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COMMERCIAL FISHING AND ITS IMPACTS ON SEABIRDS WITHIN BERLENGAS ISLANDS SPECIAL PROTECTED AREA (PORTUGAL)

BACHELOR THESIS

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ABSTRACT

Title: Commercial fishing and its impacts on seabirds within Berlengas Islands Special Protected Area (Portugal)

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The bachelor thesis is partially elaborated as a review of literature focused on natural characteristics of Berlengas Islands Special Protected Area in Portugal, commercial fishery, its impacts on seabird populations and importance of monitoring fishing activities for eco-system based fishery management. The aim of the practical part was to determine preferred fishing areas during winter season within the study area. It required analysis of historical fisheries data obtained by the Automatic Identification System (AIS) and provided by non-profit organization Portuguese Society for Study of Birds (SPEA). Received historical data were analyzed for winter season within the years 2014, 2015, 2016 and January 2017 using ArcGis software, version 10.4.1. The resulting maps present spatial distribution of fishing boats, fishing methods and spots with their highest densities.

Key words: commercial fishery, fishing methods, impacts of commercial fishery on seabirds, sustainable fishery, automatic identification system, determining of fishing areas

ABSTRAKT

Autor: Karolina Mikslová

Název: Komerční rybolov a jeho dopady na mořské ptáky v ptačí oblasti Berlengas (Portugalsko)

Tato bakalářská práce je částečně vypracována jako literární rešerše zaměřená na popis přírodních charakteristik ptačí oblasti Berlengas v Portugalsku, popis komerčního rybolovu, jeho dopadů na populace mořských ptáků a významu monitorování rybářských aktivit pro udržitelné hospodaření v rybolovu. Cílem praktické části práce bylo určit v ptačí oblasti rybolovem nejvyužívanější plochy během zimního období. To obnášelo analýzu historických dat získaných Automatickým Identifikačním Systémem (AIS), poskytnutými neziskovou organizací Portugalská Společnosti pro Studium Ptáků (SPEA). Získaná data z roků 2014, 2015, 2016 a z ledna 2017 byla zpracována se zaměřením na zimní období za pomoci softwaru ArcGis, verze 10.4.1. Výsledné mapy zobrazují prostorové rozložení rybářských lodí, metod rybolovu a místa s jejich největší hustotou.

Klíčová slova: komerční rybolov, metody rybolovu, dopady komerčního rybolovu na populace mořských ptáků, udržitelný rybolov, Automatický Identifikační Systém, určování oblastí rybolovu

CONTENT

1. INTRODUCTION

Commercial fishery is one of the most important food supplies and source of live hood for millions of people around the world. Its methods can have serious impacts on the environment and animal species. Cases about dolphins, whales and sharks incidentally caught in fishing nets are generally known. Less known and attractive for public are impacts on different animal species – such as seabirds which are dying by the thousands annually, some of the species are found on the edge of extinction just because of fishing nets.

Project Life Berlengas coordinated by Portuguese Society for Study of Birds (SPEA) concentrates on sustainable management of Berlengas Islands Special Protected Area and interactions between commercial fishery and seabirds. Berlengas SPA is located near Peniche, one of the most important fishing ports of Portugal with deeply rooted fisheries tradition. At the same time it is an important zone for wide range of seabird species as a breeding, wintering or migrating area. Berlengas Archipelago situated approximately 10km from Peniche is home to resident population of European Shag *(Phalacrocorax aristotelis)*, the biggest in Portugal. Opened waters of this protected zone are annually used as wintering grounds by hundreds of Northern Gannets *(Morus bassanus)* or the most threatened seabird in Europe - critically endangered Balearic Shearwater *(Puffinus mauretanicus)*. This region already holds a sad story warning about the negative impacts of commercial fishing on biodiversity since 2002 when the last pair of Common Murre *(Uria aalge)* had been recorded for the last time. The sharp decline of the population was caused by excessive use of synthetic fishing nets, reduction of food resources through overfishing and water contamination by hydrocarbons.

Therefore it is important to study and monitor fisheries activities, which is the main interest of this work. Where the preferred areas used by fishing boats are known, the focus on biodiversity conservation can be directed. I was happy to take the opportunity and work in SPEA as a trainee for two months. Hopefully my work about identification of fishing areas will be useful contribution to conservation efforts of Life Berlengas Project.

2. LITERATURE REVIEW

This chapter presents Portuguese Society for Study of Birds (SPEA) and its Life Berlengas Project within which this work was implemented. Therefore it describes the study area and problematic of commercial fishery, its impacts with focus on seabird populations and sustainable fishery management.

2.1 SPEA and Life Berlengas Project

"SPEA - The Portuguese Society for the Study of Birds is a scientific non-profit environmental organization that works for the conservation of birds and their habitats in Portugal. It is part of a worldwide network of environmental organizations, BirdLife International, which operates in 120 countries and aims to preserve biological diversity through the conservation of birds, their habitats and the promotion of sustainable use of natural resources" (Almeida et al., 2016). "SPEA's mission is to support research and conservation of birds and their habitats, promoting a development that ensures the viability of the natural heritage for the benefit of future generations. Due to its work SPEA is recognized since June 2012 as a public utility institution" (Berlengas, 2017).

"The project LIFE Berlengas began on 1 June 2014 will be implemented by 30 September 2018 and it is co-financed by the European Commission under the LIFE + program. It is coordinated by the Portuguese Society for the Study of Birds in partnership with the Institute for Nature and Forestry Conservation, the Peniche City Council and the Faculty of Social and Human Sciences of the New University of Lisbon, Of Tourism and Technology of the Sea of the Polytechnic Institute of Leiria as an observer" (Almeida et al, 2016).

The project contributes to the sustainable management and conservation of both of the Berlengas Islands SPA habitats, marine and insular. It is aiming to develop strategies to minimize or remove the main threats for seabird populations and endemic plants. At the same time the project promotes the sustainable use of the Berlengas Islands SPA, focusing on three key activities: fishing, recreational activities and tourism (Berlengas, 2017).

2.3 Study Area

The Special Protected Area of the Berlengas Islands (Berlengas Islands SPA) covers 102 668 ha and it is located in the Atlantic Ocean, on the continental shelf of the southwest of Portugal (39°23'N, 9°36'W). It comprises of 104ha of terrestrial area constituted by the Berlengas archipelago, situated 5.5 nautical miles (about 10 km) of Peniche and it is formed by Berlenga Island, the Estelas islands and the Farilhões-Forcadas islands. The remaining area consists of open sea (Almeida et al, 2016). The altitude ranges between 0-94 m.s.n.m (Costa et. al., 2003).

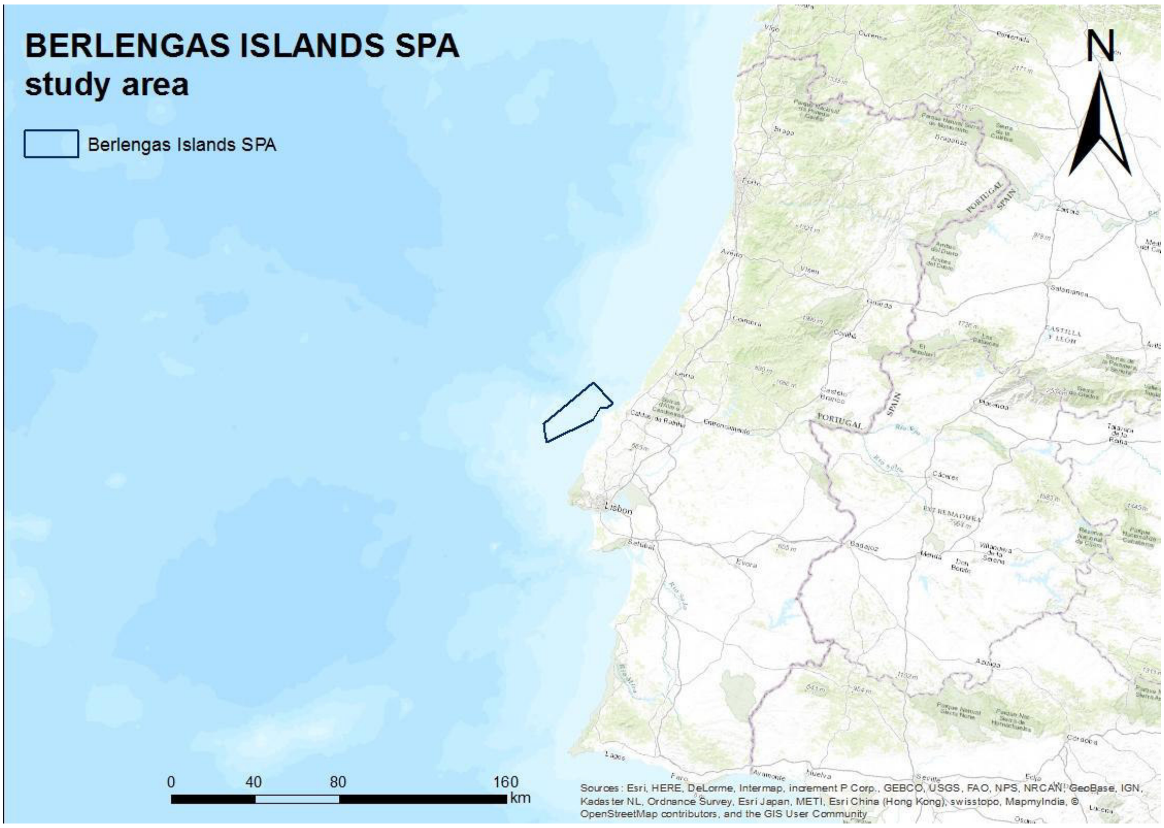


Figure 1 Location of the study area

2.3.1 Natural conditions

According to the book "Ekologie a rozšíření biomů na Zemi" Berlengas Islands SPA belongs to the marine biomes including marine ecosystems and ecosystems of seashore. Terrestrial part of the reserve within Berlengas archipelago is considered as an island ecosystem which is part of the marine biome. Significant ecosystems of Berlengas archipelago represent the rocky shore significant for bird colonies; rocks wetted by salt-spray, sand and pebble beaches. The islands are covered by low vegetation which consists of perennial, multiannual and annual herbs, indigenous and exotic species (Prach et al., 2009).

Geological composition of the archipelago differs greatly from Iberian Peninsula. It consists of complex of granitic and metamorphic rocks, and is the last remnant of the Hercynian orogeny during Carboniferous and Devonian as the result of the collision of Gondwana and Euramerica supercontinents (Berlengas, 2017).

According to Jeník and Pavliš (2011) is the climate characterized by dry summers and winter rainfalls. Humid and spring conditions last about 5 months. The average annual rainfall estimates range from 500 to 600 mm. The average annual air temperature is around 15℃, in the summer monthly averages between 18 and 20℃ (Jeník and Pavliš, 2011).

SPA Berlengas was established in 1999 within Natura 2000. In 2012 the area was 10x extended to the marine environment as a result of the project LIFE + IBAS Marinhas (2004-2008), also under the leadership of SPEA (Pardela, 2015).

The area of the Berlengas Islands SPA overlaps with other conservation designations, such as Berlengas Nature Reserve and Berlengas Archipelago and Biosphere Reserve (Almeida et.al, 2016).

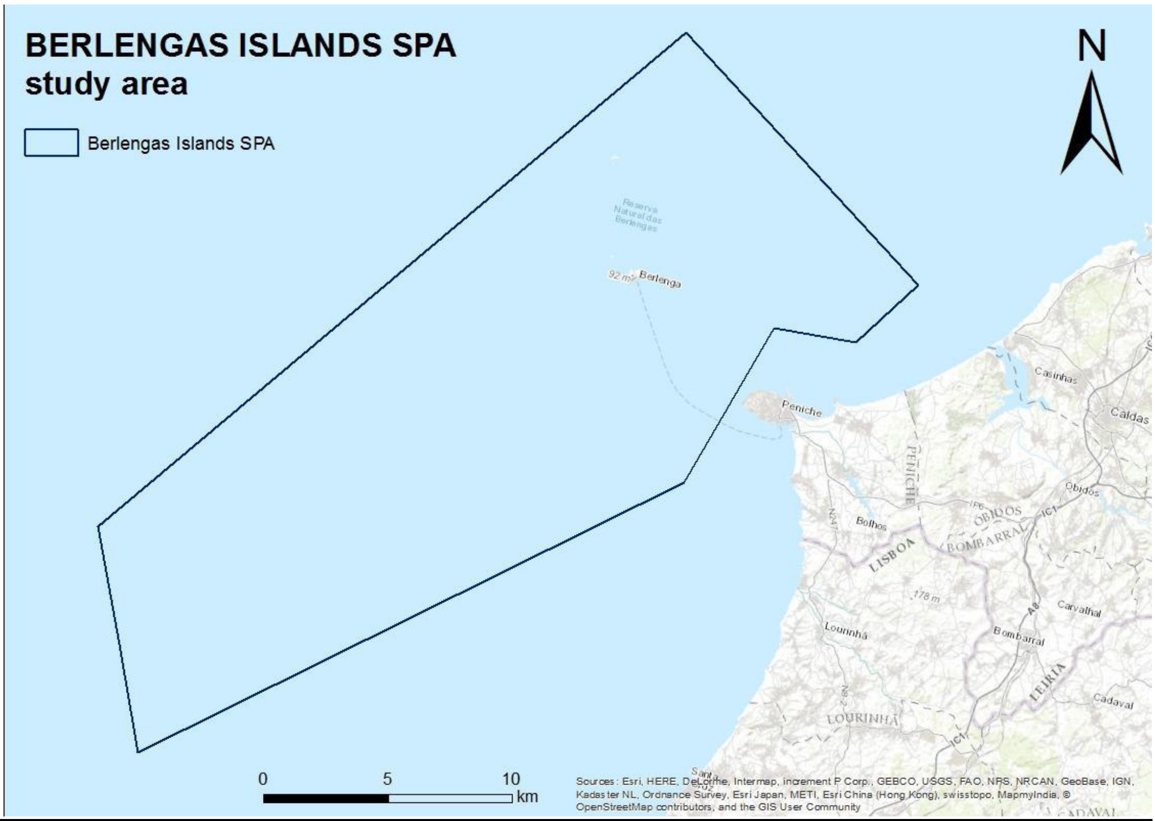


Figure 2 Map of the study area

2.4 Biodiversity of Berlengas Islands Special protected Area

"The geographical location of the Berlengas Islands SPA converges both Atlantic and Mediterranean climates, which is the basis of a high biological productivity of this area" (Meirinho et al., 2014). Berlengas Islands SPA has an ecological heritage with high conservation value, both in terms of its insular ecosystem that encompasses endemic plants, protected habitats and the breeding grounds of endangered seabirds, as well as the surrounding vulnerable marine ecosystem, one of the richest across the Portuguese coastal waters (Berlengas, 2017).

2.4.1 Fauna

The main part of the Berlengas Islands SPA extends in open sea, terrestrial part covers only 104ha (Almeida, 2016). "The zone is located south of the submarine canyon of Nazaré, on the edge of the continental shelf and in a maritime region known for its relatively high biological productivity" (ICNF, 2017).

Beside fish, representatives of fauna most affected by fishing activities in the SPA are various species of seabirds. The area, both on land and at sea, has great ornithological value. It is a breeding, wintering and migrating area of many seabird species, including the most threatened one in Europe - critically endangered Balearic shearwater (*Puffinus mauretanicus*). This species nests only in the Balearic Islands, in Spain. It occurs throughout the year in the SPA, near the continental coast, being more abundant during summer post-reproduction migration and in the autumn, with the onset of pre-nuptial migration (Meirinho et al., 2014). "Although in Portuguese waters the abundance of the species is not known in detail, there are regular records of concentrations with several hundred individuals, sometimes reaching thousands" (Meirinho et al., 2014). This species is undergoing an extremely rapid decline, the breeding population is estimated at only 2000 pairs (Dunn et al., 2007). "The main threats to the Balearic shearwater population are lack of breeding habitat, predation when breeding and incidental mortality during fishing activities" (Costa et al., 2016).

The SPA area is regularly used by northern gannet *(Morus bassanus)*, the largest seabird of Europe (Costa et al., 2011). It is present throughout the year, with a major interest during the winter and during pre-nuptial (January and February) and autumnal (September to November) migrations. The northern gannet *(Morus bassanus)* reproduces in the North Atlantic. It is an exclusively marine species that occurs in strong association with the waters of the continental shelf and slope. Outside the breeding season, it does not land on land (Meirinho, et al 2014). "The total wintering population in Portugal is unknown; however, frequent observations of the passage of thousands of individuals at various points along the coast have been recorded" (Almeida et.al, 2016).

Gray Petrel (*Calonectris bolelis*) lives most of his life in the open sea, it arrives to nest in the islands between February and last fledglings leave the nest in early November.

During this period it is common to hear its typical night-call. Population in 2011 was estimated at 1,000 pairs and is listed as a vulnerable species (Pardela, 2015).

Band-rumped storm-petrel (*Hydrobrates castro*) poses with his 20 cm body length the smallest bird species in the archipelago (Berlengas, 2017). This species nests only on the Farilhões islands between September and February. Local population was estimated at 200 pairs and its population decreases (Meirinho et al., 2014). In Portugal the species is listed as vulnerable (Pardela, 2015).

Rocky coasts of the islands are important for colonies of European shag (*Phalacrocorax aristotelis*), indigenous species of the archipelago. Cormorant population on the island Berlenga is regularly monitored. Nowadays this population represents the largest population in Portugal with approximately 80 nesting pairs (Pardela, 2015).

Throughout the year there is abundant yellow-legged gull (*Larus michahellis*). Gull is present in colonies close to the mainland and does not fly far out to sea. On the island is overpopulated and causes problems affecting native fauna and flora.

The waters of the SPA, around the archipelago especially, host a great diversity of fish, such as European seabass (*Dicentrachus labrax*), species of sea bream (*Diplodus* spp.), red porgy *(Pagrus pagrus)*, rainbow wrasse (*Coris julis*), grey triggerfish (*Balistes capriscus*) or ocean sunfish (*Mola mola*). The dusky grouper (*Epinephelus marginatus*), a species of great conservation value, arises mainly near the Farilhões islands (ICNF, 2017).

In the 1950s the surrounding area of the Berlenga Island was still important place of spawning of the school shark (*Galeorhinus galeus)* (ICNF, 2017).

The presence of large schools of sardines (*Clupeidae*) and other planktonic species (which feed on plankton) motivates the presence of several species of marine mammals, namely the common dolphin (*Delphinus delphis*), the harbour porpoise (*Phocoena phocoena*), the striped dolphin (*Stenella coeruleoalba)* dolphin, the common mink whale *(Balaenoptera acutorostrata)* and the Cuvier's beaked whale (*Ziphius cavirostris*) (ICNF, 2017).

In the coastal zone and rocks wetted by salt-spray representatives of crustaceans, molluscs, barnacles and echinoderms can be found. These include crabs (*Pachygrapsus* *marmoratus*), octopus (*Octopus vulgaris*), *Pollicipes Pollicipes* commonly known as the gooseneck barnacle, black sea cucumber *(Holothuria forskali)* or spiny starfish *Marthasterias glacialis* (Berlengas, 2017).

Terrestrial area, in addition to significant importance as a nesting spot for many seabird species, is home to an endemic lizard *Podarcis carbonell berlengensis*, subspecies of Carbonell's wall lizard (*Podarcis carbonell)* endemic to the Iberian Peninsula. Like in many islands around the world, with the arrival of humans some invasive species were brought to the islands such as black rat (*Rattus rattus*) and rabbit (*Oryctolagus cuniculus*). Their presence negatively affects native fauna and flora. The main threat is predation on birds' nests caused by rats. It is very likely that for this reason band-rumped-storm petrel nests only in the Farilhões islands, where the rat is absent. Rabbit, as an herbivore, eats all plants, which leads to destruction of vegetation. In some places, large areas are already completely free of vegetation. Another problem is related to the construction of tunnels and burrows, which changes the structure of the earth and contributes to the rapid erosion process (Berlengas, 2017; Pardela, 2015).

2.4.2 Flora

Among the most important species on the islands include three endemic species: Berlengas Thrift *(Armeria berlengensis)*, Berlengas Rupturewort *(Herniaria berlengiana)* and Berlengas Fleabane *(Pulicaria microcephala)*. Critically endangered *Armeria* is a shrub with a diameter of about 40 cm, and blooms between April and August. The flowers are small, pale pink and grouped in inflorescences at the end of a long stalk. It is easy to recognize because of the shape resembling a pillow. In recent years *Armeria* suffered a sharp decline, so its protection is urgent. *Herniaria* is a biennial or perennial succulent herb blooming between March and July. It grows close to the ground in the form of rosettes. IUCN red list states *Herniaria* as a vulnerable species. *Pulicaria* is a small, highly branched plant. Yellow flowers appear between March and July. Other important species of flora include *Angelica pachycarp*, *Mesembryanthemum crystallinum*, *Dactylis lithium* and another, also endemic species of the Iberian Peninsula.

Major threat represents an invasive Hottentot-fig *(Carpobrotus edulis)* from the *Aizoaceae* family. It was brought to the island by men for ornamental purposes, originally comes from South Africa. It covers vast areas on the islands and prevents the spread of native species. It is a perennial succulent herb with creeping up to 3 m long stem. The flowers are pale yellow, the colour gradually changed to a pale pink. The fruit is fleshy capsule. It blooms in spring and during the summer (Flora-on, 2016; Berlengas, 2017).

2.5 Fishing as a natural resource, methods, impacts and monitoring

This chapter presents fishery and its economical importance and its main impacts causing decline of seabird population. Second part explains what role plays determining fishing areas in sustainable fishery and its use. In the third part Automatic Identification system is introduced as a tool for fishing fleet monitoring, its process and use in eco-system based fishery with intention to emphasize some advantages and disadvantages of this system.

2.5.1 Fishery as a natural resource

Commercial fishery is nowadays one of the most important food supplies and direct source of live hood for around 2 billion of people around the world that live near the coast (Kaiser et al., 2011). Prach (2009) claims that less than 10% of human food comes from sea. Fisheries products are an important source of protein and a crucial component of a healthy diet. The EU's new Common Fisheries Policy states that average European consumes 24.9kg of fish or seafood per year (6 kg more than in the rest of the world), in Portugal the amount reaches 56.8 kg per person (EC et al., 2016). Fishing provides employment for millions of people - especially in the developing world (Kaiser et al., 2011). Altogether, fishing and fish farming support the livelihoods and families of the 12% of the world’s population (FAO, 2017). In Portugal, the whole fishing industry including aquaculture, processing and marketing, accounts for 38.8% of national employment (Almeida et.al, 2016).

2.5.2 Fishery in Portugal and Peniche

Fishing is deeply marked in Portuguese culture for centuries and the industry is fairly large and diversified. Around 80% of the local fleet consist of small traditional vessels and these vessels are usually polyvalent - equipped to use more than one fishing method, such as hooks, gill nets and traps used for catching highly valuated commercial species. Purse seine fishing is also part of the local fleet and sardine is its only target species (FAO, 2017; Pardela, 2016). The importance of fisheries in the county´s economy has been declining in the last decade due to the reduction in the fishing fleet by the National policies implemented to promote the reduction of fishing effort.

Peniche is a small fisheries town from where most of the fishing vessels leave leading inside the Berlengas Islands SPA and it still belongs to one of the four most important fishing ports in Portugal both in terms of the volume of fish landed and of the total number of fisherman operating. "The region has good conditions in terms of maritime transport, mainly due to its location and proximity to the commercial ports of Lisbon and Figueira da Foz" (Almeida et.al, 2016). Following table presents the main target and captured fish species by boats from Peniche. Most of the species have high economic value; the ones marked with an asterisk have the greatest economic value (Berlengas, 2017; Almeida et.al, 2016).

Figure 3 Fishing boat Mãe Purissima leaving Peniche (author)

Table 1 Main target and captured fish species by boats from Peniche (Berlengas, 2017; FAO, 2017).

Common name	**Scientific name of the species/family or genus**
Sea bass	*Dicentrarchus labrax*
Sole	*Solidae*
Sardines*	*Sardina pilchardus*
Octopus*	*Octopus vulgaris*
Cuttle fish	*Sepiida* sp.
Snapper	*Pagrus auratus*
Swordfish	*Xiphias gladius*
Lobsters	*Nephropidae*
Monkfish	*Lophius* sp.
Sea bream	*Sparidae*
Crabs	*Brachyura*
Squid	*Loligo* sp.
Atlantic chub mackerel	*Scomber colias*
Mackerel	*Scomber scombrus*
Horse mackerel*	*Trachurus trachurus*
Ray	*Batoidea* spp.
Pouting	*Trisopterus luscus*
Hake	*Merluccius merluccius*

2.5.3 Impacts and methods

While fishing provides food, income, and employment, the ever-increasing intensity, diversity of fishing operations and unsustainable way of management leads to serious environmental impacts that threaten rare species and ecosystems worldwide (Kaiser et al., 2011). The main threats consist of overfishing, eutrophication, toxic pollution, and habitat degradation (TV Nguyen, 2012). "Human influence on the marine ecosystems has been less studied than terrestrial ecosystems, but is probably the same, especially in shallow coastal areas." claims (Primarc, 2011) and continues: "Fishing boats using trawls disturb approximately 15 million km^2 of the seabed per year, which is 150 times larger area than the area of forest cut down for the same period." Today large parts of the sea are lifeless "deserts" which are recognized by the dark blue or turquoise water colour (Reichholf, 1999).

Fisheries may have adverse effects on seabirds in several quite different ways. It can have direct impacts causing mortality of seabirds or and non-direct impacts usually characterised by changing the availability for food. First of all, industrial fisheries exploit fish, which is reducing the availability for seabird to their prey and may deplete the stock. In the past, seabirds were even hunted by fisherman as bait, or for food (Furness, 2003). Another significant impact causing changes in the prey availability for seabirds are fishing discards. FAO defines discards as "that portion of the catch returned to the sea as a result of economic, legal, or personal considerations". The annual amounts of fishing discards are enormous and it is widely perceived as a problem of fisheries management (FAO, 2017). Impacts of discarding are various and create dilemma in decisions about their reduction. On one hand seabirds can take advantage of such availability of supplementary foraging resources provided by discards and reduction in discarding of fisheries appear to be having serious impact on entire seabird communities. On the other hand, in case of Yellow-legged Gull *(Larus michaellis)* present in Berlengas Islands, provision of offal and discards attracts these seabirds to feed which led to overgrowth of the population on the Islands. As a result, Yellow-legged Gull *(Larus michaellis)* dominates the Berlengas Islands and has negative impacts on local fauna and flora (Furness, 2003; Berlengas, 2017).

Nowadays, main threat, to which the Life Berlengas Project focuses its attention, is direct mortality of seabirds caused by accidental catch of seabirds in fishing gears.

It is the large diversity of target species in capture fisheries and their wide distribution that requires a variety of fishing gear and methods for efficient harvest (FAO, 2017). Fishing gears used thorough the time and space varies from simple baited hooks on a hand-line, to dynamite bombs or in case of catching very valuable fish species, expensive methods are used like spotter tracking planes and fast boats with electrified harpoons. Fishing gears are generally categorized into active and passive. "Active fishing gears are towed or moved in other ways to pursue the fish and passive fishing gears are put in the water and fish are caught when they move into the gear" (Kaiser et al., 2011). There have been two main developments that have highly increased accidental catch of seabirds – development of monofilament nylon nets which are practically invisible for diving birds and of long-line fisheries with hooks and baits which attracts seabirds. In result, seabird dies in order to steal baits from the hook or accidentally swallowing the hook (Furness, 2003).

In Berlengas protected area there were several ecosystem destructive fishing practices happening in the past which included dynamite fishing, lamp fishing, spear-fishing, beach purse seine, traps and creels. Few decades ago, all of these gears were prohibited. In the part of study area where Berlengas Nature Reserve expands the use of fishing gears are limited only for purse seine and long-line, which are the two from only a few gears that efficiently catch target species (Berlengas, 2017; Kaiser et al., 2011). In the rest of the study area all the other fishing gears are present. Those include for example gill nets, trammel nets, bottom and surface long-lines, pots and traps or bottom and otter trawls. These fishing gears especially are characterized by various negative impacts on environment and non-target species. One of the most disturbing fishing methods are bottom trawlers and dredges that interact physically with the bottom sediment, which might result in removal or damage of sedentary living organisms and are also characterized by high catch of non-target species, which frequently are discarded at sea (FAO, 2017).

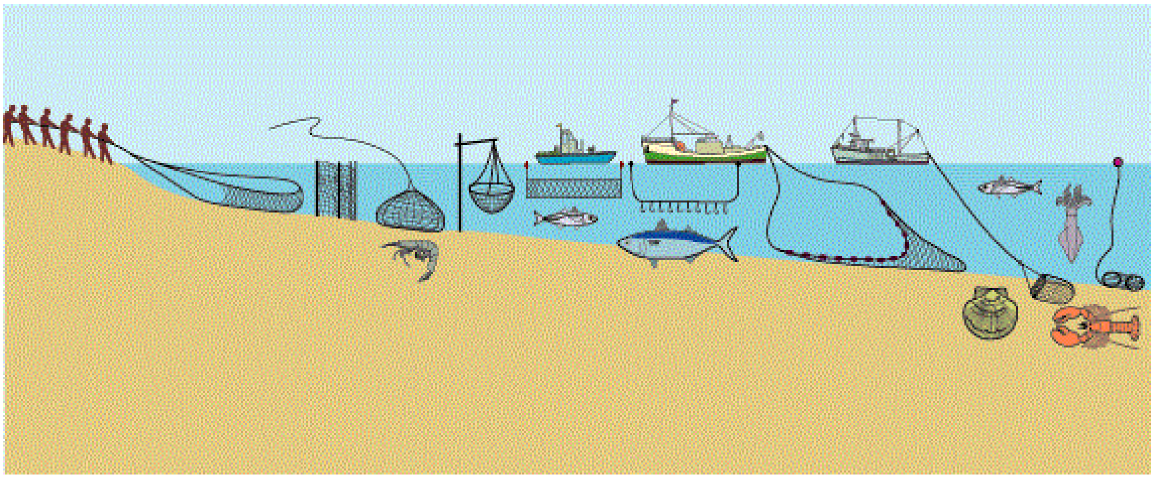


Figure 4 Fishing methods illustrated by FAO (FAO, 2017)

In commercial fishing, causing death or damage of non-target species is known as by-catch (Kaiser et al., 2011). Zador et al. (2008), defines by-catch as incidental mortality of non-target species due to fishing activity. The definition concerns non-target species of fish which are wasted and thrown back into the sea but also seabird species which are accidentally entangled in nets. It is a principal problem in fisheries management, fishing productivity and profitability and particular threat for seabirds (Cox et al., 2007). Seabirds forage in highly productive areas of the ocean, which are also targeted by commercial fishing vessels. In this position seabirds often end up accidentally caught on hooks, or entangled in nets (Birdlife, 2017). “Currently, seabird by-catch is a global important conservation issue and very often is cited as one of the causes leading to population decline of different seabird species” (Almeida et.al, 2016). Even low levels of by-catch can have catastrophic results for critically endangered seabird species such as the Balearic Shearwater (*Puffinus mauretanicus*) and other long-lived animals with slow population growth rates, including marine mammals and sea turtles (Cox et al., 2007). According to BirdLife International, at least 300 000 seabirds annually are killed only by long-line fishery (Birdlife, 2017).

In Portugal, the problem of seabird by-catch is still largely unknown and only recently has begun to be addressed (Almeida et.al, 2016). “Pioneering studies in our country found that gillnets, long-lines and purse seines have the greatest impact on seabird populations. The most susceptible species are those that dive to feed on small fish or cephalopods, such as the Cory’s shearwater or the European shag” (Berlengas, 2017). Even though the by-catch in Berlengas Islands SPA is still largely unknown there is already one sad and warning case of the Common murre (*Uria aalge*) whose population suffered a sharp decline caused by very intense fishing, which led to the complete extinction of the species on local islands (Berlengas, 2017). Thus it is really necessary to specify which gears operate within the Berlengas Islands SPA so the as accurate as possible catch rates can be estimated. “Taking into account the most abundant species of birds in the SPA and their eating habits, it is recommended that actions to monitor by-catch and testing of mitigation measures should focus primarily on purse-seine, nets and long-line fishing gear“ (Almeida et.al, 2016).

It is very difficult to monitor exact seabird by-catch but the conservation measures are quickly developing. For example it is impossible to ensure a trained observer present on every vessel but with cooperating fisherman it is possible to ensure data trough "diving-bird" identification guide developed by LOD - Birdlife partner in Lithuania for identifying dead birds in nets by fisherman on-board (Crawford and Hurrel, 2015). Another very successful by-catch mitigation measure for example in Namibia or Argentina, include bird scarers and devices that set the lines below the diving depth of the birds. Life Project Berlengas in Peniche is also testing several mitigation technologies in cooperation with local fishermen (Berlengas, 2017).

Figure 5 SPEA is already testing bird-scaring lines on fishing nets in Peniche (author)

2.5.4 Determining fishing areas and its importance in ecosystem-based fishery

As well as in forestry, the main concept in fishery is maximum sustainable yield which is characterised by (Primarc, 2011) as the largest amount of resources that we can get every year without eventually causing its exhaustion. Today ensuring that catches and profits are sustainable are no longer the only goals of sustainable fishery management. Managers are increasingly seeking to implement ecosystem-based management, where decisions take in count the ecosystem concerns and conservation of all ecosystem elements, such as seabirds (Kaiser et al., 2011). "Ecosystem-based management propounds that commercial fisheries should be managed for sustainability of the target species as well as for indirect and inadvertent impacts on non-target species and habitat" (Pikitch et al., 2004). From a fisheries management point of view, specific knowledge of threats and cooperation between fishery and conservation institutions can also prevent overly precautionary closures (Zador, et al, 2008).

In order to understand the impacts of fisheries on seabirds within the Berlengas Islands SPA and for developing sustainable management measures for fishery, it is crucial to find out where the fishing areas extend with the highest densities and what type of the fishing gears occur and dominate. Understanding movements of the boats, their preferred areas to carry fishing, collecting spatial and temporal data about vessels are the very first steps to have a picture about where the potential conflict between fishery and seabirds might occur. "The rates of seabird by-catch vary substantially between fisheries and even between vessels operating the same gear and are highly dependent on the fishing method and the target species of the fishery" (Almeida et.al, 2016). Not only the particular fishing gears should be highlighting but also the durations of the operations which vary within each method play the main role. There is in all probability different impact between vessels operating fishing only for few hours then the other ones which spend fishing all day and night or even few days in a raw.
Zador et al. (2008) adds many other factors increasing the possibility of seabirds-vessel incidents such as vessel size, onboard equipment, type of discards and seasonality of seabirds occurrence. In hand with data representing the seabird distribution within the area, specific overlap areas between fisheries and seabirds activities can be determined. Knowledge of these areas opens the door for directed research of concrete interactions between fishery and seabirds. "Where extent of overlap is well known, appropriate management measure can be crafted to reduce the potential for negative interactions" (Zador et al, 2008).

2.5.5 Automatic Identification System (AIS)

In response for the need of survey and monitoring of fishing fleet activities in marine environmental sciences, many organizations, companies, and governments are using technologies which allow detailed tracking of fishing vessels. In this work Automatic Identification System (AIS) was used to identify fishing areas. It is a tool developed in

2000 by the International Maritime Organisation (IMO) which is commonly used by marine environmental organizations to study the vessel and fishing activities though this system was not originally created for nature conservation purposes. AIS, primarily intended as a situational awareness tool, is a sophisticated radio technology which combines GPS, VHF and data processing technologies and is used by ships and by vessel traffic services for identifying and locating vessels by electronically exchanging data with other nearby ships or ashore (Exact Earth, 2015). “It is an open source, un-encrypted technology broadcast over radio, meaning that anyone with a transceiver can view nearby boats’ locations. While the signals are limited to line of sight, and thus the horizon, they are also visible to satellites flying overhead” (Visebeck et al. 2016). AIS provides data in an organised way and it fuses static and dynamic data together. Static data include including a vessel's MMSI number, its size and its destination and dynamic data include vessel's course, speed and position (All About AIS, 2012). This data are available for free for anyone with an internet connection and historical data can be publicly purchased from data vendors (McCauley et al., 2016).

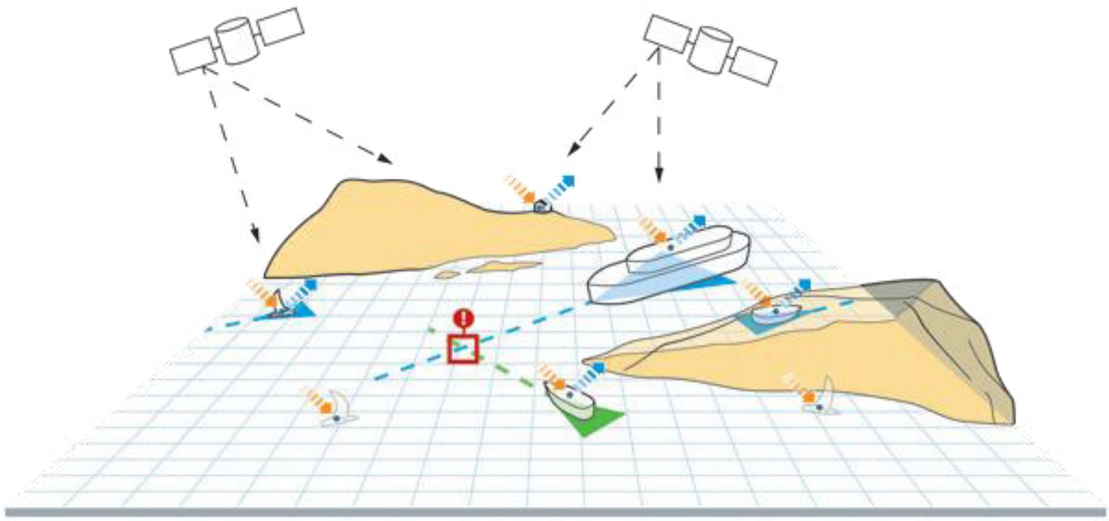


Figure 6 AIS communication between vessels, base stations and satellite (All About AIS, 2012)

AIS is already widely adopted by large fishing vessels around the globe. IMO regulations require usage of AIS by all ships of 300 gross tons and greater on international voyages and vessels of more than 500 gross tons on all voyages. Each country adopts IMO regulations differently, in some countries they are even sticker. For example in Mauritius, all fishing vessel regardless of size are equipped with AIS, on the other hand Canadian fishing vessels are completely exempted from carrying AIS. In the European Union requires the usage of AIS by all fishing vessels larger than 15 metres (Visebeck et al. 2016; McCauley et al., 2016).

The biggest advantage of AIS is its easy accessibility in comparison with Vessel Monitoring System (VMS) which already exists in many nations but the data are usually encrypted and accessible to only the government requiring the VMS (Visebeck et al. 2016). "The open technologies used by AIS, and its global use, distinguish it from other regionally administered "closed-access" systems that do not pool data across jurisdictional regions, transmit data at lower rates, and tightly restrict data access" (McCauley et al., 2016).

Though AIS provides an economical solution for receiving fishing data still there are numbers of disadvantages which are highlighted repeatedly in every source reference or study. First of all the most serious limitation for overall monitoring fishing activity in the study area and worldwide are fishing vessels smaller then 15m which are not obligated to carry AIS. Peniche harbours negligible number of small fishing fleet and missing data about these vessels activities creates a large gap in the research. "Of an estimated 2.7 million fishing vessels with motors worldwide, only about 35,000 to 45,000 are currently traceable using AIS" (Visebeck et al. 2016). Another serious and common challenge with AIS present also in the study area is the possibility of turning off the signals which allows boats that do not want to be seen to simply "disappear" from the view and hide the activity of the vessel entirely. "Unfortunately, the current lack of legislative support for AIS has stunted this system into a service that best respects vessels that do not mind being seen" (McCauley et al., 2016).

Visebeck et al. (2016) highlights the lack of satellites which sometimes interfere with each other or the talks about reports with false locations which are seen in only a small percentage of vessels and is believed to be caused by deliberate tampering or faulty equipment. McCauley (2016) mentions that AIS data are instantaneous (delays range from minutes to 1 hour) and they do not broadcast information about the operating fishing gear. All these shortcomings significantly influence the quality of the data and forces to find solutions and some basic important information (such as fishing gears) in an alternative and more time consumption way (Visebeck et al. 2016). Important information about vessel's fishing gear and other valuable additive data can be found on the FAO Fishing Vessel Finder database. Marine Traffic website also offers a helpful hand while searching for basic information or having troubles with boat identification. It provides photographs of the boats useful for boat an easy boat identification and actual boat position through AIS data.

Even though AIS needs a long series of necessary improvements which are specified in the discussion it is already an extremely helpful tool for identifying the fishing activities inside the study area. Achieved results from AIS data analysis are useful for finding solution also in many other major threats all across the ocean, such as for example illegal fishery. "AIS data have important applications in conservation science including describing baseline vessel use of a maritime area, assessing or modelling actual or potential environmental impacts, and monitoring environmental compliance. With improvements, the system will ultimately result in greater engagement by vessel companies and operators in the conservation of marine resources"(WCS, 2017).

2.6 Importance of seabirds

At sea we encounter the largest concentration of birds. The breeding colony of gulls and terns on European coasts is roughly ten times higher than the number of nesting colonies around inland freshwater. Seabirds are an attractive feature of coastal and marine culture and they are an important component of proper functions of these ecosystems (Reinchholf, 1999; Nea, 2017). They occupy a high trophic position, many of them are at the top of the food chains, and for that they are often cited as an important indicators of the health of marine and coastal ecosystems. Several species feed mostly on prey that may also be consumed by humans thus emphasizing their potential usefulness as sentinels of marine contamination. "In the Atlantic coast of Portugal has already revealed a high risk of mercury contamination in northern gannets *(Morus bassanus)* and razorbills *(Alca torda)*" (Costa et al., 2016). They are also indicators of climate changes, changes in food supplies and fish stocks. Finally they are sensitive to different kind of pollution and show the level of oil or heavy metal pollution, plastic, trash and other ocean environment pollution (Nea, 2017).

As mentioned before, Berlengas Islands SPA has great ornithological value for numbers of species migrating, wintering or breeding in the area. The following table presents wintering and migratory birds present in the SPA during the winter months from November till February on which this study is focused. The Common murre (*Uria aalge)* was last seen in the area in 2002. Species marked with an asterisk are resident to the SPA in Portugal. The greatest importance has the resident European Shag *(Phalacrocorax aristotelis)* whose population on Berlenga Island is the biggest in Portugal. Another representative species is Norhtern Gannet *(Morus bassanus)*, always present in Portuguese waters in large numbers during the winter season. Balearic shearwater *(Puffinus mauretanicus)* represents the most threatened seabird in Europe. Atlantic puffin *(Fratercula arctica)* is very attractive species, only sometimes crossing the SPA. Unfortunately it is mostly found death on the beach after strong storms (Meirinho et al., 2014).

Table 2 shows that in the Berlengas Islands SPA is present 1 critically endangered migratory and wintering specie and 3 resident species (Meirinho et al., 2014; IUCN, 2017).

Common name	**Latin name**	**IUCN status**
Atlantic puffin	*Fratercula arctica*	VU
Balearic shearwater	*Puffinus mauretanicus*	CR
Band-rumped storm petrel	*Hydrobates castro*	LC
Black headed gull	*Larus ridibundus*	LC
Common murre	*Uria aalge*	LC
Common scoter	*Melanitta nigra*	LC
European shag*	*Phalacrocorax aristotelis*	LC
Great cormorant*	*Phalacrocorax carbo*	LC
Great skua	*Catharacta skua*	LC
Northern gannet	*Morus bassanus*	LC
Razorbill	*Alca torda*	NT
Sooty shearwater	*Ardenna grisea*	NT
Yellow-legged-gull*	*Larus michahellis*	LC

2.7 Connection between forestry and fisheries

This additional chapter presents the important connectivity between the two different ecosystems – marine and forest - and their elements. There are only a few studies about such interactions. To show the context, mangrove woodlands is presented as an important forest ecosystem supporting commercial fishery activities. Thereafter the case of over-populated yellow-legged gulls shows non-direct impacts of fisheries and discards on endemic fauna and flora on the Berlengas Islands.

As an addition, two short cases are found in the chapter, one of which presents also the positive socio-economic impacts of fisheries sustainable management in tropical regions.

2.7.1 Importance of mangrove woodlands for commercial fishery

Important ecosystem forming an interface between marine and terrestrial environment are mangrove woodlands. Jeník and Pavliš (2011) define mangrove woodlands as an amphibious ecosystem growing in a coastal seaside area that is periodically flooded by salt or brackish water due to sea lows. It is an ecosystem typical for tropical and subtropical zones in America, Asia and Australia and it consists of approximately 20 tree species, mostly of representatives of genus *Sonneratia (Lythraceae), Avicennia (Avicenniaceae)* and *Rhizophora (Rhizophoraceae).* The complex root systems of mangroves provide habitat for a diversity of terrestrial and aquatic species, they are bound by interesting groups of different organisms, the most obvious of which are various crustaceans, especially crabs (e.g. *Scylla serrata* and *Uca* sp.). Thousands of Thalassinidea crustaceans and other animal species such as representatives of amphibians, insects, megabats, crocodiles and in South-East Asia also proboscis monkeys *(Nasali larvatus)* play an important role. The crowns of mangrove trees create natural habitat for wide range of birds and seabirds consisting of smaller numbers of breeding specialists, many species transcending from surrounding ecosystems or stopping during the migration. Most common representatives are calves, crayfish, cranes or pigeons (Jeník a Pavliš, 2011; Prach et al., 2009). Birds have great importance for mangrove woodlands conservation and their ecology needs to be studied more in detail for planning the suitable management strategies (Kaiser et al., 2011). Finally, the mangrove forests are characterised by high abundance of fish species. Some of them are permanent residents in mangroves, but numerous marine species use mangroves as nursery grounds thus mangroves create the main nursery biotope for these fishes (Mirera, 2007). Others, as juvenile sharks and adult bonefish, use mangroves as foraging grounds. "As a result, for much of the temperate and tropical coastal areas around the world, the mangrove ecosystem serves as the physical lattice that houses much of the food web systems for many biologically and economically important marine species" (FCF, 2015).

Many commercial finfish and shell fish species depend on mangrove habitat for part of their life cycle and millions of people benefit from mangrove-associated fisheries which provides jobs and food supplies (Sulochanan, 2013; Hutschison et al., 2014). The importance of mangrove woodlands for fisheries is widely described in the book "The role of mangroves in fisheries enhancement" by Hutschison et al. (2014). "Mangroves enhance fish production via two main mechanisms – the provision of food and of shelter. Species of interest to the fisheries sector are found at all levels of the food chain, with detritivores such as mangrove crabs, prawns and mullet; filter feeding bivalves, planktivorous fish such as herring and anchovy species, and higher consumers such as some mud crabs and many other fish including snappers and groupers. Mangrove roots and trunks provide a structure that species such as oysters can grow on" (Hutschison et al., 2014).

There are many types of fisheries benefiting from mangrove habitats various ways. Inshore mixed species fisheries are the mostly low-income fisheries undertaken in mangroves close to settlements. Inshore mollusc and crustacean fisheries generate quite high market values, and although they may still be harvested at local and small-scales. Recreational fisheries are also widely practiced. For offshore commercial fisheries operating many kilometres from the mangroves, the most important function of mangrove habitats represents the nursery habitat function for fish juveniles before they move to offshore habitats such as coral reefs. In this case the best documented are offshore prawn fisheries (Hutschison et al., 2014).

The ecological balance of food chains and mangrove fish communities can be altered by global overfishing crisis; nevertheless many fishers are still unaware of the key role that mangroves may play in supporting fisheries. Therefore raising awareness, new ideas and understanding of management of mangrove-associated fisheries is needed (WWF, 2017; Hutschison et al., 2014).

2.7.2 Over-populated yellow-legged gull (*Larus michahellis*) and its impacts on endemic flora on the Berlenga Island

The non-direct impacts of intense commercial fishery on natural terrestrial habitats, is well presented on the case of yellow-legged gull present within Berlengas Islands SPA in large numbers.

Yellow-legged gull (*Larus michahellis*) is the most abundant seabird thorough the year on Berlengas Islands and it colony is one of the largest in Europe. Gulls are birds with high capacity of adaption and reproduction. Their opportunistic diet includes fish of various species, pelagic crabs, insects and wastes generated by human activities and others. In the islands they mainly prey on the young of other seabird species or endemic Berlengas wall lizard (*Podarcis carbonell berlengensis).*

In the 20th century it recorded a strong increase of these gulls. They spread to the north and rarely also settles inland waters of Central Europe. This increase in population is related to Industrial Revolution followed by increase of domestic and industrial waste which offers an easy meal for gulls. In Portugal it was the high food availability from fishing ports and discards in hand with the excellent conditions for breeding in Berlengas Islands that has contributed for the enormous increase of the population which in 1994 reached 45000 individuals.

Yellow-legged gulls cause wide range of negative impacts on rare ecosystem on Berlenga Island. Next to the predation on local species mentioned above, the critically endangered and endemic plant species Berlengas thrift *(Armeria berlengensis)* is significantly affected by the gulls present. The high density of yellow-legged-gulls results in the excessive nitrification from their faeces. The modification of the chemical parameters of the soil causes the reduction of reproducing ability of Berlengas thrift *(Armeria berlengensis)* and other endemic plant species like Berlengas rupturewort *(Herniaria berlengiana)* or Berlengas fleabane *(Pulicaria microcephala)*. Changes in soil conditions support expansion of invasive Hottentot fig *(Carpobrotus edulis)*, another serious threat for endemic fauna and flora on the islands.

Gulls threat Berlengas Thrift *(Armerie berlengensis)* also directly through building nests in it for its attractive pillow-like shape which leads to plants death (Berlengas, 2017; Meirinho et al., 2014).

Figure 7 - This construction made by Life Berlengas project on Berlenga Island prevents the access of gulls on stands of Berlengas thrift (author).

Another case study from Mediteranean yellow-legged gull's colonies shows that during periods when the local trawl fishery is closed so no longer generating discards, the mortality of other seabirds increases due to the more intense gulls predation and kleptoparasitism (Furness, 2003).

Reinchholf claims that only the results of which have been achieved by reducing the pollution of seas, including waste from the fishing industry, have had the desired effect on the natural decline of gull's population along the coast of North and Baltic Sea (Reinchholf , 1999).

Yellow-legged gull is in the interest of Life Berlengas project and it aims to control the population numbers, in order to avoid the degradation of Berlengas ecosystem. Today the number of yellow-legged gulls in the islands already decreased to 13 000 individuals (Berlengas, 2017).

2.7.3 Case of salmon in Canadian rainforest and women empowerment in Namibia

The long-linked interactions between marine species and forest ecosystem are shown on the popular case of Pacific salmon *(Oncorhynchus)* spawn migration from the sea through the Great Bear Rainforest rivers to its creeks. This Canadian forest is the largest temperate forest in the world and home to grizzly bears *(Ursus arctos* ssp.*)* which hunt the migrating fish from the river bank and carry their prey inside the forest in order to avoid conflict with other bears. In 8 hours one bear can consume 40 salmons whose body remains decompose in the forest. The resources showed that salmons contain large quantities of nitrogen that plants need to grow and the whole 80 % of the nitrogen in the forest trees comes from the fish. “In other words, these ocean fishes are crucial for the forest’s long-term survival” (BBC, 2017).

Finally, management of fisheries and conservation of seabirds has positive socio-economic impacts which can be seen for example in Namibia. Namibia belongs to the countries with the most destructive fisheries in the world and more than 30 000 seabirds die directly every year entangled in fishing gears in its waters. That has resulted in finding a simple solution - creating bird-scaring lines that scare birds away from the fishing gear. Since the Namibian fishermen started to use these bird-scaring techniques, Albatross Task Force in Namibia developed a project and works with a local women’s empowerment group in Walvis Bay to manufacture and supply bird-scaring lines for the fisheries in the country. Today, women, whose only income was from selling jewellery made from seas shells, have already sold their products to 10% of the Namibian fleet. Thus these women become to have position in nature conservation process, fishing industry and that generates them an income and greater gender-equality in the community (Birdlife, 2017).

3. METHODOLOGY

The aim of this work is to present the boats and fishing gear spatial distribution in the Berlengas Islands SPA during the winter season 2014, 2015, 2016 and January 2017 through analysis of historical data provided by SPEA. For that it was primarily needed to determine fishing gears operating by boats within the reserve and their operating speed. The final task was to find out where is the highest density of spatial boats distribution while operating fishing in the reserve.

The methodology consists of four phases:

A. Theoretical phase

First phase started in November 2016 by collecting and studying literature sources, scientific articles and internet websites. This part had resulted in the literature part of this work widely describing the problematic with focus on fishing impacts on seabird populations and importance of studying fisheries technologies and distribution.

B. Practical phase

Between January 2017 and March 2017 practical internship took a place in Lisbon, Portugal in SPEA organization and its Life Berlengas project. Main part of the internship consisted of analysing historical fisheries data provided by SPEA, learning about fishing boats movements, fishing gears and collecting data from FAO Fishing Vessel Finder (FVF). Part of the internship was also 10-day camp work in the Berlenga Island and 1 visit of fishing port in Peniche.

C. Data collection

Three types of fisheries data were needed:

- Boats positions – point shape file for ArcGis software showing the position, speed and other data important for identification of boats activity
- Boats data – data needed for the basic boat identification (name, size, port, identification number)
- Fishing gear data – data for identification the fishing methods for each boat

Table 3 Sources of all data types. All boats position data were provided for this study by SPEA. Final dataset with all fishing positions was received by the end of February 2017

Type of data	Collected by	Provided for this study by / searched by	Format of received data
Boats positions	AIS	SPEA	Point shapefile (ArcGis)
Boats data	AIS SPEA	SPEA Internet databases	Attribute table (ArcGis) Excel file
Fishing gear data	Various data providers (FVF, 2017)	FAO FVF (FVF, 2017)	Text

Table 4 Final dataset received with months available for the winter analysis

Year	November	December	January	February
2014	✓	✓	✓	✓
2015	✓	✓	✓	✓
2016	✓	✓	x	✓
2017	x	x	✓	x

D. Data processing

When all data were collected following steps were done:

- Boats identification
- Fishing gear identification
- Determining the operation speed of each fishing gear
- Identification of fishing areas
- Identifying preferred areas for operating fishing and particular fishing gears

3.1 Boats and fishing gear identification

Boats identification is crucial for getting the basic important information such as vessel size, port and fishing gear.

First step to boat identification is to find out which boats are present in the study area, whether they are just passing or fishing. For that we need the data with boats position which also include values with the boat names and identification number.

There are various types of vessel identification numbers like for example – MMSI (Maritime Mobile Service Identity), IMO (International Maritime Organization), EU CFR (European Union Identifier) or call sign. Following steps for identifying boat were usually done using excel file with list of boats provided by SPEA or FAO FVF database and Marine Traffic database which also includes helpful picture database appropriate to confirm the accuracy of the identification. In addition European Fishing Fleet Register or Vessel Finder was used. All mentioned online databases complement each other well and together they create a great tool for correct identifying boats.

After identifying the boat it was easy to search for specific fishing gear trough FAO FVF database. Boats normally operate one or two fishing gears (primary and secondary). Fishing gears are divided into categories and types. For example category “Gillnets and entangling nets” consists of 6 different types of gillnets. Sometimes boats are operating two completely different fishing gears from different categories; in this case those boats are “polyvalent”. Identified fishing gears were consulted with SPEA field team based in Peniche. After cooperation the results, only few slight differences were found and corrected, which means that data from FAO FVF in most cases actualized last time between years 2012 and 2014 are reliable.

3.2 Determining the operation speed of each fishing gear and identification of fishing areas

There is no reliable or repeatable method for determining fishing areas so it was a long lasting process composed of searching information in scientific articles about operating speed for each fishing gear, observing specific boats, their movements and analysing their activity in ArcGis map software. Marine Traffic website again was also useful for the possibility of monitoring boats, their historical tracks and speed so it served a helpful tool for confirmation of the obtained values. It was obvious that where the points were only folded into a long line crossing a reservation at high speed, the boat was only passing through the study area. These points, usually at speed higher than 8 knots were excluded. The opposite - where the points were aggregated, the speed was lower and the boat spent in a specific area longer period of time - was considered fishing. Points aggregated in vague shapes were studied more in detail, often it became clear that these points are random and are not related together due to the difference time and dates or there were big confusing gaps between data so in the end they were considered to be of poor quality and useless. The reached results were consulted with experienced fisheries observers based in SPEA office and Peniche.

What speed is operating given fishing gear was observed and repeatedly specified during the process of identifying fishing areas and it required studying trough the literature and sources. Finally average operating speed for each gear was calculated and top operating speed was proposed.

Table 5 Method for determining break-point between fishing and not-fishing areas

Fishing gear category	**Method of identifying fishing activity**
Gillnets and entangling nets	$v < 4$ knots
Long-lines	$v < 5$ knots
Surrounding nets (purse seine)	$v < 2$ knots
Trawl nets	$v < 6$ knots

3.3 Identifying preferred areas for operating fishing and particular fishing gears

The point shape-file with identified fishing areas was analysed by Kernel density tool in ArcGis software. These areas are divided into 95%, 75% and 50% of fishing vessel positions. The resulting output highlights areas with the highest point (vessel) density within the set 3 km wide radius. These areas are considered as spots with the most intense fishing activity.

Analysis of preferred areas for fishing was done for all years separately (2014, 2015, 2016, January 2017) and for all years together, representing the use of the area in general during winter season within the last 4 years.

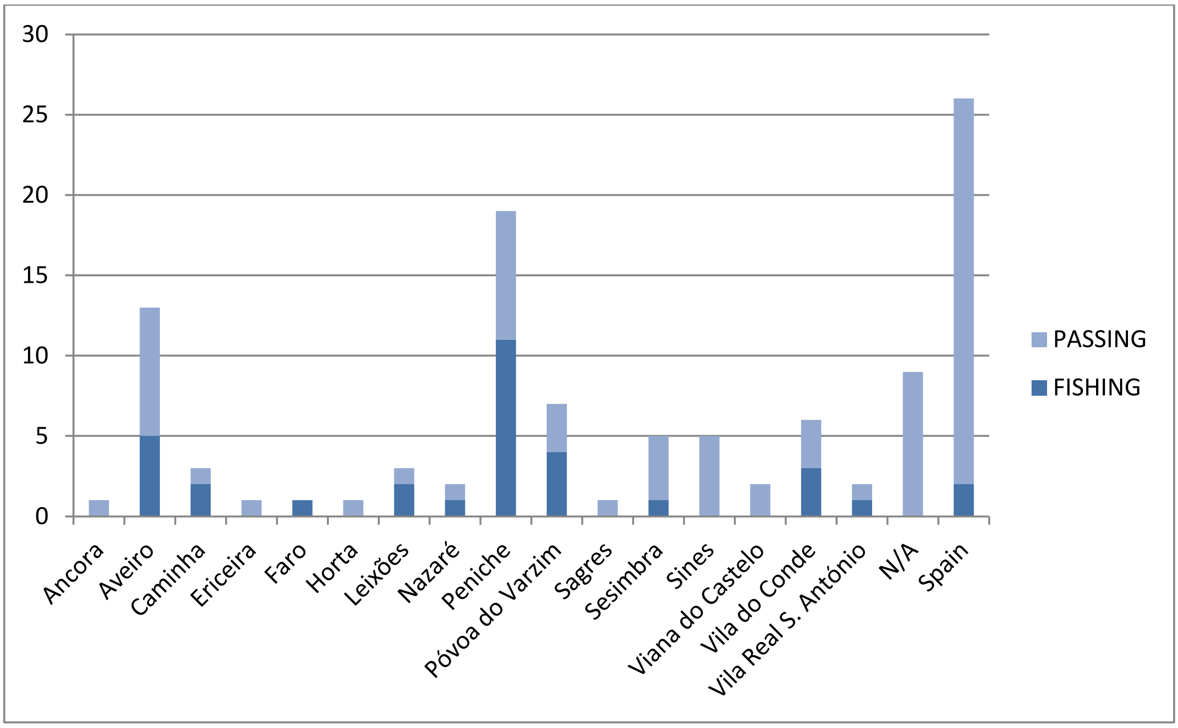
Kernel density analysis for the most used fishing gears within the study area – gillnets, purse seines, trawl nets and polyvalent – was done for each of one during the winter season generally.

4. RESULTS

4.1 Boats

The total number of 108 boats was found within Berlengas Islands SPA during the outlined winter study period. From the total 31% were fishing and 69% of boats were passing the study area without recording fishing activity.

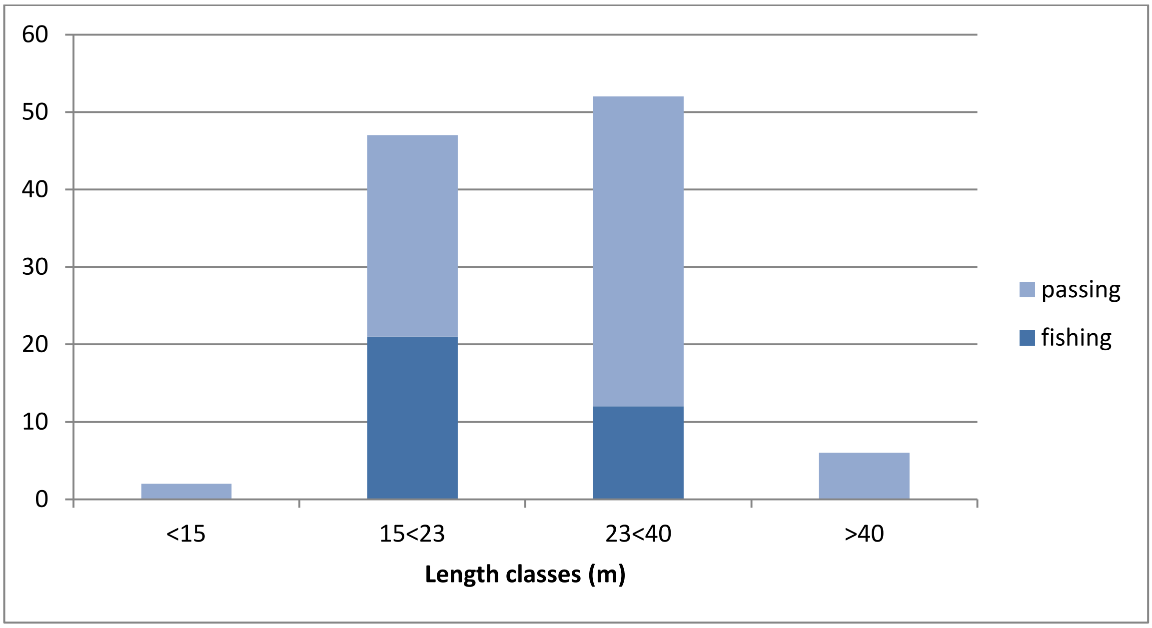
Most abundant boats active both in the reserve and outside the reserve come from the port of Peniche (19 boats) followed by boats from Aveiro (13 boats), Póvoa do Varzim (7 boats), Vila do Conde (7 boats) or Leixões (3 boats) and Nazaré (2 boats). Significant part forms group of Spainish boats (26 boats) from whose only 2 were operating fishing inside the protected area.



Graph 1 All boats recorded in the study area (passing or fishing) and their original port

All these 108 found vessels were divided in 4 length classes. There are only two boats shorter than 15 meters because these boats are not obligated to carry AIS device which causes a great limitation in the dataset due to the fact that fishing vessels operating from

Peniche are mostly smaller than this size. Boats up to 23 m represent the most abundant group fishing in the reserve. This group is followed by boats up to 40 meters. The small size of boats is also related to the fact that fishing fleet operating from Peniche is characterized by small – sized boats. No boats longer than 40 meters were recognized inside the study area, only crossin. These boats are represented by trawlers typical of their larger dimensions.



Graph 2 Representation of size categories of ships

4.2 Fishing gears

Almost all boats operate two types of gears – primary and secondary, therefore almost all boats could be generally considered as polyvalent. In this study, just to make the analysis more detailed, boats operating different fishing gears from the same group (for example primary gear – set gillnets and secondary – trammel nets) are considered as a category. In this study, category considered as “polyvalent” contains of completely different fishing gear types as it is for example in case of boats operating gillnets as a primary gear and traps as a secondary.

Fishing gears found within all 108 boats are represented by 6 categories and 10 types. Category named “Polyvalent” contains boats of various fishing gear types; more information about this category composition is described in the following text. Fishing gear types are expressed by specific FAO codes in the following tables and graphs.

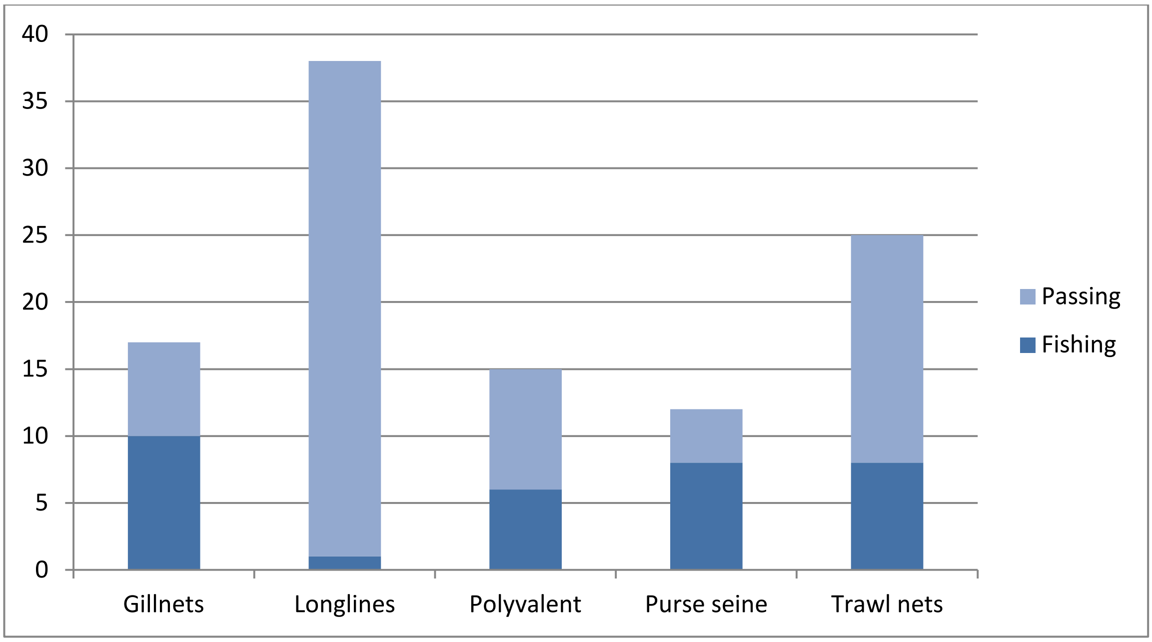
Table 6 Fishing gears present in the reserve, their names and coding

Fishing gear category (FAO)	**Fishing gear type (FAO)**	**Fishing gear code (FAO)**
Gillnets and entangling nets		
	Set gillnets	GNS
	Trammel nets	GTR
Long-lines		
	Hand-lines and pole-lines	LHP
	Drifting long-lines	LLD
	Set long-lines	LLS
Polyvalent	Various	-
Surrounding nets	Purse seine	PS
Traps	Pots	FPO
Trawl nets	Bottom otter trawls	OTB
	Mid-water otter trawls	OTM
	Bottom pair trawls	PTB

Following graphs do not express number of boats operating specific fishing gears but only the portion of fishing gear categories or types present in the reserve. The final result is overview of fishing gears operating fishing within the reserve.

The most represented categories passing or fishing in the reserve are long-lines forming 36%, followed by gillnets- 22% and trawl nets – 17%. Polyvalent category creates 15% of the total and the smallest one is represented by purse seines - 9%. (Graph 3)

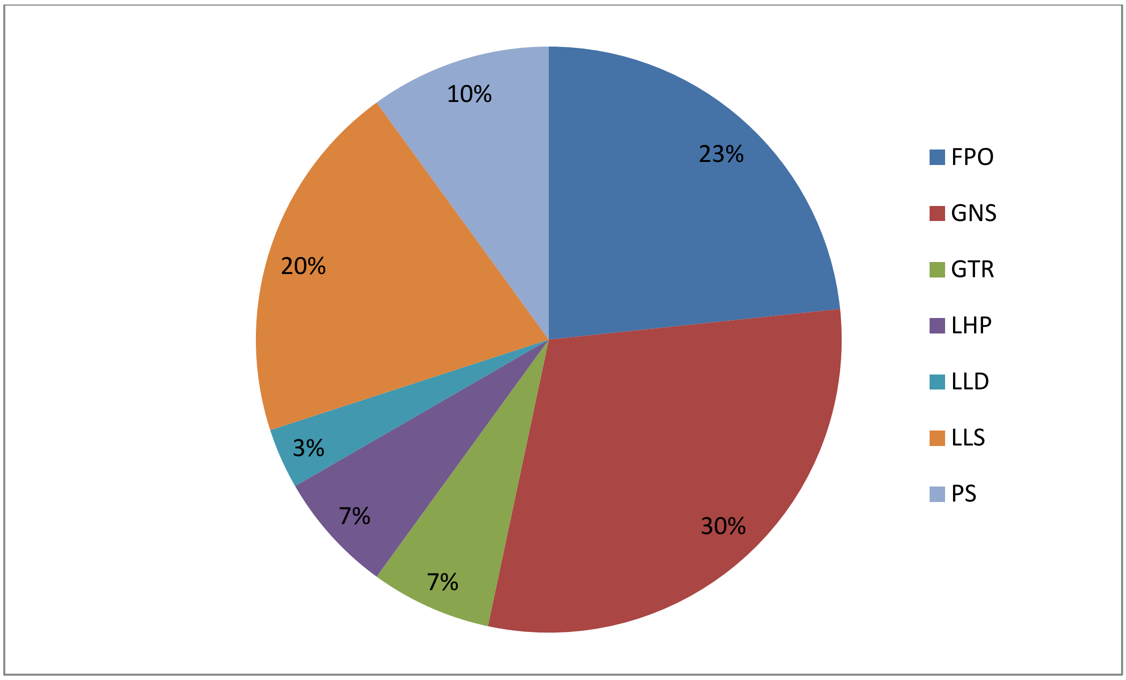
Graph 3 demonstrates that although long-lines category dominates, only 2, 6% is fishing inside the reserve. On the other hand gillnets, purse seine, trawl nets and polyvalent fishing categories have a large share of fishing activity inside the reserve.



Graph 3 Fishing gears present in the reserve (fishing or passing)

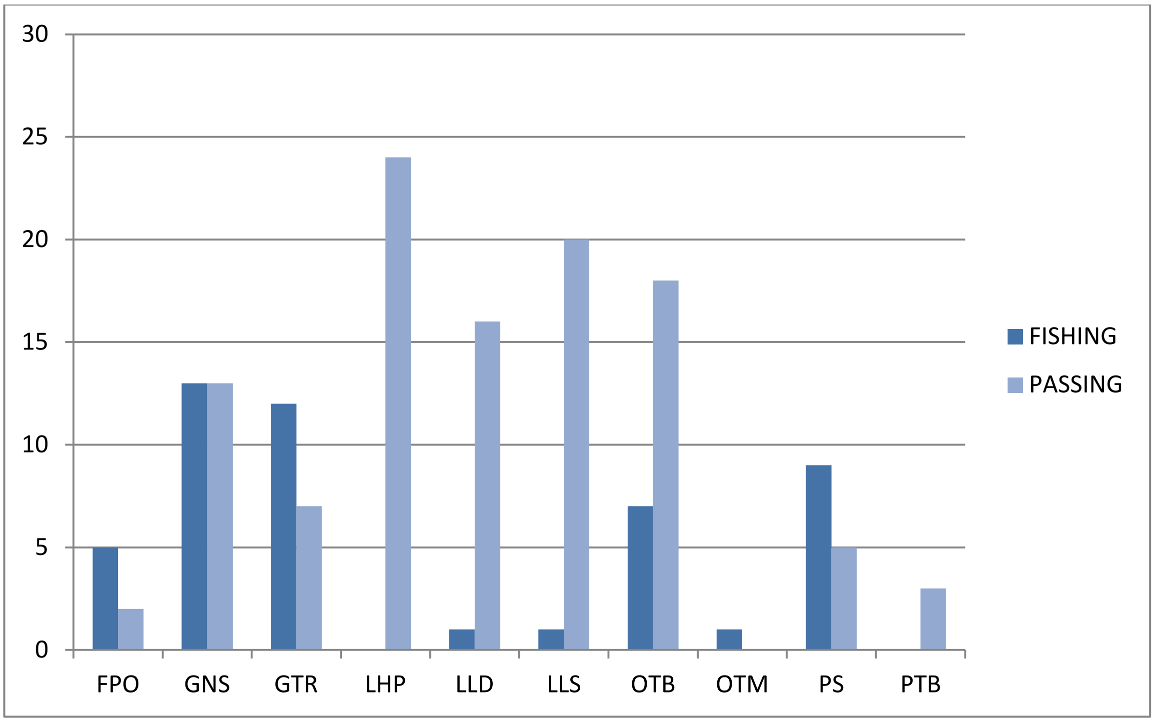
"Polyvalent" category is tricky and can hide some important data about fishing gear types. To have more detailed overview of the occurrence and importance of specific fishing gear types included in "polyvalent" and other categories, more detailed analysis was done.

Graph 4 presents the composition of polyvalent category. It consists mainly of set gillnets, traps and different long-lines – hand lines and pole-lines, set long-lines and drifting long-lines. Remaining parts are filled by trammel nets and purse seines.



Graph 4 The composition of polyvalent fishing gear category

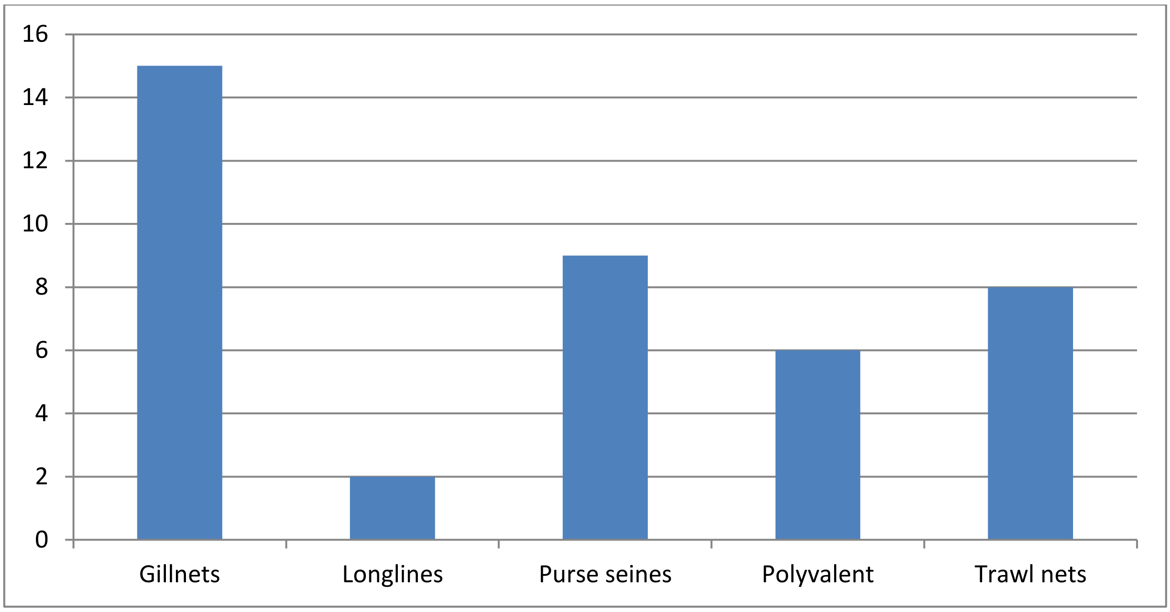
Graph 5 gives an overview about all fishing gear type current in the reserve. It shows that although gear types of "long-lines" create 30% of the polyvalent category, only about 3% are actually fishing in the reserve, concretely drifting long-lines and set long-lines. Now it is visible that the most important fishing gears operating in the reserve within the "polyvalent" category are traps, gillnets and purse seines. "Gillnets" category consist of the two most abundant fishing gears - set gillnets and trammel nets. "Trawlers" consist of bottom otter trawls, mid-water otter trawls with fishing activity within the reserve and finally bottom pair trawls which are only passing the reserve.



Graph 5 Overview of all fishing gear types current in the reserve

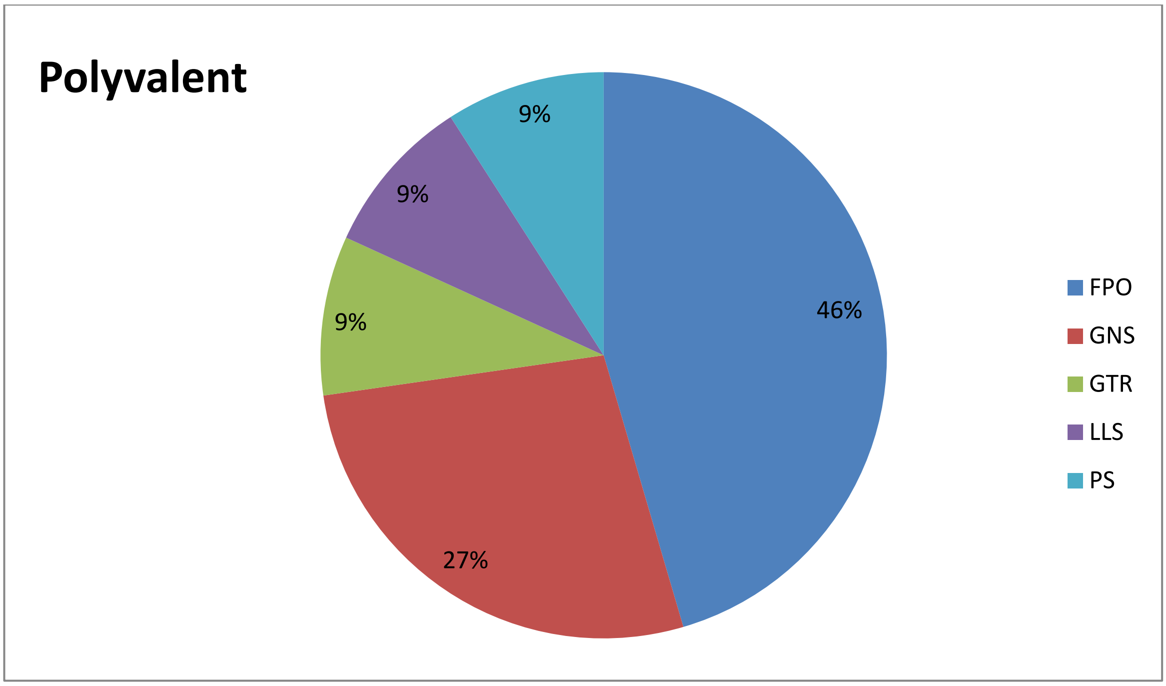
The previous graphs demonstrate that most of the long-line fishing gears were not fishing in the reserve therefore they are not useful for the next analysis; concretely hand-lines and pole-lines and bottom pair trawls are excluded completely from the following analysis focusing on fishing gears that are fishing in the reserve.

In the final result, within the total 33 boats found fishing in the Berlengas Islands SPA dominate gillnets, purse seines and trawl nets followed by polyvalent category. (Graph 6)



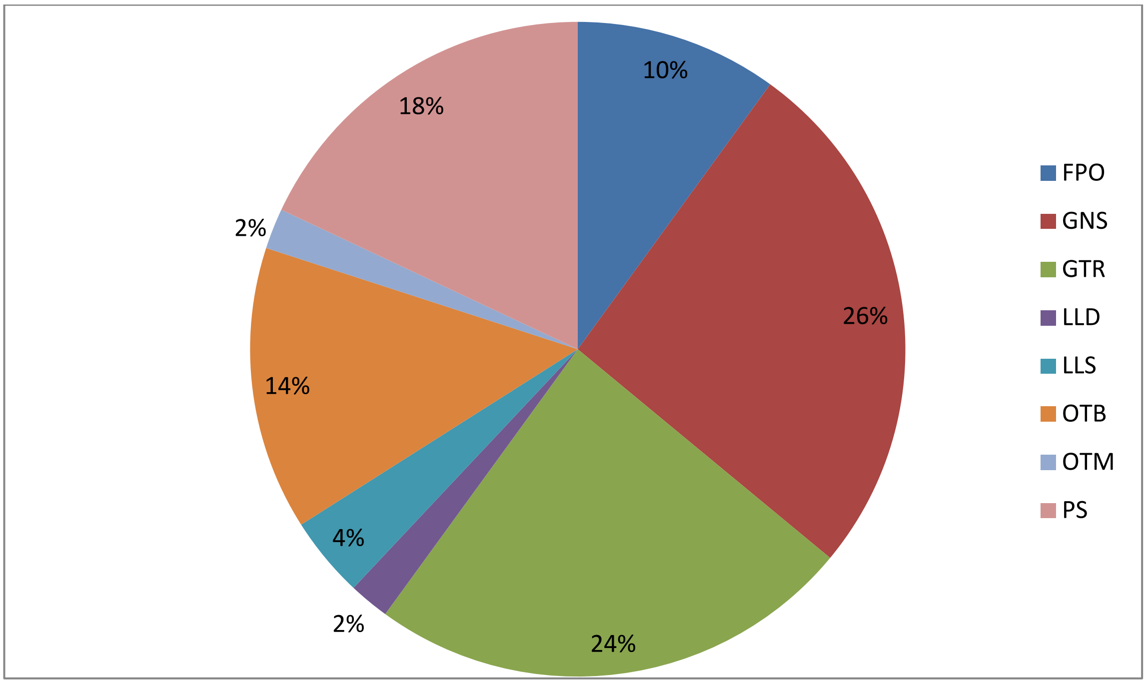
Graph 6 Fishing gear categories active inside the protected area

Half of the “polyvalent” category consists of traps and set gillnets. The remaining 18% consist of set long-lines, trammel nets and purse seines.



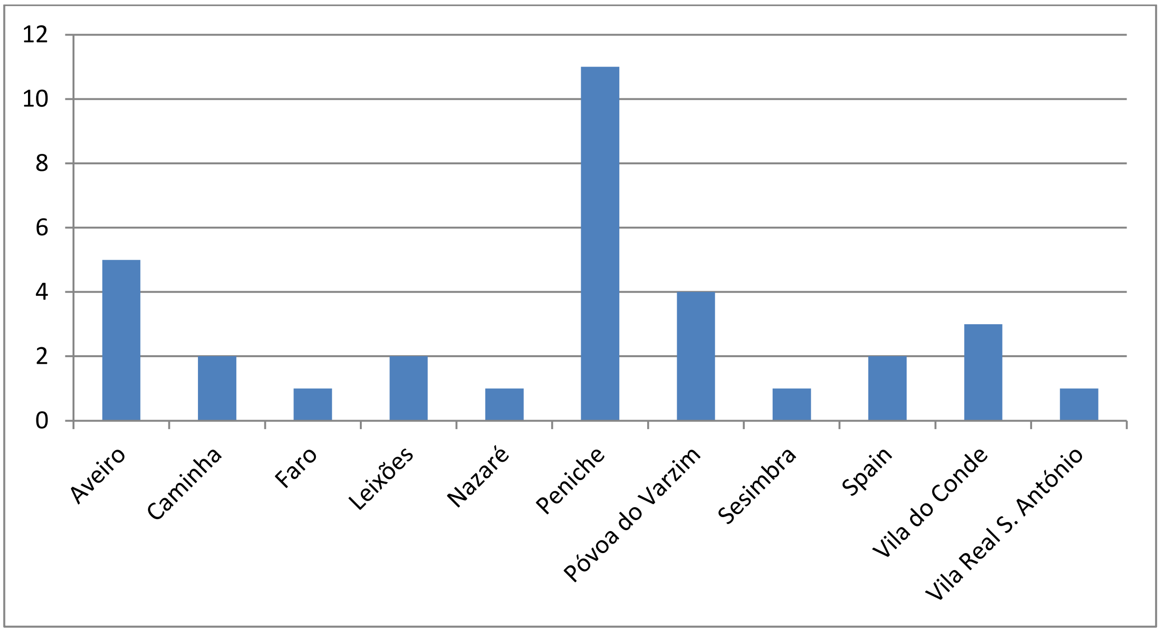
Graph 7 Composition of polyvalent category active in the protected area

The final composition of all fishing gear types operating within the reserve during the analysed period is characterised by 8 fishing gear types (5 categories). The dominate group represent set gillnets, trammel nets and purse seines. Together they create almost 70% of all fishing gear types. 24% is filled by traps and bottom otter trawls. Only 8% remains for drifting long-lines, set long-lines and mid-water otter trawls.



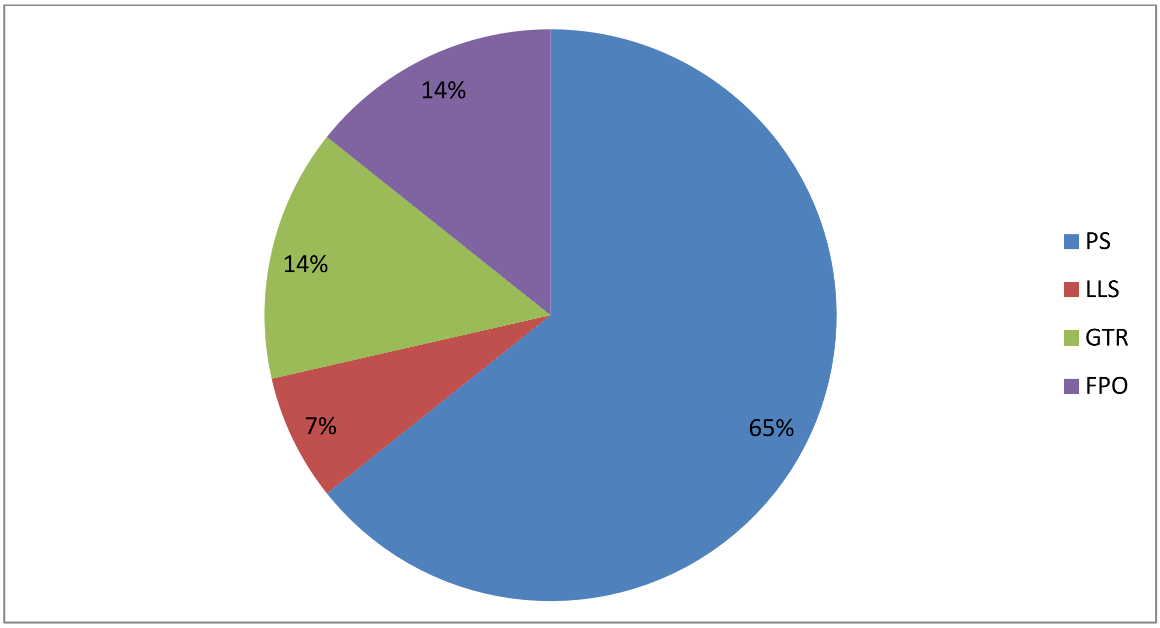
Graph 8 Overview of all fishing gear types active within the reserve

All boats operating fishing inside the reserve are Portuguese boats dominating by 33% made up of local fishing fleet from Peniche. The second most abundant boats come from port of Aveiro (5 boats) and Vila do Conde (3 boats). Only 7, 6% of the Spanish fishing fleet with original 26 reports are operating fishing inside the SPA.



Graph 9 Fishing boats active in the reserve and their origin port

The local fishing fleet based in Peniche is characterized by boats operating purse seines and polyvalent fishing gears. Polyvalent boats operate mostly trammel nets and traps which together create 28% and the remaining part consists of purse seines (65%). (Graph 11)



Graph 10 Characterization of methods operating by boats based in Peniche

Fishing gear identification analysis provided a wide overview of all fishing gears present within the reserve whether they were active in our outside the study area. The final analysis focused only on fishing gears actively fishing in the reserve expresses the highest abundance of specific fishing gear categories active within the area and therefore only those were found useful for the next analysis. These categories are – gillnets and entangling nets, trawl nets, surrounding nets (purse seines) and polyvalent.

4.3. Identified fishing areas and operation speed of each fishing gear

The result of all identified areas is a point shape file where each point represents one boats position at certain time. The total number of points is 12 967 which represents 33 boats fishing in the reserve during the studied period.

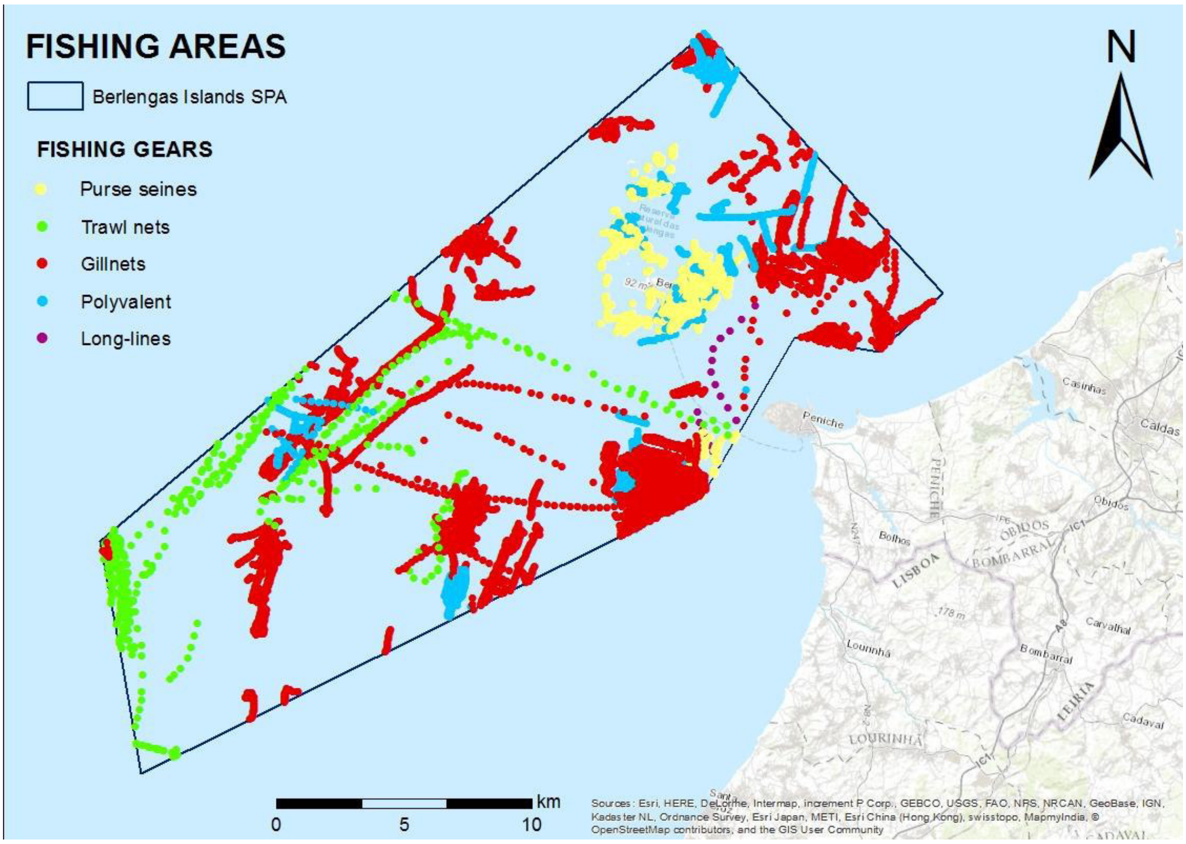


Figure 8 Fishing areas identified for winter season (2014, 2015, 2016, 2017). Colours represent particular fishing gear category.

After assigning the fishing gear to each ship it, the average operating speed for each gear was calculated.

Table 7 Average operating speed of concrete fishing gears

Fishing gear category	**Average operating speed (knots)**
Gillnets and entangling nets	1,3 knots
Long-lines	3,2 knots
Surrounding nets (purse seines)	0,8 knots
Trawl nets	3,6 knots

4.4 Preferred areas for operating fishing

Created map provide simple spatial information about the fishing boats occurrence and their preferred areas for fishing. Area covered by boats is divided into 95%, 75% and 50% of reported vessel positions considered actively fishing. The resulting output highlights areas with the highest point (vessel) density within the set 3 km wide radius. These red coloured areas are considered as spots with the most intense fishing activity (50%), followed by orange (75%) and grey (95%) as the spots with lowest boats density.

During the analysed 4-years period there were found 3 fishing hot-spots.

Following pictures provide closer look at the boats activity within each of the last 4 years. During the analysed 4-years period there were found various fishing hot-spots scattered throughout the reservation. It shows that the fishing intensity was almost always present around the islands and southern border of the SPA. Thus right in these spots the fishing areas are current with the highest density and are the most important for further attention. This distribution of fishing vessels corresponds with high biodiversity of waters surrounding the islands and the fact, that small fishing fleet operating from Peniche generally operate fishing closer to the mainland then in opened sea.

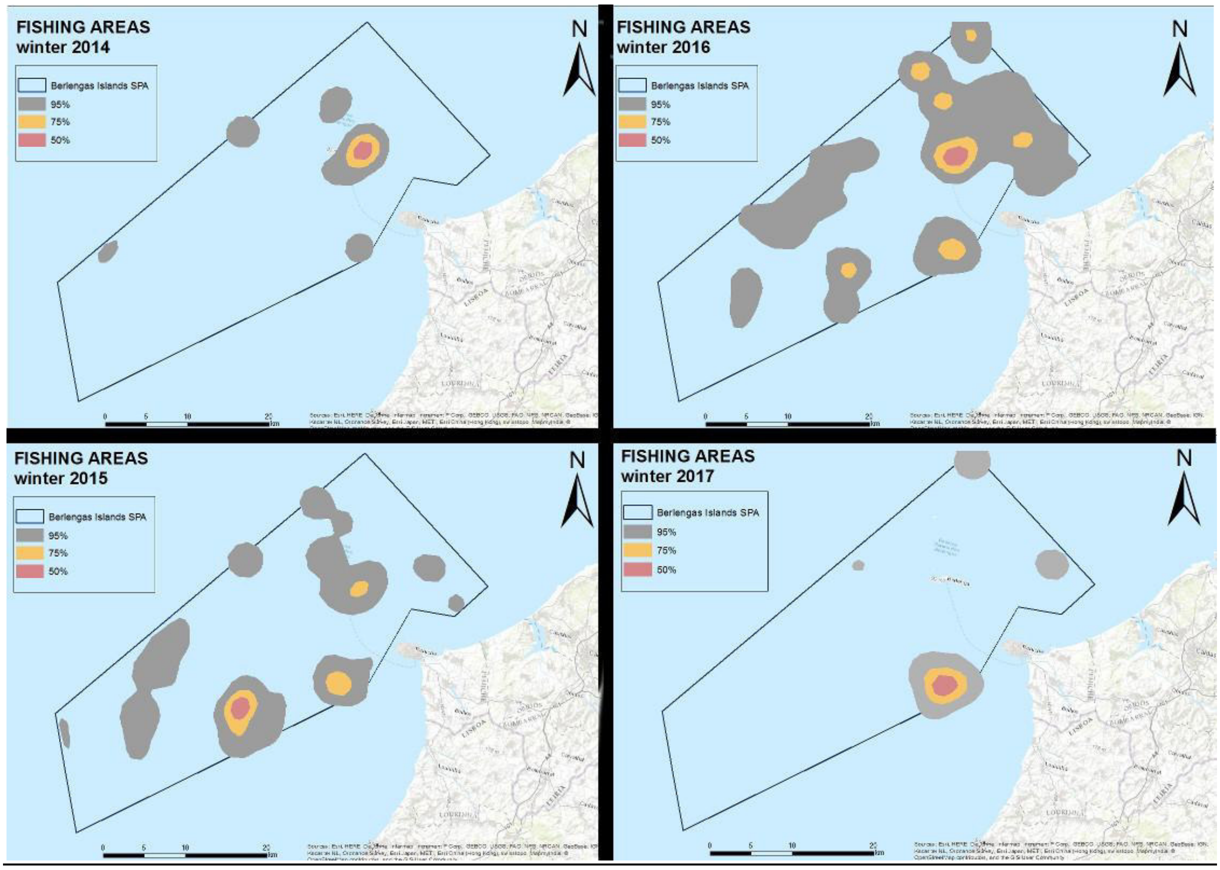


Figure 9 view of distribution of boats within the study period – years 2014, 2015, 2016 and January 2017

Final map of fishing areas is an analysis of all years together, highlighting the most important fishing spots within these 4 years. The positions of the tree found fishing hot-spots confirm that the strongest fleet activity occurred in waters closer to the shore of the islands or mainland. These hotspots are mainly presented by boats operating gillnets (set gillnets and trammel nets), traps, purse seine and trawl nets.

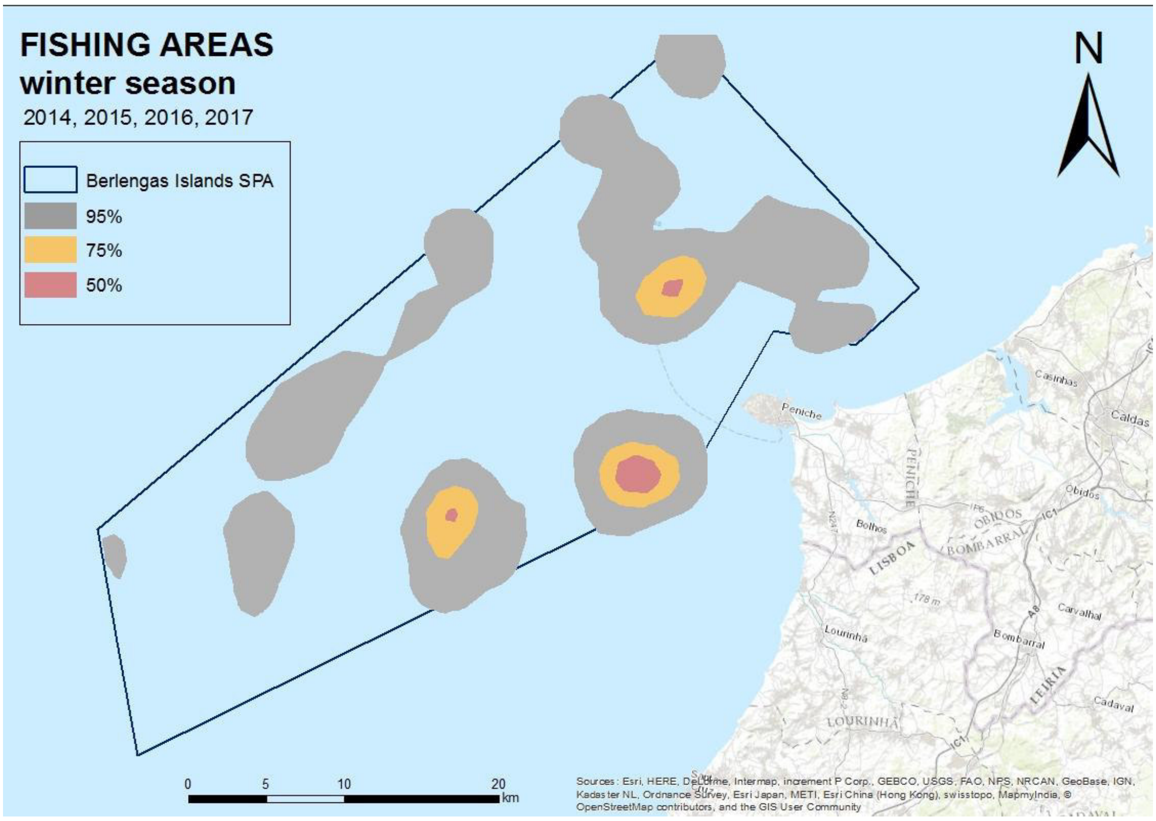


Figure 10 Fishing areas extension through the whole study period

4.5 Preferred areas for operating particular fishing gear

Following maps demonstrate where in the reserve were the given fishing gears mostly operating within the study period.

Purse seine fishing gear is performed especially around the Berlengas archipelago. Besides long-lines, purse seine is the only fishing gear allowed in the area of Berlenga Natural Reserve which consist of the islands and surrounded waters to a depth of 520m. This fishing gear operates generally near the coast; therefore another spot with higher fishing activity is found at the border of the reserve, close to the Portuguese coast.

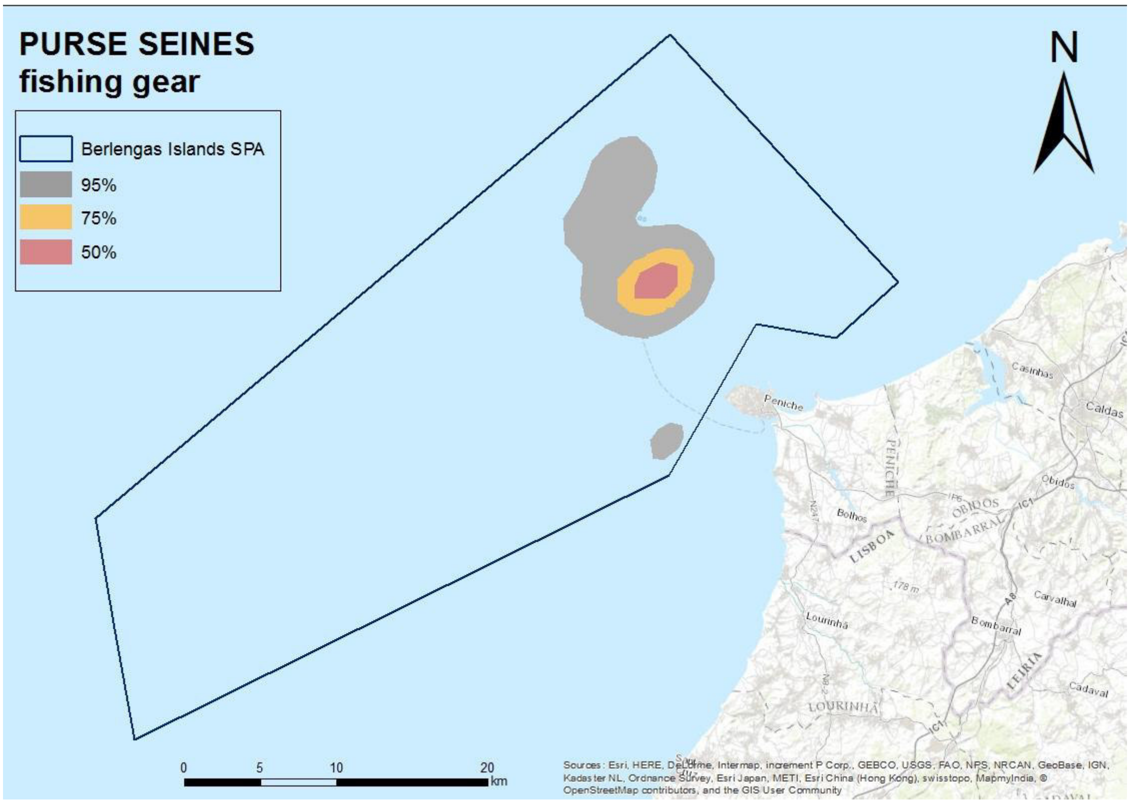


Figure 11 Preferred areas for purse seines within Berlengas Islands SPA trough the study period

Gillnets, considering set gillnets and trammel nets, cover a large part of the reservation, with the exception of the adjacent protected waters of the islands and eastern border of the SPA. The main fishing hotspots are found close to the southern border of the reserve, near mainland.

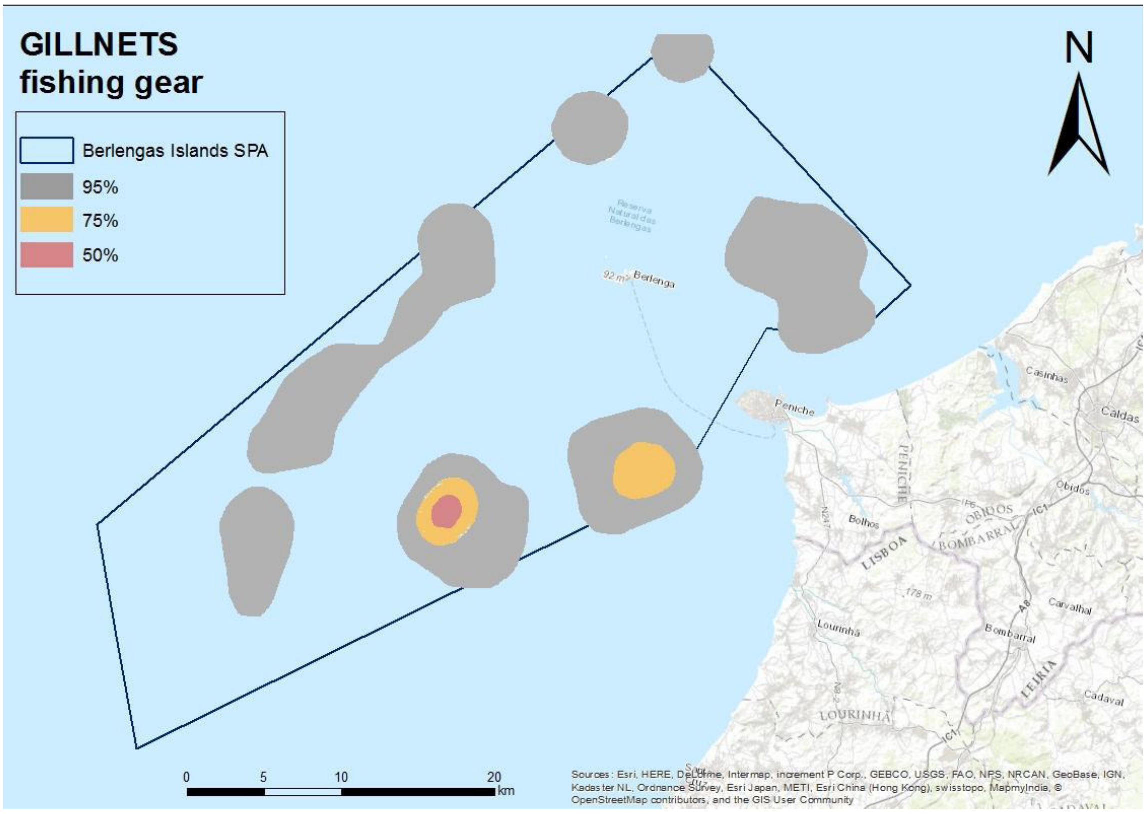


Figure 12 Preferred areas for gillnets within Berlengas Islands SPA trough the study period

Map with trawl nets distribution represents mostly bottom otter trawls. It was already mentioned in the previous text that boats operating trawl nets were in most cases Spanish boats only passing the reserve, so that these preferred operating outside the borders further in opened sea. Also in the following map is visible that the most important fishing spot for trawlers lies only on the northern and especially western border of the reserve.

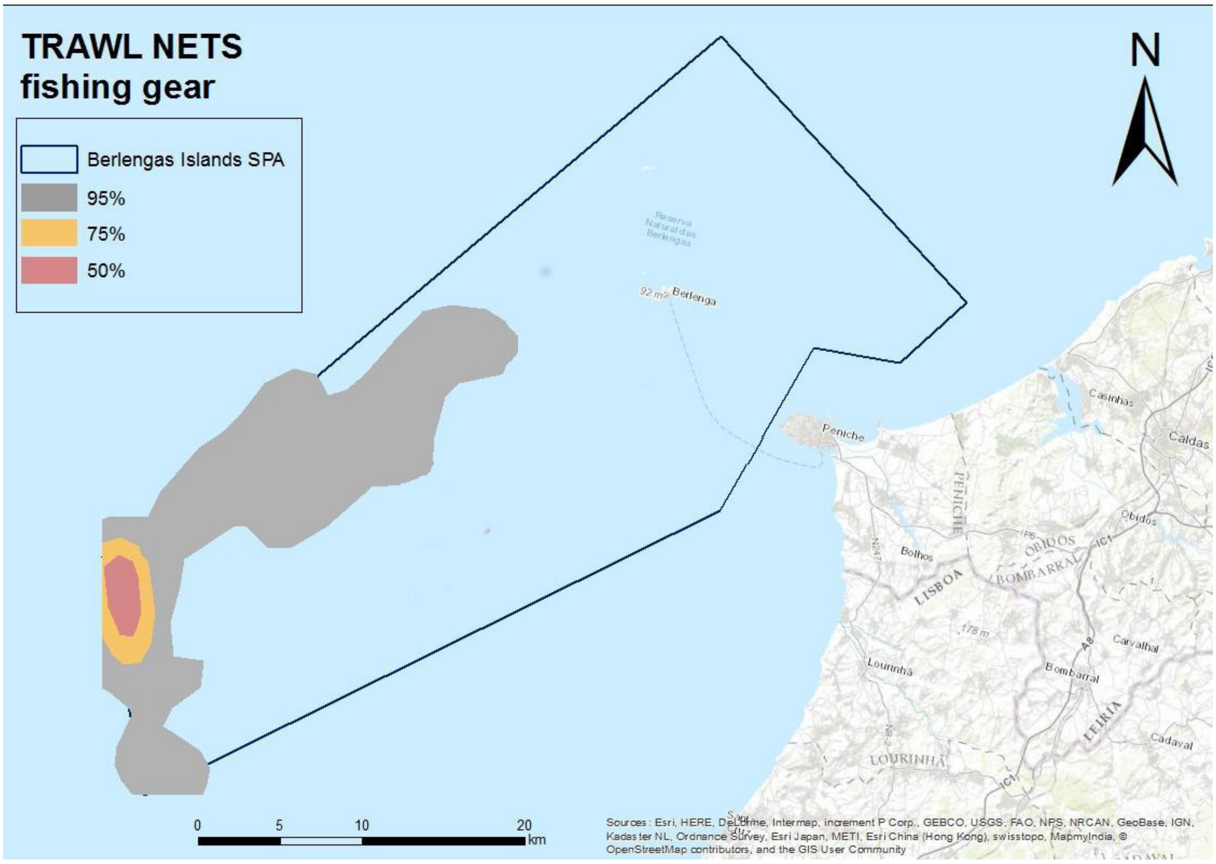


Figure 13 Preferred areas for trawl nets within Berlengas Islands SPA trough the study period

Polyvalent boats operate long-lines, purse seines, traps, trammel nets and set gillnets. Boats concentrated close to islands operate mostly traps, purse seine or long-lines. The main part of boats is concentrated on the southern border of the SPA, operating set gillnets, trammel nets or traps. Still this map provides only an approximate view at the fishing gear distribution due to the difficulty of analysing polyvalent boats and their specific gear activity.

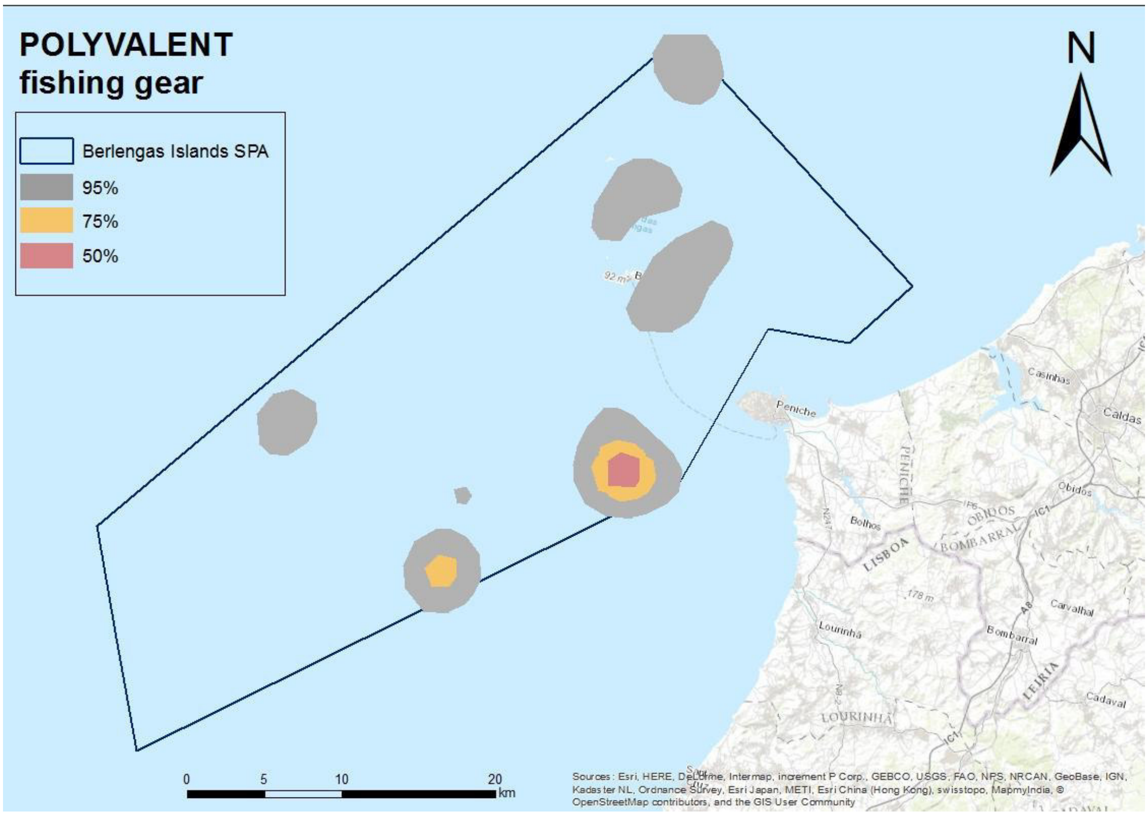


Figure 14 Preferred areas for polyvalent boats within Berlengas Islands SPA trough the study period

5 DISCUSSION

There is no standardized method providing estimation of fishing effort and it is still developing. All results in this study were found out trough studying literature and detailed experimental analysis of provided data, especially focusing on speed values and differences between them. That was very time consuming but necessary to obtain as accurate and correct results as possible. Obtained results were compared with different studies and discussed with the experienced field work team of SPEA based in Peniche. The whole process was more difficult because of the AIS data shortcomings described here and in more detail in the literature part, chapter Automatic Identification System (AIS) (1.4.5.).

The very first task in this work was boat identification and here already come the first shortcomings causing big gap in collected data. As mentioned in previous chapters, fishing fleet present in Berlengas Islands SPA and port of Peniche mostly consist of boats smaller than 15 meters which are not detected by AIS system as it is not obligated for these boats. The need of increasing the number of vessels required to carry the device is not a problem present only in this study area but is often mentioned in studies using Automatic Identification System (Visebeck et al. 2016; McCauley et al., 2016; Almeida et al., 2016). European Union's regulation mandating that all vessels over 15 metres carry AIS devices is already very successful comparing to other countries around the world. Nevertheless, in case of ports like Peniche consisted of smaller vessels than 15 meters, it is still significantly limiting the efforts of fishing activity estimation.

Another obstacle to research is the possibility of turning off the device which was apparent on boats that were reported within the SPA only in the morning, while leaving to the fishing area and then only appears again later in the evening while going back to the port. "IMO member states and regional fisheries management organizations should begin enforcing proper use of AIS. Simply having an AIS unit aboard a vessel but failing to use it properly can no longer be viewed as legal compliance" (McCauley et al., 2016). "We know it is possible to have regulations that prevent the disabling of such devices. Iceland has a strict policy in effect, and we see almost no gaps in broadcasts from the countries' roughly 1300 vessels that use AIS" (Visebeck et al. 2016).

AIS, when present and responsibly maintained by fisherman on-board, provide very valuable data and it already has success in marine environment conservation resources. For improvements, primarily policy interventions are required. “Technologies will continue to improve in coming years, increasing the accuracy of tracking and monitoring of fishing efforts in the ocean. With the proper policy and sufficient funding, every fishing vessel on the ocean could be equipped with AIS, allowing real-time tracking and monitoring of how ocean resources are used and managed” (Visebeck et al., 2016). Finally, to motivate fishermen for using the AIS device responsibly, certification of their products could be helpful by proving their sustainability and cooperation with environmental organization. “Additional AIS applications include use by sustainable seafood certifiers wishing to promote fisheries that transparently share harvest data, governments fulfilling seafood traceability requirements, local authorities aiming to decrease collisions between ships and marine mega-fauna, and overseeing development of seabed mining operations”(McCauley et al., 2016).

Another task of this work was observing the operating speed of fishing boats which was crucial for the determination of fishing areas present in the SPA.

Many sources and articles already described the methods of determining operation of trawl nets and it is not difficult to search for basic information about this gear. These studies were also developed using some form of speed-based differentiation to identify the fishing activity (Lee, 2010). But that is not the case of other fishing gears. Only a few studies provide concrete information about operation speed of specific gear. The whole thing is complicated also due to the large variety of target fished species. Some species are cached at higher speed, others at very low speed level. Therefore speed values of specific fishing gear determined in one area, do not need to agree in different study area. Results presenting the average operating speed of fishing gears active within Berlengas Islands SPA are contribution for developing methods of identifying fishing areas within this study area.

To exclude boats that are not fishing, filter for speed higher than 8 knots was used considering all gears. Lee (2010) chose even narrower range: “The data indicated that the use of a 1–6-knot speed filter provides an effective means of distinguishing most of the fishing activity for all gears.”

In this study the operation speed was determined for following fishing categories – gillnets (set gillnets and trammel nets), trawl nets (mainly bottom otter trawls) and surrounding nets (purse seines). Following table provides comparison with resulted methods of determining break limit speed for fishing and non fishing activity from different sources and studies.

The results obtained show that the breakpoint between fishing and non-fishing activity was always around 4-6 knots which closely agrees with Lee (2010) - "The breakpoint between the peaks was at speeds of 5–6 knots always."

Table 8 Comparison of methods determining breaking point between fishing and non-fishing activity

Fishing gear category	**Obtained method for this study**	**Various published methods**	**Source**
Gillnets and entangling nets	v < 4 knots	v <6 knots	(S.N., 2002)
Long-lines*	v < 5 knots	v <4-7	(DomingoA.,2014)
Surrounding nets (purse seine)	v < 2 knots	Not found	-
Trawl nets	v < 6 knots	v <6 knots v <7 knots v <8 knots	(Lee, 2010)

Obtained method was used in the last step - identifying fishing areas and their preferred spots for operating fishing. Resulting map include analysis focused only on winter season. Resource about fisheries activities within the Berlengas Islands SPA made by SPEA, shows that fishing activity during winter season is generally lower than in the previous summer and spring months, especially in case of purse seines where the lowest activity was reported during November and December followed by higher abundance during January and February (Almeida et al., 2016). Still it does not mean that the threats for seabird population are smaller as their abundance is changing thorough the year and especially in winter there are many wintering and migrating species, as for example highly abundant wintering Northern Gannet *(Morus bassanus)* and other species named in chapter 1.4.

Resulted maps provide only simple spatial information about vessel positions and their density within the studied area during the winter season. For more detailed and accurate study of fisheries intensity much other significant information should be required such as duration of operations or amount of fishes captured in given fishing areas. What is constantly preventing the accurate research of fishing gear activity is the high number of polyvalent boats present in the reserve. It is impossible to distinguish where are operating for example only traps or specific types of long-lines. In this study, to have more detailed overview about the fishing gears operating trough the reserve, the division in fishing gear categories was applied but it is still not obvious where are operating specific gear types separately, like in case of set gillnets or trammel nets. This problematic might explain why there are most of the studies available focused on trawl nets as they very often operate only one type of fishing gear type. Also in this study trawl nets were almost always represented by bottom otter trawls and no secondary gear. That is also true especially about boats operating purse seines within the reserve where only in one case were present two gears at one boat. Therefore it could be considered that the most accurate results in this study, talking about identification of specific fishing gear type activity, are results presenting purse seines activity. That is a positive conclusion because purse seine is the most common fishing gear type within the analysed local fishing fleet based in Peniche. It is also one of the two allowed fishing gear within the Berlengas Natura Reserve, therefore it has access to the most protected locality within the Berlengas Islands SPA where there is also higher risk of interaction with seabirds living on the islands and depending on their prey within surrounded waters.

6 SUMMARY

This work is a result of cooperation with non-profit organization called Society for Study of Birds (SPEA) based in Lisbon, Portugal within its Life Berlengas Project which started in June 2014 and will be implemented by September 2018. This project focuses on sustainable management of natural resources within the protected area called Berlengas Islands Special Protected Area which consists of Berlengas Archipelago and surrounded waters of Atlantic Ocean. One of the main interests of this project is studying and finding effective solutions of negative interactions between commercial fishery and seabird population.

Theoretical part describes fishery as a natural resource, importance of monitoring commercial fishing activities in sustainable fishery management and negative interactions between seabirds and commercial fishery. Aim of the practical part was to identify preferred fishing areas and distribution of fishing methods operating within Berlengas Islands Special Protected Area (SPA) in Portugal during the winter season. Historical data from years 2014, 2015, 2016 and January 2017 were analysed in ArcGis software, version 10.4.1., and the final resulting map presents the areas with highest boat density, considered as areas with strongest commercial fishing activity within the SPA.

From the results of the work follow that there were 108 boats present in the reserve, from whose 33 were operating fishing. Boats are mainly of small dimensions up to 40 meter length operating mainly gillnets, purse seines and large part is represented by polyvalent boats. Final map represents 3 main fishing hot-spots located around the Berlengas Archipelo and at the southern border of SPA.

Obtained results provide information about fishing gears and their operating speed which are useful for future analysis of fishing areas and it is a contribution for developing standardized method for determining fishing activity within the reserve. Created maps are a contribution for Life Berlengas Project and SPEA which can always use these results for further analysis for example in direct studies of interaction between fisheries and wintering and migrating seabird species present in the reserve.

7 REFERENCES

7.4 References

ALL ABOUT AIS - All About AIS, 2012 - All About AIS. *All About AIS* [online]. 2012 [cit. 2017-04-22]. Available from: http://www.allaboutais.com/index.php/en/

ALMEIDA, A., Oliveira, N., Santos, A., Gutiérrez, I. & Andrade, J. 2016 *Caracterização da interação das aves marinhas com artes de pesca. Relatório da Ação A4, Projeto Life Berlengas*. Sociedade Portuguesa para o Estudo das Aves, Lisboa

ALMEIDA A pesca em Portugal: Nem tudo o que vem á rede é peixe. *Pardela: REVISTA DA SOCIEDADE PORTUGUESA PARA O ESTUDO DAS AVES*. SPEA, 2016, (53), 3

ARCOS, J.M. (compiler) 2011. International species action plan for the Balearic shearwater, Puffinus mauretanicus. SEO/BirdLife & BirdLife International

BARTUMEUS, F. et al. Fishery discards impact on seabird movement patterns at regional scales. *Current Biology*, 2010, 20.3: 215-222

BBC - BBC future: How salmon help keep a huge rainforest thriving. *BBC* [online]. London: BBC, 2017 [cit. 2017-04-25]. Available from: http://www.bbc.com/future/story/20140218-salmon-fertilising-the-forests

Berlengas - *Berlengas: Berlengas Project* [online]. 2017 [cit. 2017-04-03]. Available from: http://www.berlengas.eu/

Birdlife, -*Birdlife* [online]. 2017 [cit. 2017-04-04]. Avaible from: http://www.birdlife.org/europe-and-central-asia

COSTA et al., 2016 - Persistent organic pollutants and inorganic elements in the Balearic shearwater *Puffinus mauretanicus* wintering off Portugal. *Marine pollution bulletin*, 2016, 108.1: 311-316

COSTA, H. ; DE JUANA ARANZANA, E., SIMÓ, J. M. V., *Aves de Portugal: incluindo os arquipélagos dos Açores, da Madeira e das Selvagens*. Lynx Edicions, 2011

COSTA, (ed.). *Zonas importantes para as aves em Portugal*. 2003. Meirinho et al., 2014 - MEIRINHO, A., et al. Atlas das Aves Marinhas de Portugal. *Sociedade Portuguesa para o Estudo das Aves, Lisboa*, 2014

COX, T. M., et al. Comparing effectiveness of experimental and implemented bycatch reduction measures: the ideal and the real. *Conservation Biology*, 2007, 21.5: 1155-1164

CRAWFORD, R. a S. HURREL. What lies beneath seabird bycatch in gillnet fisheries. *World Birdwatch*. 2015, 3.

DE JUANA, E.; GARCIA, E.. *The birds of the Iberian Península*. Bloomsbury Publishing, 2015

DUNN, E.; BEDS, S. G. The case for a Community Plan of Action for reducing incidental catch of seabirds in longline fisheries. *BirdLife International, Cambridge*, 2007

EC-EUROPEAN COMMISSION, et al. Facts and figures on the Common Fisheries Policy-Basic statistical data. 2016

EXACTEARTH: Should I Track Global Fishing Activity with VMS or AIS? *ExactEarth: ExactBlog* [online]. Canada: ExactEarth, 2015 [cit. 2017-04-22]. Available from: http://blog.exactearth.com/blog/should-i-track-global-fishing-activity-with-vms-or-ais

FAO - Fishing Vessel Finder: Fisheries and Aquaculture department. *Food and Agriculture Organization of the United Nations: FAO Fishing Vessel Finder* [online]. Italy: FAO, 2017 [cit. 2017-04-25]. Available from: http://www.fao.org/figis/vrmf/finder/search/#quick

FAO FVF - FAO Fishing Vessels Finder (FVF): Fishery Records Collections. *FAO Fishing Vessels Finder (FVF): Fisheries andAquaculture Department* [online]. FAO: FAO, 2017 [cit. 2017-05-03]. Available from: http://www.fao.org/fishery/collection/fvf/4/en

FCF - The 2nd International Symposium on Mangroves as Fish Habitat: Mangroves as Fish Habitat Abstracts. *Fisheries Conservation Foundation* [online]. Illinois: FCF, 2015 [cit. 2017-04-25]. Available from: http://www.fishconserve.org/mangrove-as-fish-habitat-program-and-abstracts/

Flora-on, 2016 - Flora-on: Flora de Portugal. *Flora-on: Flora de Portugal* [online]. Portugal: Sociedade Portuguesa de Botânica, 2016 [cit. 2017-05-02]. Dostupné z: http://flora-on.pt/

FURNESS, Robert W. Impacts of fisheries on seabird communities. *Scientia Marina*, 2003, 67.S2: 33-45

HUTCHISON, J.; SPALDING, M.; ZU ERMGASSEN, P.. The role of mangroves in fisheries enhancement. *The Nature Conservancy and Wetlands International, UK*, 2014

ICNF - ICNF: Instituto da Conservacão da Natureza e das Florestas. *ICNF: Instituto da Conservacão da Natureza e das Florestas* [online]. Portugal, 2017 [cit. 2017-04-09]. Avaible from: http://www.icnf.pt/portal/

IUCN, 2017 - http://www.iucnredlist.org/

JENÍK, J., PAVLIŠ J., 2011. *Terestrické biomy: lesy a bezlesí Země*. Brno: Mendelova univerzita v Brně

KAISER, M. J. *Marine ecology: processes, systems, and impacts*. Oxford University Press, 2011

LEE, J.; SOUTH, A. B.; JENNINGS, S.; Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. *ICES Journal of Marine Science: Journal du Conseil*, 2010, fsq010

MARINE TRAFFIC - *MarineTraffic.com* [online]. 2017 [cit. 2017-04-25]. Available from: https://www.marinetraffic.com/en/ais/home/centerx:-9.400/centery:39.400/zoom:12

MCCAULEY, D. J., et al. Ending hide and seek at sea. *Science*, 2016, 351.6278: 1148-1150

MIRERA, D. HO. *The Effects of Mangrove Habitat Degradation on Fish Abundance and Diversity In Ungwana Bay, Kenya*. 2007. PhD Thesis. Egerton University

NEA - Seabirds. N*ORWEGIAN ENVIRONMENTAL AGENCY* [online]. Norway: NORWEGIAN ENVIRONMENT AGENCY, 2017 [cit. 2017-04-24]. Available from: http://www.miljodirektoratet.no/en/Areas-of-activity1/Species-and-ecosystems/Seabirds/

NGUYEN, T. V., Ecosystem-based fishery management: a review of concepts and ecological economic models. *Journal of Ecosystems and Management*, 2012, 13.2

PARDELA, *As aves em revista Pardela Pardela: REVISTA DA SOCIEDADE PORTUGUESA PARA O ESTUDO DAS AVES*. 2015, (51)

PIKITCH, E., et al. Ecosystem-based fishery management. *Science*, 2004, 305.5682: 346-347

PRACH, K.; ŠTECH, M.; ŘÍHA, P.. *Ekologie a rozšíření biomů na Zemi*. Scientia, 2009

PRIMACK, R. B.; KINDLMANN, P.; JERSÁKOVÁ, J.. *Úvod do biologie ochrany přírody*. Portál, 2011

REICHHOLF, J., B. P. KREMER and K. JANKE. 1999. *Moře a pobřeží: ekologie mořských životních prostředí Evropy*. Ilustroval F. WENDLER, přeložil J. ČIHAŘ. Praha: Ikar

SALY N., T., Saly N. "Gill nets and their operation." Central Institute of Fisheries Technology, 2002

SCHREIBER, E. A.; BURGER, Joanna (ed.). *Biology of marine birds*. CRC Press, 2001

SULOCHANAN, B.. Mangrove ecosystem and its impact on fisheries. 2013

SVENSSON, L., et al. *Ptáci Evropy, severní Afriky a Blízkého Východu*. Ševčík, 2012

VISBECK, M.; MARSHALL, P.; DOUVERE, F.. Marine World Heritage and climate change: Challenges and opportunities, 2016

Wildlife Conservation Society. (2016, February 11); Marine vessel tracking system also a lifesaver for wildlife. *ScienceDaily*. Retrieved April 22, 2017 Available from www.sciencedaily.com/releases/2016/02/160211190012.htm

WWF, 2017 - Mangrove forests: threats: Mangrove forests are one of the world's most threatened tropical ecosystems. *WWF Global: World Wide Fund For Nature* [online]. WFW, 2017 [cit. 2017-04-25] Available from: http://wwf.panda.org/about_our_earth/blue_planet/coasts/mangroves/mangrove_threats/

ZADOR, S. G., et al. Determining spatial and temporal overlap of an endangered seabird with a large commercial trawl fishery. *Endangered Species Research*, 2008, 5.2-3: 103-115

7.2 List of figures

7.3 List of tables

7.4 List of graphs

7.4. List of annexes