preventive measure before it reaches Deserta Island, because many studies around the world already pointed this exotic species as high level concern for seabird breeding failure (Huyser *et al.* 2000, Cuthbert & Hilton 2004, Wanless *et al.* 2007, Smith *et al.* 2010). Nevertheless, results show that the seabird colonies in Deserta Island already face pressures by native predators and some measures could help to control their effect on breeding success of gulls and terns.

Gulls and terns do not spatially overlap much in Deserta Island but this result without the spatial history on how colonies were established in each year does not allow concluding the existence of competition for areas between these groups as the widely described pattern in literature (Kress 1983, Moris & Tessier 1992, Blokpoel *et al.* 1997, Nur & Sydeman 1999, Donehower *et al.* 2007, Smith *et al.* 2010). Anyway to prevent possible consequences of these interactions, a simple method to avoid competition and predation of both gulls and raptors was used by Moris & Tessier (1992) and Blokpoel *et al.* (1997) and could easily help to improve breeding success especially of terns. The method consists of using metal lines along the colony so that big birds as gulls and raptors would not reach terns while the terns could arrive and leave without difficulties (Moris & Tessier 1992, Blokpoel *et al.* 1997). Also, Kress (1983) suggests using playback and decoys to attract individuals to settle the colony. If none of these techniques work, an alternative is to reallocate predators out of the Reserve. Or in last case, to eradicate predators from Deserta Island collecting their adults, eggs and chicks (Kress 1983, Nur & Sydeman 1999, Donehower *et al.* 2007) however we reinforce the use of this last measure only if all other measures failure and if seabird populations still decrease. The use of any managing action in colonies must include a complete monitoring of seabird populations status before, during and after managing.

Finally, overfishing and climate change seem to be affecting seabird colonies in the Arvoredo Marine Biological Reserve (Hogan *et al.* 2010) but these are hard factors to manage since marine species move in and outside the Reserve after shoals and do not consider arbitrary boundaries imposed by managers. Possibilities of overfishing around the Reserve and the movement of species between areas demonstrate that complementary conservation strategies are necessary (Yorio 2009). The Arvoredo Marine Biological Reserve has an important role reducing predatory fishing in the area; however, its managers must join large-scale integrated coastal management and marine spatial planning because seabirds depend on restrictions and proper managing of fisheries also in near areas (Yorio 2009). As noticed by Yorio (2009), the governance scale of marine protected areas such as the studied Reserve should not be locally restricted and only on issues during the breeding season. Seabirds breeding in the Reserve move out to other territories and also species breeding in other countries come to the Reserve during the non-breeding season such as penguins

and albatrosses. Therefore, managing must be integrated to other entities and goals from a regional to an international scale.

Seabirds have a tendency to follow shoal movements (Croxall 1987, Diamond 1978, Furness 1978, Furness & Camphuysen 1997) and their dependence on fish resources may be also used as a flagship for conservation (Croxall *et al.* 2012). Presence of other species such as the Snowy-Crowned Tern (*Sterna trudeaui*) using both Deserta Island and Galé Islets as stopover site highlights the Reserve's fish stocks importance for seabirds. The Arvoredo Marine Biological Reserve protects many seabirds and their presence in that area confirms the regional habitat quality and marine productivity (Cairns 1988, Cherel & Weimerskirch 1995, Diamond & Devlin 2003, Furness & Camphuysen 1997). Only few places in Brazil protect migrants and colonies such as those observed in the Arvoredo Marine Biological Reserve.

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