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Status and conservation of Madeiran Storm-petrel *Oceanodroma castro* in Farilhão Grande, Berlengas, Portugal: relevance to the management plan of this protected area

Ana Rita Neto Mendes

Dissertação

Mestrado em Ecologia e Gestão Ambiental

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Antes o vôo da ave, que passa e não deixa rasto,

Que a passagem do animal, que fica lembrada no chão.

A ave passa e esquece, e assim deve ser.

O animal, onde já não está e por isso de nada serve,

Mostra que já esteve, o que não serve para nada.

A recordação é uma traição à Natureza,

Porque a Natureza de ontem não é Natureza.

O que foi não é nada, e lembrar é não ver.

Passa, ave, passa, e ensina-me a passar!

Alberto Caeiro, in "O Guardador de Rebanhos - Poema XLIII"

Heterónimo de Fernando Pessoa

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Thanks to all of you!

Resumo

A ordem Procellariiformes é uma das mais diversas das aves marinhas do mundo, podendo variar entre os grandes albatrozes, que podem atingir os 11kg, e os pequenos paínhos, que podem chegar a pesar 20g. Estas aves são geralmente cosmopolitas e sociais, e apresentam-se distribuídas por todos os oceanos do mundo. Taxonomicamente, a ordem Procellariiformes está num estado de fluxo, com novas e enigmáticas espécies a surgir dentro de populações de *taxa* conhecidos.

Muitas das espécies de Procellariiformes são migradoras de longa distância, e algumas delas estão entre as mais numerosas do planeta. Algumas espécies desta ordem estão entre as espécies de aves mais ameaçadas do mundo. Existem atualmente 125 espécies de Procellariifomes reconhecidas, e quase metade dessas espécies apresentam estatuto de conservação Crítico, Em perigo ou Vulnerável, de acordo com os critérios da International Union for Conservation of Nature (IUCN).

Entre as ameaças existentes está a perturbação humana e risco de introdução de espécies predadoras nas colónias, a poluição luminosa, a captura acidental por redes de pesca e, ainda que exista baixo risco de colisão, os moinhos de energia eólica são outra das ameaças. A sua baixa produtividade anual, longa época de reprodução, tardia maturação reprodutiva e grande longevidade torna-os vulneráveis às perturbações. A exploração direta também é uma conhecida ameaça que pode levar à extinção colónias inteiras. A disponibilidade de ninhos adequados nas ilhas não habitadas e livres de predadores que ainda restam está de algum modo a limitar o tamanho das populações reprodutoras mundiais.

Os arquipélagos dos Açores, da Madeira e das Berlengas são extremamente importantes para as aves marinhas, e albergam várias colónias de Procellariiformes importantes, incluindo espécies endémicas. Nos Açores nidifica a maior população do Atlântico de Cagarra *Calonectris diomedea borealis*. Na ilha da Madeira nidifica a única colónia do mundo de Freira-da-Madeira *Pterodroma madeira*, que tem estatuto de conservação de Em perigo, e nidifica também nesta ilha a maior população de Portugal e Macaronésia de Bobo-pequeno *Puffinus puffinus*. Os arquipélagos das Desertas e das Selvagens, classificados como Reserva Natural, albergam a única população da Europa de Freira-do-bugio *Pterodroma deserta* e a maior população do Atlântico de Alma Negra *Bulweria bulwerii*. Nas Selvagens nidifica a maior colónia mundial de Cagarra.

O arquipélago das Berlengas é a área de nidificação mais importante para aves marinhas em Portugal Continental, albergando as únicas colónias conhecidas de Procellariiformes do continente, e a maior colónia de Gaivota-de-patas-amarelas *Larus michahellis* do país. O arquipélago das Berlengas faz parte da Reserva Natural da Berlenga, protegida por lei desde 1981. A Área de Proteção Especial para as Aves Selvagens foi criada nas Berlengas, e integrada na Rede Natura 2000, sendo depois expandida em 2012. Uma área com o dobro do tamanho da presente Área de Proteção Especial, que a inclui, foi identificada pela Sociedade Para o Estudo das Aves (SPEA) como uma Área Importante para as Aves e o arquipélago foi ainda declarado uma Reserva da Biosfera pela UNESCO em 2011.

Apesar da avifauna marinha que se reproduz na costa portuguesa ser modesta quando comparada com outros sectores costeiros da Europa, a zona costeira de Portugal é influenciada por ventos de norte e ventos de sudoeste tropicais-temperados, e dá lugar a fenómenos de *upwelling*, que tornas as águas altamente produtivas. Estes fatores contribuem para as características únicas da costa portuguesa.

O Roque-de-castro *Oceanodroma castro* apresenta uma população mundial de 150000 aves, distribuída por arquipélagos dos oceanos Atlântico e Pacífico. Em Portugal Continental a espécie apenas foi encontrada no arquipélago das Berlengas, no grupo dos Farilhões. Nos Açores, apesar de se pensar que existiam duas populações de Roque-de-castro (uma "de verão" e uma "de inverno"), um estudo recente revelou que se tratavam de duas espécies, e assim surgiu o Paínho-de-Monteiro *Oceanodroma monteiroi*.

O Roque-de-castro reproduz-se durante os meses frios e tende a nidificar em ilhas isoladas livres de predadores. No Farilhão os ninhos encontram-se em fendas nas rochas ou debaixo de Chorão.

A espécie foi descoberta nos Farilhões em 1980 por um faroleiro, mas só descrita oficialmente em 1983, e é a única colónia reprodutora que existe perto da Europa Continental. O Farilhão é um ilhéu não habitado e isolado, livre de predadores e onde existem também colónias reprodutoras de Cagarra *Calonectris diomedea borealis,* Gaivota-de-patas-amarelas *Larus michahellis* e Corvo-marinho-de-crista *Phalacrocorax aristotelis* A época de reprodução do Roque-de-castro no Farilhão Grande tem início em Setembro/Outubro e termina em Janeiro/Fevereiro.

Apesar do seu estatuto de conservação global ser Pouco preocupante, o Roque-de-castro apresenta estatuto Vulnerável em Portugal Continental, por ser uma espécie colonial com uma população pequena, com uma área de ocupação reduzida em apenas um local.

Tendo em conta a falta de informação atual existente sobre a população de Roque-de-castro no Farilhão Grande, tentámos neste trabalho avaliar o tamanho da população reprodutora no ilhéu, avaliar o sucesso reprodutor da época de 2011-2012, além da avaliação da ocupação dos ninhos implementados em 2002-2003. Tentámos ainda com este trabalho verificar se existia, e qual era, o impacto da população de Gaivotas-de-patas-amarelas sobre a população de Roque-de-castro no Farilhão Grande.

Com o objetivo de aumentar o número de locais de nidificação disponíveis para o Roque-de-castro, foram construídos mais ninhos artificiais.

Os resultados deste trabalho sugerem que a população de Roque-de-castro do Farilhão Grande se tem mantido relativamente estável desde a sua descoberta em 1980, e verificou-se também que não existem atualmente ameaças diretas à população, mas devem ser tomadas medidas de prevenção.

O método de escutas noturnas é útil para avaliar as variações anuais na abundância da população da ilha, mas por si só não permite obter uma estimativa do tamanho da população. Esta técnica é muito útil para avaliar a abundância relativa de aves na colónia ao longo da época de reprodução. Fatores como a fase da lua, o vento e a fase da época reprodutora podem influenciar as contagens de vocalizações, mas neste caso só se verificou o efeito da fase da época

reprodutora, com o pico de abundância de Roque-de-castro no Farilhão em Outubro de 2012, que corresponde à fase de postura dos ovos.

A população de Roque-de-castro no Farilhão Grande foi estimada através do método de Lincoln, com base nos dados de captura-marcação-recaptura de Outubro de 2012, em cerca de 500 indivíduos. Tanto este método como o de vocalizações apresentam erro relativamente à estimativa da população nidificante, pois os indivíduos não-reprodutores representam uma proporção variável da taxa de captura.

Foram encontrados 68 ninhos no Farilhão Grande, resultado de uma contagem feita em Outubro de 2012, mas o número total de ninhos deve ser muito mais elevado, pois há uma grande área do ilhéu de difícil acesso, o que não permitiu a contagem. No entanto, a área prospetada neste trabalho foi muito superior à de trabalhos anteriores, e há que ter isso em conta em comparações com resultados desses trabalhos.

A avaliação dos tipos de ninhos de Roque-de-castro presentes no Farilhão Grande revelou que estas aves apresentam preferência por ninhos em substrato de rocha, e por ninhos em rocha protegidos por Chorão. Verificou-se também que estas aves dão preferência a ninhos de entrada pequena, onde estão mais protegidos de perturbação e predação. Foram construídos 36 novos ninhos artificiais e espera-se que venham a ser ocupados nas próximas épocas reprodutoras.

A estimativa da população de Gaivota-de-patas-amarelas revelou que esta diminuiu ligeiramente desde os últimos censos. Após a avaliação da dieta das gaivotas através da análise de regurgitações, concluiu-se que estas não representam atualmente uma ameaça para a população de Roque-de-castro.

O Chorão, apesar de ser uma planta exótica invasora introduzida pelo homem, e ocupar uma grande parte da superfície do Farilhão Grande, revelou-se importante para o ilhéu, pois protege-o da erosão, conservando o habitat de nidificação do Roque-de-castro, e das outras aves que aqui nidificam.

As técnicas usadas neste trabalho devem ser reproduzidas em trabalhos futuros neste ilhéu, com esta colónia, de modo a permitir uma monitorização contínua da população de Roque-de-castro no Farilhão Grande. A população nidificante de Roque-de-castro dos Farilhões é pequena, o que suscita preocupações de conservação, e recomenda-se ações que permitam o aumento da população. As medidas de gestão e conservação sugeridas devem ser usadas também em outras colónias de Procellariiformes, com características semelhantes, e onde a disponibilidade de habitat de nidificação esteja restrita ou comprometida.

Palavras-chave: *Oceanodroma castro,* gestão de habitat, conservação, Farilhão Grande, estado.

Abstract

The order Procellariiformes is one of the most diverse orders of seabirds of the world. They are generally colonial and spread over all the oceans. Some species are among the most numerous, but some are among the most threatened seabird species of the world. The threats to Procellariiformes include human disturbance and risk of introduction of predatory species, light pollution and bycatch.

The Portuguese archipelagos (Azores, Madeira and Berlengas) are very important to seabirds and house several colonies of Procellariiformes. The Berlengas archipelago is the most important area for seabirds in Portugal, harboring the only known mainland colonies of Procellariiformes, and the biggest colony of Yellow-legged Gull *Larus michahellis* in the country.

The Madeiran Storm-petrel *Oceanodroma castro* has a worldwide distribution, over the Atlantic and Pacific oceans. In Portugal mainland it is only found in the Berlengas archipelago, in the small islet Farilhão Grande.

The Madeiran Storm-petrel breeds during the cold months, in isolated, predator free islands. Although its worldwide population has a conservation status of Least Concern, in Portugal mainland this species is classified as Vulnerable.

This work aimed to assess the status of the population of Madeiran Storm-petrel in Farilhão Grande, to improve the nesting habitat availability on the island by building artificial nests, and assess the effect of the population of Yellow-legged Gull on the population of Madeiran Storm-petrel.

The results of this work suggest a relatively stable population of Madeiran Storm-petrel since its discovery in 1980, and that currently there are no direct threats to the population, nevertheless preventive measures are advised. The population and the artificial nests should be monitored regularly to evaluate the success of this habitat management measure. The measures suggested in this paper could be used in other colonies of Procellariiformes, where the availability of nesting habitat is reduced or compromised.

Keywords: *Oceanodroma castro*, habitat management, conservation, Farilhão Grande, status.

Contents

Introduction

The Order Procellariiformes is divided in four families: *Diomedeidae* (albatrosses), *Procellariidae* (petrels and shearwaters), *Hydrobatidae* (storm-petrels), and *Pelecanoididae* (diving petrels). This group is among the most diverse of all seabirds in both size and form, and is also the most wide-ranging. They vary in size, from the big albatrosses, which can weigh up to 11kg, to the small storm-petrels that can weigh as little as 20g. As a group they are cosmopolitan birds, occurring in all the world's oceans, from the seas of Antarctica to the High Arctic. Many Procellariiformes are long-distance migrants, and species like the Short-tailed Shearwater *Puffinus tenuirostris* and Wilson's Storm-Petrel *Oceanites oceanicus* are generally considered to be among the most numerous seabirds on the planet (Birdlife International, 2013). Large Procellariiformes are often colonial and found in open environments, and for that reason not easily overlooked, but there are also several small and discrete species. Taxonomically, the order Procellariiformes is in a state of flux, with new enigmatic species appearing from within populations of known taxa. For example, the North Atlantic population complex of *Oceanodroma castro*, has been suggested to actually represent four different species (Robb *et al*., 2008). Another example happens in the eastern Pacific, where enigmatic species are suggested within the population complex of *Oceanodroma leucorhoa* (Howell *et al*., 2010).

Storm-petrels include some of the least known and most mysterious species of seabirds in the planet, such as Hornby's Storm-Petrel *Oceanodroma hornbyi*, Lowe's Storm-Petrel *Oceanites gracilis galapagoensis*, and the New Zealand Strom-Petrel *Fregetta maoriana*, whose breeding sites remain undiscovered (del Hoyo *et al*., 1992). In Chile, a new species of *Oceanodroma* genus was described in 2013 (Harrison *et al*., 2013).

Procellariiformes are among the most threatened birds in the world (Baillie *et al*., 2004). There are 125 currently recognized species of Procellariiformes, and 55 of those (44%) have a conservation status classified as Critical, Endangered or Vulnerable according to IUCN criteria (BirdLife International, 2000). Another 14 species (11%) have a status of Near threatened and 4 species are insufficiently known to allow a conservation classification.

The human colonization of most archipelagos around the world has devastating effects on Procellariiformes populations, mainly due to the introduction of mammalian predators e.g. cats, foxes, ferrets, pigs, rats and even mice. Direct exploitation is another threat known to extinguish several colonies of seabirds around the world (Croaxall *et al*., 2012). The availability of suitable nesting sites on the remaining uninhabited and predator-free islands and islets is somehow limiting the size of the global breeding populations. Furthermore, from the 104 species whose nesting habits are well known and documented, 75% nest in burrows or crevices (Schreiber and Burger, 2001) and there is evidence of intra and inter-specific competition of suitable nesting cavities in some colonies (Harris, 1969; Ramos *et al.*, 1997; Gardner and Wilson, 1999).

In mixed species colonies of cavity-nesting Procellariiformes, the larger species are likely to be at considerable competitive advantage in disputes over nest occupancy. It has been documented that Cory's Shearwater *Calonectris diomedea* can kill adult Bulwer's petrels *Bulweria bulwerii*, Little

Shearwaters *Puffinus assimilis* and Madeiran Storm-petrels *Oceanodroma castro* when enlarging previously occupied nest cavities for their own use (Ramos *et al*., 1997).

Most of the Procellariiformes are active at night, which allows them to avoid predators, particularly important during the breeding season, when returning to and leaving their nesting sites (Montevecchi, 2006). Many nocturnal seabirds are sensitive to the disorientating and often damaging influences of artificial light (Montevicchi, 2006), and attraction to artificial light sources has been recorded in at least 21 species of Procellariiformes, as well as in many other seabird groups and has an adverse effect on some globally threatened populations (Reed *et al*., 1985). Coastal light pollution has a particularly dangerous impact on burrow-nesting petrels and shearwaters. Every year around the world, thousands of young petrels are disorientated and grounded because of artificial light as they attempt to make their first flights out to sea, a phenomenon known as 'fallout' (Reed *et al*. 1985, Telfer *et al*. 1987, Le Corre *et al*. 2002, Rodríguez and Rodríguez 2009). Grounded young petrels often die from their injuries or, unable to take off, perish to predation or starvation (Montevecchi, 2006).

Other known source of perturbation is related with fishing activities (Croaxall *et al*., 2012). Procellariiformes are known to compete directly with human fisheries (Cowx, 2003), however, few studies have actually quantified this form of competition (Karpouzi, 2007). The accidental capture of seabirds in fishing gear is named bycatch. Longline or gillnet fishing are documented to cause severe effects to seabirds in several parts of the world (e.g. Lewison *et al*., 2003, 2004). Overall, seabird bycatch is estimated at least 160 000 (and potentially in excess of 320 000) *per* year (Anderson *et al*., 2011). Finally, a quite recent potential threat is due to offshore wind farms. Despite the low collision probability, large groups of offshore windmills may induce birds to avoid such areas (Exo *et al*., 2003).

Procellariiformes have low annual productivity, long breeding seasons, late reproductive maturation and the high longevity makes them especially vulnerable to disturbance factors, namely predators in their nesting colonies (Sanz-Aguilar, 2008). The key to their persistence is adult survival (Saether & Bakke, 2000).

The Azores EEZ is very important to seabirds, especially during the breeding season. In this archipelago breeds the largest population in the Atlantic of Cory's Shearwater *Calonectris diomedea borealis* (50 000-100 000 pairs) (Monteiro *et al*., 1996; Birdlife International 2013), as well as other small populations of Procellariiformes, like Manx Shearwater *Puffinus puffinus* (only in Corvo and Flores islands, *ca* 200 pairs (Monteiro *et al*., 1999)), Little Shearwater (840 - 1530 pairs; Monteiro *et al*., 1999), Bulwer's Petrel (50-70 pairs; Monteiro *et al*., 1999), Madeiran Storm-petrel (250-300 pairs; Monteiro *et al.*, 1996, 1999) and the endemic Monteiro's Storm-petrel *Oceanodroma monteiroi* (250-300 pairs; Bolton *et al*., 2008).

The Madeiran archipelago is also important, having the only colony in the world of Zino's Petrel *Pterodroma madeira* nesting on the main island (Zino *et al*., 2001), that is classified as Endangered (BirdLife International, 2012). Madeira island also houses the largest population of Manx Shearwater in Portugal and Macaronesia: 2500-10000 birds (Cabral *et al*., 2005). Desertas and Selvagens archipelagos are uninhabited by people and classified as Nature Reserves. On Desertas islands breeds the only European population of Fea's Petrel *Pterodroma feae* (Jesus *et al*.,

2009), and the largest Atlantic population of Bulwer's Petrel (Cabral *et al*., 2005). Selvagens islands are also very important to seabirds, with the largest colony in the world of Cory's Shearwater nesting here (Granadeiro *et al*., 2006), as well as the largest colonies in the North Atlantic of White-faced Storm-Petrel *Pelagodroma marina* and Little Shearwater, and important numbers of Madeiran Storm-petrel within Europe (Cabral *et al*., 2005).

The Berlengas archipelago is the most important breeding area for seabird species in Portugal mainland, supporting the only known colonies of Procellariiformes, and the largest colony of Yellow-legged Gull *Larus michahellis* in the country. Around 980-1070 pairs of Cory's Shearwater (Lecoq *et al*., 2001) and around 250 pairs of Madeiran Storm-petrel (Granadeiro *et al*., 1998), as well as 25 000 Yellow-legged gulls (ICNB/RNB, 2008, unpublished data) and 80 pairs of European or Common Shag *Phalacrocorax aristotelis* (Lecoq, 2012).

Although the marine avifauna breeding in the Portuguese Coast is considered modest when compared with other coastal sectors from Western Europe, it has features that make it unique, result of an intermediate position in relation to the groups of seabirds influenced by northern winds, and the avifauna influenced by temperate-tropical winds (Fisher & Lockley, 1954). Winds along the Portuguese coastline are seasonal, being most frequently from the Southwest during winter (November - February), and mostly from the north during the summer (March – October), inducing a strong upwelling during this period (Fiúza *et al*., 1982). The winter winds from the Southwest produce surface flow towards the shore, alternating with summer winds from the north, which produce flow away from the shore, generating coastal upwelling from March - April through October-November (Pardal & Azeiteiro, 2001). The strength and extension of upwelling are connected to local winds and to the geophysical surroundings (Fiúza, 1982, 1983). The upwelling areas are highly productive, as the case of the waters surrounding the Berlengas archipelago (Fiúza, 1983).

Oceanographic characters of the study area

The Madeiran Storm-petrel *Oceanodroma castro* breeds in the eastern Atlantic from Berlengas and Azores archipelagos (Portugal) down to Ascension Island and Saint Helena (UK), in the Pacific off eastern Japan, on Kauai, Hawaii (USA) and on the Galapagos Islands (Ecuador) (del Hoyo *et al*. 1992). The global population was estimated by Brooke (2004) in 150 000 birds (Birdlife International, 2013).The distribution area in Europe, during the breeding season, includes Spain (the Canary islands) and Portugal (Azores and Madeira archipelagos, including the Desertas and Selvagens islands, and the Berlengas archipelago) (Birdlife International, 2012). In Continental Portugal this species is only found on some islets of the Berlengas archipelago, the Farilhões (Teixeira & Moore, 1983).

The first studies of genus *Oceanodroma* in the Azores suggested the presence of two populations of Madeiran Storm-petrel breeding annually in the Azores (Monteiro & Furness, 1996). However, a study of the two populations in 2008 confirmed the occurrence of two different species, showing a marked temporal segregation in the timing of breeding: the "hot-season" population was

named Monteiro's Storm-petrel *Oceanodroma monteiroi* and the "cold-season" population remained Madeiran Storm-petrel. There are morphological differences between them: Monteiro's Storm-petrel is smaller in terms of body mass, its wings are proportionally longer, the tail is longer and deeply forked and they have shorter and thinner bills (Monteiro & Furness, 1998; Bolton *et al*., 2008). There are also differences in their vocalizations, both in duration of the nest call and structure of the breath notes that punctuate the purr phrases (Bolton, 2007). Monteiro's Storm-petrel's call has a shorter breath note, and fewer syllables than the Madeiran Storm-petrel's. Another difference is the timing of the wing moult, which starts towards the end of the breeding season. The Monteiro's Storm-petrel is on primary moult in October, whereas the Madeiran Storm-petrel completes primary moult in August (Bolton *et al*., 2008).

The Madeiran Storm-petrel breeds during the winter months, with a breeding season going from September/October to January/February (Granadeiro *et al*., 1998). This species tends to nest in isolated islands, free of predators. Each female lays only one egg, and apparently there's no reposition in case of accidental loss (Schreiber and Burger, 2001).

Despite the fact that the worldwide conservation status is Least Concern (BirdLife International, 2013), in Portugal mainland, the Madeiran Storm-petrel is classified as Vulnerable (Cabral *et al*., 2005) because it's a colonial species with a small population, with a reduced occupation area and only one location. In the Azores the Madeiran Storm-petrel is classified as Vulnerable (Cabral *et al*., 2005) because it's a colonial species with an extremely reduced occupation area, with just 8 colonies which have been suffering a continued decline in the extension quality of its habitat.

The discovery of this species in Farilhões occurred in July of 1980, when it was found by a light keeper in a burrow containing two white eggs, among the stones of a loosely built wall. The breeding of *Oceanodroma castro* in the Farilhões was formally described by Teixeira & Moore (1983) after their visit to the islets in 1981, when they estimated the breeding population in ca. 50 pairs. The colony was not visited by ornithologists until 1994, when Granadeiro *et al*. (1998) made monthly visits to the islet during the breeding season, from October to February, estimating the population in 200-400 pairs.

The colony of Madeiran Storm-petrels in the Farilhão is the only known breeding colony near the European mainland. Since the census made in 1998, the colony has only been visited in 2002/2003, with three visits to the islet (Magalhães, 2003) and another single visit in 2006, in an attempt of track the petrels using VHF transmitters (made as part of the LIFE04 NAT/PT/000213 project). The last estimate of the population for the Farilhão Grande was approximately 125 pairs (Magalhães, 2003), based on capture-recapture methods. The population breeding in Farilhões is therefore rather small, which poses conservation concerns, and advise action towards increasing the population size, therefore decreasing the likelihood of extinction.

The Farilhão Grande is a small islet free of ground predators, where Cory's Shearwater *Calonectris diomedea*, European Shag *Phalacrocorax aristotelis* and Yellow-legged Gull *Larus michahellis* also breed. This later species is known to prey on Madeiran Storm-petrels in some regions (e.g. Matias & Catry, 2010). The access to the islet is very restricted, so there is currently little impact from humans.

Over the last century, there has been an increase in populations of many species of seagulls all over the world. Among other factors, the organic waste available in dumps and landfills and, especially waste originated by the expanding fishing industry have been named as important causes for the fast increase in seagull populations (e.g. Furness *et al*., 1992; Oro *et al*., 1995; Duhem *et al*., 2008). These changes lead to over-population of seagulls in many areas, which can result in very high predation rates in relation to other seabirds with which they share the breeding grounds (e.g., Stenhouse & Montevecchi, 1999; Oro *et al*., 2005). The impacts of this predation in other seabird populations can be severe, particularly when natural prey (and even prey from anthropogenic sources) becomes rare. In some cases it became necessary to apply management measures, in order to correct densities, although there have been variable results (Oro and Martínez-Abraín, 2007).

The Berlengas archipelago is the most important breeding area for seabird species in Portugal mainland, since it supports the only known colonies of Procellariiformes. Around 980-1070 pairs of Cory's Shearwater (Lecoq *et al*., 2011) and around 250 pairs of Madeiran Storm-petrel (Granadeiro *et al*. 1998) nest here, as well as thousands of Yellow-legged Gulls (around 25 000 birds, according to the 2008 survey; ICNB/RNB, unpublished data) and 82 pairs of European or Common Shag (Lecoq, 2012).

The Berlengas archipelago is part of the Nature Reserve of Berlenga, protected by Portuguese law since 1981. In 1999 the Special Protection Area (SPA) for Wild Birds was created for the Berlengas Islands, integrated directly in the Natura 2000 network, and expanded in 2012. An area with double the size of the present SPA, including it, was identified by SPEA as an Important Bird Area (IBA) for seabirds (Ramírez *et al*., 2008). The archipelago was also recently declared a Biosphere Reserve by UNESCO (unesco.org, 2011).

Considering the lack of recent information about the state of the Madeiran Storm-petrel population in the Farilhão Grande, this work aimed 1) to estimate the current breeding population, 2) to examine the breeding success of the Madeiran Storm-petrel during the season of 2011-2012, 3) to assess the pressure on the Madeiran Storm-petrels by the breeding and wintering population of Yellow-legged gulls, 4) to evaluate the success of habitat improvement measures implemented in 2002-2003, and 5) to increase the number of nest availability by building artificial nests.

Methods

Study site

This study was conducted in Farilhão Grande, one of the Farilhões, a small group of isolated gneissic islets in the Berlenga archipelago, lying about 18 km off the Portuguese coast (39° 29' N, 09º 33' W). The Farilhão Grande is the biggest of the islets, with about 7 ha, and it's characterized by steep cliffs with a maximum height of 94m. The islet has never been inhabited and is only visited briefly by lighthouse personnel and only exceptionally by fishermen (Granadeiro *et al*., 1998). The only land vertebrate known from the Farilhões is the small lizard *Podarcis bocagei berlengensis,* while the Black Rat *Rattus rattus,* so common at nearby Berlenga, is absent (Teixeira & Moore, 1981). Today, a significant part of the island is covered by the Hottentot Fig *Carpobrotus edulis*, which was deliberately introduced, probably in the 50's, during the construction of the automatic lighthouse (Granadeiro *et al*., 1998).

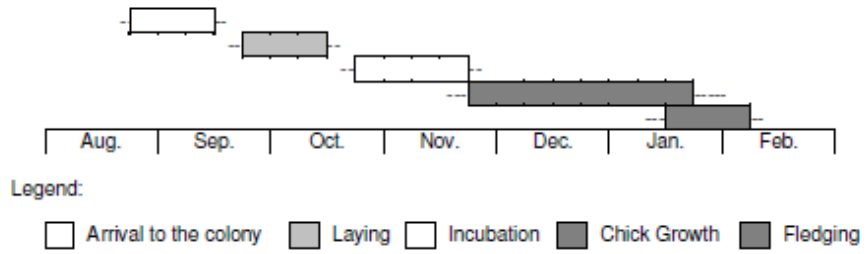

Figure 1: Breeding phenology of Madeiran Storm-petrel in Farilhão Grande (Granadeiro *et al.*, 1998).

The visits planned for the field work (appendix A) were based on the breeding phenology of the Madeiran Storm-petrel (fig. 1). Due to bad sea conditions, some of the visits could not be undertaken, which made it difficult to determine the breeding success for the season of 2011-2012. A visit was made each month, lasting 3-4 days, except in the month of November of 2011 in which two visits were made to the islet.

Nocturnal Vocalizations

The assessment of nocturnal vocal activity to obtain information on distribution and population size has been applied to various species of Procellariiformes (Monteiro *et al*., 1999; Bolton, 2001).The methodology used was based on the work conducted by Bolton in 2008. During each visit, excluding the first of the 2 visits of November 2011, the visit of January 2012 and May 2012, a transect was walked between the Northwest tip of the islet, about 40m from the lighthouse, ending next to the shelter located at the small peer at sea level, going through the single existing track. This track (about 320m long) was divided in small transects with enough distance to walk 1 min at a slow pace. Each line transect was covered by 2 observers who registered, independently, the number of individual vocalizations of Madeiran-Storm petrels, during a 1 minute walk. In order to

compare the counts of line transects with the counts of listening points, between each transect, the observers stopped for 1 minute to count the vocalizations. Each session included a total of 8 points and 7 transects, and it took about 20 minutes to cover the track. In order to assess the variation of the Madeiran Storm-petrel's level of activity during the night, in each visit the transects were repeated 4 times, with intervals of 30 minutes, being the first transect made about 40 minutes after sunset, when the activity of the Madeiran Storm-petrels generally begins. The measured call rates give an index of vocal activity and not the number of individuals calling.

Capture-mark-recapture of Madeiran Storm-petrels

Three capture sessions were performed with vertical mist nets, the first on 16 November 2011, the second on 18-19 January 2012 and the third on 9-10 October 2012. For the first two sessions, with 1 night of capture on the first and 2 nights on the second, 4 nets of 15m were set up in the Eastern part of the islet, along the trail (3 with 3 pockets and 1 with 4 pockets with 20x20mm mesh) (fig. 2). The 3rd session, more intensive, included 2 nights of capture with ten 15m nets, although no more than 8 were open at the same time (fig. 4). In this session, we used 5 nets with 3 pockets (30x30mm mesh), 4 with 3 pockets (20x20mm) and 1 with 4 pockets (20x20mm). Two nets were set up north of the lighthouse, another 2 south of the shelter and 6 on the Eastern part of the island, along the trail. The mist nets were open, daily, 30 minutes after sunset and visited in 1 hour intervals, in order to minimize the time the birds stayed on the nets, and subsequent stress.

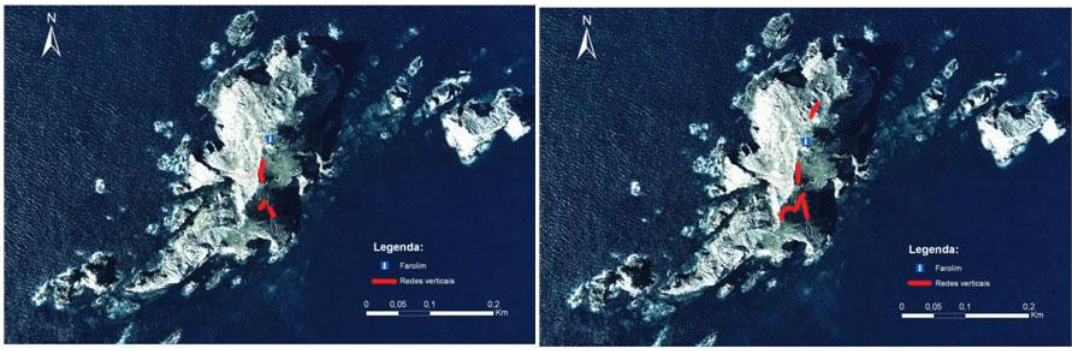

Figure 2: Location of the mist nets used in Farilhão Grande (red lines) for the capture of Madeiran Storm-petrels on 16 November 2011 and 18-19 January 2012 (left); on 9-10 October 2012 (right).

The population size was estimated based on the capture-recapture data, and using the Lincoln method. In general, the capture-mark-recapture (CMR) method assumes that when a portion of a population is marked, released and then redistributed among the entire population, the portion of birds marked in a second sub-sample is equal to the portion within the population as a whole. Bibby *et al*. (1992) established that the most suitable method to estimate population size of colonial waterbirds is Lincoln method. The Lincoln method is based on the following formula:

- To recaptures r > 20:

$$P = \frac{a\,n}{r}$$

$$Var\ P = \frac{a^2\ n\ (n-r)}{r^3}$$

- To recaptures r < 20:

$$P = \frac{a(n+1)}{r+1}$$

$$Var\ P = \frac{a^2(n+1)(n-r)}{(r+1)^2(r+2)}$$

- Confidence intervals of 95% (CI95%) = ±1,96*SE

$$SE = \sqrt{\frac{a^2(n+1)(n-r)}{(r+1)^2(r+2)}}$$

Where:

P = Population estimate
a = no. of individuals originally marked
n = no. total of individuals captured in second sample
r = no. of individuals marked in the first sample and captured in the second sample

Ground search and nest monitoring

During the visit of 16-17 November 2011, the Northwest, North and East sides of the island were ground searched for the purpose of counting active nests of Madeiran Storm-petrel. The inaccessible places were searched with the support of a rock climbing team. For every nest found, it was recorded its GPS location and its state (no. of adults, chick or egg). Between 8 and 11 December 2012, the nests were counted again, this time in a larger area, including the South and Southeast sides. However, some inaccessible areas were not visited due to the absence of a rock climbing team. In addition to the parameters registered in 2011, it was also registered for each nest, the width of the entrance, the depth of the chamber and the nest substrate (rock, Hottentot fig and/or natural vegetation). The most accessible nests were selected and marked with a numbered tag, to allow future location and monitoring. Whenever possible, the adult and/or chick in the nest were marked with a metallic ring.

Building and maintenance of artificial nests

In 2002-2003, several support walls had been built along the trail, between the small peer site and the lighthouse shelter, to be used by the Madeiran Storm-petrels as nesting sites (Magalhães, 2003). During the visits these walls were searched with the aim of finding active nests. In December of 2012 there was an action of maintenance and recovery of the two walls, which showed evidence of the effects of erosion factors.

We built 36 artificial nests, 20 in plastic plant pots and 16 with stones, located in easily accessible areas, so the monitoring is quicker, minimizing possible negative impacts. The nests were built from plastic pots with 16cm diameter (on the base) and 10cm height. On the side of the pot, an entrance was made with 5cm diameter to allow the birds to access the chamber (fig. 3). Each vase was put on a hole on the ground, in a way that the entrance would be at ground level. The pots, previously punctured for water draining, were filled with small stones and some soil to serve as substrate, filling up about 2-3 cm of the vase. A plastic plate with a bigger diameter than the vase was used as a lid, stopping water from entering the nest. The lid was covered by an isolating membrane (the same material used in roof isolation) and stones secured with PUR foam. This technique gives the nests a natural look, increases the heat insulation and makes the monitoring easy. We also built some nests using stones, arranged to form burrows. Whenever needed the stones were secured with PUR foam. Each nest has a small entrance with about 6cm diameter. All the nests were numbered with white ink.

The pot nests were disposed in 4 groups of 5 nests. The GPS location of each group was registered. Since it was very difficult to assess the number of available nests in the walls originally built by Magalhães (2003), we assumed 25 potential nests, as mentioned in her study.

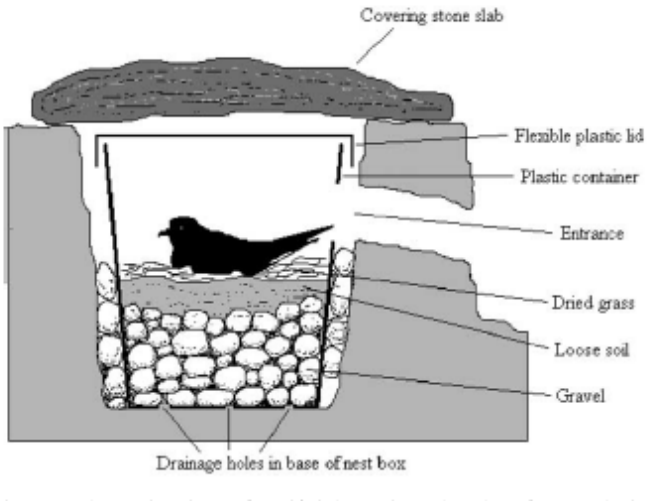

Figure 3: Schematic view of artificial nesting chamber for Madeiran Storm-petrels. The internal dimensions of the nest chamber were 16 cm diameter and 10 cm height, with an entrance of 5cm diameter. The bottom was lined with small stones and soil, for stability, and to facilitate drainage of surface water away from the nest. The entrance tunnel was protected with small stones, to reduce the amount of the light reaching the nest and to prevent rainwater draining into the nest. The lid was covered externally with an insulating material and small stones were secured with PUR foam (Bolton *et al*., 2004).

During the visits in October and December, all artificial nests, including the walls, were monitored to assess occupation. We registered the contents of the nests: number of adults, chick or egg. For the artificial nests built during this operation, it was also registered the Madeiran Storm-

petrels occurrence by signs (feathers or excrements) prospection. Evidence of humidity inside the nests was also recorded.

Population size of Yellow-legged Gull

During the visit of 22-23 May 2012 to Farilhão Grande, the active nests of Yellow-legged Gulls *Larus michahellis* were counted. The nests of the East side and a small area on the West side were counted at distance, using binoculars 8x42 due to the difficult access, and all the other nests were visited and the number of eggs/chicks was counted. The GPS location of all accessible nests was registered. During the 3 visits between May and December of 2012, we counted all the Yellow-legged Gulls, adults and immatures, present on each islet of the Farilhões group plus the individuals sitting in the water between the islets. The counting was carried out 1-2 times *per* visit, at the end of the day, from various vantage points of the Farilhão Grande, in order to estimate the number of gulls using the islets during the non breeding season.

Analyzing the diet of the Yellow-legged Gull

During the visits between August and December 2012 we collected regurgitations of Yellow-legged gulls in several points of Farilhão Grande and stored them in individual containers for later laboratory analysis. The analysis consisted in the identification and quantification of species in the regurgitations, using a reference collection of rigid fish structures (otoliths, vertebrae and other bones), in order to characterize the diet of the gulls and investigate the presence of Madeiran Storm-petrel remains.

The quantification of species was based on the identifiable parts of the animal present on the regurgitations. For the crabs, the pincers were laid out in pairs (as they appear on the crab) and counted on the side with higher number of pincers. It was considered 1 individual *per* each possible pair; for the fish, it was considered one individual *per* group of vertebrae seeming to belong to the same species. For the feathers, it was only registered the presence, since there was no other elements of birds for identification. The frequency of occurrence used was the number of regurgitations where the species appeared divided by the number of total regurgitations.

Results

Population estimate of Madeiran Storm-petrel

Nocturnal Vocalizations

In order to count the vocalizations, 140 point counts and 124 line transects were made. Generally, there was a good agreement between the values of points and transects, and between both observers, with the bigger difference registered in October (fig. 4). The effect of the time of night on the call rate was only noticeable in October, with a decrease in the vocalizations along the night of the surveys. The lowest mean rate of vocalizations was registered in August 2012, with a maximum of 5 heard vocalizations. The highest rate of vocalizations was observed in October 2012, with a maximum of 44 heard vocalizations in a single point count (table 1). In November 2011 and August 2012, the moon was in the first quarter phase, and in October and December 2012, it was on last quarter phase. The phase of the moon doesn't seem to have influenced the rates, but the date did influence the average number of vocalizations. In August and December there were much lower call rates than in October (laying time of the breeding season). The average wind strength in August was 3, and in October and December was 2 (Beaufort scale). The strength of the wind might have influenced, but it's not certain and this factor is a large source of error if taken in consideration. The stronger winds occurred in August, but that is also when there are fewer birds on the island, as mentioned before.

Table 1: Mean call rate (mean no. of vocalizations/min ± standard deviation) calculated for each visit, based on the nocturnal vocalizations of Madeiran Storm-petrel registered for point counts and line transects.

Visit	Time	Points				Transects			
	(1st count)	*n*	Mean	SD	Max	*n*	Mean	SD	Max
Nov-2011	20:29	32	10,2	6,55	30	28	9,5	5,90	23
Aug-2012	21:20	36	0,7	1,23	5	32	0,75	1,13	5
Oct-2012	20:00	36	17,8	8,53	44	32	12,2	7,63	28
Dec-2012	18:41	36	6,6	6,43	29	32	4,5	4,90	21

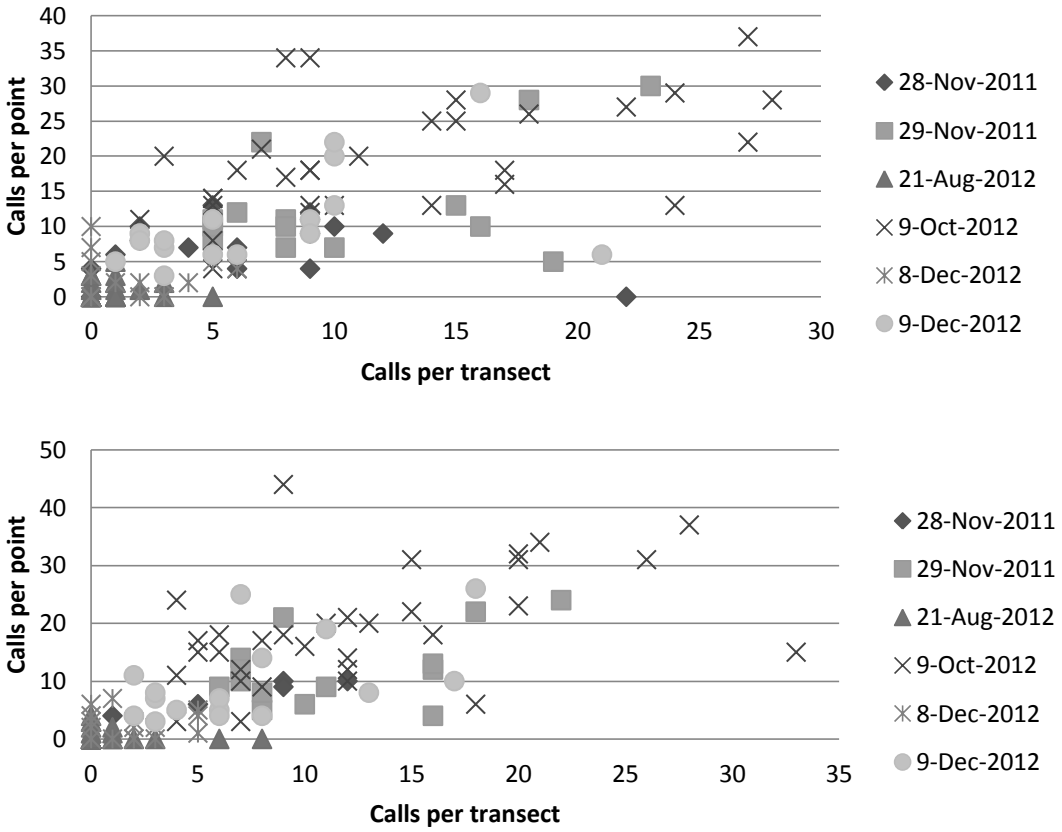

Figure 4: Comparison between observer 1 (top) and observer 2 (bottom), between calls per point and calls per transect, for each date.

Capture-Mark-Recapture

During the 2 sessions of November 2011 and January 2012, 33 different petrels were captured, in which only 1 was recaptured. The reduced number of recaptures made it impossible to estimate the size of the population for 2011. In October 2012, 89 birds were captured on the first night and 117 on the second. Given that 22 were recaptures from the 1st day, the result was a total of 184 different petrels. Based on the captures made in 2012, we estimated the population in 473.3 ± 163.9 birds (P ± IC95%; table 3). In November 2011 the moon was on 1st quarter phase and the wind strength was weak, in January 2012 the moon was on last quarter phase and the wind strength was weak, and in October 2012 the moon was on last quarter phase and the wind strength was moderate.

Table 2: Population estimate using Lincoln's method for recaptures higher than 20: no. of Madeiran Storm-petrels based on the captures of 2012 in Farilhão Grande.

	a	n	r	P	Var	SE	CI95%
r < 20	89	117	22	473,3	8268,4	83,62	± 163,9

Ground search and monitoring the nests

During the visit made in November 2011, 29 nests were found in natural burrows. We covered around 35% of the area of the island during the ground search for nests of Madeiran Storm-petrel. Those 35% represent about 2.4ha of the island (fig. 4). This value must be under-estimated, as the area was calculated based on a plan traced over an air photo of the Farilhão, hence not considering the accentuated slopes. Of the 29 nests found, 8 had only the adult (including 1 with 2 adults), 11 had the adult with an egg (including 2 nests with 2 adults), 2 had the adult and chick, 2 had just the chick, 5 just had an egg (probably abandoned) and 1 was empty with a strong Storm-petrel scent and feathers (probably occupied but without breeding attempt) (table 3).

On the 2nd visit of November 2011, 5 nests were found active on the walls built by Magalhães (2003), in which, 1 had an adult, 1 had 2 adults, 1 had an adult and an egg, 1 with strong evidence of unsuccessful occupation (egg shell, feathers and excrements) and 1 had a chick. We also monitored 6 nests found on the previous visit, 3 of which had chicks, 2 had an egg and 1 had an abandoned egg (table 3).

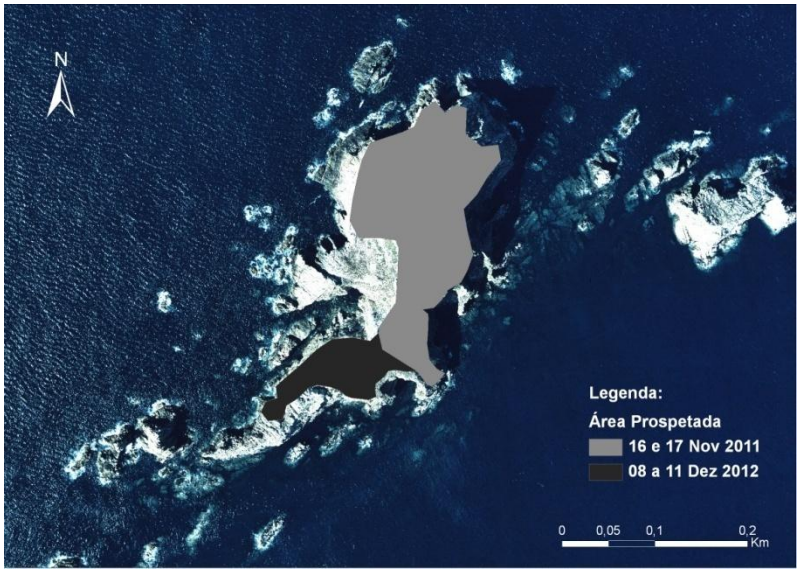

Figure 5: Ground searched area for nests of Madeiran storm petrels in the Farilhão Grande: light grey is the area searched in 16-17 of November of 2011; in dark grey (plus the light grey) the area searched in 8-11 of December of 2012.

During the last visit of the 2011-2012 breeding season, made in 18-19 of January 2012, no ground search was performed, but a total of 12 were revisited, in order to have a general idea of the breeding success of the Madeiran Storm-petrel in Farilhão. In those 12 nests, 2 were inactive (as they were when found for the 1st time), 2 failed before hatching, 2 despite having adults, it was never registered any egg or chick, 5 had chicks, and 1 was considered left by the chick, due to its developed state in the previous visit (there was no evidence of predation or death) (table 3). Despite the small sample size, the breeding success rate was around 50%.

In the only visit made in the season of 2012-2013 in which ground search for nests was made, the covered area exceeded 50% of the island, with more than 3ha prospected. Once again, this value represented an under-estimation of the true area. We checked 68 nests, excluding the artificial nests, 29 of which with an egg and 14 with a chick, the remaining containing either egg shells, feathers, adults, abandoned eggs, or excrements. Within this set, 2 nests with 1 adult preyed at the entrance of the nest and another 2 with the chick dead inside the nest. In 2011, we also found 3 adult petrels and another 3 in 2012 on the track of the island, again showing clear evidence of predation. Most of the adults captured at the nest on the Northwest, North, Northeast and East side of the island, were marked, and none of the individuals found in the South side was marked.

During the monitoring we also marked 22 individuals found inside the nests, including 13 chicks.

Table 3: Number of nests counted on each visit and condition of the nest. The abandoned nests included 17 nests with abandoned egg, 2 with dead chick and 2 with dead adult. The artificial nests are not included in the table.

Date	Visited nests	Only adults	Egg	Chick	Evidence of presence	Abandoned nests
16-17 Nov 2011	29	8	11	4	1	5*
28-29 Nov 2011	11	2	3	4	1	1*
18-19 Jan 2012[(1)]	12	2	-	6**	-	2*
8-11 Dec 2012	68	7	16	29	10	14***

[(1)] revisited nests
* with abandoned egg
** one had already left the nest
*** 10 with abandoned egg, 2 with 1 dead adult and 2 with dead chick

Based on this data, we calculated the occupation rate and the hatching rate for the season of 2012-2013, which were 66.2% ((no. of eggs + no. of chicks)/ total no. of nests) and 64.4% (no. of chicks/ (no. of eggs + no. of chicks)) respectively.

In 62 nests assessed for their substrate, we found that rock was the most frequently used by Madeiran Storm-petrels, being present in more than 56.6% of the nests (35 nests) found in rock substrate (fig. 5). About 27% of the nests (17 nests) were in substrate of rock and Hottentot fig *Carpobrotus edulis*, and the least used substrate is other vegetation (1 nest in Hottentot fig + other vegetation and 1 in rock + other vegetation). The higher values of occupation rate and hatching rate were found in nests in rock substrate and rock + Hottentot fig substrate (table 4). The laying success for nests in Hottentot fig + other vegetation substrate is 100% because we only found one nest and it had an egg (tablw 4). These values were obtained using the same method mentioned before.

From the measurements taken from 62 nests, we verified that the average width of the nest entrance is 127.9mm (±74.5mm) and the average depth of the nest chamber is 282.7mm

(±180.8mm). In the smaller nests we verified that there were more chicks and more eggs, and there was no evidence of predation, but in nests larger than 145mm we found less eggs and less chicks, 2 dead Madeiran Storm-petrels (1 adult and 1 chick, in separate nests) and 1 nest with an abandoned egg.

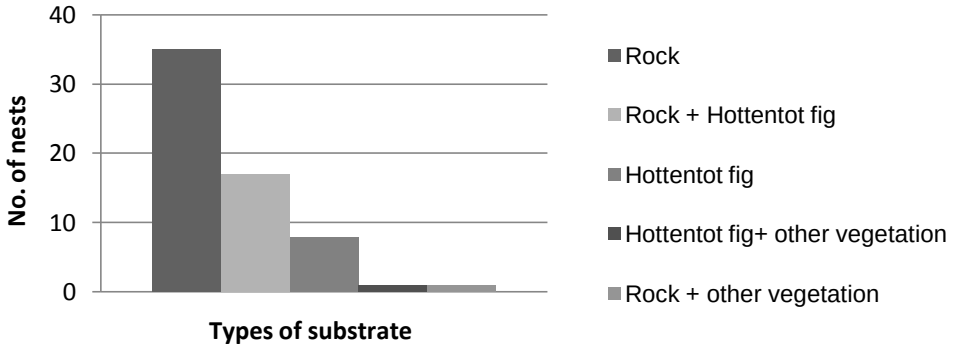

Figure 6: Different types of substrates observed in Madeiran Storm-petrel's nests.

Table 4: Laying and hatching success rates for different Madeiran Storm-petrel nest substrates found in Farilhão Grande.

	Rock	Rock + Hottentot fig	Hottentot fig	Hottentot fig + other veg.
Eggs	9	4	2	1
Chicks	16	10	1	0
Occupation rate	71.43%	82.35%	37.5%	100%
Hatching rate	64%	71.4%	33.3%	0%

Monitoring of artificial nests

Only one of the nests built with stones in August 2012 showed clear evidences of occupation. The egg was found abandoned at the nest entrance, during the visit of December. In other 3 nests (pots) we found feathers of Madeiran Storm-petrels inside. All 36 artificial nests were dry (the 20 pot nests and 16 stone nests), with no signs of water infiltration from the previous days. There were no signs of breeding in the nests on the walls.

Population size of Yellow-legged Gull

We counted 172 Yellow-legged gull nests on the accessible or visible areas of the island. Considering that only the caves on the West side of the island were not visited, and even the steepest cliffs were searched using binoculars, we believe we counted more than 95% of the nests. The 5% error is estimated based on the cliffs searched with binoculars, in which the vegetation or

more prominent rocks could hide some nests. Based on that, the breeding population estimate is of 180 couples. In May of 2012, none of the nests closely searched had chicks; however, in the 24 nests searched from a distance it was not possible to determine the number of eggs or presence of chicks, due to the parents being on the nest when they were not disturbed. The average number of eggs *per* nest was 2.64 eggs (n=148), with a maximum of 3 and a minimum of 1 egg. In August 2012, 865 Yellow-legged Gulls were counted in Farilhão Grande and 2160 sitting in the water and surrounding islets. In October only 12 gulls were counted in Farilhão Grande, and there were no gulls on the other islets or sitting in the water. During the last visit, on December 2012, 8 gulls were on Farilhão Grande and 441 were sitting in the water and surrounding islets.

Analyzing the diet of the Yellow-legged Gull

We analyzed 60 regurgitations of Yellow-legged Gulls, collected during all the visits to Farilhão Grande (26 collected in August 2012, 21 in October 2012 and 13 in December 2012). There was no evidence of predation of the gulls on the Madeiran Storm-petrels in the analyzed regurgitations, and the most frequent element of their diet in the Farilhão Grande is the Henslow's Swimming Crab *Polybius henslowii.* Although in a low percentage (table 5), some fish species were found on the samples of August and October 2012. It should also be noted that in some samples (ca. 35%) we found some feathers that were not identified, and in the more shattered samples, with no identifiable crab pincers, we considered the presence of at least 1 individual *Polybus henslowii*.

During the CMR session in November 2011, at least one Barn Owl *Tyto alba* was seen flying around the capture nets. In one of those occasions, the owl was spotted attacking a Madeiran Storm-petrel that was caught in the nets, but it was a failed attempt. This species doesn't breed in Farilhão Grande and it was probably an individual in migration or dispersed. In the visit of December 2012, we found some regurgitations consisting entirely of feathers and bones of Madeiran Storm-petrel, which may belong to birds of prey and not sea gulls.

Table 5: Occurence frequency (in %) of the prey found in regurgitations of Yellow-legged Gulls collected from Farilhão Grande in 2012.

	Aug-12 (%)	**Oct-12** (%)	**Dec-12** (%)
Polybius henslowi	100	100	100
Macroramphosus scolopax (?)	3.9	0	0
Scomber sp.	3.9	0	0
Trisopterus luscus	3.9	0	0
Belone belone(?)	3.9	0	0
Unknow fish *sp.*	7.7	9.5	0
Feathers	57.7	9.5	30.8
Total of regurgitations	26	21	13

Discussion

The data gathered during this study suggests that the population of Madeiran Storm-petrel breeding on Farilhão Grande Islet has remained relatively stable since its discovery back in 1980. There are currently no direct threats to the population, but preventive management actions are recommended to reduce risk of invasion by terrestrial predators and undue human disturbance.

The evaluation of the vocal nocturnal activity to get information about the distribution and size of a population has been applied to many species of Procellariifomes (Monteiro *et al*., 1999, Bolton, 2001). Breeding is confirmed when nocturnal activity is regularly recorded and an estimate of abundance is obtained from the intensity of the calls of flying birds. The highest mean rate recorded in this work was 17.89 calls/min in October 2012. This rate was higher than the one recorded by Magalhães in 2003 (15.4 calls/min), but much lower than the rate recorded by Bolton (2001) in Ilhéu da Praia, Azores (28.1 calls/min), where the population of Madeiran Storm-petrel was estimated in 200 breeding pairs (Monteiro *et al*., 1999).

Bolton (2001) showed that factors such as the phase of the breeding season, the wind and the moon phase, can have effects on the surveys of the nocturnal vocalizations. The monitoring of October was made during the laying time of the breeding season, as well as in a last quarter moon night with wind strength of 2 (Beaufort scale). Bolton (2001) noticed, that the higher call rates were recorded when there was less light intensity, and that there is a decline in the mean call rate during the course of the breeding season. As shown by the results of this study, the time of the breeding season does seem to influence the call rate. In August and December the call rates were very low, as in August is too early in the breeding season, so there are very few Madeiran Storm-petrels present in Farilhão Grande, and in December the breeding season is coming to an end, hence the low call rates registered in this visit. During October is the laying time of the breeding season, so there are high numbers of Madeiran Storm-petrels in the islet, hence the higher call rates shown in the results. In this study the phase of the moon had no influence in the call rate, as the visibility was similar during the surveys (first quarter phase in November 2011 and August 2012, and last quarter phase in October and December 2012).

According to Bolton (2001), the wind speed can influence the mean call rate, but as he verified, there was no influence of this factor in winter populations. It is impossible to assess the effect of the wind without eliminating other variables, but in this work we think there were no differences in call rates relating to the conditions of the wind.

The time of the night only showed influence in the call rates of the October visit, but in general there is no pattern showing influence of the time of the night during the surveys. This is in accordance with the conclusions of Bolton (2001) for winter populations of Madeiran Storm-petrel.

Vocalization surveys reveal presence or absence and relative abundance of birds in inaccessible habitats with relatively low cost and effort, when other methods might be impractical. During a survey, one single bird could be responsible for various vocalizations, so the number of vocalizations does not directly indicate the number of birds in the area (Keitt, 2005). The measurement of nocturnal vocalization rates may be a valuable technique for assessing the relative abundance of birds, and for determining the annual or seasonal variations in the colony size, in

conjunction with more established methods, such as the use of mist nets, and sound devices with the calls of Madeiran Storm-petrel near the nets (Furness & Baillie, 1981; Ratcliffe *et al*., 1998). Judging by the results of this work, the nocturnal call rate is useful to understand the higher or lower abundance of birds in a certain area, but it's not a valuable method do determine the size of a population, by itself. Surveys for nocturnal vocalizations are useful in determining the locations of Storm-petrels colonies (Radcliffe *et al*., 1998) and in the case of Farilhão Grande, in determining the locations with higher concentration of nests, but for more detailed work it presents more difficulties, because the numbers of non-breeding birds will be higher and the visual detection of suitable habitat is impaired. Call rates should be measured during the early stages of the breeding season, when breeding males are most vocally active and few non-breeders are present (Ratcliffe *et al*., 1998), but there's always some error related to the non-breeders. More research is necessary to establish if nocturnal call rate could be used alone to census populations, without the need to use any other measure of population size.

The population estimate obtained using Lincoln's method, based on the data from the CMR of October 2013, suggests a population of 473.3 (±163.9) individuals. This result is higher than the 258.3 individuals estimated by Magalhães (2003), but it's close to the 200-400 pairs estimated by Granadeiro *et al*. (1998), and it is much higher than the 50 pairs of Madeiran Storm-petrels estimated by Teixeira & Moore (1983). The results of this study suggest a relatively stable population of Madeiran Storm-petrel in Farilhão Grande, considering the larger area covered in this work. The capture of individuals marked in previous works should be noted, at least 2 marked in 1994 and 2 in 2002, showing birds at least 17 and 9 years old, respectively. The capture-mark-recapture technique is an established method used for population estimation in many ecological studies. However, as for the nocturnal vocalizations, wandering non-breeders may represent a problem for this method, as they may comprise a big and variable proportion of the capture rate at colony sites (Furness & Baillie, 1981).

Some precautions should be taken before assessing any trends of this population, because the covered area in this work is very large comparing to previous works, and this should be taken into consideration when comparing results. This factor in considered crucial to estimate absolute values. The sampled area in 2002 may have been significantly smaller, as only four mist nets were used, and a smaller number of petrels was captured in the course of 3 nights (82 on the 1st and 2nd nights and 62 on the 3rd). There are several works showing that petrels are loyal to a certain place (e.g. van Franeker, 2001), and so this capture-mark-recapture method may tend to relate only to the number of individuals in a certain area of the island.

Something to take into consideration as well, is that a great portion of the adult Madeiran Storm-petrels found in nests in the Northwest, North, Northeast and East slopes of the island, were marked, but none of the birds found in the south side of the island was marked, which shows insufficient coverage of the capture method, and thereafter an underestimate of the population. For locations like small islets, the capture-mark-recapture method may be adequate, because almost all the area can be covered by capture nets.

We directly counted 68 nests, and checked the 20 artificial nests. An estimate of the population size based on the number of nests found, gives us a total of 136 individuals, which is not in accordance to the estimate from the CMR method. This shows that probably a lot of potential nesting sites were not found. The nests of the Farilhão Grande are found underneath Hottentot fig, in small burrows on the ground, close to rocks or underneath them.

The number of nests counted in 2012-2013 is much higher than the number counted in the previous season. This is probably due, mainly, to the increase of the ground searched area. The South area of the island has the higher density of nests, where we found 15 nests in an area of about 20 m^2. This method works best when all the areas of a location are easily accessible, which isn't the case of the Farilhão, where there must be many more nests that were not counted, due to the difficulty of reaching certain areas of the island. We also calculated the occupation and hatching rates for the nests found during this visit, and although these are important values, they are limited to only one visit. Also, when looking at the occupation and hatching rates, it must be taken in consideration that they were calculated for the nests checked, and if the rates for the entire island would be calculated, they could be different.

The results from the occupation and hatching rates calculated for each nest substrate found during the ground search show the preference of the Madeiran Storm-petrel for nesting in rock and rock + Hottentot fig substrate. Considering the large area ground searched, the natural vegetation doesn't seem to be relevant to the Madeiran Storm-petrel. At the time of the ground search the natural vegetation was very developed and only 2 nests were found associated to it.

From the measurements taken from the entrance of the nests, we verified that bigger nests are more vulnerable to disturbance and predation. It was in nests with the entrance larger than 145mm that we found 2 preyed Madeiran Storm-petrels (1 adult and 1 chick). The number of smaller nests (<150mm) was greater than the number of larger nests, and also there were more eggs and chicks on the smaller nests. Based on these results and the results of the nest substrates we presume that this is the preference of the Madeiran Storm-petrel: small nests in rock substrate, where they are more protected from any external disturbance.

During this work we built 36 artificial nests. With the recovery of the walls built by Magalhães (2003), we expect to count on 25 nests already available in 2002, making a total of 61 artificial nests in Farilhão Grande. Although only 1 nest has been subject of a failed breeding attempt and on other 3 we have found evidence of Madeiran Storm-petrel activity inside, it's very likely that, during the following seasons, a higher portion of these nests will be occupied successfully. In previous works (Bolton, 2004) the occupation rate of artificial nests was as high as 27-41%, and the nesting rate of the artificial chambers was 10-19%, and although during this work there were sound devices near the artificial nests, with the nest call of the Madeiran Storm-petrel, in Farilhão Grande there's no need for sound devices, due to the small size of the islet, the placement of the artificial nests near natural nests, and the proximity between natural nests.

Teixeira (1983) counted 200 pairs of Yellow-legged Gull in every islet of the Farilhões group. Granadeiro *et al*. (1998) counted a population of 100-300 pairs in just the Farilhão Grande. In this

work we counted 172 breeding pairs in the island, which suggests a decrease of the population since the census made in 1998, although over the last 15 years the population seems to not have changed considerably. The presence of Yellow-legged Gulls on the island outside of their breeding season is also constant, counteracting the almost absence of the species outside the breeding season reported for the beginning of the 90's (Granadeiro *et al*., 1998). It would be important to understand which factors are responsible for this variation, including the control actions performed since 1994 in the Berlenga Island. These actions included the control of adults between 1994 and 1996, killing 38 000 Yellow-legged Gulls. Since the factors causing the growth of the population didn't change, in 1999 it was implemented an annual measure of egg control, in an attempt to reduce the number of Yellow-legged Gulls being born and stabilize the population growth. Since 1999, 60 000 eggs *per* year are made unviable in Berlenga Island, which has restrained the growth of the Yellow-legged Gull population (ICNB, 2007).

During the season of 2012-2013 the impact of the population of Yellow-legged Gulls on the population of Madeiran Storm-petrel was assessed by analyzing gull regurgitations and counting of the number of gulls using the island through the year, especially during the Madeiran Storm-petrel's breeding season.

In this work we tried to assess if the pressure by the gulls on the Madeiran Storm-petrel could have adverse effects on its long term survival. Although the Yellow-legged Gull is a known predator of small seabirds in the Mediterranean (Oro *et al*., 2005), in all the regurgitations analyzed, no evidence of predation on Madeiran Storm-petrels was found. These results suggest that the population of Yellow-legged Gull does not represent an important threat to the population of Madeiran Storm-petrel in Farilhão Grande. The only evidence of predation was found on two Madeiran Storm-petrels dead at the entrance of their nests, but it is not certain if they were preyed by gulls. It should be noted that the island is visited by other species that can predate on Madeiran Storm-petrels, namely nocturnal birds of prey.

The Farilhão Grande is exposed to the action of erosive agents and that diminishes the availability of breeding grounds by degradation of the habitat. We theorize that Cory's shearwater may present a threat to the nests of Madeiran Storm-petrel, as they are present in great numbers in Farilhão Grande and have been reported excavating nests of small petrels (Ramos *et al*., 1997). Another potential threat to this population is the disturbance by humans and, particularly, the risk of introduction of predatory species on the island.

Draft Action Plan for Madeiran Storm-petrel

The main potential threats for this population are: loss of habitat by erosion factors, intensive predation by increased population of gulls and disturbance by humans with possible risk of introduction of predatory species on the island. Below, we identify some actions which can be included in a Conservation Plan for this species.

Improving nesting conditions (priority: medium): In order to improve the breeding conditions for Madeiran Storm-petrels, we propose building more artificial nests. Despite the fact that nests built with stones in previous work (2003) did not show evidence of occupation in 2012, in 2011 six nests were found occupied, including one with chick. The nests built with stones are greatly exposed to the effects of erosion, a problem that is amplified by the steep terrain. The nests can be fixed or improved in annual visits to the island just before the breeding season. In the long term this action will probably deliver positive results. In fact, these nests present the preferred features showed by the Madeiran Storm-petrel, having a small entrance and being secure, and they were shown to be readily accepted in other islands (Bolton, 2004). There should be an annual monitoring of these artificial nests at the beginning of each breeding season and if there is occupation of the artificial nests, the implementation of more should be promoted. For future works, it might be useful to place a small device fixed to the ground of the artificial nest, which can be moved by the bird, or even cameras if possible, to better assess the visiting rate. The use of this type of artificial nest is important for managing the population, since it has a low cost and makes the monitoring of the nests very easy.

Monitoring and maintaining the habitat (priority: medium/high): Most of the vegetated area in Farilhão is currently occupied by Hottentot fig *Capobrotus edulis*, which was probably introduced when the small light-house was being built. The original vegetation (composed of *Arisarum vulgare, Armeria berlengensis, Asplenium marinum, Beta maritima, Bromus rigidus*, *Calendula suffruticosa algarbiensis, Chenopodium murale, Cochlearia danica, Crithmum maritimum, Dactylis marina, Desmazeria marina, Frankenia laevis, Leontodon taraxacoides, Lobularia marítima, Mercurialis ambígua, Orobanche amethystea, Plantago coronopus, Polycarpon alsinifolium,* Violet *Romulea bulbocodium bulbocodium, Sagina maritima, Schrophularia sublyrata, Seneco gallicus, Silene latifolia mariziana, Sonchus oleraceus, Spergularia rupícola, Suaeda vera, Umbilicus rupestres, Urtica membranacea* (PORNB)) has only remained in relatively small areas, and currently have a very minor territorial expression. The expansion of Hottentog fig has ensured a considerable amount of nest sites for the Madeiran Storm petrel, and its sudden elimination would have severe impacts in terms of increased erosion and destruction of nest cavities. Furthermore, removing a significant part of this exotic species would be logistically challenging. Therefore, a detailed mapping of the vegetation should be undertaken and areas with original flora should be identified. Essays in these areas should aim at expanding the original vegetation, at the expense of introduced species.

Monitoring the breeding population (priority: high): The monitoring of the nests and, to a lesser extent, the capture-mark-recapture method, using the same 8 nets as used in this work in order to enable comparison of results, should ensure an accurate assessment of the population in the future. A major effort should be undertaken to standardize the monitoring efforts (e.g. by detailed mapping of individual nests), to enable long-term comparisons. The monitoring of the nests should consist in two surveys carried out each year: at the beginning and at the end of the breeding season. The 1st survey should aim to count the number of pairs attempting to breed, by counting the occupied nests, and the 2nd should aim to determine the breeding success by counting the number

of fledged young. This should be made annually for the next 5 years and, afterwards, once every two years, to detect any critical changes to the stability of the population. There should be research for other potential breeding areas, namely the other islets of the Farilhões group.

Controlling the access to the island (priority: high): The Farilhões are part of the Total Protection Area of the Berlengas Natural Reserve, and so it is interdicted the entrance on the islet without ICNF's authorization. However, there's a gap in the legislation: the reserve is divided in terrestrial area and marine area, being the intertidal zone included in the marine area. This part of the Farilhões is not included in the Total Protection Area, as well as the intertidal of the other islets, there being nothing to prohibit activities at the time of low tide, as long as it's behind the tide line. The access to the island should require, in addition to the ICNF's authorization, prior warning to the wardens, and all visitors should be briefed into the risks of introducing invasive species, the code of conduct on the reserve and also of safety measures.

Monitoring the evolution of Yellow-legged gulls (priority: high): We strongly recommend the onset of a monitoring program of Yellow-legged gulls *L. michahellis* in Farilhão, both during the breeding and wintering season. Data from the breeding season would be an important complement in relation to the control program currently carried out by ICNF targeted at this species. Any growth in the wintering population should be carefully monitored as this species can produce severe impacts in storm-petrel populations (e.g. Oro, 2005; Catry, 2010). The effectiveness of deterrent device to avoid gull roosting in the islands could be tested (e.g. using falcon call during the day or sounds). For future works concerning the potential effects of the Yellow-legged Gull population on the Madeiran Storm-petrels, we suggest the use of phototraps, which showed its potential in other studies with Procellariiformes (Oliveira *et al*., 2013) (although it's only useful if the disturbance or predation happens near the nest), and direct observation with image intensifier' binoculars in visible moon nights or with infra-red light. Given the relatively low effort required, we suggest that monitoring of the population of gulls should be made regularly (every year) to keep track of the size of the population, as a preventive measure.

Education and dissemination (priority: medium): Lastly, the natural values of the Berlengas Natural Reserve should be promoted and advertised, and the wardens of the Reserve should be trained in monitoring, management and some technical aspects of the research programs. Actions for public information should be promoted.

Research (priority medium): Current research effort should be targeted at obtaining vital statistics for this population, including its size, population structure, breeding success, and annual survival. The existing technology (and the small population size) does not encourage the generalized use of light-level geolocators, except with extreme caution. Nonetheless, it may be worth making some preliminary tests with the lightest geolocator to identify of non-breeding areas. Some effort should also be devote to improving the reliability of monitoring methods for small petrels.

Final remarks

The Madeiran Storm-petrel colony in Farilhão Grande is the only mainland Storm-petrel colony in Portugal and in the Atlantic coast of Europe and contributes to the relatively low diversity of breeding seabirds in mainland. This study suggests a relatively stable population of Madeiran Storm-petrel in Farilhão Grande, and the measures suggested in the draft action plan should be taken in order to maintain this stability or even increase the numbers.

One of the reasons the artificial nests were not occupied during the time of the study was the fact that they were already built during the breeding season, but we expect this action to be important and effective as a measure of habitat management and conservation for this species.

The residual effect of the wintering Yellow-legged Gull population on the Madeiran Storm-petrel should be noted. A regular monitoring program should assess any significant increase in numbers, which could become a cause for concern for the stability of Madeiran Storm-petrel population.

Despite being an exotic invasive plant, the Hottentot fig revealed importance for protection of the nests, not only of Madeiran Storm-petrel, but also of Cory's Shearwater. Any actions of regeneration of natural vegetation of the island should take this into account.

In order to enable the continued monitoring of the population of Madeiran Storm-petrel in Farilhão Grande, future work should use the same methods as this work, to allow comparison of results.

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References

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

Baillie, J. E., Hilton-Taylor, C., Stuart, S. N. (2004). IUCN Red List of Threatened Species. A Global Species Assessment. *IUCN, Gland, Switzerland and Cambridge, UK*. XXIV: 191 pp.

Belda, E. J., Sánchez, A. (2001). Seabird mortality on long line fisheries in the western Mediterranean: factos affecting bycatch and proposed mitigating measures. *Biological Conservation* 98: 357-363.

Bibby, C. J., Burgess, N. D., Hill, D. A. (1992) Bird Census Techniques. *British Trust for Ornithology and the Royal Society for the Protection of Birds*: 257.

Bolton, M. (2001). Development and evaluation of techniques for monitoring threatened procellariiform species in the Azores archipelago. *Small Project Grant RSPB/Birdlife Final Report* (*not published*)

Bolton, M. (2007). Playback experiments indicate absence of vocal recognition among temporally and geographically separated populations of Madeiran Storm-petrels *Oceanodroma castro. Ibis* 149: 255-263.

Bolton, M., Campos, A., Hothersall, B., Medeiros, R. (2004). The use of artificial breeding chambers as a conservation measure for cavity-nesting procellariiform seabirds: a case study of the Madeiran storm petrel (*Oceanodroma castro*). *Biologica Conservation* 116: 73-80.

Bolton, M., Bried, J., Friesen, V.L., Furness, R. W., Gómez-Díaz, E., Medeiros, R., Roscales, J. L., Smith, A.L. (2008). Monteiro's Storm-petrel *Oceanodroma monteiroi*: a new species from the Azores. *Ibis* 150: 717-727.

Brooke, M. D. (2004). *Albatrosses and Petrels Across the World (Bird Families of the World)*. Oxford University Press, Oxford.

Cabral, M. J., Almeida, J., Almeida, P. R., Dellinger, T, Ferrand de Almeida, N., Oliveira, M. E., Palmeirim, J. M., Queirós, A. I., Rogado, L., Santos-Reis, M. (2005). Livro Vermelhos dos Vertebrados de Portugal. *Instituto da Conservação da Natureza*: 659p.

Cowx, I. G. (Ed.). (2003). *Interactions between fish and birds: implications for management*. Fishing News Books.

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

Del Hoyo, J., Elliot, A., Sargatal, J. (1992). Handbook of the Birds of the World. Barcelona: Lynx Editions.

Duhem, C., Roche, P., Vidal, E., Tatoni, T. (2008). Effects of anthropogenic food resources on yellow-legged gull colony size on Mediterranean islands. *Population ecology*, *50*(1): 91-100.

Exo, K. M., Garthe, S., Huppop, O. (2003). Birds and offshore wind farms: a hot topic in marine ecology. *Bulletin-Wader Study Group*, *100*: 50-53.

Fisher, J., Lockley, R. M. (1954). *Sea-birds*. Collins.

Fiúza, A.F. (1983). Upwelling patterns off Portugal. *Coastal Upwelling its sediment record. Springer US*: 85-98.

Fiúza, A. F., Guerreiro, M. R., Macedo, M. E, (1982) Climatological space and time variation of the Portuguese coastal upwelling. *Oceanologica acta*, vol. 5, no. 1.

Furness, R. W., Baillie, S. R. (1981). Factors affecting capture rate and biometrics of Storm Petrels on St Kilda. *Ringing & Migration*, *3*(3): 137-148.

Furness, R. W., Ensor, K., Hudson, A. V. (1992). The use of fishery waste by Gull populations around the British Isles*. Ardea 80*: 105-113

Gardner, P., Wilson, K. (1999). Burrow competition between Chatham petrels and broad billed prions: the effectiveness of burrow blockading as a management strategy. *Science for Conservation* 131B: 23-37.

Gomes, C., Draper, D., Marques, I., Rosselló-Graell, A. (2004) Componente Vegetal do Plano de Ordenamento da Reserva Natural das Berlengas.

Granadeiro, J. P. (1995). O Estudo de aves marinhas em Portugal. *Chioglossa*, Vol. Esp. 1: 69-73.

Granadeiro, J. P., Catry, P., Dias, M. P., Rebelo, R., Santos, C. D., (2006). Numbers and Population Trends of Cory's Shearwater *Calonectris diomedea* at Selvagem Grande, Northeast Atlantic. *Waterbirds* 29: 56-60.

Granadeiro, J. P., Grade, N., Lecoq, M., Morais, L., Santos, C., Silva, M. C., (1998). Breeding Madeiran Storm-petrels *Oceanodroma castro* on the Farilhões islands, Portugal. *Proceedings of the IV Mediterranean Seabird Symposium: Seabird Ecology and Coastal Zone Management in the Mediterranean.*

Harris, M. P. (1969). The Biology of Storm-petrels in the Galápagos Islands*. Proceedings of the California Academy of Sciences* Vol. XXXVII, No. 4: 95-166.

Harrison, P., Baird, K. A., Dowdall, J., Enright, S., Fahy, K., Gaskin, C. P., Gilligan, J., Jaramillo, A., Lillie, G., Metz, S. M., O' Keeffe, M., Pearman, M., Sallaberry, M. (2013). A new Storm-petrel Species from Chile. *The Auk* 130(1): 180-191.

Howell, S., Feenstra, J. S., Hunefeld, W. T., Mcgrath, T. (2010). Occurrence and identification of the Leach's Storm-petrel (Oceanodroma leucorhoa) complex off southern California. *North American Birds* 63: 540-549.

Jesus, J., Brehm, A., Gomes, S., Menezes, D., Nogales, M., Oliveira, P. (2009). Philogenetic relationships of Gadfly Petrels *Pterodroma spp.* from North Eastern Atlantic Ocean: Molecular evidence for specific status of Bugio and Cape Verde petrels and implications for conservation. *Bird Conservation International* 19: 199-214.

Karpouzi, V. S., Pauly, D., Watson, R. (2007). Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment. *Marine Ecology Progress Series*, *343*: 87-99.

Keitt, B. S. (2005). Status of Xantus's Murrelet and its nesting habitat in Baja California, Mexico. *Marine Ornithology*, *33*: 105-114.

Le Corre, M., Jouventin, P., Ollivier, A., Ribes, S. (2002). Light-induced mortality of petrels: a 4-year study from Réunion Island (Indian Ocean). *Biological Conservation*, *105*(1): 93-102.

Lecoq, M., Andrade, J., Crisóstomo, P., Morais, L., Mourato, E. (2012) Censo da População Reprodutora do Corvo-marinho-de-crista no Arquipélago das Berlengas em 2012. *Relatório da Acção A – Actividade 2. Projecto FAME.* Sociedade Portuguesa para o Estudo das Aves, Lisboa (*not published*)

Lecoq, M., Andrade, J., Geraldes, P., Ramírez, I. (2011) First complete census of Cory's Shearwaters *Calonectris diomedea borealis* breeding at Berlengas Islands (Portugal), including the small islets of the archipelago. *Airo* 21: 31-34.

Lewison, R. L., Crowder, L. B. (2003). Estimating fishery bycatch and effects on a vulnerable seabird population. *Ecological Applications*, *13*(3): 743-753.

Lewison, R. L., Crowder, L. B., Freeman, S. A., Read, A. J. (2004). Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology & Evolution*, *19*(11): 598-604.

Magalhães, M. C. (2003) Monitoring Madeiran Storm Petrel *Oceanodroma castro* Population Size and Breeding Habitat Improvement on Farilhão Grande, Berlengas Archipelago, Portugal. *Portuguese Society for the Study of Birds, Final Report* (*unpublished*)

Matias, R., Catry, P. (2010). The diet of Atlantic Yellow-legged Gulls (*Larus michahellis atlantis*) at an oceanic seabird colony: estimating predatory impact upon breeding petrels. *European Journal of Wildlife Research*, *56*(6): 861-869.

Monteiro, L. R., Furness, R. W. (1998) Speciation through temporal segregation of Madeiran storm petrel (*Oceanodroma castro*) populations in the Azores? *Philosophical Transactions of the Royal Society Series B. Biological Sciences 353*(1371): 945-953.

Monteiro, L. R., Furness, R. W., Ramos, J. A., (1996) Past and present status and conservation of the seabirds breeding in the Azores archipelago. *Biological Conservation* 78: 319-328.

Monteiro, L. R., Bearhop, S., Feio, R. S., Furness, R. W., Groz, M. P., Hilton, G., Laranjo, M., Monteiro, P. R., Neves, V. C., Pereira, J. C., Ramos, J. A., Thompson, D. R., Thompson, K. R. (1999). Status and distribution of Fea's Petrel, Bulwer's Petrel, Manx Shearwater, Little Shearwater and Band-Rumped Storm-Petrel in the Azores Archipelago. *Waterbirds* 22 (3): 358-366.

Montevecchi, W. A. (2006). Influences of artificial light on marine birds. *Ecological consequences of artificial night lighting*: 94-113.

Oliveira, N., Lecoq, M., Andrade, J., Geraldes, P., Ramírez, I. (2013). Avaliação da predação de rato-preto *Rattus rattus* nas crias de cagarra *Calonectris diomedea borealis* da Ilha da Berlenga. *Projeto FAME. Sociedade Portuguesa para o Estudo das Aves*, Lisboa (*unpublished*).

Oro, D., Bosch, M., Ruiz, X. (1995). Effects of a trawling moratorium on the breeding success of the Yellow-legged Gull *Larus cachinnans*. *Ibis*, *137*(4): 547-549.

Oro, D., Furness, W. R., Léon, A., Minguez, E. (2005). Estimating predation on breeding European storm-petrels (*Hydrobates pelagicus*) by yellow-legged gulls (*Larus michahellis*). The Zoological Society of London 265: 421-429.

Pardal, M., Azeiteiro, U. M. (2001). Zooplankton biomass, abundance and diversity in a shelf area of Portugal (the Berlenga Marine Natural Reserve). *Arquipélago*. *Life and Marine Sciences* 18A: 25-33.

Ramírez, I., Amorim, P., Geraldes, P., Meirinho, A., Paiva, V. (2008). Áreas Marinhas Importantes para as Aves em Portugal. *Projecto LIFE04NAT/PT/000213, Sociedade Portuguesa Para o Estudo das Aves*. Lisboa

Ramos, J. A., Moniz, Z., Monteiro, L. R., Sola, E., (1997). Characteristics and competition for nest cavities in burrowing Procellariiformes. *Condor,* 99: 634-641.

Ratcliffe, N., Shepherd, M., Vaughan, D., Whyte, C., (1998). Development of playback census methods for Storm Petrels *Hydrobates pelagicus*. *Bird Study*, *45*(3): 302-312.

Rodríguez, A., Rodriguéz, E. (2009). Attraction of petrels to artificial lights in the Canary Islands: effects of the moon phase and age class*. Ibis*, 151: 299–310.

Sæther, B. E., Bakke, Ø. (2000). Avian life history variation and contribution of demographic traits to the population growth rate. *Ecology*, *81*(3): 642-653.

Sanz-Aguilar, A. (2008). Storm petrel demography and population dynamics at Benidorm island. Status and conservation of seabirds in the Iberian Peninsula, *GIAM 2008. SEO-BirdLife*.

Schreiber, E. A., Burger, J. (2001) eds. *Biology of marine birds*. CRC Press.

Stenhouse, I. J., Montevecchi, W. A. (1999). Indirect effects of the availability of capelin and fishery discards: gull predation on breeding storm-petrels. *Marine Ecology Progress Series*, *184*: 303-307.

Teixeira, A. M., Moore, C. C. (1983). The breeding of the Madeiran petrel *Oceanodroma castro* on Farilhão Grande, Portugal. *Ibis*, *125*(3): 382-384.

Van Franeker, J. A., Cleland, S., Creuwels, J. C., Robertson, G., van der Veer, W. (2001) Unexpected effects of climate change on the predation of Antarctic petrels. *Antarctic Science* 13: 430-439.

Zino, F., Biscoito, M., Buckle, A., King, S., Neves, H. C., Oliveira, P., Vasconcelos, A. (2001) Conservation of Zino's petrel *Pterodroma madeira* in the archipelago of Madeira. *Oryx* 35 (2): 128-136.

Resolução do Conselho de Ministros n.º 180/2008 de 24 de Novembro. Diário da República Nº 228/08 – 1ª série. Presidência do Concelho de Ministros. Lisboa

Biosphere Reserves, Portugal, Berlengas. Downloaded from http://www.unesco.org/ in 2012.

BirdLife International (2013) IUCN Red List for birds. Downloaded from http://www.birdlife.org in 2013.

Controlo do Crescimento da Colónia de Gaivota-de-patas-amarelas (*Larus michahellis*) da ilha da Berlenga. Downloaded from http://portal.icn.pt/ in 2012.

Appendix

A.

Scheduled visits for the field work, with the list of proposed activities. In grey are represented the visits initially planned and the "x" marks the visits made.

Activity	2011				2012					
	Oct	Nov	Dec	Jan	May	Aug	Sep	Oct	Nov	Dec
Capture and mark		x		x				x		
Nocturnal Vocalizations		x		x		x		x		x
Characterization and marking nests			x					x		x
Recovery of the artificial nests built in 2002-2003						x				
Building new artificial nests						x		x		
Assess of the occupation rate of the artificial nests								x		x
Monitoring the breeding success								x		x
Census of Yellow-legged Gull					x	x		x		x
Collect regurgitations of Yellow-legged Gull					x	x		x		x

B.

Nests of Yellow-legged Gull counted in May of 2012 in Farilhão Grande.