

Marine traffic and potential impacts towards cetaceans within the Madeira EEZ: a pioneer study

Inês de Sena Amaral da Cunha

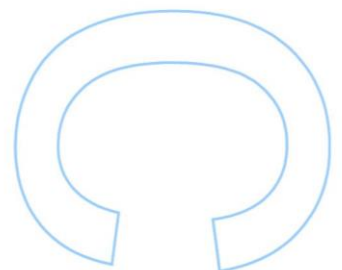
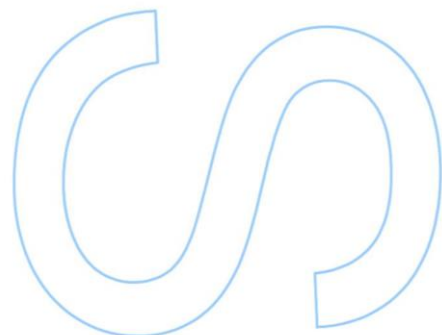
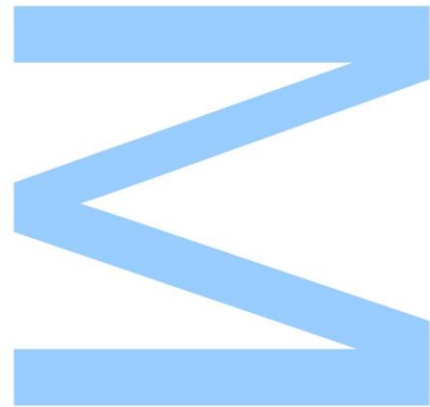
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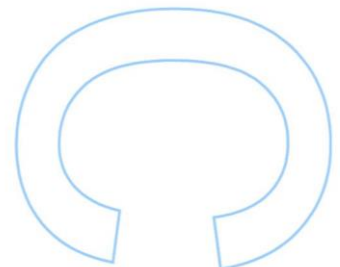
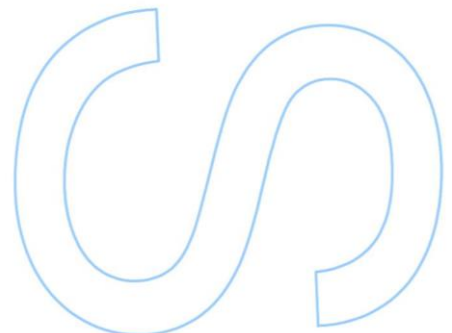
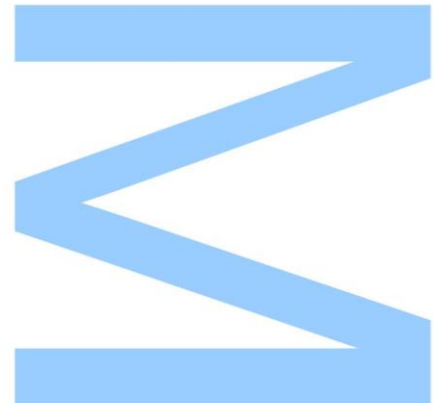
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Todas as correções determinadas pelo júri, e só essas, foram efetuadas.
O Presidente do Júri,

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Abstract

In present times, the anthropogenic disturbances towards wildlife are becoming more frequent. The human population growth is followed by an increase of harmful inputs towards the environment. Marine traffic is one of them and has been associated with a high disturbance potential towards wildlife species. This negative effect is expected to increase alongside the traffic expansion. Thus, maritime traffic characterization is a valuable contribute towards wildlife conservation measures. Cetaceans, in the quality of “umbrella species” might reflect the sustainability of an ecosystem. The present study takes place in the Autonomous Region of Madeira Exclusive Economic Zone (EEZ), tagged by substantial biodiversity where cetaceans are included. Through this project, under the guidance of the Madeira Whale Museum and resorting to traffic data collected by nautical surveys conducted by the previous and Automatic Identification System (AIS) data provided by Ports Administration of the Autonomous Region of Madeira (APRAM), a first attempt to characterize the in and offshore traffic and infer the potential impacts towards cetaceans, within the Madeira EEZ, is stated here. Attending to the AIS data analyses, the offshore traffic corresponds to approximately 22% and 17% of the traffic verified in the Baltic and North seas, respectively. It is mostly composed by cargo boats, circulating over fixed routes and mostly using the area as a passage zone towards different destinations. Cruises intersect the area to reach Funchal port. The number of recreational boats is underestimated. The level of inshore traffic is hard to infer, since it is a small area encompassing a shipping route, but it represents 1.17% of the traffic of the strait of Gibraltar. An inshore common “high used corridor” by both vessels and cetaceans was identified, standing as a potential conflict zone. However further studies are needed in order to infer the real level of impact towards cetaceans.

Keywords: AIS, Marine traffic, Cetaceans

Resumo

Nos tempos atuais, as perturbações antropogénicas para a vida selvagem tornam-se mais frequentes. O crescimento da população humana é seguido por um aumento de fatores prejudiciais ao meio ambiente. O tráfego marítimo é um deles e tem sido associado a uma elevada potencial perturbação para as espécies selvagens. Com a expansão do tráfego marítimo é esperado um aumento deste efeito negativo. Assim, a caracterização do tráfego marítimo é um contributo valioso para medidas de conservação da vida selvagem. Os Cetáceos na qualidade de "espécies guarda-chuva" podem refletir a sustentabilidade de um ecossistema. O presente estudo teve lugar na Zona Económica Exclusiva da Região Autónoma da Madeira, marcado por uma substancial biodiversidade, onde os cetáceos estão incluídos. Através deste projeto, sob a orientação do Museu da Baleia da Madeira e recorrendo a dados de tráfego recolhidos aquando de censos náuticos levados a cabo pela respetiva equipa de investigação, e pelos dados de *Automatic Identification System* (AIS) fornecidos pela Administração dos Portos da Região Autónoma da Madeira (APRAM), realizamos uma primeira tentativa para caracterizar o tráfego *inshore* e *offshore* e inferir os potenciais impactos na população de cetáceos, dentro da Zona Económica Exclusiva (ZEE) da Madeira. Atendendo às análises de dados AIS, o tráfego *offshore* corresponde a aproximadamente 22% e 17% do tráfego verificado nos mares Báltico e do Norte, respetivamente. Este é na sua maioria composto por barcos de carga, circulando em rotas fixas e usando a área principalmente como uma zona de passagem para diferente destinos. Barcos Cruzeiros atravessam a área para chegar ao porto do Funchal. O número de barcos de recreio não é representativo. O nível de tráfego *inshore* é difícil de inferir, tratando-se de uma pequena área que abrange uma rota de navegação, representando 1.17% do tráfego do estreito de Gibraltar. Foi identificado um corredor *inshore* comum ao tráfego e aos cetáceos representando uma potencial zona de conflito. Porém, são necessários mais estudos para inferir o nível real de impacto nos cetáceos.

Palavras-chave: Tráfego marítimo, AIS, Cetáceos

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Abbreviations

AIS – Automatic Identification System

APRAM – Ports Administration of the Autonomous Region of Madeira / Administração dos Portos da Região Autónoma da Madeira

ASCOBANS – Agreement on the Conservation of Small Cetaceans

COG – Course Over Ground

EEZ – Exclusive Economic Zone

GIS – Geographic Information System

GPS – Global Positioning System

GT – Gross Tonnage

HNS – Hazardous and Noxious Substances

IFAW – International Fund for Animal Welfare

IMO – International Maritime Organization

IWC – International Whaling Commission

MARPOL – International Convention for the Prevention of Pollution from Ships

MWM – Madeira Whale Museum

NE – North East

NGO – Non-governmental organization

PAHs – Polycyclic Aromatic Hydrocarbons

Photo-ID – photo-identification

PSSAs – Particular Sea Sensitive Areas

PTS – Permanent Threshold Shift

SD – Standard Deviation

SOG – Speed Over Ground

SOLAS – International Convention for the Safety of Life at Sea

SW – South West

TTS – Temporary Threshold Shift

UNEP – United Nations Environment Programme

VHF – Very High Frequency

VOS – Voluntary Observing Ships

WHO – World Health Organizations

WMO – World Meteorological Organization

1. Introduction

In the condition of top rank predators, cetaceans' population status might reflect the sustainability of an ecosystem (Kaschner et al., 2001). Thereby, they stand as “umbrella species”, whose conservation simultaneously implies the preservation of the species of which they depend.

Cetaceans are wide-ranging marine mammals so it is important to portrait the interactions between these species and its habitat (Zacharias and Gregr, 2005).

The industrial revolution has promoted a notorious enlargement of human population (DeMaster et al., 2001). Thus, in present times, anthropogenic factors have grown to become somewhat part of wildlife habitat.

Whales and dolphins are exposed to several human activities, some more intrusive than others. Marine traffic is among them and has been associated with a high disturbance potential towards these species. This negative effect is doomed to increase with the level of traffic. (Nowacek et al., 2001).

The International Maritime Organization (IMO) is an agency created in 1948 by the United Nations with the intent to promote international maritime safety, shipping security and pollution control by establishing an appropriate regulatory framework, including the approval of mandatory ship reporting systems (IMO - International Maritime Organization, 2013). Since January 2005, by the IMO's International Convention for the Safety Of Life At Sea (SOLAS) every ship with gross tonnage (GT) equal or superior to 300 and all passenger ships of every size have to be equipped with AIS devices. The Directive 2009/17/EC established timelines by which different sizes of fishing boats, large vessels and vessels over 15 m will have to present AIS devices (International Whaling Comission, 2011). Thus, the Autonomous Region of Madeira is under the same rule (Ministério da Agricultura do Mar do Ambiente e do Ordenamento do Território, 2012).

AIS consists on a ship-to-ship and ship-to-shore message system based on a VHF signal (161.9765 mHz and 162.025), which provides static and dynamic information along each vessel trip (Gregory et al., 2012).

AIS based traffic related studies are recurrently addressed, for either waterways design, marine spatial planning or safety management purposes, based on traffic characterization, pointing out congestion areas or ship collision risk zones, for instance (Başar, 2010; Maes, 2008; Mou et al., 2010; Pan et al., 2012; Yeo et al., 2007).

The AIS system was created for quantification of vessel operation drives, but has been widely used for cetaceans conservation purposes (Evens et al., 2011; International Whaling

Comission, 2011; Leaper and Panigada; McGillivray et al., 2009; Merchant et al., 2012; Silber et al., 2002; Ward-Geiger et al., 2005).

It was already verified that cetaceans might be affected by watercraft, manifesting behavioural changes (Piwetz, 2012) that might trigger alterations in habitat use, temporary displacement and drop of energy consumption. When continuously submitting the animals to these impacts, long term consequences, such as changes in survival rates or population size, might follow (Bejder et al., 2006; Constantine et al., 2004; Nowacek et al., 2001). However, it is difficult to infer the real anthropogenic activity significance on cetaceans from other natural factors due to spatial and temporal gaps between cause and effect. Just the same, variables such as species, age, gender, reproductive condition and level of habituation might influence how animals respond to human disturbance. The long life stand of cetaceans aligned with the limited research and funding makes it hard to monitor or predict long-term effects (Bejder and Samuels, 2003).

Vessel disturbances towards cetaceans might be inflicted in different ways, through boat-based (eco)tourism, fishery interaction or/(and) ship strike or water noise and pollution.

Through the last decades, due to the vast expansion of marine traffic, cetaceans have been victims of ship strikes all around the world (Carrillo and Ritter, 2008; Gregory et al., 2012; Laist et al., 2001; Waerebeek et al., 2007).

Vessel strike might be defined as “a forceful impact between any part of a watercraft, most commonly the bow or propeller and a live cetacean often resulting in death or physical trauma. Sub lethal injuries compromises the fitness of the individual interfering with its foraging abilities, predator avoidance and reproduction aptness (Waerebeek et al., 2007).

Ship strikes records always followed the ship craft evolution, starting at the 19th century, when ships started to be able to travel at 13 – 15 Kn, later becoming more frequent between the 50's and the 70's, following the expansion of ship and speed increase. After the 80's the number of vessels has become relatively stable, and the incidence of ship collisions did not increase much (Laist et al., 2001).

Now a days regarded at the same level as by catch (Waerebeek et al., 2007), ship strike was acknowledged as a real threat towards whale populations among the globe and is now being targeted by various mitigations strategies, especially in the regions where overlapping areas of marine traffic and cetaceans were detected, some supported by even IMO itself (Gregory et al., 2012).

The two more extensive reviews on the matter depicture the current situation in both Northern (Laist et al., 2001) and Southern (Waerebeek et al., 2007) hemispheres. The fin, right,

humpback and sperm whales were reported as the most frequently hit species in both hemispheres, while grey whales would also be target in the Northern hemisphere and Bryde's, blue, and sei whales in the Southern (Laist et al., 2001; Waerebeek et al., 2007). Unlike what some of the related literature implies, small cetaceans might also suffer vessels collisions (more frequently involving small watercraft), even though the more aggravating cases, where lethal strikes are more common, are usually related with species living in neritic, estuarine or fluvial habitat, while other species like common bottlenose dolphins, killer, short-finned pilot and pygmy sperm whales, suffer a less aggravating impact, where many collisions are not lethal (Waerebeek et al., 2007).

Some "hot spots" (areas with high density of both cetaceans and vessels, where ship strike negatively interferes with the dynamics of the cetacean population) have already been identified around the world (Gregory et al., 2012; International Whaling Commission, 2011; Panigada et al., 2006; Ritter, 2007).

Yet, the real level of impact inflicted by ship strikes in cetaceans species or populations is still hard to infer since the required information to accomplish that is not easily available and sometimes is even unreachable, like the ship logbooks, for instance. Reporting systems are only implemented in some areas and it is not certain they are always fulfilled (Waerebeek et al., 2007). Useful information related with ship strike consist on the species (including sex, age, behaviour – feeding, migrating, reproducing, etc. - time of the year) and vessels (according to the type, noise impact and speed), geographic region and the surrounding environment (Vanderlaan and Taggart, 2007).

All types of vessels can be related with ship strike (Carrillo and Ritter, 2008; Waerebeek et al., 2007). Incidents involving small vessels (< 20 m length) were expected to be less frequent assuming they usually operate in good weather conditions, disposing of a better level of visibility towards the surrounding environment, allowing them to detect any struck objects more easily (Laist et al., 2001). However, vessel strikes with small cetaceans are more frequently caused by small vessels (Waerebeek et al., 2007) and recent reports exposed cases of vessel collisions lead by sailing boats, for example (Ritter, 2012).

Ship collisions physical evidence on stranded cetaceans might be identified as massive blunt impact trauma (bone fracture) or (long) deep (parallel) slashes on the blubber or on the dorsal aspect most likely caused by propellers (Laist et al., 2001).

It may also happen that whale floating carcasses might be hit and later being accounted for strandings resulting from ship strike. These false positive might be possible to detected considering usually cetaceans sink after they die and when coming back to the surface the carcass floats belly up, so in case it gets hit post mortem the physical evidence would be on the ventral part of the body and not on the dorsal (Waerebeek et al., 2007).

The risk associated with ship strike is relevant not only for the cetaceans community, but might also overflow and compromise the human safety, as cases have been reported where ship collisions with whales have resulted in the injury or death of vessel passengers (André et al., 1997; Honma et al., 1997).

On the other hand, cetaceans have grown to attract a significant interest among the general public, prompting the increasing of a large industry based on the delivery of recreational whalewatching opportunities (Jelinski et al., 2002). People are eager to experience cetaceans in their natural environment (Orams, 2000). However, whalewatching, as a branch of ecotourism, is surrounded by great controversy regarding its benefits, slash costs, quivering between economic development and ecological sustainability.

The concept of ecotourism itself is somewhat ambiguous, as on one hand it represents a profitable and somewhat non-damaging economic resource, well applied in a wildlife conservation strategy, and on the other hand, if not duly managed, the economic incentives might be conveyed into more intrusive forms of human expansion instead of conservation measures, and so become the source of environmental degradation (Isaacs, 2000). The concept of ecotourism and its environmental impacts have been discussed since 1970s, when the flue of nature tourism started to inflate (Goodwin, 1996). Many definitions of “ecotourism” were attempted, most of the times prescriptively (making it hard to use them practically) even though no definition has been universally accepted (Goodwin, 1996). Among other alternatives, ecotourism might be designated as an environmental responsible experience which promotes the conservation of biodiversity, supports the welfare of the native community and endorses learning and responsible actions and involvements designed for the tourists and the tourism industry, based on the lowest level of consumption of non-renewable resources (UNEP IE/PAC, 1992). The polemic lies on the sustainability of this trend, i.e., the likelihood of overflowing the environmental carrying capacity through the over-use of natural resources by the tourists, as no form of tourism is without environmental, economic and social impacts (Goodwin, 1996). Thus, building a market based on ecotourism its conditioned by its capability to keep the long-term existence of other natural-area benefits (Isaacs, 2000). Wildlife related recreation engages instructive actions towards the protection of habitat and biodiversity, rising the travellers’ awareness and sensitivity towards the ecosystem and its processes, but is not entirely benign, with inherent (at least relatively) impact on the target species (Isaacs, 2000; Jelinski et al., 2002).

Tourism is now taken as the fastest growing and dominant economic system worldwide, associated with a growth rate of 9%, representing equally an opportunity and a threat towards

the environment preservation (Goodwin, 1996; Isaacs, 2000).

Human cultures and cetaceans have always strolled entwined, while whales and dolphins would be looked out for the variable matters that could be extracted from them or simply for observation. Whalewatching emerged in California, during the 1950s, but only in 1982 it began to be taken as a valid financial alternative to whaling, after the implementation of the moratorium on commercial whaling by the International Whaling Commission (IWC), as an effort to save whales from the risk of extinction that they were facing during that decade (Conor et al., 2009). After this, whales started to be regarded as a profitable asset worth protecting on its own right and for the marine ecosystems. In 1994, IWC recognizes whalewatching as a sustainable “use” of cetacean resources, accepting it as a growing tourist industry associated with a significant input to the economy of many countries and a major influence in education and scientific knowledge (Conor et al., 2009).

Whalewatching quickly widespread and nowadays occurs all around the world, accounting for 2.1 billion dollars of profit and the attraction of more than 13 million participants from 119 countries, led by approximately 3,300 operators (equivalent to an estimated 13,200 people). With a 3.7% year global average growth, whalewatching keeps expanding notably through the continents with an average annual progress of 17%, 10% and 7% in Asia, Central America and Europe, respectively (Conor et al., 2009). This fast expansion, however, was not escorted by the measure of the short or long-term effects of tourism on cetaceans' behaviour (Constantine et al., 2004).

Several of the whalewatching targeted species are classified as endangered and consequently, the impact of a close approach by tourist boats has become a major concern (Orams, 2000). However, the geographical proximity of the vessel is not the only and maybe not the most aggravating concern, as factors like the type of vessel, the associated noise and how it operates could impose a greater disturbance on whales (Orams, 1997, 2000).

Nevertheless, the recognition of potential negative externalities linked to whalewatching does not mean it is inevitably destructive, as it is always less damaging than its former alternative: whaling (Isaacs, 2000). Besides, whalewatching proved to be a reliable platform of opportunity for scientific purposes and public awareness towards cetacean conservation (Erbe, 2002; Ferreira, 2007; Ritter, 2012). Therefore, IFAW in collaboration with other NGOs, fight to influence IWC to prevent the collateral damage associated with whalewatching, by guarantying its function in a sustainably manner (Conor et al., 2009).

Whalewatching also represents a sort of income to the locals, incentive them to praise their native species, as the conservation of whales and dolphins would not be possible if local communities held hostility towards them (Conor et al., 2009; Goodwin, 1996).

Marine pollution and water noise inflicted by watercraft can also represent a serious threat towards wildlife, even though its consequent effects are even harder to quantify.

The impact associated with marine traffic pollution has been already acknowledged and confronted. About 4 decades ago the International Convention for the Prevention of Pollution from Ships highlighted areas where high traffic activity threatened significant ecological and oceanographic valuable resources. Thus, the release of oil, ballast water and plastics within these areas (starting with the Baltic, Mediterranean, Black and Red seas) was limited. Consequently, the IMO, weighting their ecological, socioeconomic or scientific status and susceptibility to degradation, identified Particular Sea Sensitive Areas (PSSAs), including either regional seas or big ocean areas (Johnson et al., 2001).

During the 40s of last century most ships were powered by steam turbines, however, nowadays the majority of the world's fleet runs by a diesel engine, since these are more economic than other propulsion systems, consuming less fuel. Most bunkers are residuals fuels obtained through secondary refining technologies meant to extract the maximum amount of distillates from crude oil. Consequently, residual fuels contain high concentrations of contaminants (sulphur, ash, asphaltenes and metals). These contaminant substances are being constantly released into the marine environment (through leakage, spills, breakages, etc.) since 70 to 80% of commercial shippers prefer the cheapest residual fuel to any other distillate oils of higher grade (Corbett, 2002).

Ships are responsible for 14% of the nitrogen emissions prevenient from fossil fuels and 16% of total sulphur resultant from oil consumption, in other words, ship engines are one of the strongest combustion sources of pollution per ton of used fuel. It is estimated that about 10 teragrams (Tg) of NO_x and about 8 teragrams of SO_x are annually realised by ships (Corbett, 2002).

As one of the most mediatic environmental threats, oil spills impacts are already familiar. The increase of tanker operations and frequent accidents resulting in oil spills, brought up the growing attention towards its ecological impact starting in the middle of the 19th century (Shahidul Islam and Tanaka, 2004). It is estimated that a million tons of persistent oils are discharged every year into the sea (Smith, 1970). The absence of waste reception and treatment facilities in the ports, aligned with lack of efficient legislation and surveillance, ships usually discharge their oil waste in the sea (Shahidul Islam and Tanaka, 2004). Oil spills impose physically damages in the wildlife and its habitat and exposes them to an elevated level of toxicity, affecting a wide range of marine organism connected through a complex food chain. Consequently, organism might be victims of acute or lethal effects and subject to the long

lasting sub-lethal toxic effects (U. S. Environmental Protection Agency, 2000). These sub-lethal effects might result in great damage to the marine populations, impairing reproduction functions or induce cancer in the organisms (Shahidul Islam and Tanaka, 2004). The ecosystem recovery hangs on the pollution site and intensity (Yamamoto et al., 2003).

Polycyclic Aromatic Hydrocarbons (PAHs) were classified by the World Health Organization (WHO) as one of the priority pollutants and one of its main anthropogenic causes of discharge into the sea are oil spillage (Marsili et al., 2001). Cetaceans have a limited detoxifying capacity (Fossi et al., 1997), thus presenting greater vulnerability when facing contaminate substances. A case study undertaken by Marsili et al., 2001 proved that Mediterranean cetaceans, apart from other types of chemical stress, are also subject to PAHs and that the sample carcinogenic input increase variation (between 1993 and 1996) was probably consequent from the Heaven tanker spillage in the area, and consequent leak of 144,000 tons of oil.

Shipping is also the main way of transport of chemical products (McKay et al., 2006). The increasing of chemical cargo rises the odds of accidental spillage, resulting in different impacts on the environment according to the Hazardous and Noxious Substances (HNS) properties (Neuparth et al., 2011). A HNS is considered any substance (except oil) capable of, when dropped in the sea, presenting a threat to the human health and other marine life and affect other legitimate exploitations of the sea (International Maritime Organization, 2000). Chances of occurrence of a HNS incident area relatively small, but not uncommon in present time.

There is not much information available related with HNS impacts on marine organism, which slows down the process of identifying and lead contingency plans towards these threats. The considered most dangerous HNS characteristics towards marine biota are its level of toxicity, bioaccumulation potential, persistence and carcinogenic effects, meaning a combination of high to moderate level of these factors stands as the biggest menace resulting from a spill (Neuparth et al., 2011).

Anthropogenic sounds are a relatively recent input in the marine environment, arriving along with the industrialization period (Southall, 2005).

“Sound” can be described as the resultant effect of a vibrating object in the adjacent environment, i.e., a general definition of acoustic energy. It is possible to distinguish, from the receivers point of view, two types of sounds: (1) “signals”, when the sound carries biologically significant information (call from a conspecifics or a prey location); (2) “noise” when the sound is a product of multiple sources and does not contain any biological significant information (much more frequent) (Southall, 2005). There are two types of noise present in marine

environment: (1) natural noise (such as undersea earthquakes, volcanic eruptions, lightning strikes on the water surface, noise resultant from biological activity, or even breaking waves or precipitation, i.e., innocuous background acoustic fuzziness/blur (Southall, 2005); (2) anthropogenic noise (e.g. underwater explosions - nuclear and otherwise; seismic exploration - undertaken by oil and gas industries; and naval sonar operations) (Weilgart, 2007).

Shipping traffic, appears to be a significant fraction and one of the main sources of anthropogenic ocean noise input, along with the ones just mentioned above (Weilgart, 2007).

Merchant and fishing vessels add a yearly energy output of 3.8×10^{12} J as an ocean noise source, which can be quite loud. The acoustic harassment devices used to keep cetacean away from fishing nets (attempting to prevent them from stealing the fish) and recreational boats also integrate the ocean anthropogenic noise levels (European Science Foundation, 2008). Hence, the successive increase of commercial shipping in some regions seems to be a plausible foundation for the background noise intensification through the last decades (International Whaling Commission, 2005). Thus, the potential impact of shipping noise in cetaceans has been addressed as an important issue (Southall, 2005).

Standing as a vocal taxonomic group, provided with highly sophisticated auditory systems (able to cover a wide range of frequencies), cetacean rely on hearing as their principle sense (vision underwater is only suitable in short distances, while sound can spread through thousands of kilometres), thus ocean noise pollution represents a real menace towards these species and might be the reason behind some eventual strandings and mortality incidents, among other disturbances or chronic effects such as "masking", altered vocal behaviour, hearing damage, stress level increase, important habitat displacement and bends in migration routes (Weilgart, 2007). Fish are equally affected by water noise which might interfere with their daily procedures such as feeding, reproduction, communication, navigation, predation and hazard avoidance (Popper, 2003), indirectly affecting cetacean, as their prey.

However, the lack of conclusive documents of cetacean population-level effects is under the controversy attached to the implications of ocean noise (Weilgart, 2007). Only 22 of the approximately 125 species of living marine mammals have been studied for their hearing capabilities and many of these studies would comprise small sample sizes (Southall, 2005).

Mysticeti, due to their auditory morphology, are more sensitive to and emit infrasonic calls (low frequency sounds between 10 and 20 Hz) that can travel through large distances (≥ 100) (Southall, 2005). Even though Mysticeti are not supposed to use echolocation, their low frequency calls might provide them some general environmental information (Weilgart, 2007) while Odontoceti reveal a fairly good hearing sensitivity and produce sonic and ultrasonic sounds (mid- and high frequency sounds from 1 to 150 kHz) via biosonar (use of sound for

biological means) or echolocation clicks (Southall, 2005). However, even though cetaceans are able to produce very loud sounds it does not necessarily mean they can equally stand similar intensity of anthropogenic ocean noise, i.e., some natural and anthropogenic sounds might be acoustically identical but diverging either in frequency, duration or directionality, for instance. Considering the ocean noise environment is very loud and changeable by itself, probably cetaceans came to genetically evolve becoming more resilient towards pressure changes from noise, through generations, but not at the same rate as the actual increasing bumping of anthropogenic noise, specially attending to species with long life cycles, such as whales (Weilgart, 2007).

Ocean noise might also lead to temporarily or permanent hearing loss (respectively TTS – Temporary Threshold Shift or PTS – Permanent Threshold Shift – loss of the ear inner cells) of marine mammals, being it more likely to occur as the level and duration of the sound increases (Weilgart, 2007). Theoretically, whales could be susceptible to permanent hearing loss when exposed to certain level of noise instigated by persecuting or surrounding whalewatching boats (Erbe, 2002). Nevertheless, a temporary hearing loss could be as fatal to the animals, since a short period of time might be enough to be caught unaware of a predator or any other significant threat. Noise frequencies might be harmful to cetaceans even if outside their hearing range (skin sensations, vertigo, fat emboli, among other effects) (Weilgart, 2007).

Masking (the veiling effects of noise) is stated as the primary hearing consequence of vessel noise on marine mammals and its potential aggravation varies according to the relation between signal and noise. Even if cetaceans developed strategies to dodge masking effects (e.g.: directional hearing, call's frequency or amplitude shift), there is still a limit of adaptation (Weilgart, 2007).

Anthropogenic noise could aggravate bycatch or ship collisions incidents by disabling cetaceans to detect fishing gear or oncoming vessels.

All the previous information hopefully enlightened the importance of the marine traffic modelling for Nature conservation purposes, supporting the management of interactions between anthropogenic disturbances and wildlife.

About half the world's human population is living near the coast (DeMaster et al., 2001), making coastal cetaceans even more exposed to these type of disturbances, especially when surrounded by developed areas, where they are exposed to cumulative anthropogenic effects (Piwetz, 2012).

The present study takes place in the Autonomous Region of Madeira Exclusive Economic Zone. As an island and a touristic attraction point, set in the middle of the Atlantic Ocean, Madeira Islands are constantly surrounded and sought out by traffic.

The Madeira Whale Museum (MWM) was created in 1990 aiming for the cetacean research and conservation in the region, among other purposes. From the year 2000 until the present, several procedures regarding the evaluation and distribution of the effective cetacean population have been conducted, along with photo-ID studies. Whalewatching and fishing activities interactions and its potential impact towards cetaceans were also addressed, as well as the investigation of strandings found in the Madeira shores (Freitas et al., 2004a).

Madeira archipelago is devoid of continental shelf, i.e., large sea depths are found a few miles from the land, reason why typical oceanic species get closer to the shore. Besides representing reference points through the cetaceans' migration routes, oceanic archipelagos represent points of higher productivity amid the vast ocean and offer good conditions for reproduction, breeding, socialisation and resting activities. Thus, as most of the islands, it represents a feeding, reproductive and breeding ground for various species. A large variety of cetaceans was already identified by the MWM, such as the Atlantic Spotted Dolphin (*Stenella frontalis*, Cuvier, 1829), Striped Dolphin (*Stenella coeruleoalba*, Meyen, 1833), Short-beaked Common Dolphin (*Delphinus delphis*, Linnaeus, 1758), Bottlenose Dolphin (*Tursiops truncatus*, Montagu, 1821), Risso's Dolphin (*Grampus griseus*, Cuvier, 1812), Short-finned pilot whale (*Globicephala macrorhynchus*, Gray, 1846), Blainville's Beaked Whale (*Mesoplodon densirostris*, Blainville, 1817), Sowerby's Beaked Whale (*Mesoplodon bidens*, Sowerby, 1804), Cuvier's Beaked Whale (*Ziphius cavirostris*, Cuvier, 1823), Pygmy Sperm Whale (*Kogia breviceps*, Blainville, 1838), Sperm Whale (*Physeter macrocephalus*, Linnaeus, 1758), Minke Whale (*Balaenoptera acutorostrata*, Lacépède, 1804), Bryde's Whale (*Balaenoptera edeni*, Anderson, 1879), Sei Whale (*Balaenoptera borealis*, Lesson, 1828), Fin Whale (*Balaenoptera physalus*, Linnaeus, 1758), among others (Freitas et al., 2004a).

Information regarding the traffic pattern distribution is still lacking in the Madeira shores. Therefore, under the wing of the Madeira Whale Museum, a first attempt to cover that gap is presented here.

Thus, the main goals of the present study are the: (1) preliminary spatial and temporal characterization of the in and offshore marine traffic comprised in the Exclusive Economic Zone of the Autonomous Region of Madeira; (2) identification of zones of high and low level of traffic activity in the same area, according to the type of vessel; (3) recognition of potential areas of conflict between watercraft and cetaceans. For this purpose, the following analyses was based on the coordination of AIS data provided by the *Administração dos Portos da Região Autónoma da Madeira* (APRAM) and observational data gathered through sea surveys conducted by the Madeira Whale Museum (MWM).

Furthermore, the long temporal period coverage and categorized traffic data collection

by the MWM allowed a strong based analyses, presenting rare attributes, not easily available and crucial for the assessment of traffic potential impacts towards cetaceans within the study area.

2. Methodology

In order to characterize the vessel temporal and spatial distribution in the offshore and inshore waters of Madeira Archipelago we created marine traffic maps based on two different types of data: (1) records collected during the field work surveys carried out by the Madeira Whale Museum (MWM) research team; (2) AIS data supplied by APRAM.

The first type of data was used to build inshore traffic density maps, later compared with cetacean index presence maps constructed over MWM data gathered along the same time period. This allowed an overview of the regional marine traffic pattern, making it possible to identify heavier and lower vessel inshore traffic density zones, and detect possible areas of conflict between cetaceans and vessels.

The second type of data was used for 2 different purposes: (1) preliminary characterization of the Madeira offshore traffic; (2) corroboration of the inshore traffic density maps (previously described) during the data analyses.

We ran both a spatial and temporal analyses, grouping the available data according to boat type and season. The summer and winter semester were defined as the period comprehended between June and October/ November and May, respectively.

2.1 Study Area

The research focused on the Madeira Archipelago Exclusive Economic Zone (figure 1). Including Madeira, Desertas and Porto Santo, this volcanic islands cluster is located in the Atlantic Ocean between 32 and 33° N and between 16 and 17° W, at approximately 635 Km from Africa's west coast. Madeira stands significantly isolated from the closest mainland and nearby islands by depths greater than 2000 m, surrounded by a few steep submarine canyons, with a small continental shelf, and on the grasp of the Gulf Stream current, thus presenting favourable conditions to hold a substantial level of marine biodiversity (Aguin-Pombo and Pinheiro de Carvalho, 2009).

The "offshore" traffic area comprises the entire Madeira EEZ, while the "inshore" traffic study was focused on an area extending out 12 Miles from the shore (figure 2). This area was segmented into 8 nautical sectors (table 1), intended to cover bathymetries from 0 to 2500 m.

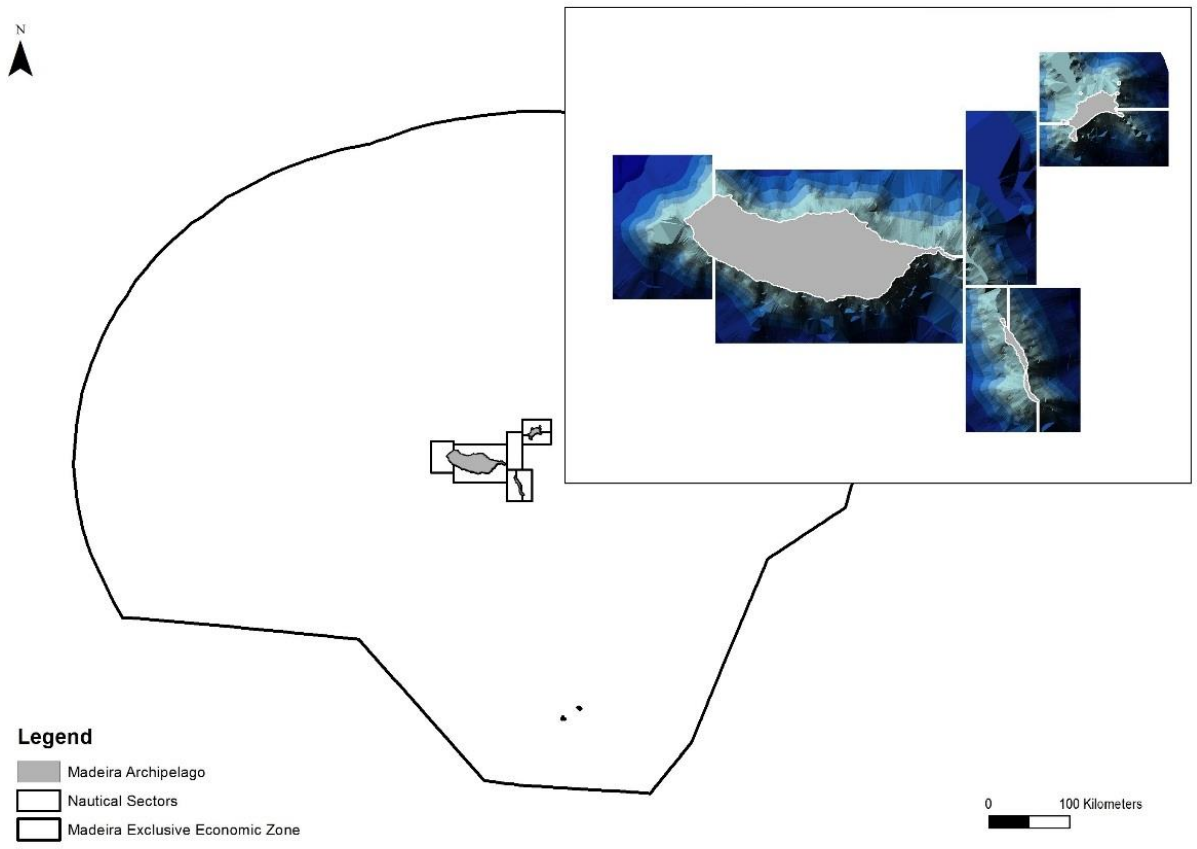


Figure 1- Study area

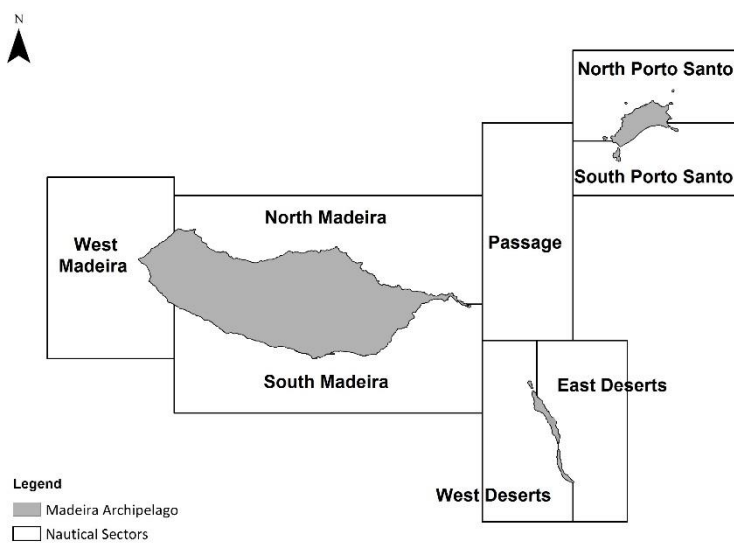


Table 1– Nautical sectors classification

Sector	Classification
1	North Madeira
2	West Madeira
3	South Madeira
4	East Deserts
5	West Deserts
6	Passage
7	South Porto Santo
8	North Porto Santo

Figure 2 - Inshore traffic area and corresponding nautical sectors

2.2 Madeira Whale Museum collected data

2.2.1 Field work methods

The data used in this research was not directly collected in the field by the author, but rather a compilation of assembled data acquired over the years (from 2001 to 2012) through sea surveys carried out by the Madeira Whale Museum research team.

Nevertheless, we thought still compulsory to briefly describe the field work methodology, clarifying the conditions under which the data in question was obtained.

Resuming, the sea surveys took only place with Beaufort sea state ≤ 3 . The research boat, “Zíphius”, consisted on a steel sailing vessel with 2 platform of observation (one placed in the bow and the other in the stern). On board, an ideal number of 5 or at least 4 observers would be placed in different positions (figure 3), rotating every hour. Observers 1, 2 and 3 covering particular visual angles while screening the sea, plus the annotator and steersman registering the information and manoeuvring the boat, respectively (or the last one doing both tasks, if only 4 observers were available).

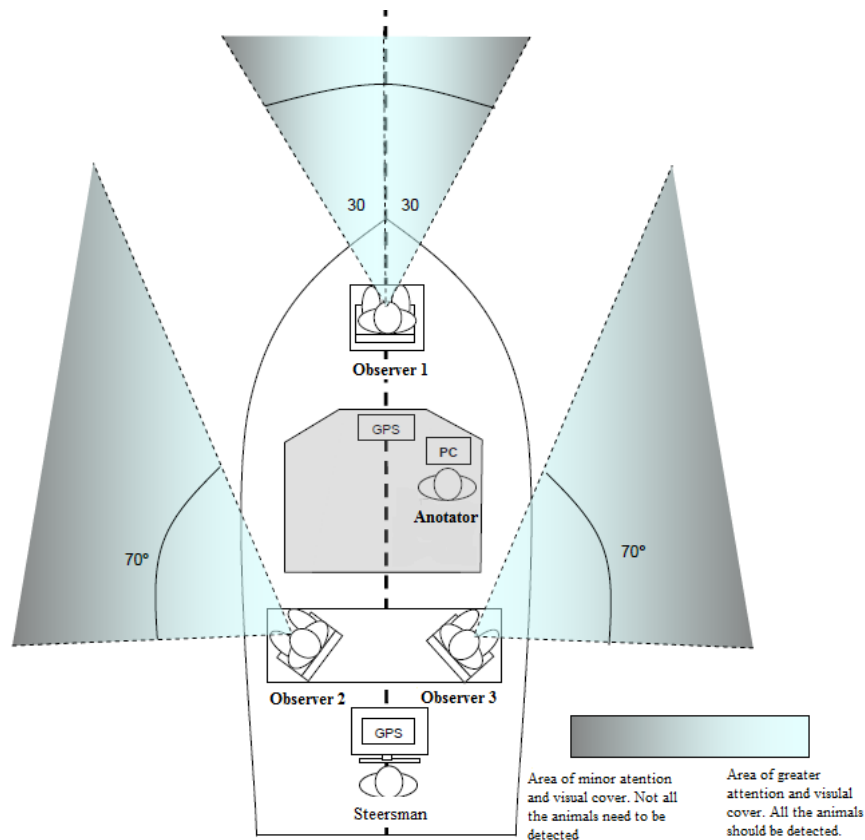


Figure 3 -On board observers' disposition illustration (Dinis et al., 2010)

Each sector of the study area was sampled on average twice every 3 months, with zig-zag transects. Each transect started at a random chosen point at one of the sector edges

While on observation effort sheets would be filled every hour (or by the occurrence of a significant change in any environmental parameter) with information regarding cetacean sightings as well as data of other factors such as the marine traffic in the closest surrounding area.

2.2.1.1. Traffic information records

The traffic information records included encounter time, observed vessel(s) type(s) (table 2), number of boats of each type, level of visibility and the annotators' name, as exemplified in table 3. Every single vessel sighting was tagged with the research boat GPS position at the moment of the sighting, i.e., the longitude and latitude considered do not correspond to the precise position of the targeted vessels, but to the research boat location at the time the vessels were recorded. Thus, one pair of coordinates might correspond to more than one vessel, according to the number of boats spotted at a particular time. The vessel estimated distance and direction was not take into account either. For this reason, it should be underlined that: the points projected on the resulting maps do not represent the real location of each detected vessel but the location of the research boat, thus being associated to a maximum error range of 15 miles radio (the maximum distance at which a vessel would be identified, taking in consideration of observation platform and the height of the observed vessel), variable according to the vessel type/height (smaller boats are only possible to detected at much closer ranges). Furthermore, considering that traffic information was collected every hour while the observer position was shifting, it is expected that eventually some vessels might have been registered more than once and considered as different vessels, depending on its trajectory (it could change the course direction and pass the research boat again unrecognised) and observational conditions. This was something taken into account during the analyses and results interpretation.

The data collected was separated in 3 sample periods according to the vessels' classification: (1) 2001- 2009: vessels were classified only as ships, recreational boats or fishing boats; (2) 2010 – 2012: whale-watching and big game fishing were added to the vessels classification list; (3) 2011-2012: fishing boats start to be classified according to the fishing type.

Table 2 - Vessel type description

Vessel type	Description
Recreational boat	Private vessels with less than 24 m length
Fishing Boat	Commercial fishing boats of any size <ul style="list-style-type: none"> • Tuna fishing • Black scabbard fishing • Recreational demersal fishing
Type of fishery	
Big Game Fishing boats	Sportive fishery boats
Ships	Private or commercial vessel with more than 24m length
Whale Watching Boats*	Maritime-touristic commercial vessels with less than 24m length
Other type of boat	Targeted boat does not fit any of the above features**

- RB - Recreational Boats
- S - Ships
- FB - Fishing Boats
- TP - Type of fishery
- BGFB - Big Game Fishing
- WWB - Whale Watching Boats
- OB - Other Boats

* At each sighting would be indicated how many whale watching boats where in the presence of cetaceans

** The specification of the boat would usually be registered in the "Notes" field

Visibility classification

- 0 - visibility ≤ 1 nmi
- 1 - 1 nmi < visibility ≤ 3 nmi
- 2 - 3 nmi < visibility ≤ 5 nmi
- 3 - visibility > 5 nmi

Table 3 - Example of available data parameters

Index	Project	Sector	Latitude	Longitude	Time	Visibility	RB	S	FB	TF	BGFB	WWB	OB	Notes	Anotator
347	CNSMII	S3	32.57669449	-16.96459770	09/06/2011 12:37:18	3	0	2	4	RD	1	0	0		CR/NM
348	CNSMII	S3	32.64856720	-17.19405174	16/09/2011 07:39:56	3	0	0	1	RD	0	0	0		AH
349	CNSMII	S3	32.57934952	-17.07730865	16/09/2011 09:34:57	3	2	0	2	RD	0	0	0		JV
350	CNSMII	S3	32.63365936	-16.92033577	16/09/2011 11:13:00	3	1	0	2	RD	0	0	0		FA
352	CNSMII	S1	32.76182556	-16.69642830	26/09/2011 10:07:08	3	0	1	1	RD	0	0	0		FA
353	CNSMII	S1	32.76911163	-16.73815918	26/09/2011 10:40:22	3	0	0	2	RD	0	0	0		JV/AH
354	CNSMII	S1	32.85750580	-16.80061913	26/09/2011 11:43:25	3	0	0	2	RD	0	0	0		AH/MB
355	CNSMII	S1	32.83776093	-17.00357437	26/09/2011 14:56:08	3	0	0	1	RD	0	0	0		CN
356	CNSMII	S1	32.91202164	-17.11086273	26/09/2011 16:03:56	3	1	0	1	RD	0	0	0		AH
357	CNSMII	S1	32.91551208	-17.19947243	27/09/2011 07:19:46	3	0	0	1	RD	0	0	0		AD
358	CNSMII	S1	32.87305450	-17.10029793	27/09/2011 08:34:40	3	0	0	1	Esp	0	0	0		CR

2.2.1.2. Cetacean information records

A dedicated field sheet would be filed every time a whale or dolphin were spotted, where the observer would note down, among other factors (but irrelevant for the presence study and thus disregarded), the date and time of sighting; estimated distance (animal or group of animals distance towards the research boat by the time they were first detected); azimuth (of the animal or group of animals taken from the bow, by the time they were first sighted); species and respective number of individuals; minimum number of animals (in dolphins case they would count and consider the number of individuals that come to the surface at the same time); medium number of animals (best estimated of the observed group size – pondered between 2 or 3 observers); maximum number of animals (if these were dolphins this value may be considered as the estimated number of animals by surface for 10 seconds) and the number of calves.

In view of the information just mentioned these data bear a greater level of precision comparing to the traffic data described above.

2.2.2. Mapping vessels estimated locations

The gathered data was displayed within a Geographic Information System (GIS), resorting to ArcInfo GIS 10.1 (ESRI, Redlands, CA, USA).

The vessel locations were plotted in a vector environment over a grid with resolution of 3.704 x 3.704 Km (2 x 2 nautical miles), comprising the inshore traffic area. The Madeira Archipelago coast lines and defined maritime sectors were also overlaid within the same range.

We associated the correspondent observation effort value to every grid cell, in order to evidence which areas were more intensely surveyed, representing it through a colour gradient along the grid, composing an effort matrix. The effort was measured as the sum of Km of track line of the research boat in each cell.

Subsequently, the results were represented in 3 types of maps: (1) Pie chart maps, where the proportion of every type of boat was represented per cell (2) Plot of vessel locations projected over the effort matrix where the sighting points were represented with variable diameters according to the number of boat detections associated with each pair of coordinates; (2) vessel sightings distribution density matrix (number of boats per effort unit – Km) maps, in which each grid cell corresponds to a vessel density value calculated by dividing the number of boats by the observation effort for each cell and represented also through a colour gradient

over the grid. Low levels of effort in certain cells might lead to unduly high sighting rates. Thus, in order to avoid outliers, i.e., discrepant levels of vessel density capable of misleading the data reading (low covered grid cells crossed by an high number of vessels once in one site, for example), we established a minimum value of effort per cell under which it would not be taken into account in the analyses. The bottom value 5 Km (grid diagonal extent) (Fortuna, 2006). Consequently, any grid cell associated with an effort value inferior to the stated minimum accepted would be filtered out and not quantified in neither of the resulting GIS maps. This procedure was systematically applied in all the resultant maps constructed attending to the vessel type and sample seasonality. Thus, a seasonal analyses was only possible for density distributions correspondent to vessel types collected since 2001 until 2012, i.e., ships, recreational and fishing boats.

2.2.3. Cetaceans Index Presence Maps

The cetaceans' species distribution across the area was represented through pie chart maps, where the proportion of sightings of each species was represented per cell, over a 2 x 2 nautical miles grid cell.

2.3 AIS Data

The AIS data used in the following project was a courtesy of APRAM who offered the support after all the objectives, data required, analytical methods and confidentiality agreement were presented by the MWM administration.

These data inherent accuracy and linked vessel attributes granted a different type of information otherwise impossible to obtain through direct observational data collection (field work), corroborating the previous described data and the analyses of the vessels density mapping.

However, even though this kind of data has revealed itself very useful and accurate, it has some limitations: even though AIS covers a great variety of vessel types (Evens et al., 2011) smaller recreational boats might not dispose of such devices; the AIS transmission range can vary and be limited depending on the transmitting and receiving aerials height as well as meteorological conditions, affecting the spatial coverage (dependent on the VHF signal range from the coast), specially at greater distances from Funchal (Eiden and Martinsen, 2010; Leaper and Panigada; Mou et al., 2010). Another problem related with the AIS data was the

discontinuity of the sample period, as not every month of each year was available and there could be a 30 day period correspondent to one month and only 3 days representative of another month.

The required ship report information (table attributes) included the vessel name, equipment ID, position date, destination, predicted time of arrival, speed, speed over ground (SOG), course over ground (COG), navigation status, draught, four dimension measures of the vessel, heading, type of boat and additional cargo information. Just to clarify, SOG consists on a derived speed output calculated by GPS or Loran and represents the vessel true speed over ground. The table attribute Speed does not correspond to the actual speed by which the vessel is moving over the ground, unlike SOG. Same way COG indicates the actual direction the vessel is taking, regardless of the information indicated by the compass, which is displayed as the vessel's heading (direction to each it is pointed and not towards the way it is moving).

2.3.1 Data base management

The data files were directly extracted from the original data base provided by APRAM using a SQL program, supported by a virtual machine (VM Workstation 8.0) , holding the Windows Server R2 x64, installed in a Windows 8 environment.

Due to the volume of information the manipulation of these data was very difficult and time consuming, implying shifting between alternative strategies.

The data analyses was based on a Geographic Information System (GIS) environment so the first step consisted on being able to open and edit the files in a format compatible for mapping locations within a GIS software.

Some of the raw text files obtained weighed 20 Giga bytes (correspondent to one month period), making it impossible to deal with using standard software such as Excel, Note Book, Access or even Textpad. Dividing the files into shorter units of data (representing shorter temporal periods) was not a definitive solution either. Therefore, aided by an expert in programming, we resorted to a set of successive file converters. By coordinating 3 programs we obtained an output containing only the georeferenced information within a polygon that encompassed Madeira EEZ, the table attributes that we were interested in and a sample of all the AIS points (lines in AIS tables), reducing the of points to be handled, making the file lighter, easing the data projection in ArcMap. In the last step only one point was registered in each thousandth degree cell, by restraining the writing of extremely spatially close data in the output file, which enabled routes reconstruction, although possibly with associated sample bias in

areas of heavy route crossing.

The initial intention was to follow the methodology undertaken in previous studies (Leaper and Panigada; Silber et al., 2002; Ward-Geiger et al., 2005) expressing the vessel traffic density as the sum of the distances travelled across an area per unit time, in a month period. This would imply, using ArcMap 10.1, exporting the data as a point shapefile, add it to a personal geodatabase and convert it to a line feature class. The obtained output would be projected over and intersect a grid shapefile making it possible to determine the length of a route segment crossing each grid cell. However, when trying to automatically convert the entire point shapefile into lines according to the ID and data position of each pair of coordinates, some routes would be wrongly connected (the polyline output would contained a bigger number of different ID equipment, i.e., vessels routs, than the original points shape). This problem might be caused by the fact that some routes were disconnect by gaps absent of coordinates points that were not registered due to inappropriate weather conditions interfering with the AIS signal. The solution could pass through editing the resulting shape correcting the wrong connections or creating each route through an attribute selection according to each vessels name. However, considering each file (comprising one month period) could hold the information of about 300 boats, both available time and means were not enough to fulfil the task by either one of the described strategies.

2.3.2. Mapping vessels positions tracks

Even though it was not possible to use these data on its full potential for the project at hand, we thought it still pertinent to use it. Therefore, AIS data points coordinates were projected in a vectorial GIS environment, where the vessels routes would be perceptible, even though not in a polyline shape file format.

The presenting maps are meant to be only representative of each month of traffic and to be used and interpreted only in such terms. We picked the first week from each month (except for March from which we used last week, the only available data). Thus, some months might be represented in more years than others, according to the available data along the years from 2008 until 2012. We thought a 7 days period would be enough to illustrate the traffic scenario (Eiden and Martinsen, 2010) while keeping the maps still perceptible.

The different vessel types discriminated in the AIS data based were grouped as classified in table 4.

Table 4 – Considered categories of AIS data

AIS Vessel Classification	
Cargo ships	Cargo Boats
	Cistern
Cruise ships	Passangers
Leisure vessels	WIG (Wing in Ground Effect) craft
	High Speed Craft
	Pratical Dinghy
Other type of vessels	Tugboat
	Vessel
	Ship
	No clasification

2.3.3. Speed Matrix Maps

Resorting to another file converter a text file would be automatically transformed into a raster output (in ASCII format) that could be directly projected in ArcMap. This raster file associates the medium SOG value to each pixel, creating speed matrix maps. The speed matrix maps correspondent to the offshore traffic area present a grid of 10 x 10 nautical miles pixel while the speed matrix maps correspondent to the inshore traffic area are represented through a grid of 2 x 2 miles pixel.

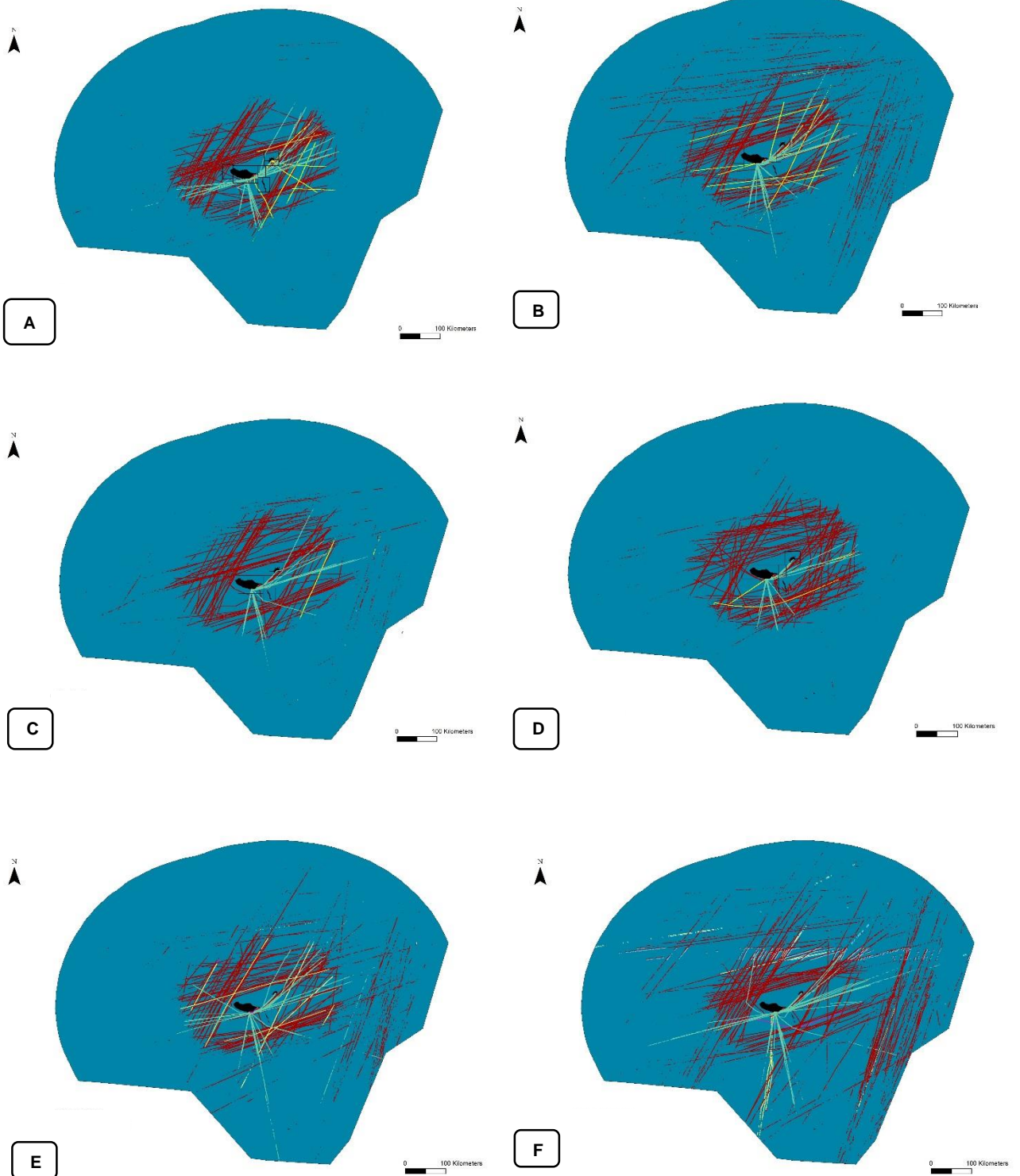
2.4 Statistical treatment

The inshore traffic data was tested using Shapiro-Wilk and Kolmogorov-Smirnov tests. All types of vessels revealed a non-parametric distribution ($P < 0.05$). Thus, the maps were analysed resorting to non-parametric tests. Kruskal-Wallis was run to infer if the pattern distribution would differ significantly among the different sectors and, if $P < 0.05$, a Mann-Witney test would be applied in order to find out which sectors in particular were significantly diverse. The presented descriptive statistics, graphics and histograms, were calculated or created by resorting to the SPSS and Excel software programs.

3. Results

3.1. AIS Data

3.1.1. Offshore traffic



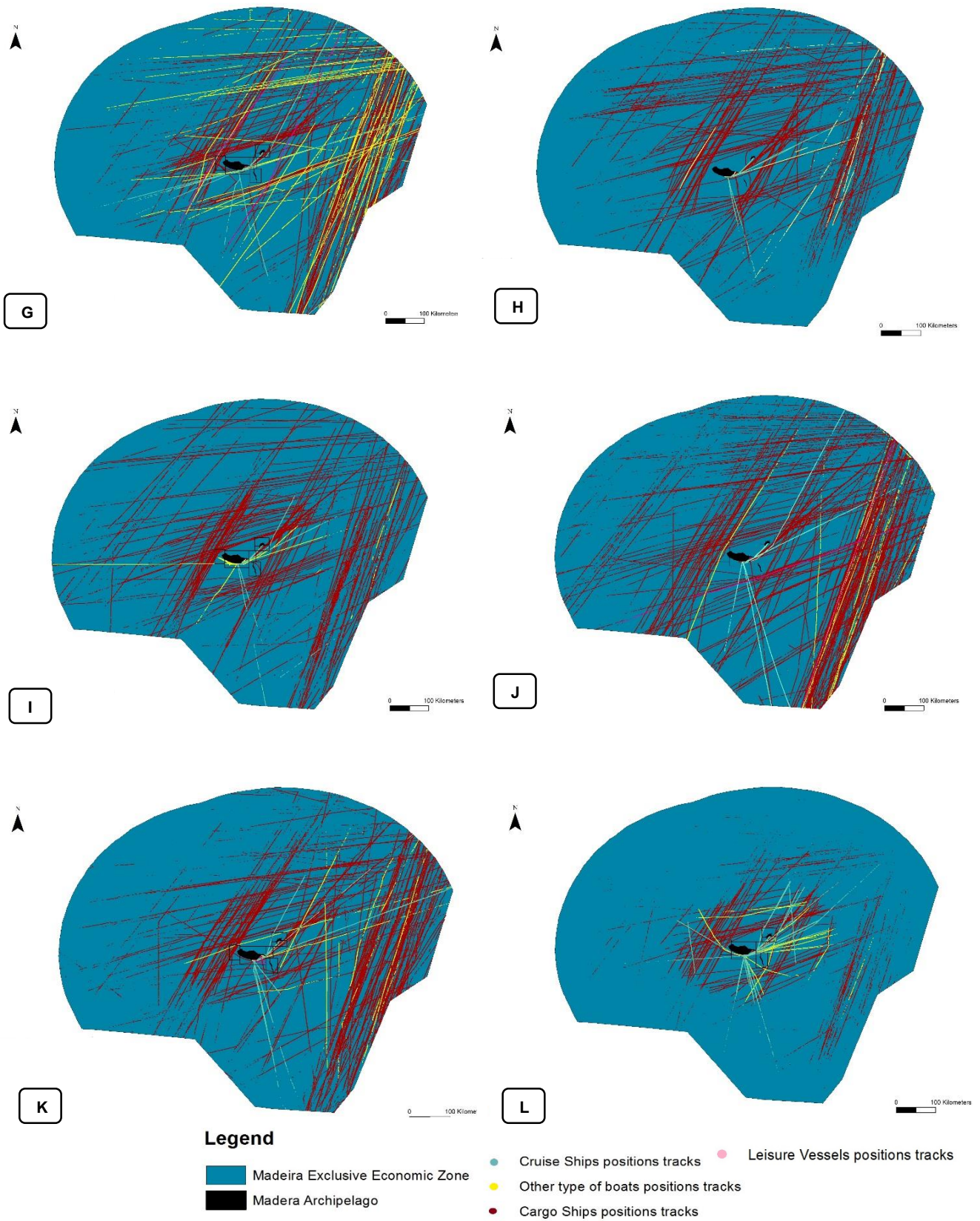


Figure 4 Vessel position tracks projected over the Madeira EEZ area. Some areas show higher track density – shipping lanes. The maps are displayed by season: winter (A-G) and summer (H-L). For the months available in at least 2 years of data (see table 5) only one representative month (the one apparently presenting less coverage gaps) is displayed: A – November 2008; B – December 2008; C – January 2009; D – February 2009; E – March 2010; F – April 2010; G – May 2008; H – June 2011; I – July 2008; J – August 2008; K – September 2009; L – October 2008. The remaining maps can be consulted in Annex I.

The AIS sample data used for the present project is presented in table 5.

Table 5 – AIS data available months

	2008	2009	2010	2011
January		●		
February		●		
March			●	●
April			●	●
May	●		●	●
June	●		●	●
July	●		●	
August	●			●
September		●		
October	●			
November	●			
December	●			

● Winter season
● Summer season

Table 6 – Weekly descriptive statistics correspondent to the offshore traffic distribution year round and during the winter and summer seasons. The presented values were only based on one representative week of each available month data.

	Mean	SD	Minimum	Máximum
General distribution	188	54	101	302
Winter distribution	168	48	101	242
Summer distribution	212	53	158	302

The number of vessels crossing the Madeira EEZ varies between 100 and 300 vessels per week (figure 5), more active during the summer season (table 6, figure 5). The highest picks take place during the summer months (August 2008 and September 2009) and the lowest during the winter season (February 2009 and May 2011), with an average of approximately 188 boats per week. In some month representations, the number of vessels might be underestimated since some maps (e.g.: figure 4 –A, B,C,D, L) do not present a full spatial coverage (large gaps between points from the same route), probably due to AIS transmission range flaws (Evens et al., 2011; Leaper and Panigada; Mou et al., 2010)

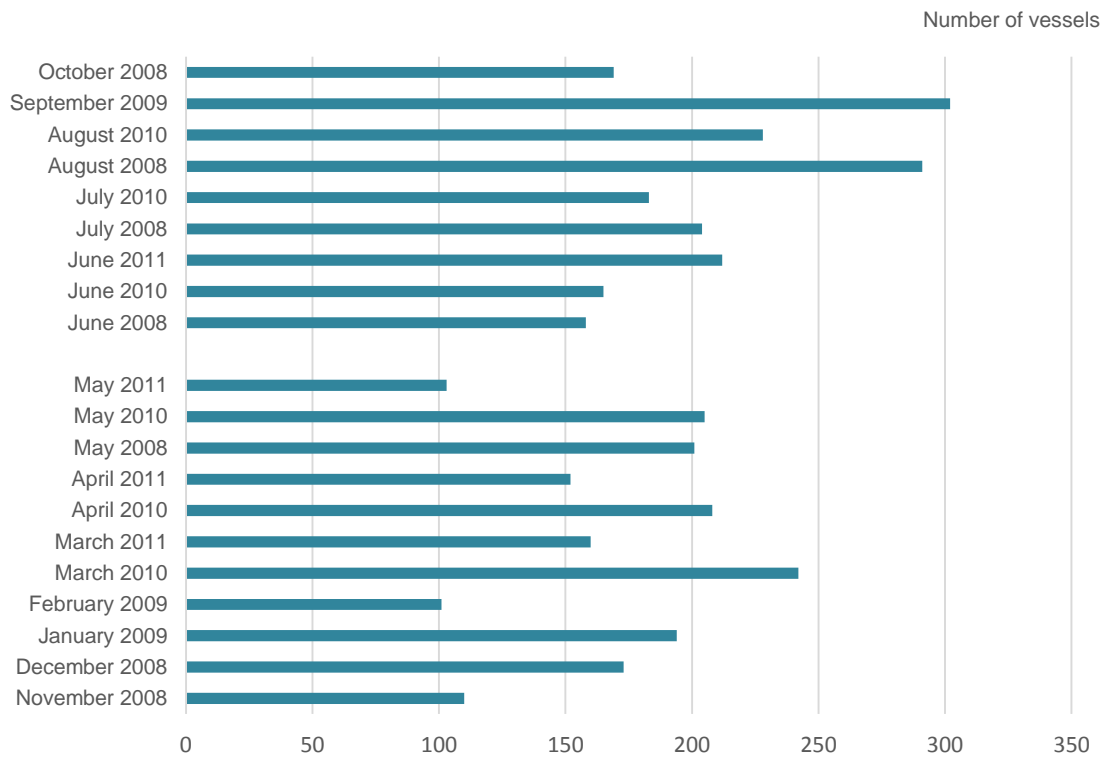


Figure 5 Histogram representing the number of vessels per week of each representative month during the summer (June – October) and winter (May – November) seasons.



Figure 6 Histogram displaying the percentage of vessel type incidence per each representative month.

The number of vessels stated here is also certainly underestimated as no AIS data on fishing vessels was available. Still, Madeira ZEE level of traffic seems less aggravating when comparing with some of the busiest waterways in the world, such as the Baltic or the North sea. The Baltic sea, with a surface area of approximately 146 000 square miles, is intersected by an average of 1291 vessels per week (0.009 vessels per area unit). While the North sea, comprising approximately 290 000 square miles is crossed by an average of 3582 vessels per week (0.012 vessels per area unit) (Eiden and Martinsen, 2010). Madeira EEZ, comprising approximately 110 000 square miles corresponds to about 75% or 38 % of the last areas, respectively, intersected by an average of 0.002 vessels per area unit, which corresponds to approximately 22% and 17% of their traffic, respectively.

Traffic composition does not seem to vary much, with cargo ships representing at least 70% of all traffic, followed by either unclassified vessels or cruises/ferries, in variable proportions (figure 6). Recreational boats might be underrepresented since many of them may not be equipped with AIS devices (Eiden and Martinsen, 2010; Evens et al., 2011; International Whaling Commission, 2011; Leaper and Panigada; Mou et al., 2010) . On one hand, its percentage should still be smaller when comparing to cargo or cruises, as they would circulate mostly in inshore waters, considering they are light vessels (short rides), on the other hand a lot of sailing boats cross the Atlantic Ocean and many of them pass through Madeira on their way to the Canary Islands or the Caribbean. This type of traffic is more frequent during the autumn season (between October and December) while they can take advantage of the Elysian winds.

An outlier (May 2008) stands out from the remaining representative months (figure 6 and figure 4 – G), where the “other type of vessels” category presents a bigger slice of the traffic composition. The “type of boat” AIS field is filled by the operator. Looking to figure 4 and considering the overall traffic representative maps and then focusing on figure 4 – G map in particular, it is possible to infer that probably many of the vessels included in the “other type of vessel” category are actually cargo. Thus, this outlier may be explained by a simple discrepancy in the AIS reports, which by chance, were very frequent in that period.

It is possible to identify 5 shipping lanes which seem to be recurrent in every representative map: 3 presenting a NE – SW orientation, one at the West side and the other two at the East side of the islands; two orientated through an E – W axe: one at South and the other at North of the island. The NE – SW shipping lane located further from the Madeira island shore seems to be more intensively used. These shipping lanes appear to be mostly used by cargo ships.

Even though some cargo ships are headed to Caniçal or Funchal, the study area seems

to be mostly a crossing zone for cargo ships, heading different destinations, branching to different regions, as North Sea, Middle East, North and South America or the Mediterranean region, some of the most regular destinations. Cruises/ferries, on the other hand, cross the area in order to reach Funchal Port, as one of the voyage stops.

3.1.2. Inshore traffic

The following analyses was based on the same AIS data previously presented considering only the traffic circulating inside the nautical sectors (see Methodology chapter, section 2.1).

Table 7 - Descriptive statistic correspondent to the inshore traffic distribution year round and during the winter and summer distributions. The presented values were calculated based on a representative week of each available month of the AIS data sample.

	Mean	SD	Minimum	Máximum
General distribution	34	5	27	42
Winter season	36	4	27	40
Summer Season	32	6	27	42

The inshore traffic area comprises around 2012 square miles, intersected by an average of 34 vessels per week (table 7, figure 7), i.e. 0.017 vessels per area unit, which surpass the correspondent values for the two busiest traffic areas considered above (Baltic and North seas). However, the area comprising the nautical sectors corresponds to approximately 1.4% and 0.7% of Baltic and North Seas surface areas, respectively, and includes a shipping route, branching to the Madeira and Porto Santo islands main ports. Thus, a considerable traffic concentration over a much smaller area would lead to such results. Therefore, in order to put in perspective, the study area should be compared with others areas with similar traffic features.

The strait of Gibraltar is located between the southern coast of Spain and the northern coast of Morocco and is an important shipping route since it is the only connection between the Atlantic Ocean and the Mediterranean Sea. Ship collisions with whales are frequent in that area. It comprises a surface area of roughly 1363 square miles, corresponding to approximately 68% of the inshore traffic study area, and is crossed by an average of 1975 vessels per week, i.e., approximately 1.45 vessels per unite area, per week (International Whaling Comission, 2011) .Thus, the inshore traffic of the study area corresponds to about 1.17% of the strait of Gibraltar’s traffic. The strait of Gibraltar is the second area with the most intense traffic in the World, which should also be taken into account when comparing these results.

The Pelagos Sanctuary for Mediterranean marine mammals is located in the northern Mediterranean Sea, where the cetacean population is suffering serious impacts due to ship collisions. It covers a surface area of around 33 784 square miles. The inshore traffic study

area corresponds to approximately 6% of this area. The Pelagos Sanctuary, as an area of intense traffic, accounts for around 191 vessels per week, i.e., 0.0057 vessels per area unit (Mangos and André, 2012; Souffleurs d'Ecume, 2012). Even though the weekly number of vessels per unite area of the present inshore traffic is superior to the Pelagos' Sanctuary, it should be kept in mind we are comparing areas of different sizes, where the smaller area, the Madeira's inshore traffic, includes a shipping route, i.e., big concentration of vessel in a small area.

The number of vessels circulating near shore varies between 27 and 42 boats per week, year round (table 7). Unlike what was verified for the offshore traffic, inshore traffic might be slightly more active during the winter season, when cruises cross the area more frequently (figures 7 and 8).

Considering the inshore traffic composition, the area is mainly intersected by cargos (figure 8). As mentioned above, cruises would only cross the area to reach Funchal port, while cargos will mostly pass it towards different destinations. Thus, as expected, cruises occupy a bigger slice among the inshore traffic composition. Recreational boats are underrepresented.

Container shipping traffic is the most significant share of seaborne trade and though it is still uncertain how shipping density will continue to evolve around the world, chances are ship fleet will keep expanding at the same pace or even faster from now on, thus some predictions point to an approximate doubling of large vessels worldwide in the next decades (Southall, 2005), and this is expected to be reflected in the Madeira island waters. Bearing in mind cargo ship were classified as the largest pollutants (Corbett, 2002), its increase should not come free of impact on the marine ecosystem. In case of any dangerous cargo ships disasters, the penalties will be felt in the surrounding environment (Mou et al., 2010).

For over a century (roughly) large passenger vessels dominated as the main transoceanic transport, decreasing their popularity between 1960's and 1970's and rising again in the last 40 years, aligned with the proliferation of cruise ships (Davenport and Davenport, 2006). Actually, cruise ship tourism turned out to be the more successful travel sector, characterized by an annual passenger growth rate of 7.2 % since 1990. The ship tourism expansion is connected to the degradation of marine sensitive areas, standing behind air and water pollution, and so has been subject to a considerable number of national and international environmental regulations (Harris et al., 2012). Main related ecological problems consist in the illegal discharge of substances (essentially oil and other hydrocarbons) and on the production of considerable amounts of garbage, waste water and sewage (considering the largest vessels

carry < 5000 people, including passengers and crew, they can be perceived as authentic mobile cities), that are often discharged directly in the sea (Davenport and Davenport, 2006).

According to IMO estimations, each passenger produces approximately 3.5 Kg of garbage and solid waste per day and a typical cruise ship discharges about 1 million litres of black water during one week voyage (Harris et al., 2012).

Ferries carry tourists and frequently also their vehicles. Their sizes and travel frequencies are often much greater than the ones associated with the local or commercial traffic (Davenport and Davenport, 2006). Apparently, no study has focused on the environmental impact of ferry traffic on its own, but similar effects to cruise ships are expected (Corbett, 2002; Harris et al., 2012).

To sum it up, even though the Madeira ZEE traffic is not comparable to the busiest waterways, chances are it will keep expanding, and might come along to some risks which will be pointed out further ahead in the present project.

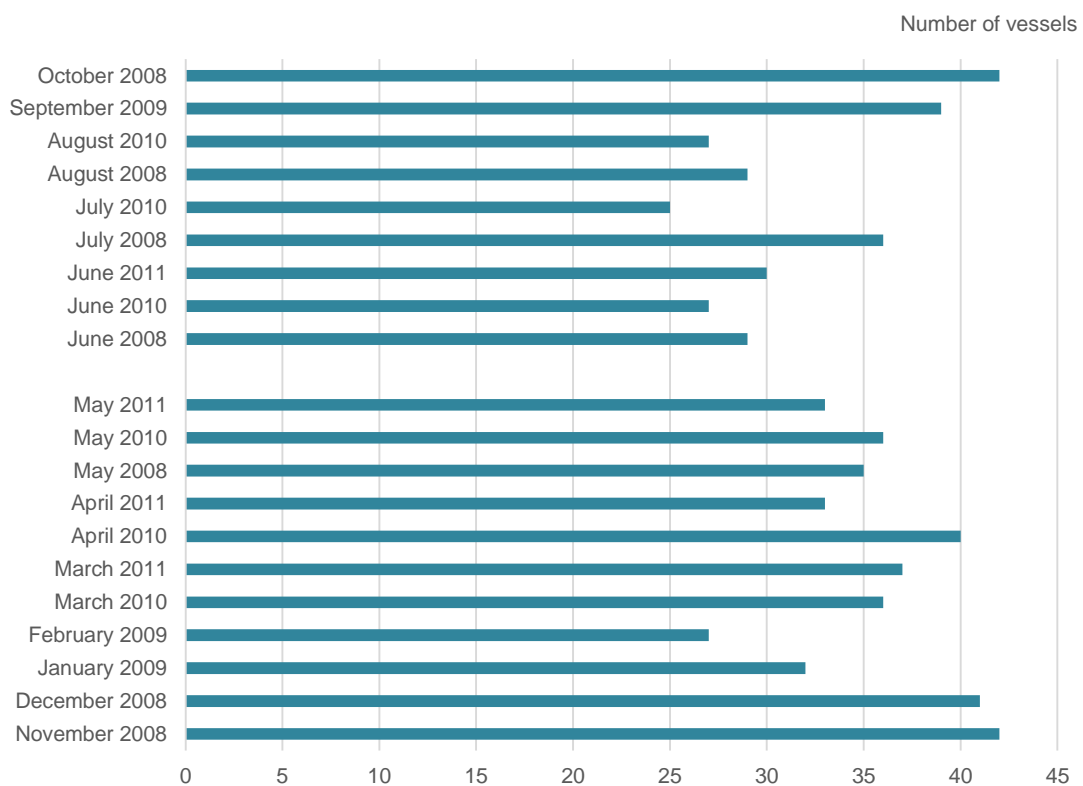


Figure 7 - Histogram representing the number of vessels per week of each representative month during the summer (June – October) and winter (May – November) seasons

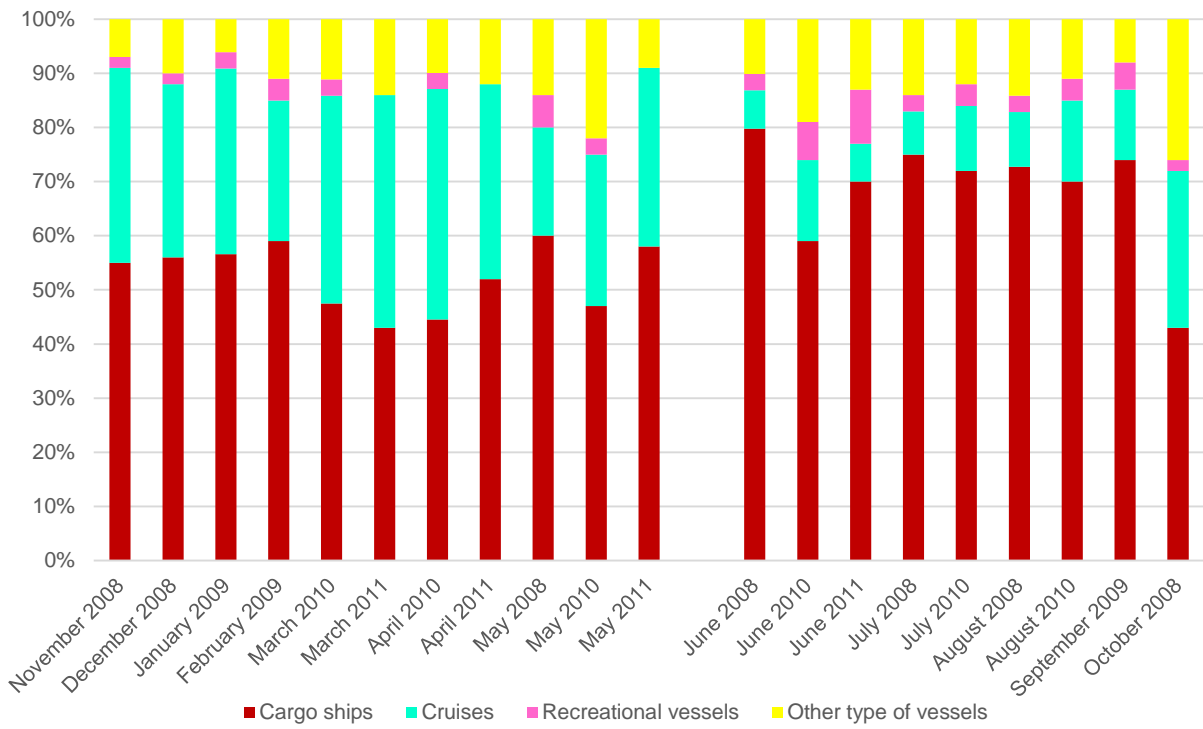


Figure 8 Histogram displaying the percentage of vessel type incidence per each representative month

3.2. Madeira Whale Museum collected data

3.2.1. Total vessels

The annual and monthly coverage of the visual sea survey effort is presented in table 8.

Table 8 – Years and months for which there was effort and data collected on boat traffic in the Madeira inshore waters

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	●							●			●	●
February	●							●				●
March	●							●	●		●	●
April	●	●						●	●		●	●
May	●	●						●		●	●	●
June		●		●			●	●	●	●	●	
July	●	●		●				●		●		●
August	●	●		●						●		
September	●	●					●	●		●	●	
October		●					●	●		●	●	
November							●			●	●	
December	●						●				●	●

● Winter season
● Summer season

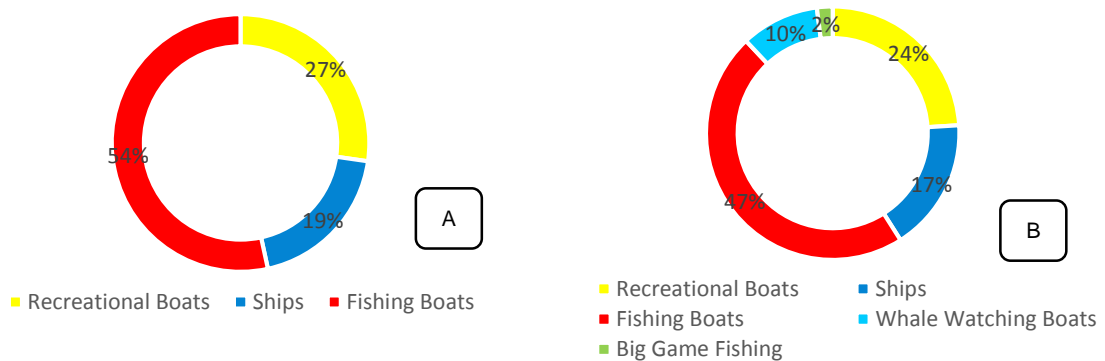


Figure 9 – Vessel type proportion between 2001 and 2009 (A) and between 2010 and 2012 (B) sample periods.

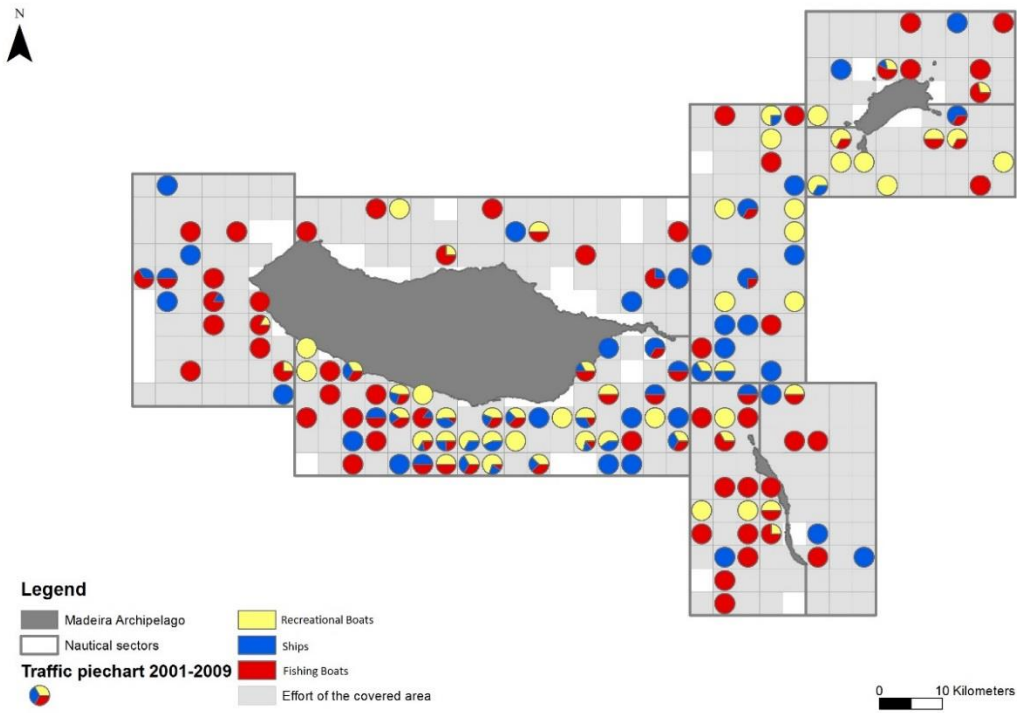


Figure 10- Inshore traffic distribution represented through a pie chart per grid cell representing the proportion of each type of vessel sighted in that location through the period of 2001-2009.

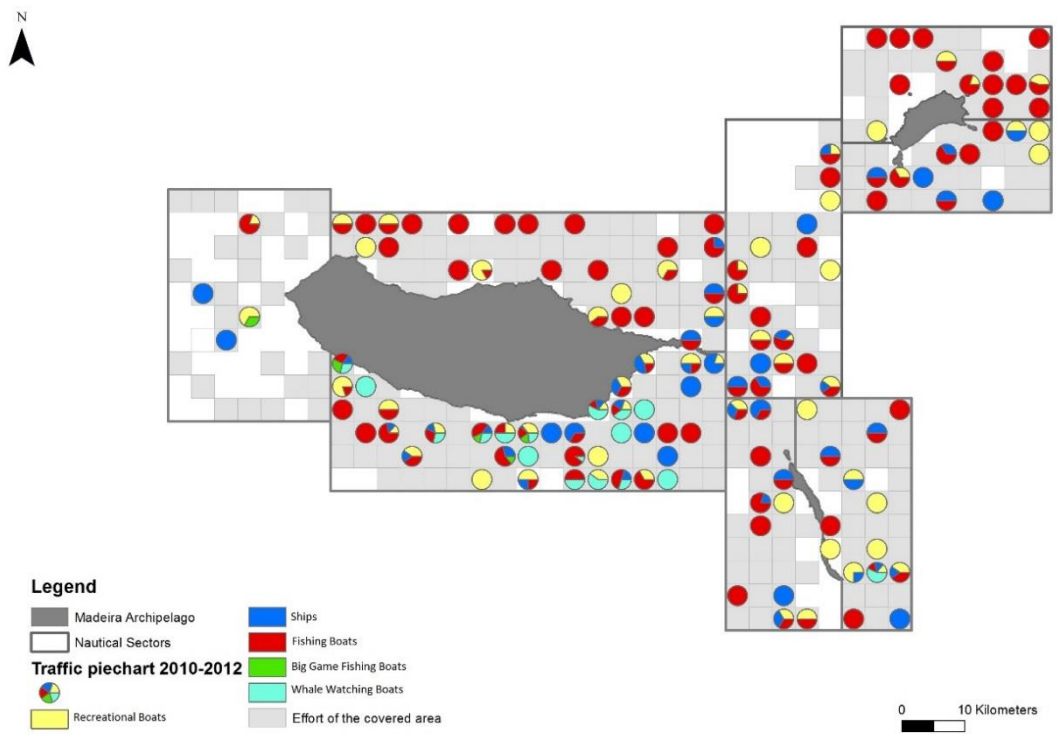


Figure 11 - Inshore traffic distribution represented through a pie chart per grid cell representing the proportion of each type of vessel sighted in that location through the period of 2010-2012.

A total of 830 vessels were sighted during the MWM surveys, 401 between 2001 and 2009, and 429 between 2010 and 2012. The percentage of each type of boat registers during the different periods is represented in figure 9. Considering both periods, fishing boats seems to be the most common type of vessel in the area, followed by recreational boats and ships.

Attending to figures 10 and 11, sector 3 apparently hosts every kind of vessel, sector 2 is mostly crossed by ships and fishing boats, sectors 1, 5 and 8 are more frequently occupied by recreational and fishing boats, while sectors 4, 6 and 7 are intersected by either fishing boats, ships or recreational boats.

After the presentation of the general traffic distribution, each type of vessel will be analysed independently (table 9). The normality of the data distribution was tested by the Shapiro-Wilk and Kolmogorov-Smirnov tests. All types of vessels revealed a non-parametric distribution ($P < 0.05$).

Table 9 – Descriptive statistics of each density - number of boats per effort unit (Km) - distribution map according to the type of vessel and seasonality

		Mean	SD
Total vessels	<i>General distribution</i>	0.66	0.42
	<i>Winter distribution</i>	0.64	1.48
	<i>Summer distribution</i>	0.51	1.34
Ships	<i>General distribution</i>	0.14	0.42
	<i>Winter distribution</i>	0.14	0.41
	<i>Summer distribution</i>	0.13	0.47
Recreational Boats	<i>General distribution</i>	0.17	0.46
	<i>Winter distribution</i>	0.17	0.57
	<i>Summer distribution</i>	0.19	0.70
Fishing Boats	<i>General distribution</i>	0.29	0.54
	<i>Winter distribution</i>	0.33	0.80
	<i>Summer distribution</i>	0.20	0.59
Whale Watching Boats	<i>General distribution</i>	1.39	0.98
Big Game Fishing Boats	<i>General distribution</i>	0.02	0.01

The descriptive statistics data (arithmetic mean, standard deviation, minimum and maximum) for each density distribution, general (figure 12 and 13) and seasonal (figures 14 and 15; 16 and 17), according to the sector, are presented in table 10.

Table 10 - Descriptive statistics of each density (number of boats per effort unite) distribution map by sector

	Mean	SD	Median	Minimum	Maximum
General distribution					
sector 1	0.42	0.69	0.06	0.00	3.76
sector 2	0.41	0.86	0.00	0.00	4.15
sector 3	1.60	2.16	0.90	0.00	10.35
sector 4	0.30	0.57	0.00	0.00	2.73
sector 5	0.41	0.57	0.31	0.00	3.10
sector 6	0.56	0.72	0.36	0.00	3.28
sector 7	0.31	0.34	0.23	0.00	0.95
sector 8	0.66	0.95	0.34	0.00	3.72
Winter distribution					
sector 1	0.51	1.33	0.00	0.00	8.53
sector 2	0.50	1.18	0.00	0.00	5.39
sector 3	1.42	2.56	0.42	0.00	15.56
sector 4	0.47	1.21	0.00	0.00	6.75
sector 5	0.43	0.85	0.00	0.00	4.94
sector 6	0.47	0.74	0.00	0.00	3.37
sector 7	0.29	0.48	0.00	0.00	1.76
sector 8	0.52	0.88	0.00	0.00	4.06
Summer distribution					
sector 1	0.29	0.71	0.00	0.00	3.17
sector 2	0.27	0.93	0.00	0.00	4.90
sector 3	1.20	2.34	0.00	0.00	13.38
sector 4	0.24	0.98	0.00	0.00	6.30
sector 5	0.35	0.58	0.00	0.00	2.20
sector 6	0.58	1.17	0.00	0.00	4.72
sector 7	0.25	0.44	0.00	0.00	1.64
sector 8	0.45	1.30	0.00	0.00	6.07

Kruskal-Wallis test was applied to general and seasonal traffic density distributions in order to detect significant differences between the sectors. All distributions are heterogeneously distributed across the area ($P < 0.05$). Consequently, Mann-Witney test was applied, intending to find out which sectors were statistically different between each other and to detect seasonal variations in the same sector.

Marine traffic and potential impacts towards cetaceans within the Madeira EEZ: a pioneer study

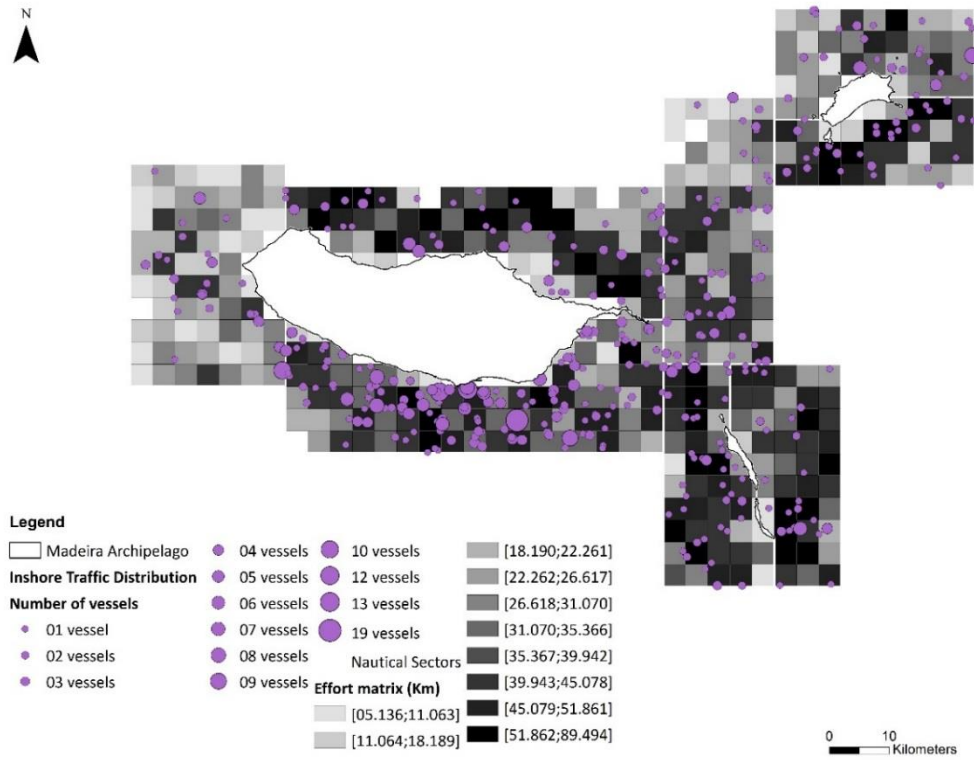


Figure 12 - Plot of all vessel locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

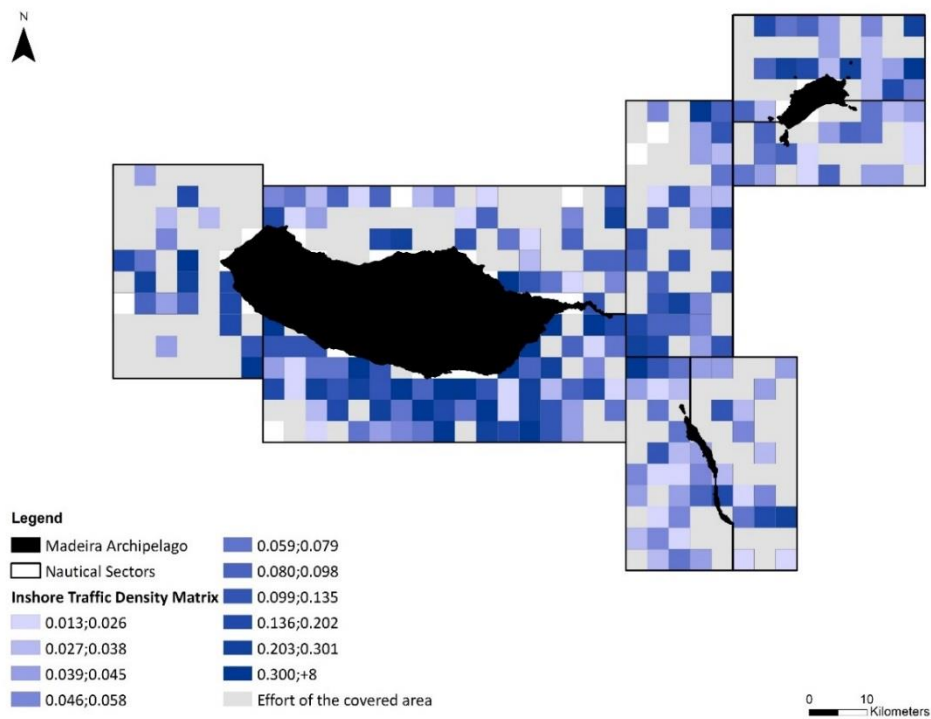


Figure 13 - General vessel sightings distribution density matrix

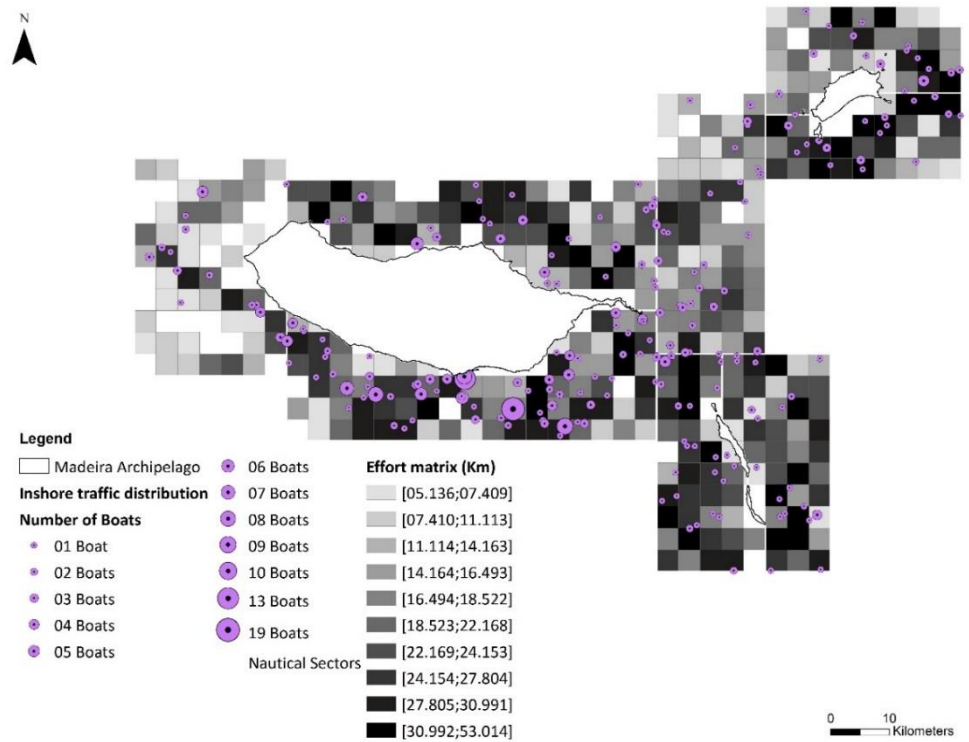


Figure 14 - Winter Season: Plot of vessel locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

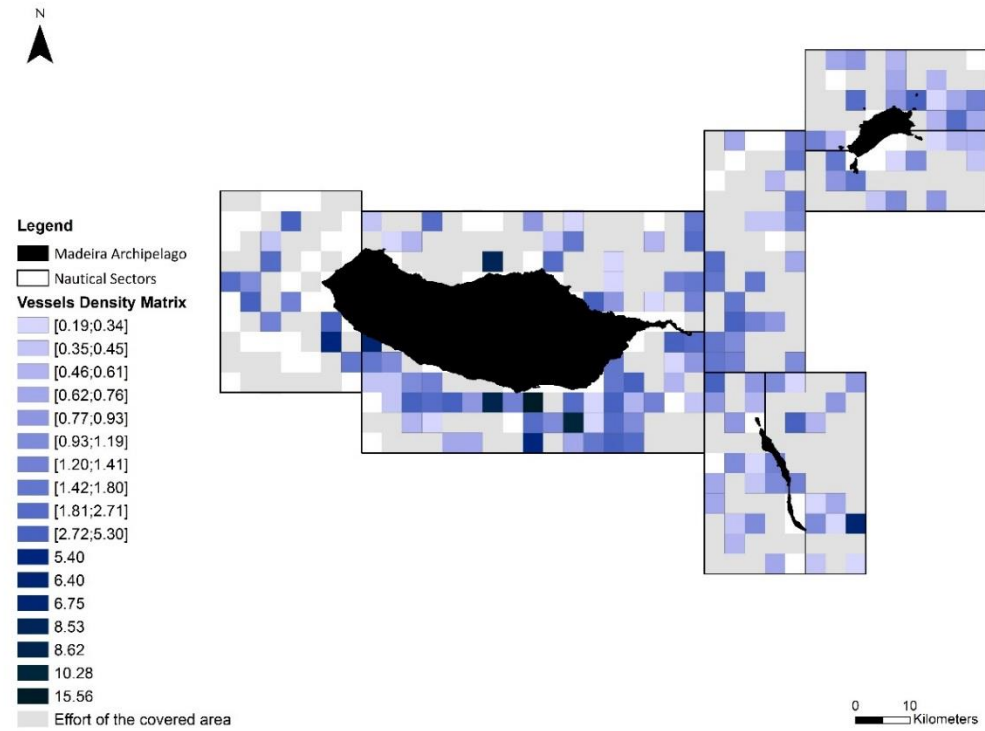


Figure 15 – Winter vessel sightings distribution density matrix

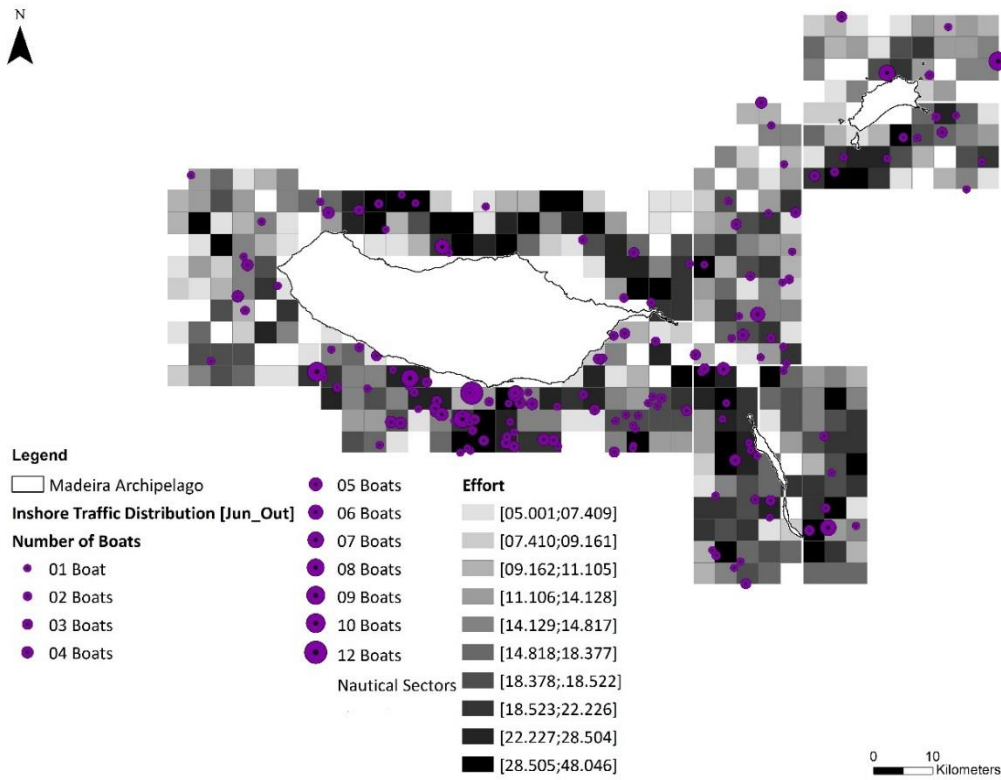


Figure 16 - Summer Season: Plot of vessel locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

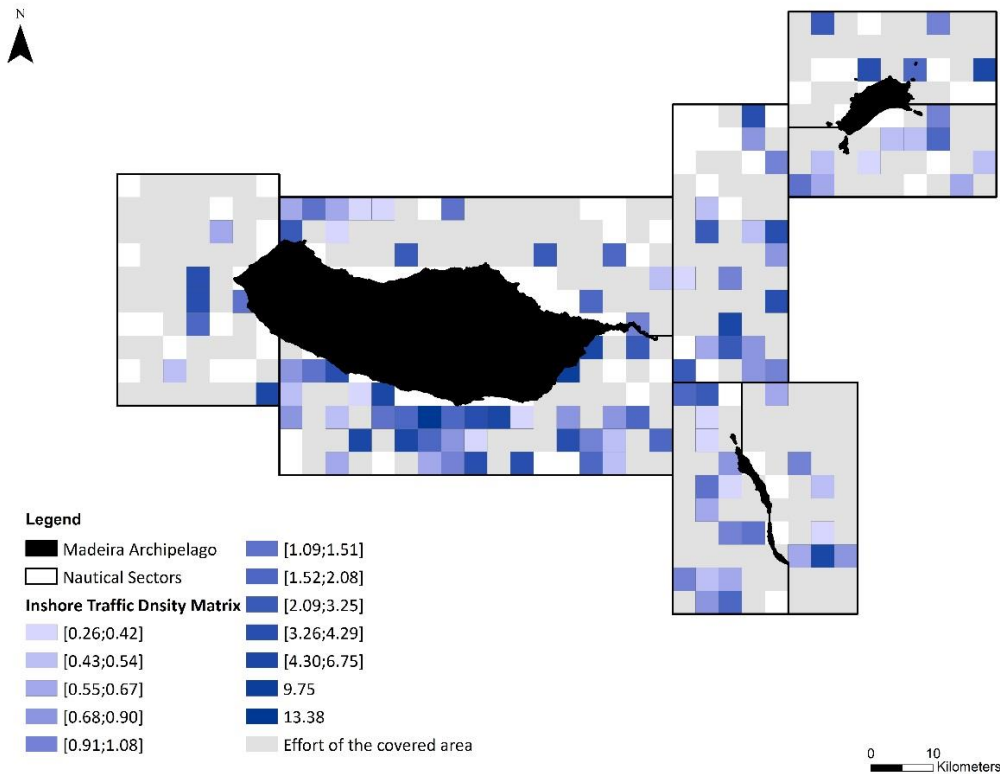


Figure 17 - Summer vessel sightings distribution density matrix

for $P < 0.05$), apparently more active during the Winter.

These pattern can only be explained attending to each type of vessel distribution independently, as subsequently presented.

3.2.2 Ships

Descriptive statistics data for each distribution, by sector, are listed in table 14.

General (figures 18 and 19), winter (figures 20 and 21) and summer (figures 22 and 23) ships density distributions were separately analysed to detect significant differences between the sectors by the Kruskal-Wallis test. All distributions confirmed an heterogeneous distribution across the study area ($P < 0.05$).

The Mann-Witney test was applied in order to detect which sectors were statistically different among each distribution and to find possible distribution pattern variations in the same sector according to the season.

Table 14 - Descriptive statistics of ships general and seasonal density - number of boats per effort unite (Km)-distribution, by sector

	Mean	SD	Median	Minimum	Maximum
General distribution					
sector 1	0.03	0.11	0.00	0.00	0.60
sector 2	0.14	0.59	0.00	0.00	4.15
sector 3	0.35	0.66	0.18	0.00	4.20
sector 4	0.06	0.16	0.00	0.00	9.13
sector 5	0.08	0.20	0.00	0.00	0.97
sector 6	0.15	0.31	0.00	0.00	1.29
sector 7	0.07	0.13	0.00	0.00	0.46
sector 8	0.06	0.19	0.00	0.00	0.80
Winter distribution					
sector 1	0.02	0.09	0.00	0.00	0.51
sector 2	0.12	0.69	0.00	0.00	4.90
sector 3	0.32	0.72	0.00	0.00	3.82
sector 4	0.05	0.19	0.00	0.00	0.90
sector 5	0.11	0.29	0.00	0.00	1.48
sector 6	0.17	0.42	0.00	0.00	1.96
sector 7	0.05	0.13	0.00	0.00	0.46
sector 8	0.05	0.20	0.00	0.00	0.94
Summer distribution					
sector 1	0.04	0.16	0.00	0.00	0.90
sector 2	0.13	0.57	0.00	0.00	4.06
sector 3	0.27	0.56	0.00	0.00	3.23
sector 4	0.11	0.31	0.00	0.00	1.36
sector 5	0.05	0.22	0.00	0.00	1.35
sector 6	0.12	0.28	0.00	0.00	1.08
sector 7	0.07	0.19	0.00	0.00	0.79
sector 8	0.04	0.23	0.00	0.00	1.35

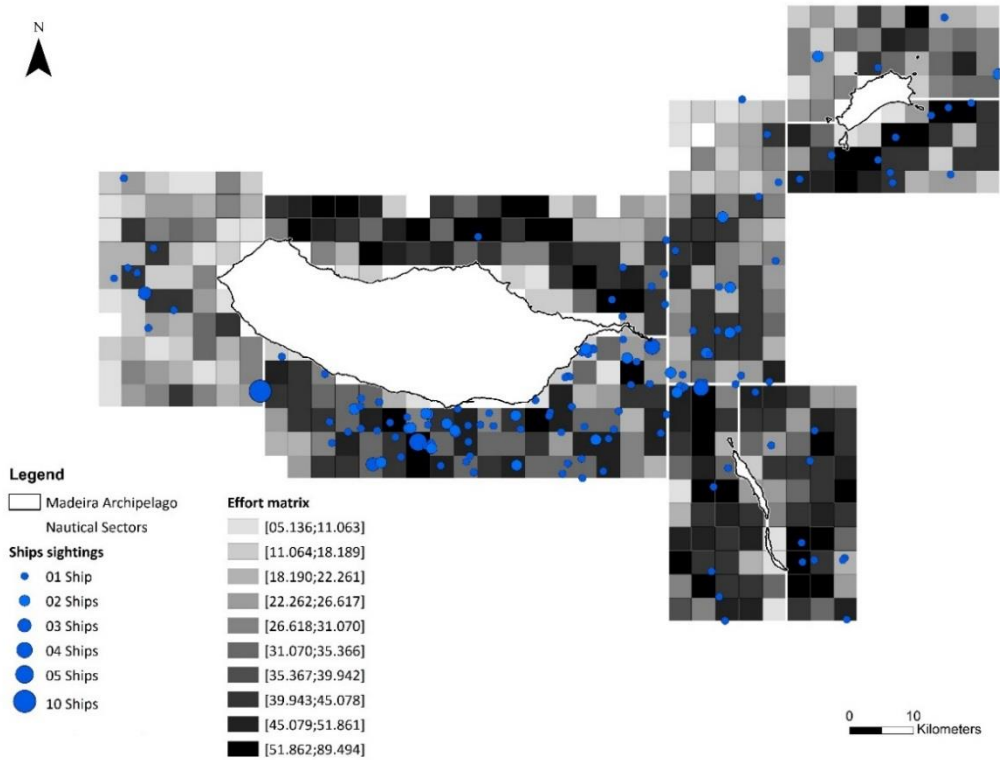


Figure 18 - Plot of ships sightings locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

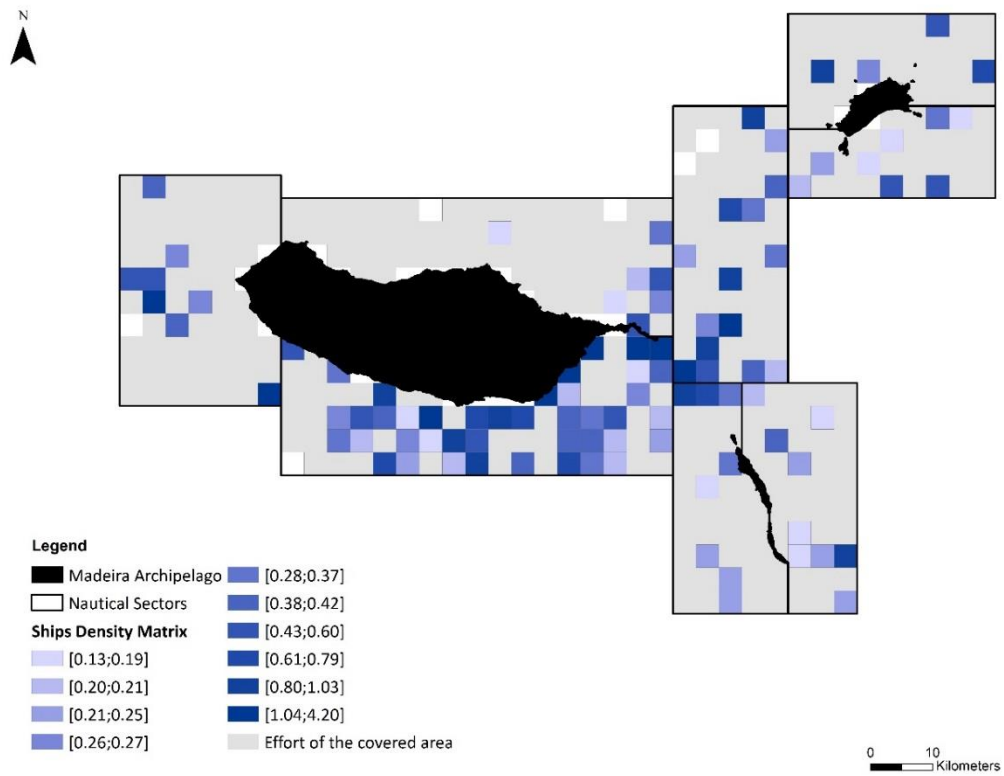


Figure 19 - General ships sightings distribution density matrix

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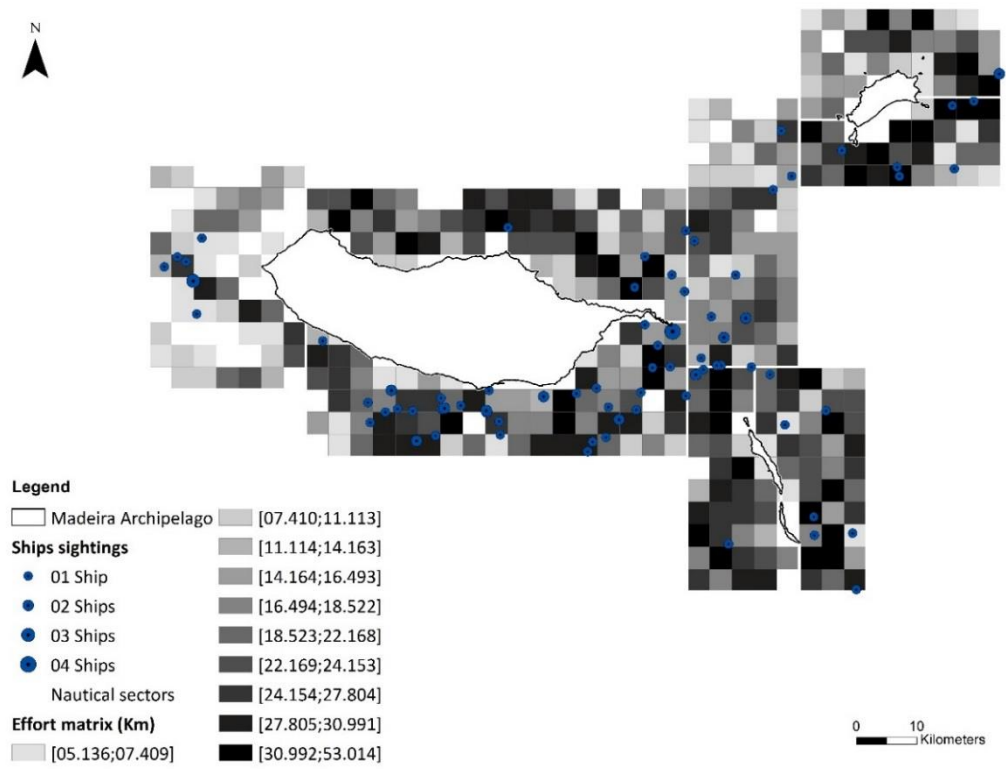


Figure 20 - Winter Season: Plot of ships sightings locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed

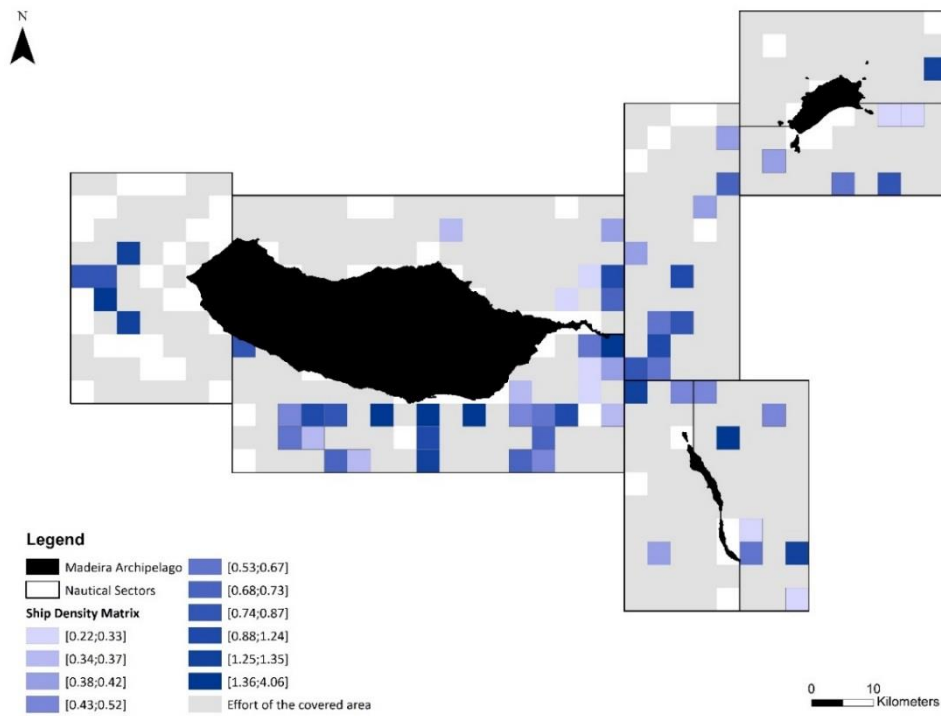


Figure 21 - Winter ships sightings distribution density matrix

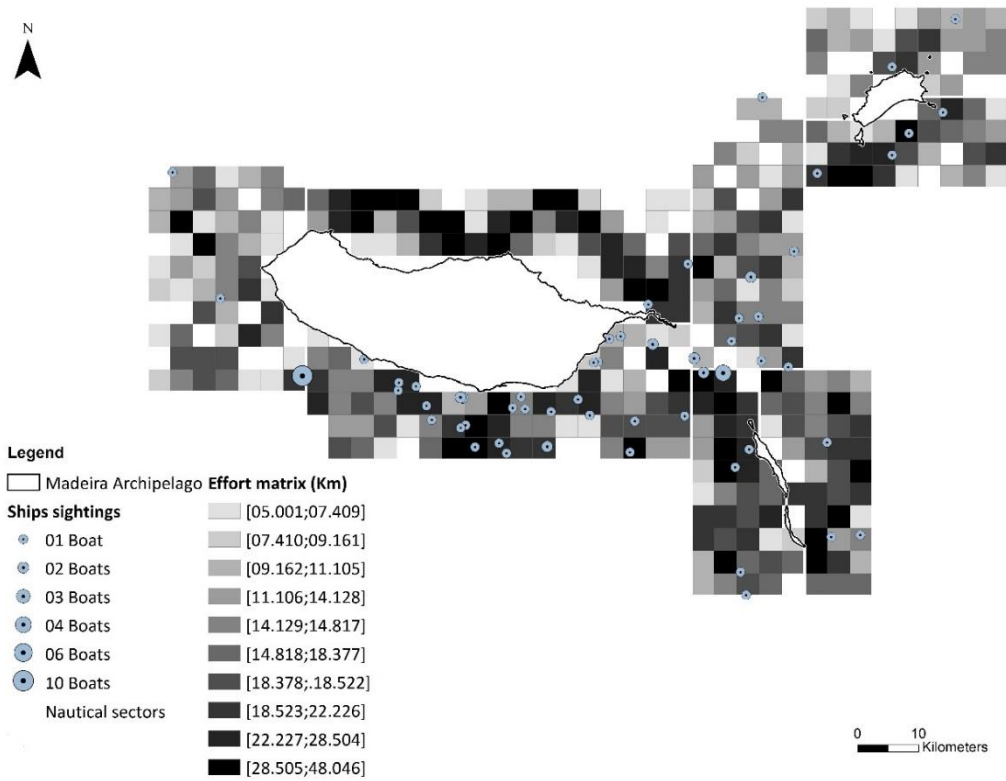


Figure 22 - Summer Season: Plot of ships sightings locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed

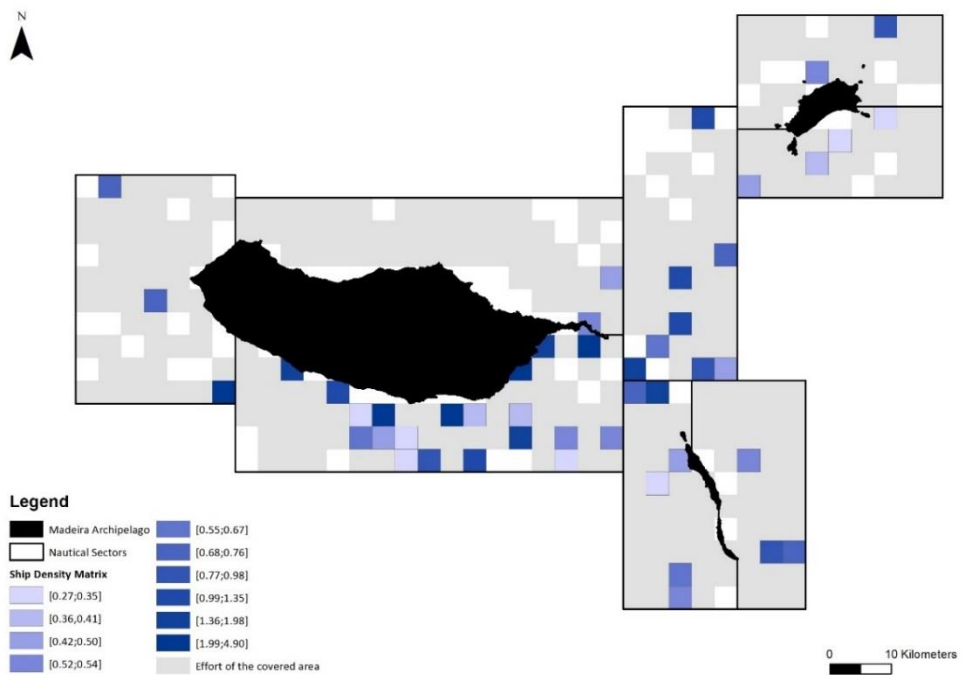
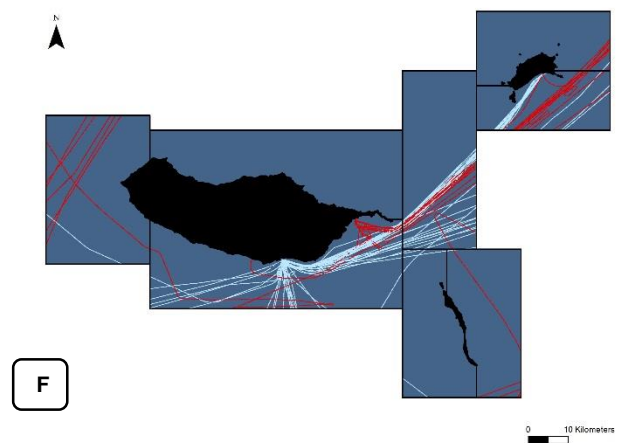
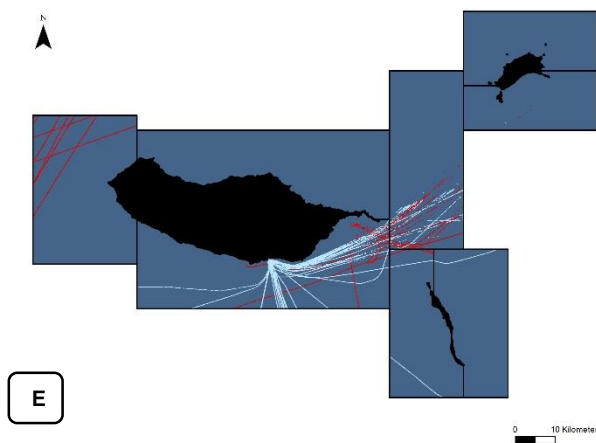
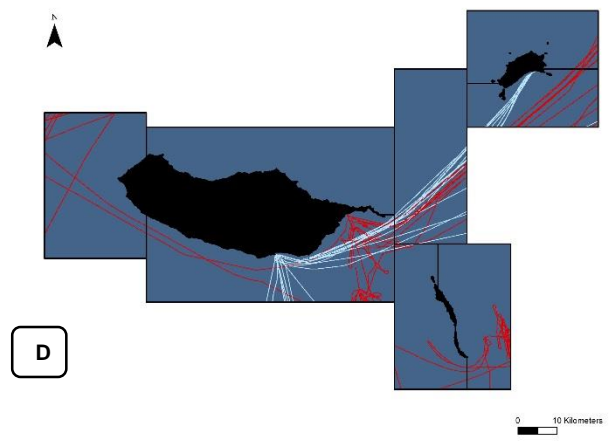
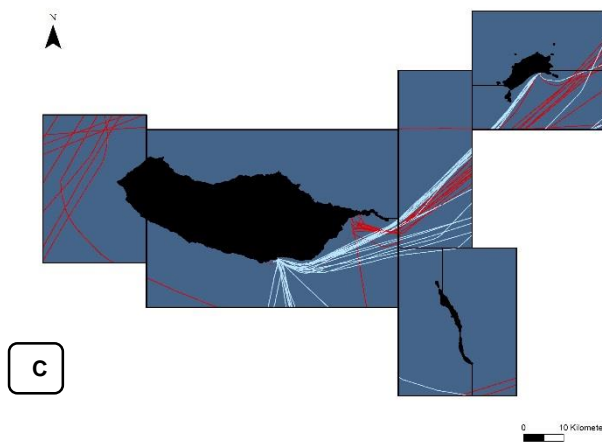
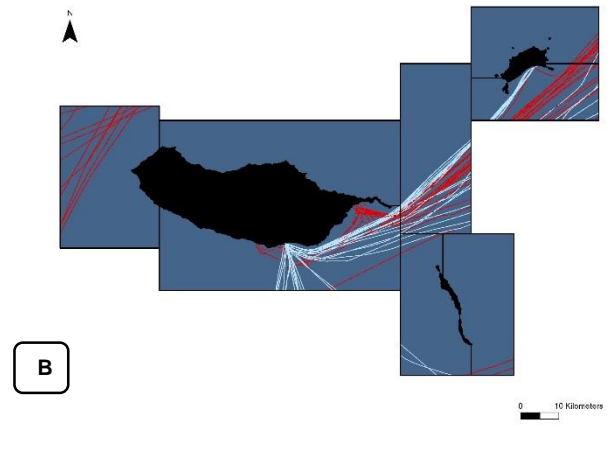
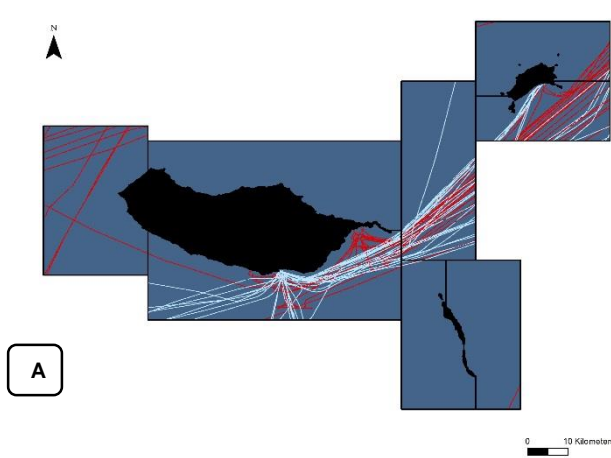


Figure 23 - Winter ships sightings distribution density matrix



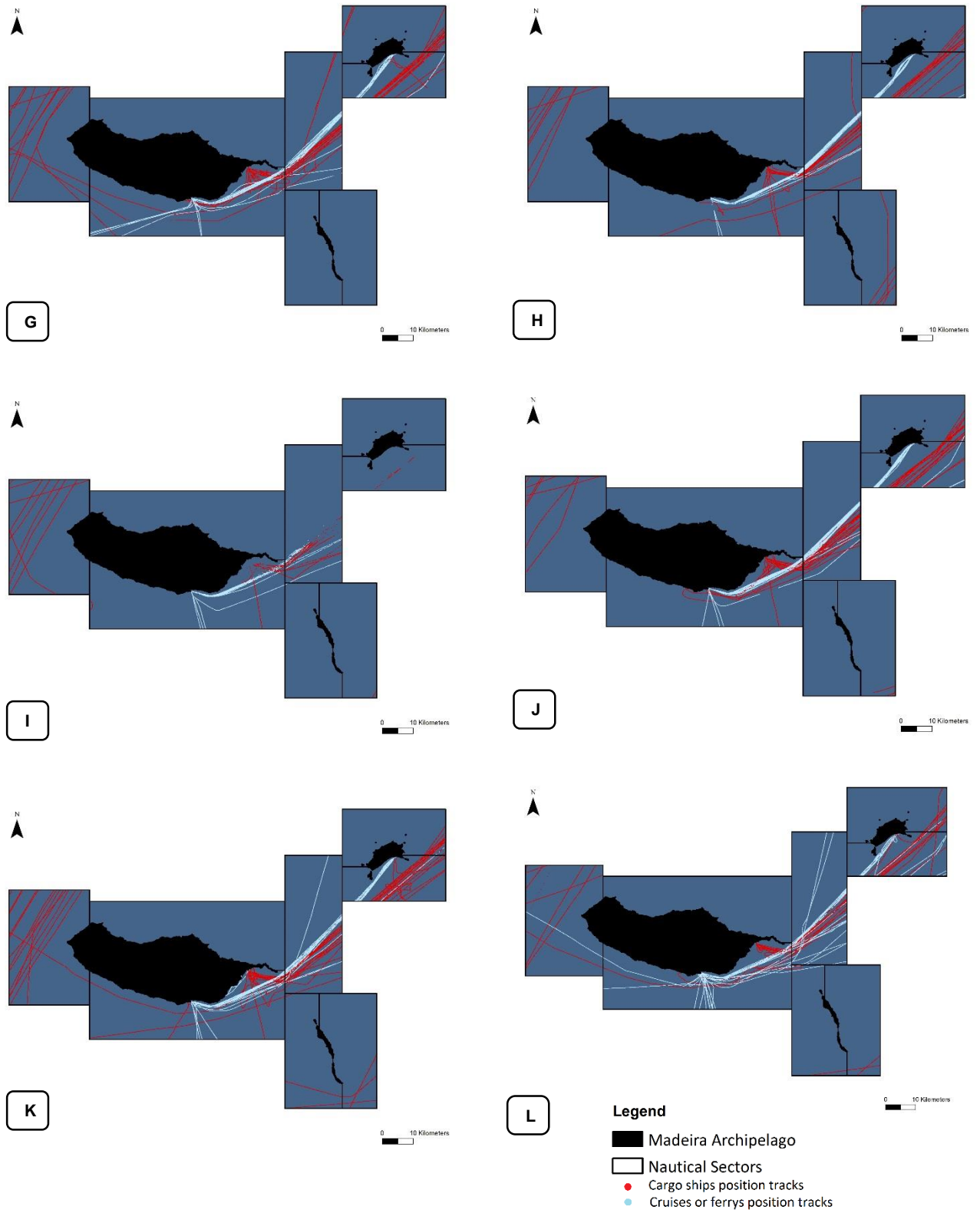
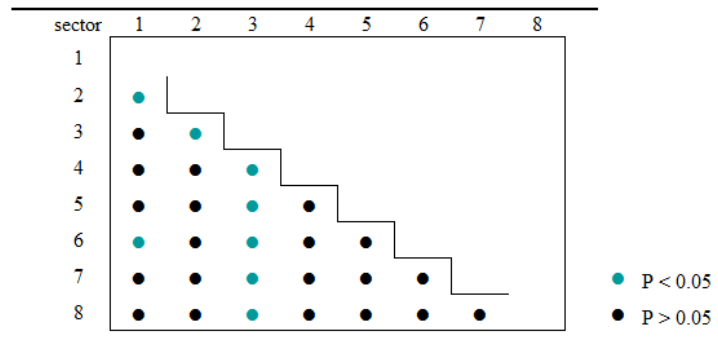


Figure 24 - Ships position tracks projected over the inshore traffic area. Some areas show higher track density – shipping route. The maps are displayed by season: winter (A-G) and summer (H-L). For the months available in at least 2 years of data (see table 5) only one representative month (the one apparently presenting less coverage gaps) is displayed: A – November 2008; B – December 2008; C – January 2009; D – February 2009; E – March 2010; F – April 2010; G – May 2008; H – June 2011; I – July 2008; J – August 2008; K – September 2009; L – October 2008. The remaining maps can be consulted in Annex II.

The analyses of the density map representing the ship general distribution (table 15) indicates that some sectors are more intensively used than others. Sector 3 density pattern turned out to be significantly different from all the other sectors. This should be expected since both island main ports (Funchal and Caniçal) are located in South Madeira, eye lighting it as the “busiest” traffic zone. A significant difference was also found between the sectors 6 and 1. Considering sector 1, along with

sector 8, appear to be the areas with the lowest traffic level, this might indicate sector 6 should also have a slightly higher ship traffic activity in comparison to the remaining sectors. Sectors 4 and 5 seem to present a similar level of traffic. Sector 7, though presenting similar statistics descriptive factors to sectors 4 and 5, attending to the figure 25 – A, in the correspondent boxplot, the density values seem to be more aggregated above the average and without so many outliers, indicating a more steady density pattern in dose values, i.e., a more elevated level of traffic.

Table 15 - Mann-Witney tests results – Comparison of the ships sightings general density distribution in the sectors of the study area



T

Table 16 - Mann-Witney test results – Comparison of the ships sightings winter density distribution in the sectors of the study area

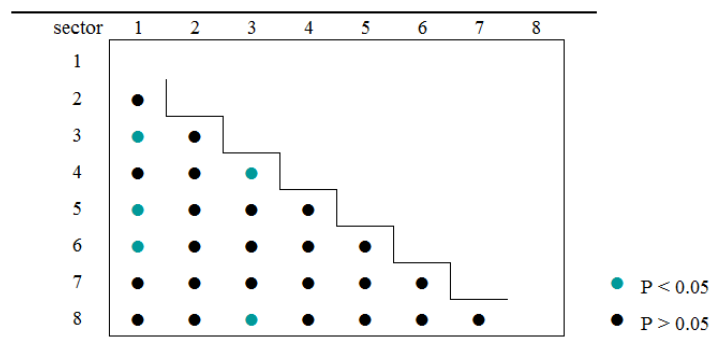
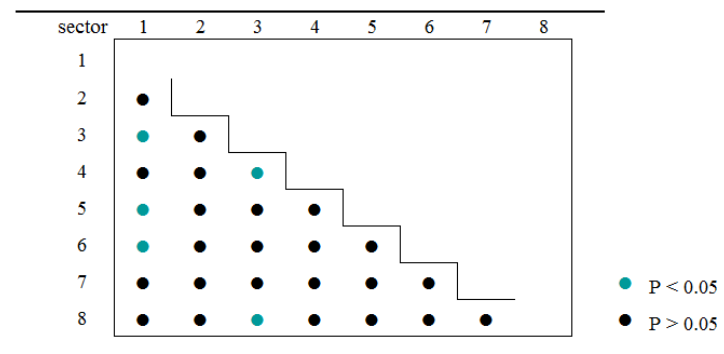


Table 17 - Mann-Witney test results – Comparison of the ships sightings summer density distribution in the sectors of the study area



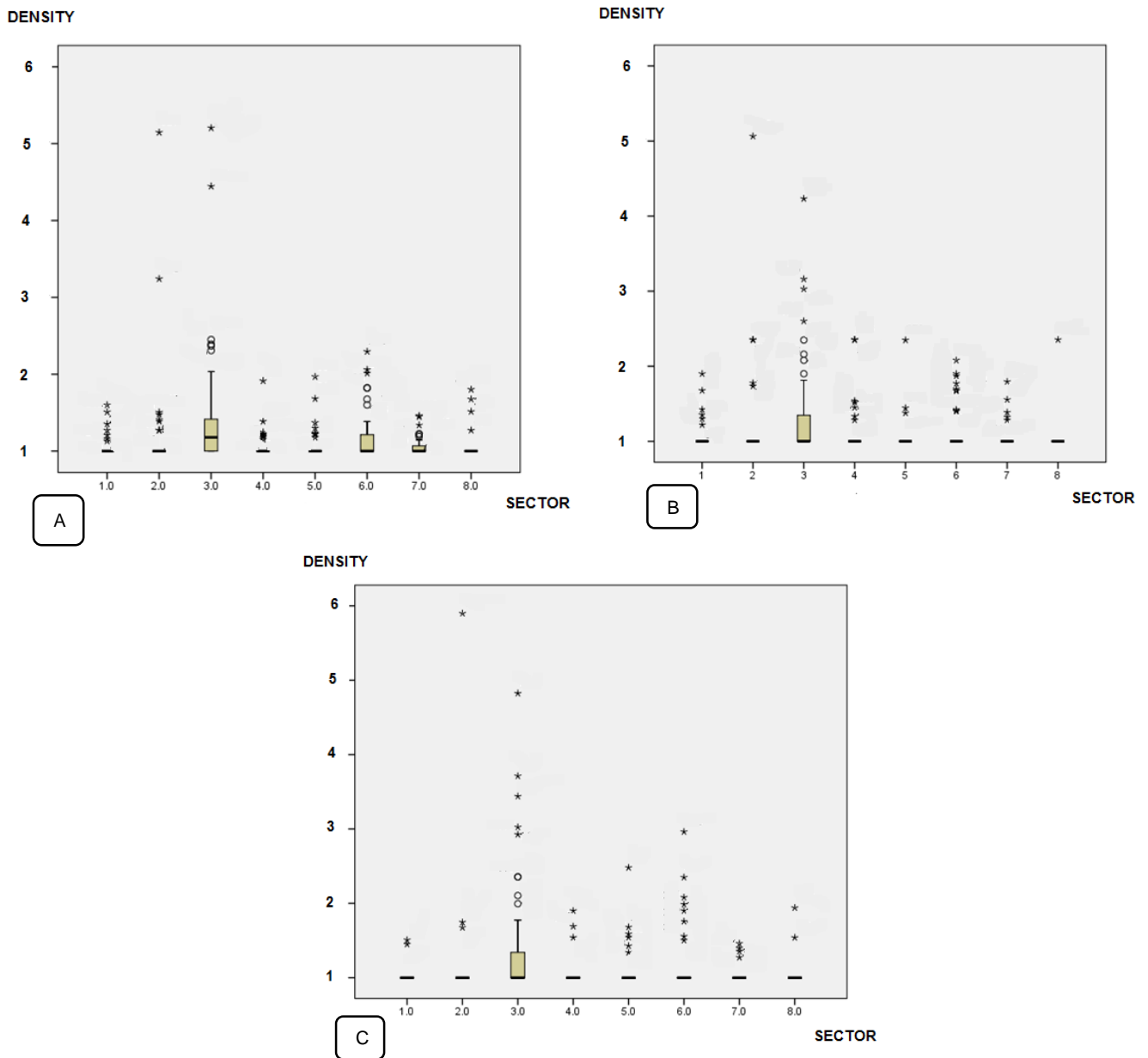


Figure 25 - Boxplot correspondent to each sector during ships general (A), winter (B) and summer (C) distributions. The upper lines of boxes include the data distribution from the third quartile, and upper and lower horizontal bars show minimum and maximum group sizes unless outliers (o) or extremes (*) are present, in which case the horizontal bar is defined as the third quartile plus 1.5 or 3, respectively. The width of the bars is proportional to sample size.

Attending to the ships winter pattern distribution (table 16), sector 3 stands out again as the more intensively crossed area (figure 25 – B). A significant difference was found between the sector 3 and sectors 1, 4, 5 and 8, the lower traffic zones. Unlike the general distribution pattern, sector 3 is not significantly different from sectors 6 or 7, indicating the traffic activity level might also be significant in these two sectors during this season. Traffic level in

sectors 6 and 8 is also considerably different distinguishing North Porto Santo as the lowest traffic zone, since sector 6 did not stand out from any of the other low traffic sectors (sectors 4 and 5).

The ships distribution pattern along the summer period (table 17) does not seem to vary much from the previous description. The most significant difference is that sectors 3 and 5 are not so strongly divergent anymore, while a significant traffic level discrepancy was found between sector 5 and sector 1 which might indicate an increase of traffic activity in West Deserts sector during this season (though no significant difference was detected when comparing it with the same sector during the winter time). Apart from this, sector 3 still holds the position of the higher traffic area, significantly different from sectors 1, 2, 4 and 8.

No significant differences were found when comparing the same sector across the different seasons ($P > 0.05$).

If we cross the analyses provided by the maps above, with the ones based on AIS data (figure 24), South Madeira, encompassing the two main ports (Funchal and Caniçal), clearly stands out as the “busiest” zone and it is also possible to identify a “high used” corridor extending across the South Madeira, Lane and South Porto Santo sectors (which goes accordingly with statistic results stated above, especially when considering the season patterns separately). This passage is transited by both cargo, cruises and ferries, most of them stopping in Funchal, Caniçal or Porto Santo ports and a few just crossing the sector following further destinations.

The majority of tracks crossing West Madeira sector are mainly cargo boats in transit and heading towards multiple destinations (such as Rio de Janeiro, Lisbon, Amsterdam...), which might explain the patch present in the ships density map, in the same sector. As mentioned before in a previous chapter (section 3.1.1), most of cargos ships that cross the area are headed towards the more sought out traffic areas, such as the North or Baltic seas or Gibraltar.

Considering all the months representations, sector 1 is almost never intersected by any ship track, standing out as the lower traffic sector, which means its traffic level might be being overrated in the presented density maps. The cells in sector 1 with ship density values are on the East lower corner, close to sector 6. As mentioned before, the ship plots represented in the map do not correspond to the exact location of each ship, but to the observational boat location by the time these were detected. Thus, one pair of coordinates might correspond to more than one vessel(s), according to the number of boats spotted at a time and the vessel estimated distance and direction towards the research boat are also unknown. Hence, possibly those ships might have been sighted from North Madeira sector, while they were passing sector 6 heading to sector 3.

Most cruises and ferries stop in Funchal port as a passage harbour, only to carry on route to different destinations (Gibraltar, Malaga, Tenerife... among others).

A very defined route, running year round, goes from Funchal to Porto Santo port. *Lobo Marinho*, a local ferry, is the only ship that makes that path, 6 days a week (in summer time twice a day).

The routes pattern do not seem to vary much according to the season.

The cargo ships main port of call in the archipelago is Caniçal port, and less frequent routes towards Funchal and Porto Santo ports. Major imported and exported products from the region are transported through the sea and most transactions (77%) start or stop in Caniçal port (15 % dropped and 85 % loaded cargo), and only 18 % in Porto Santo (92 % dropped and 8% loaded cargo) and 5% in Funchal (92% dropped and 8% loaded cargo) (DREM - Direção Regional de Estatística da Madeira, 2012).

3.2.3 Recreational boats

The descriptive statistics data of each distribution, by sector, can be consulted in table 18.

Same statistical treatment previously mentioned was applied to each recreational traffic distribution pattern (general and seasonal) and none of them seems to be equally distributed across the area, as all Kruskal-Wallis tests presented significant results for $P < 0.05$. The results of the Mann-Witney tests subsequently used can be checked in tables 19, 20 and 21.

Table 18 - Descriptive statistics of recreational boats general and seasonal density -number of boats per effort unite (Km) -- distribution, by sector

	Mean	SD	Median	Minimum	Maximum
General distribution					
sector 1	0.01	0.34	0.00	0.00	2.26
sector 2	0.02	0.01	0.00	0.00	2.26
sector 3	0.45	0.77	0.00	0.00	4.13
sector 4	0.11	0.31	0.00	0.00	1.75
sector 5	0.12	0.33	0.00	0.00	1.75
sector 6	0.20	0.44	0.00	0.00	2.46
sector 7	0.12	0.20	0.00	0.00	0.62
sector 8	0.12	0.30	0.00	0.00	1.35
Winter distribution					
sector 1	0.18	0.77	0.00	0.00	5.12
sector 2	0.06	0.19	0.00	0.00	0.91
sector 3	0.38	0.89	0.00	0.00	6.09
sector 4	0.11	0.44	0.00	0.00	2.70
sector 5	0.01	0.33	0.00	0.00	1.80
sector 6	0.14	0.32	0.00	0.00	1.35
sector 7	0.13	0.28	0.00	0.00	1.06
sector 8	0.01	0.25	0.00	0.00	1.21
Summer distribution					
sector 1	0.03	0.17	0.00	0.00	1.14
sector 2	0.00	0.00	0.00	0.00	0.00
sector 3	0.55	1.22	0.00	0.00	7.64
sector 4	0.05	0.16	0.00	0.00	0.63
sector 5	0.07	0.17	0.00	0.00	0.68
sector 6	0.34	0.93	0.00	0.00	4.05
sector 7	0.12	0.29	0.00	0.00	1.09
sector 8	0.13	0.53	0.00	0.00	2.69

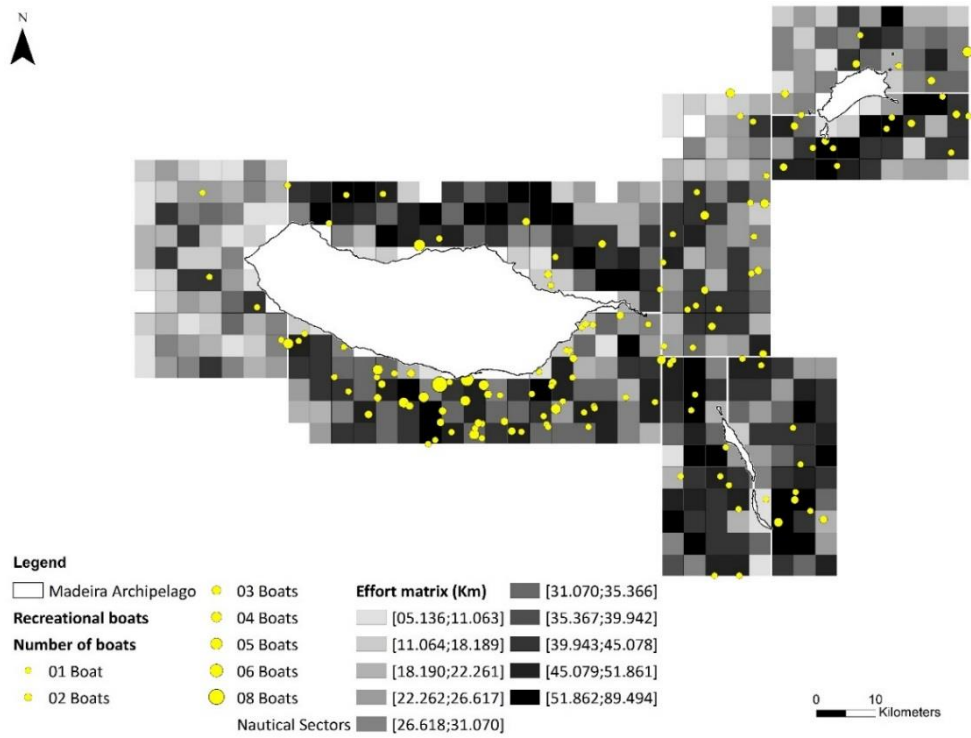


Figure 26 - Plot of all recreational boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

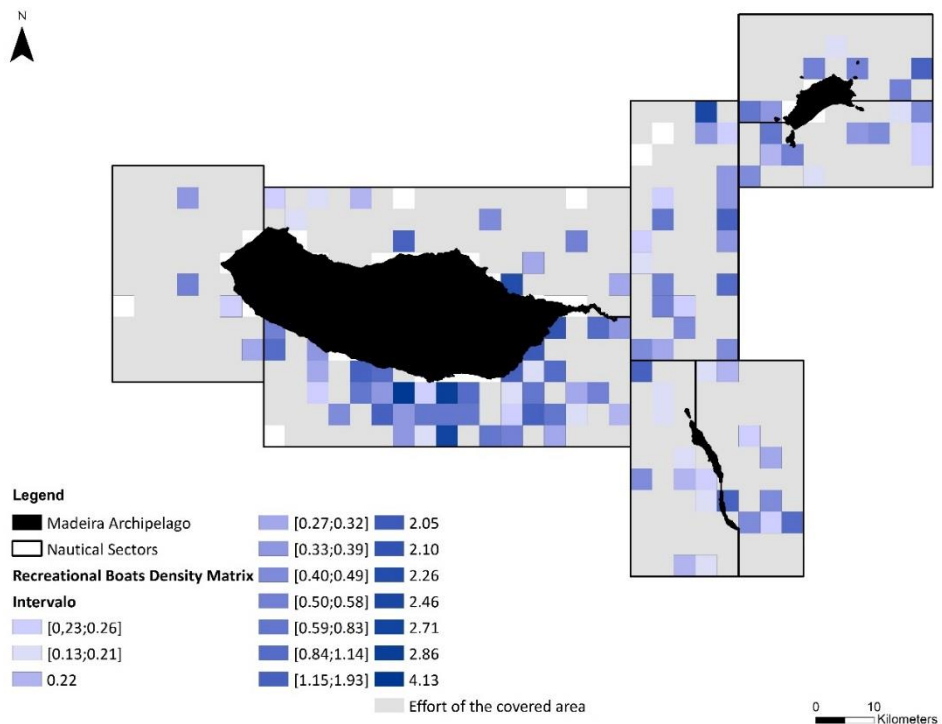


Figure 27 - Recreational boats sightings distribution density matrix

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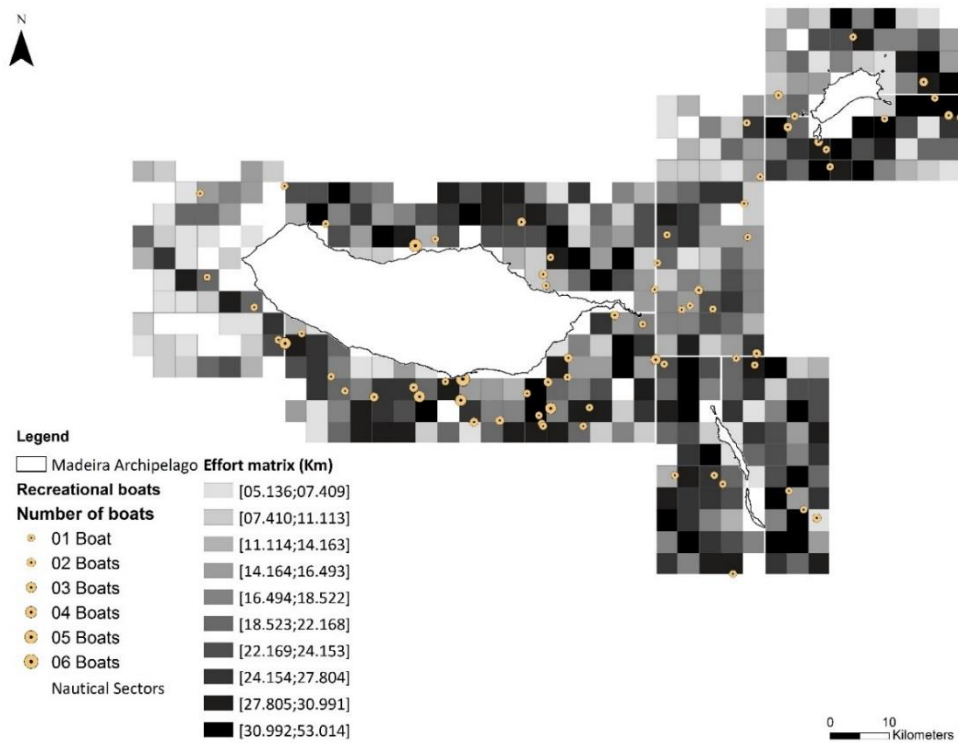


Figure 28 – Winter season::Plot of all recreational boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

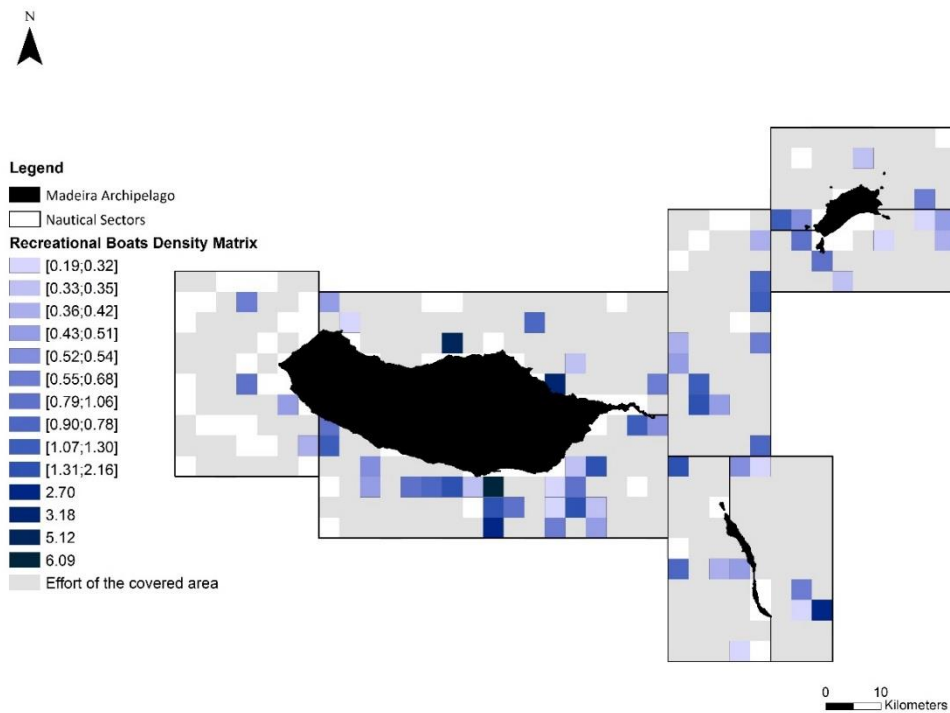


Figure 29 - Winter recreational boats sightings distribution density matrix

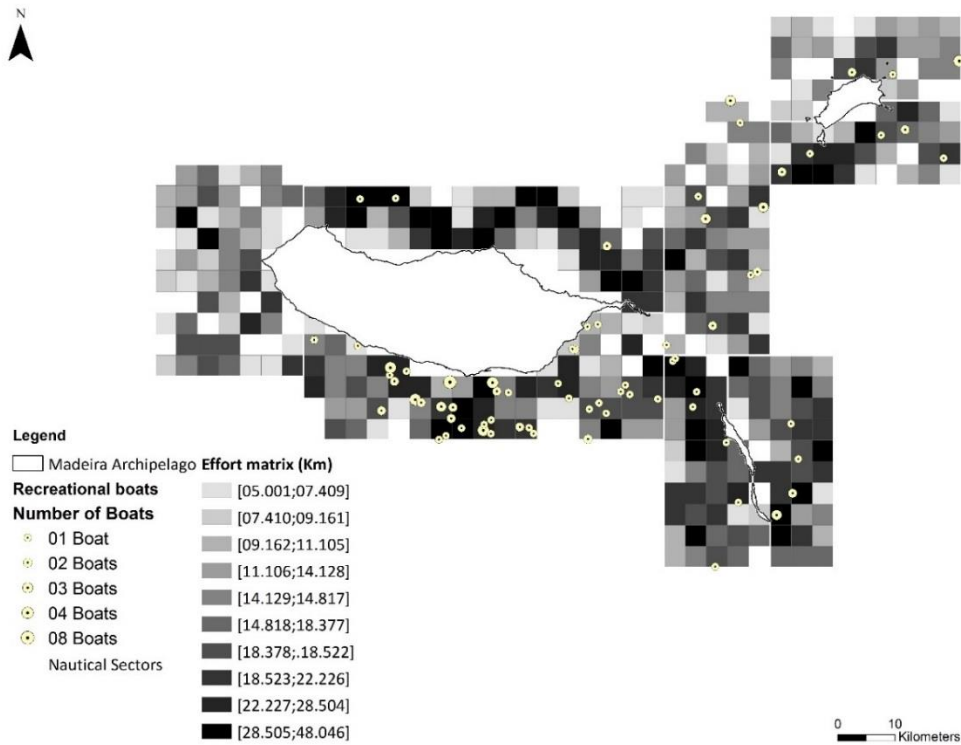


Figure 30 - Summer season::Plot of all recreational boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable circle diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

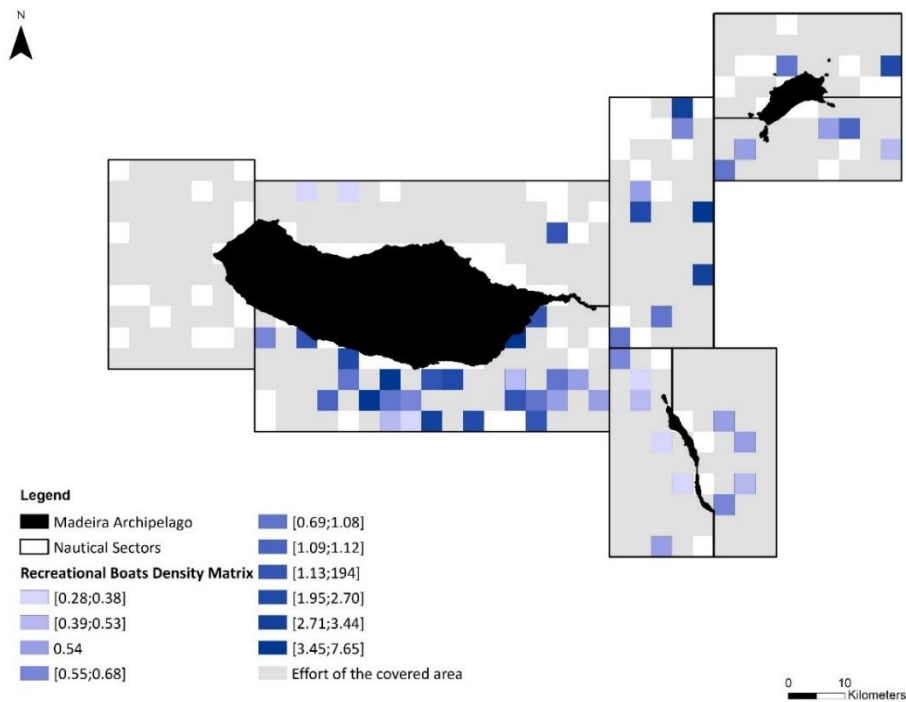


Figure 31- Summer recreational boats sightings distribution density matrix

this case. According to IMO's requirements, only international voyaging ship with gross tonnage (GT) of 300 or more tons and all passenger ships (size irrelevant), have to be equipped with AIS gear (International Whaling Commission, 2011). Thus, since we are now considering vessels with a maximum size of 24 m, this comparison did not seem relevant, as most of these would not be fairly represented in the AIS maps.

The location of small vessels is associated with a shorter sight range when detected, i.e., the research boat needs to be closer so that the observers may sight them. Thus, these plots are expected to be more accurate than ship's plots, for instance.

Unlike large vessels, recreational boats can also resort to small ports. Besides the two main ports (Funchal and Caniçal), many small ports, accessible to light vessels, are located in South Madeira again standing out as the "more intensively used" sector. The previously mentioned "high used" corridor, crossing the sector 3, 6 and 7, seems also to be a preferential path for recreational boats, in both general and seasonal distributions. Sector 6 includes the passage to Porto Santo island and sector 7 holds the Porto Santo port, which, resembling the ships pattern distribution, might explain the intensity of traffic along these sectors. Nevertheless, recreational boats are also spread throughout the different sectors, since they can use different small ports through all the island shore not usable by large vessels. West Madeira sector seems to be crossed more frequently during the winter season.

3.2.4 Fishing boats

There will be presented two distinct groups of fishing traffic distribution pattern maps: (1) the first group comprises data collected from the year 2001 until 2012, without attending to the fishing boat type; (2) the second group, a section of the previous, represents the boats registers collected on surveys running from 2011 to 2012, when fishing vessels started to be classified according to the fishery type: (1) tuna fishing boats (16%, $n = 23$); (2) black scabbard fish fishing boats and (13%, $n = 18$); (3) recreational demersal fishing boats (71%, $n = 102$). In the last group each type of fishery was independently represented.

3.2.4.1 Fishing boats (2001-2012)

The descriptive statistics of the general (figure 32 and 33) and seasonal (figure 34 and 35, 36 and 37) fishing boats density distributions, according to each sector, are listed in table 22.

The results of the Kruskal-Wallis tests revealed significant differences between the sector's density patches in the general and summer season density maps ($P < 0.05$). The Mann-Witney test results are presented in table 23 and 24, for both general and summer distributions, respectively.

Sectors 4, 6 and 8 distribution pattern seems to vary according to the season (Mann-Witney tests significant results for $P < 0.05$).

Considering the general pattern distribution and crossing the reading of table 23 and figure 38 - A, sector 3 and sector 2 appear to be the more and the less intensively used areas, respectively. Sectors 3 outrivals every sector except west deserts and north Porto Santo. These last two sectors (5 and 8), are also significantly different from the ones with the lower traffic intensity, sectors 2 and 4, thus standing in the middle range of traffic level. Sector 1 seems to be more active than sectors 2 and 4.

During the summer season, based on the interpretation of table 24 and figure 38 - C, the fishing traffic activity seems to drop in sectors 4, 6 and 8. Sectors 3 and 5 appear to be the more active traffic zones. Sector 3 is significantly different from sectors 2, 4, 6 and 8. Sector 5 presents a considerable higher level of traffic than sectors 2 or 4, the lower traffic zones. Sector 1 stands out from sector 4, meaning it might be slightly more active sector.

Table 22 – Descriptive statistics of fishing boats general and seasonal density - number of boats per effort unite (Km) - distribution, by sector

	Mean	SD	Median	Minimum	Maximum
General distribution					
sector 1	0.29	0.46	0.00	0.00	1.76
sector 2	0.23	0.59	0.00	0.00	3.38
sector 3	0.52	0.77	0.24	0.00	5.10
sector 4	0.01	0.21	0.00	0.00	0.91
sector 5	0.22	0.27	0.18	0.00	1.07
sector 6	0.21	0.35	0.00	0.00	1.64
sector 7	0.11	0.18	0.00	0.00	0.54
sector 8	0.48	0.75	0.00	0.00	2.70
Winter distribution					
sector 1	0.31	0.69	0.00	0.00	3.41
sector 2	0.36	1.01	0.00	0.00	5.40
sector 3	0.48	1.21	0.00	0.00	9.20
sector 4	0.25	0.64	0.00	0.00	2.71
sector 5	0.30	0.49	0.00	0.00	1.80
sector 6	0.23	0.43	0.00	0.00	1.64
sector 7	0.11	0.24	0.00	0.00	0.82
sector 8	0.43	0.85	0.00	0.00	4.07
Summer distribution					
sector 1	0.23	0.70	0.00	0.00	3.17
sector 2	0.17	0.65	0.00	0.00	3.38
sector 3	0.35	0.72	0.00	0.00	3.66
sector 4	0.04	0.17	0.00	0.00	0.90
sector 5	0.19	0.35	0.00	0.00	1.12
sector 6	0.13	0.49	0.00	0.00	3.37
sector 7	0.01	0.22	0.00	0.00	0.71
sector 8	0.25	0.79	0.00	0.00	3.37

Not much information regarding the fishing activities comes out in the open, making it more difficult to infer a possible pattern explanation. As previously mentioned, the maps in question are representative of the general fishing traffic distribution, regardless of the fishing type, making it even harder to come up with a possible sustainable theory, since different fisheries run through difference seasons and might occur in preferential depths, depending on the gear and target species, i.e., different fishing types are associated with different features.

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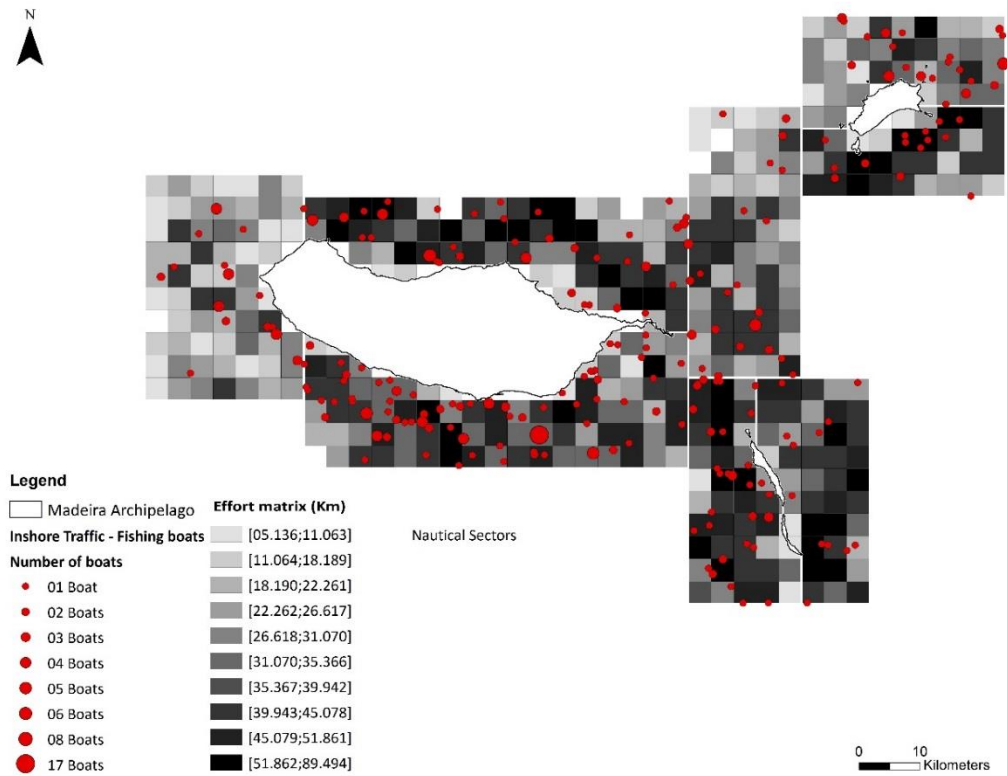


Figure 32 - Plot of fishing boats sighting over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

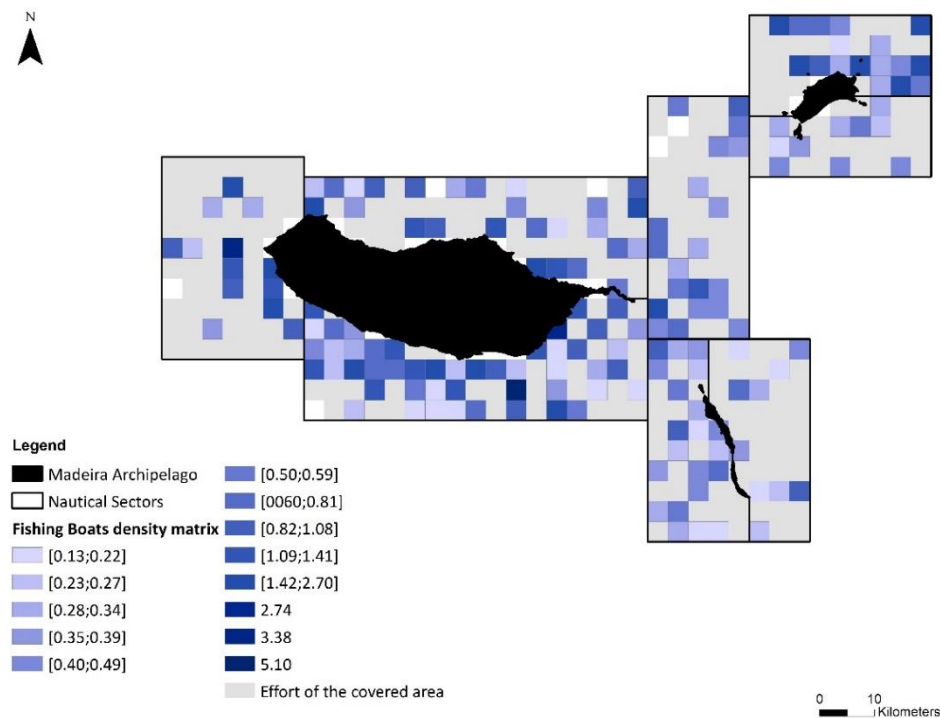


Figure 33- Fishing boats sightings distribution density matrix.

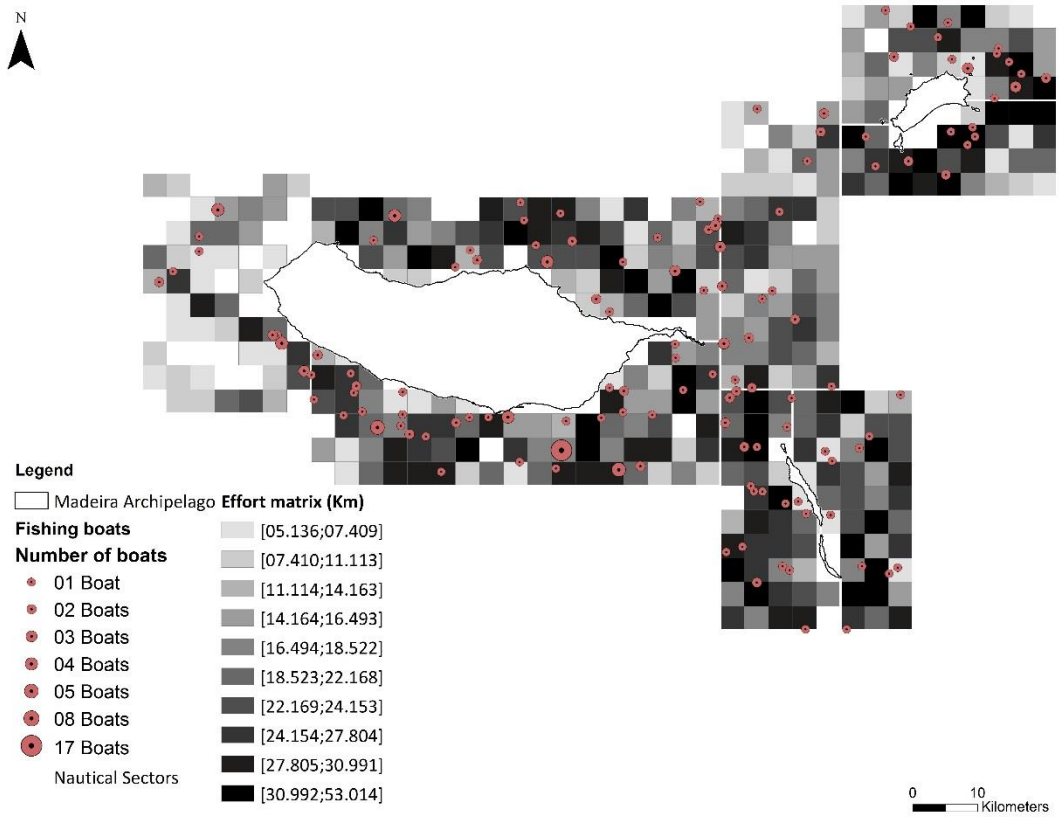


Figure 34 Winter season: Plot of fishing boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

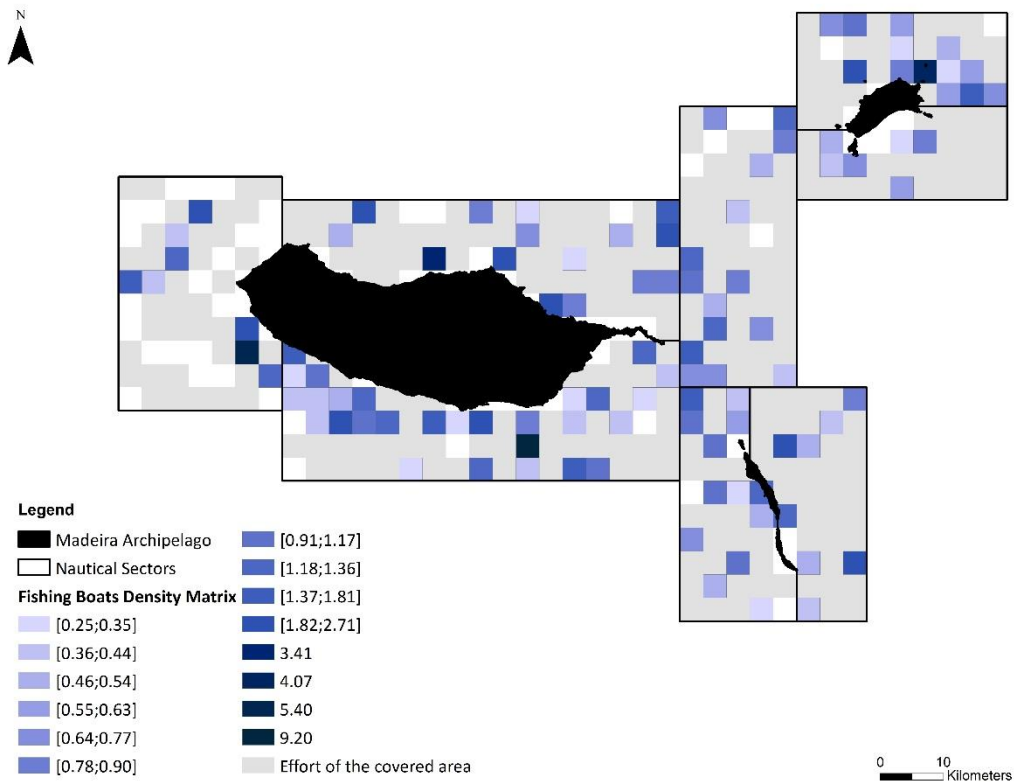


Figure 35 Fishing boats sightings distribution density matrix during the winter season.

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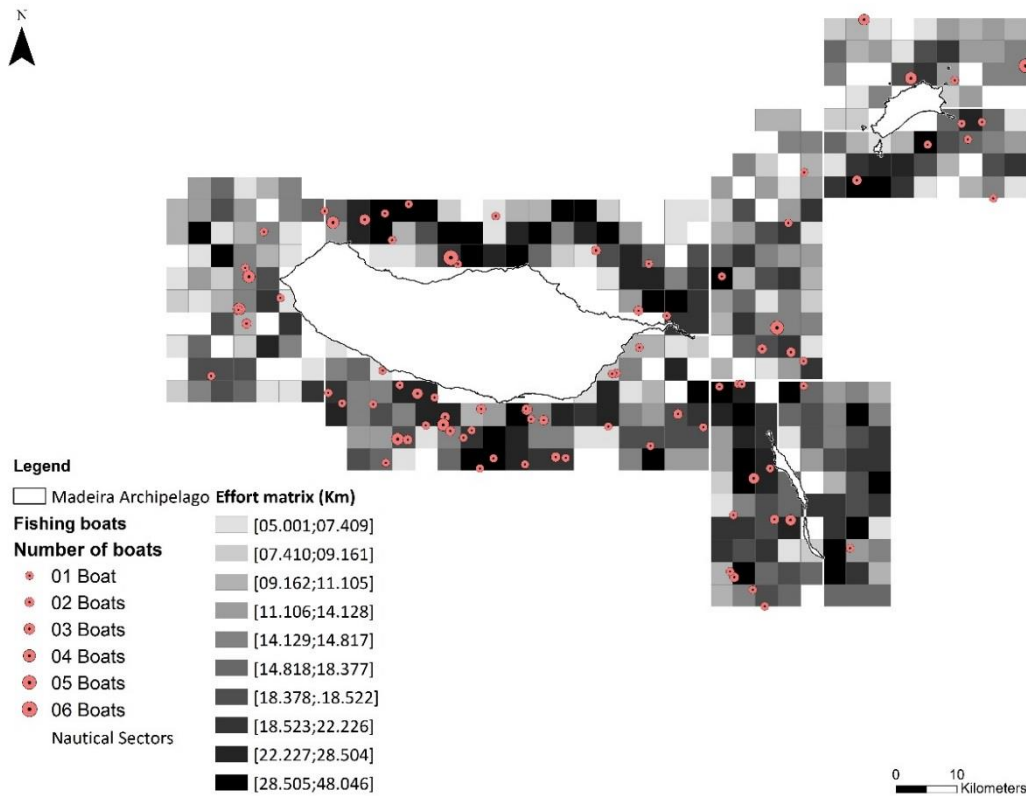


Figure 36 - Summer season: Plot of fishing boats sightings over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed

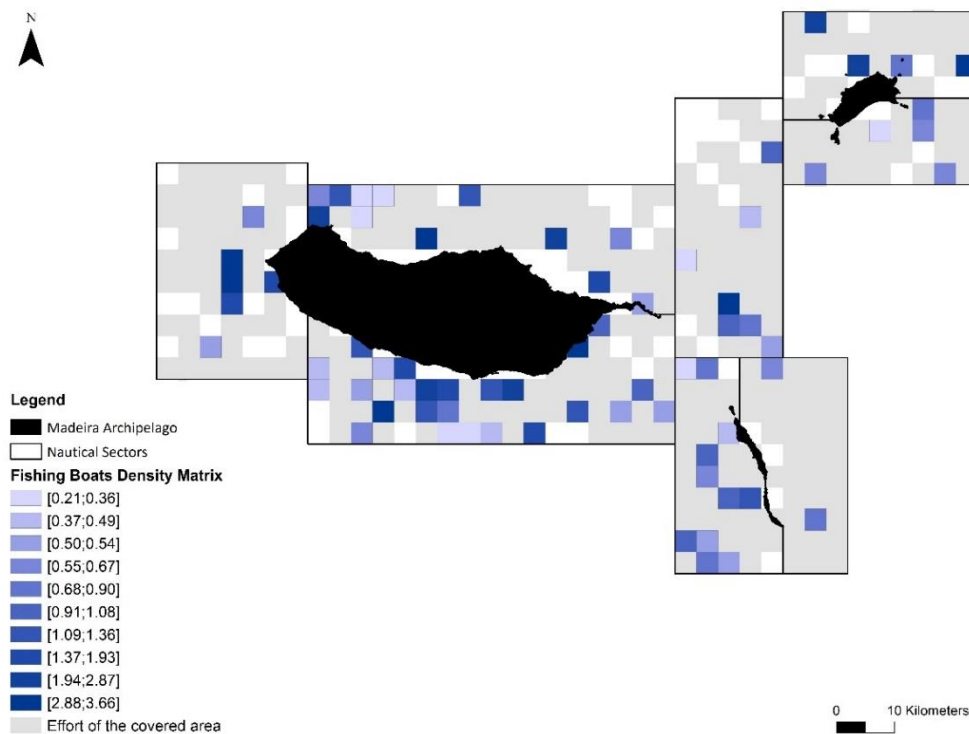


Figure 37 - Fishing boats sightings distribution density matrix during the summer season

years, mostly due to the drop of captured volume of tuna (-26,3%) and black scabbard fish. (-22,9%). It kept dropping in 2011 with a sudden rise in 2012 (+29.5% of unloaded tonnes) (Instituto Nacional de Estatística, 2011, 2012, 2013). Thus, the low activity during the summer season might be explained by the lack of pray, at some point during the sampling period, and the consequent movement of the fleet to other areas where the schools would be more abundant.

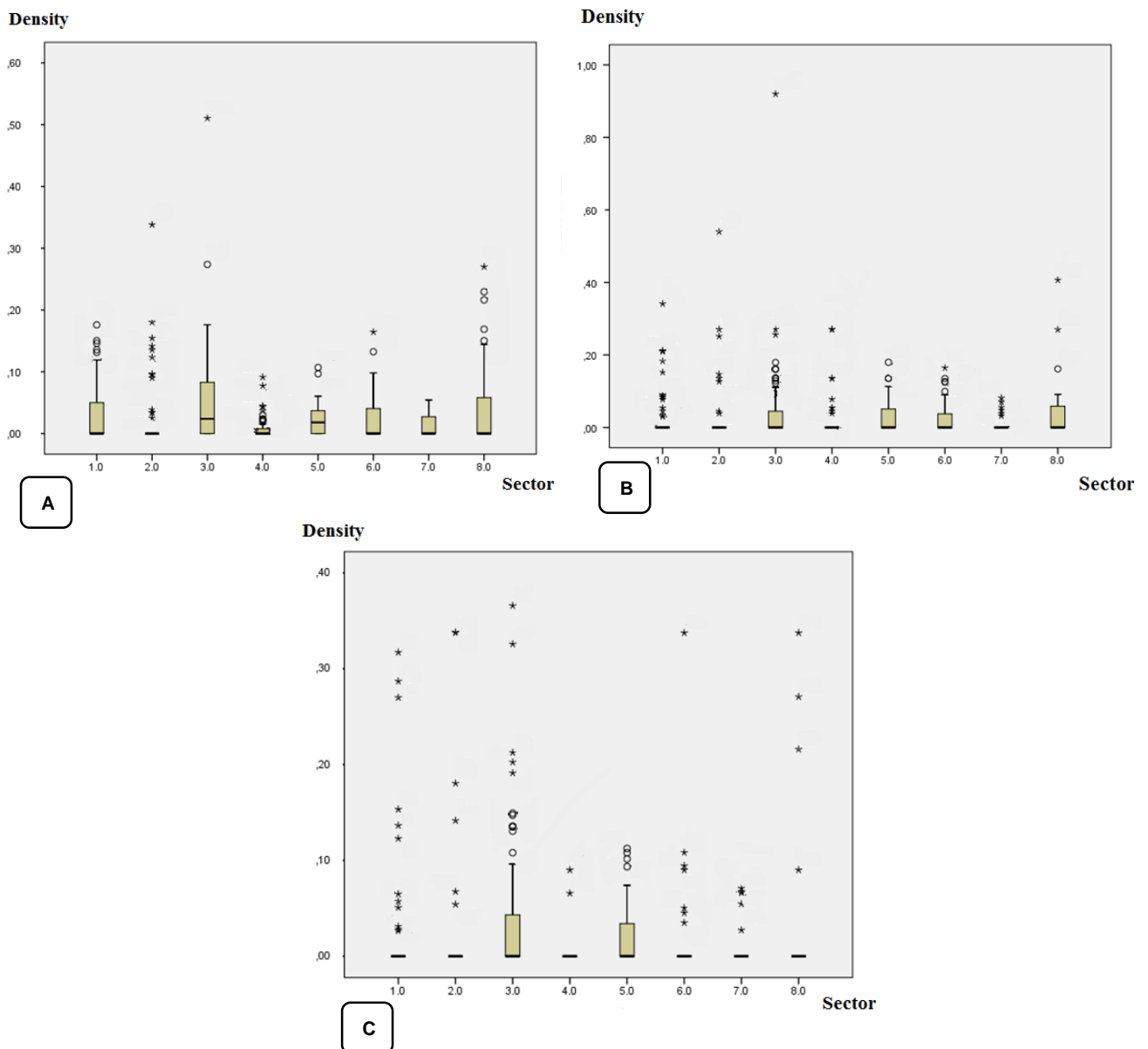


Figure 38 - Boxplot correspondent to each sector during fishing boats general (A), winter (B) and summer (C) distributions. The density values correspond to 0.1 x the values displayed in the matrix maps (figures 33, 35 and 37). The upper lines of boxes includes the data distribution from the third quartile, and upper and lower horizontal bars show minimum and maximum group sizes unless outliers (○) or extremes (*) are present, in which case the horizontal bar is defined as the third quartile plus 1.5 or 3, respectively. The width of the bars is proportional to sample size

3.2.4.2 Fishing boats (2011-2012)

Only a general spatial pattern distribution of the following distributions is presented, since the available data was not significant enough for a seasonal representation. Sector 2 was much less surveyed (inferior effort cover) when compared to the remaining sectors, which might have led to such results.

A) Tuna fishing boats

During the year 2012, 5761 t of tuna were captured in the Madeira shores, representing 55% of the total landings and 45% of the fisheries economic income (Instituto Nacional de Estatística, 2013).

Tuna fishing is undertaken in boats with more than 15 m size using the pole and line technique. Small purse-sein nets are used only to catch the bait (small pelagic, like mackerel or horse-mackerel), which usually happens during the night (Direção-Geral das Pescas e Aquicultura, 2007; Feio et al., 2002; Silva et al., 2011). The target tuna species in the Madeira region are the bigeye (*Thunnus obesus*), skipjack (*Katsuwonnus pelamis*), albacore (*T. alalunga*), yellowfin (*T. albacares*) and blue fin (*T. thynnus*) (Instituto Nacional de Estatística, 2013).

Tuna fishing season usually runs through the months of April until the end of October (figure 7), when tuna migrates across the area. This fishing activity, however, might be very unpredictable with variable number of captures over the years (Instituto Nacional de Estatística, 2013), depending on the availability and migration routes of the schools (Silva et al., 2011). Tuna is a highly mobile predator (Golet et al., 2007) and climate changes can influence the tunides migratory cycle or promote the overexploitation in other fishing areas (Direção-Geral das Pescas e Aquicultura, 2007). According to previous studies undertaken around the Azores islands, the location of tuna fishing events might be very changeable, with a spatial pattern shifting over the years. Fishermen usually sought out tuna schools using binoculars and relying on sea bird or floating objects as indicators (Silva et al., 2011). Therefore, tuna fishing boats density pattern should also be very variable. According to the Kruskal-Wallis test results, the tuna fishing fleet distribution is not significantly different between sectors ($P=0,05$). The descriptive statistics of the tuna fishing boats density distribution (figures 39 and 40), by sector, might be consulted in table 25.

Table 25 - Descriptive statistics of tuna fishing boats density - number of boats per effort unit (Km) - distribution, by sector

	Mean	SD	Median	Minimum	Maximum
sector 1	0.01	0.41	0.00	0.00	2.79
sector 2	0.00	0.00	0.00	0.00	0.00
sector 3	0.02	0.14	0.00	0.00	0.88
sector 4	0.09	0.33	0.00	0.00	1.49
sector 5	0.00	0.00	0.00	0.00	0.00
sector 6	0.03	0.20	0.00	0.00	1.35
sector 7	0.11	0.37	0.00	0.00	1.79
sector 8	0.20	0.52	0.00	0.00	2.16

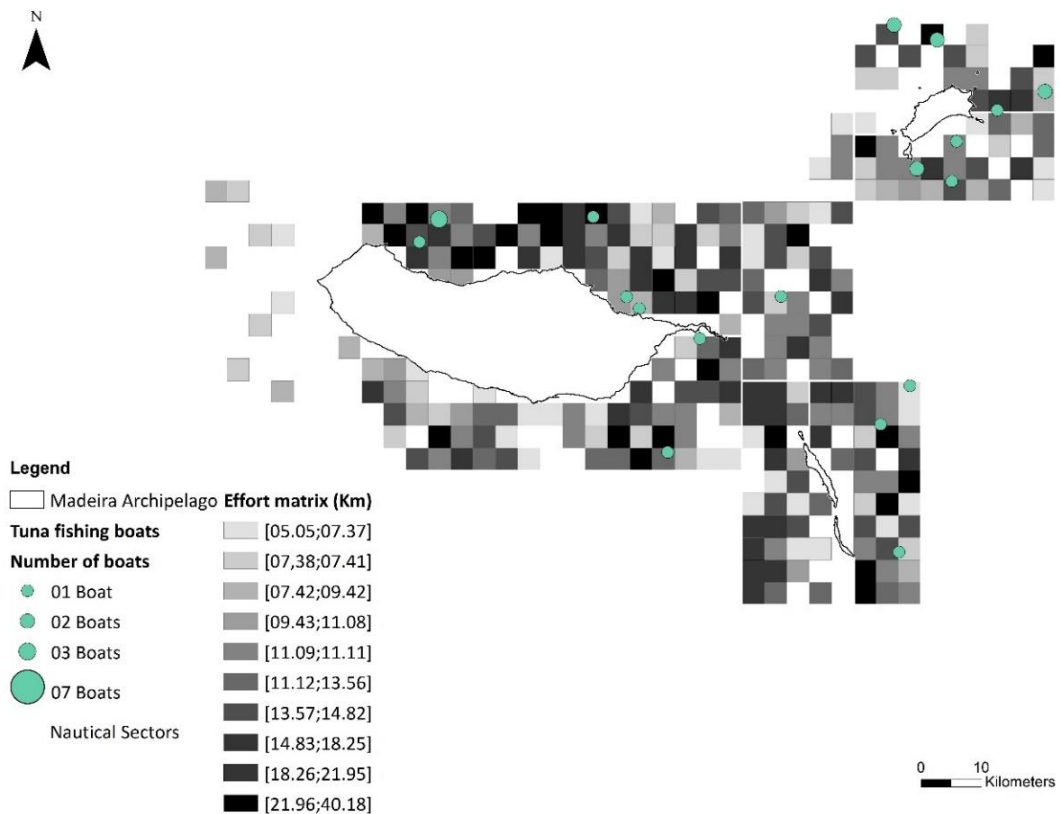


Figure 39 - Plot of tuna fishing boats sighting locations over the effort grid. Each coordinate point might correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

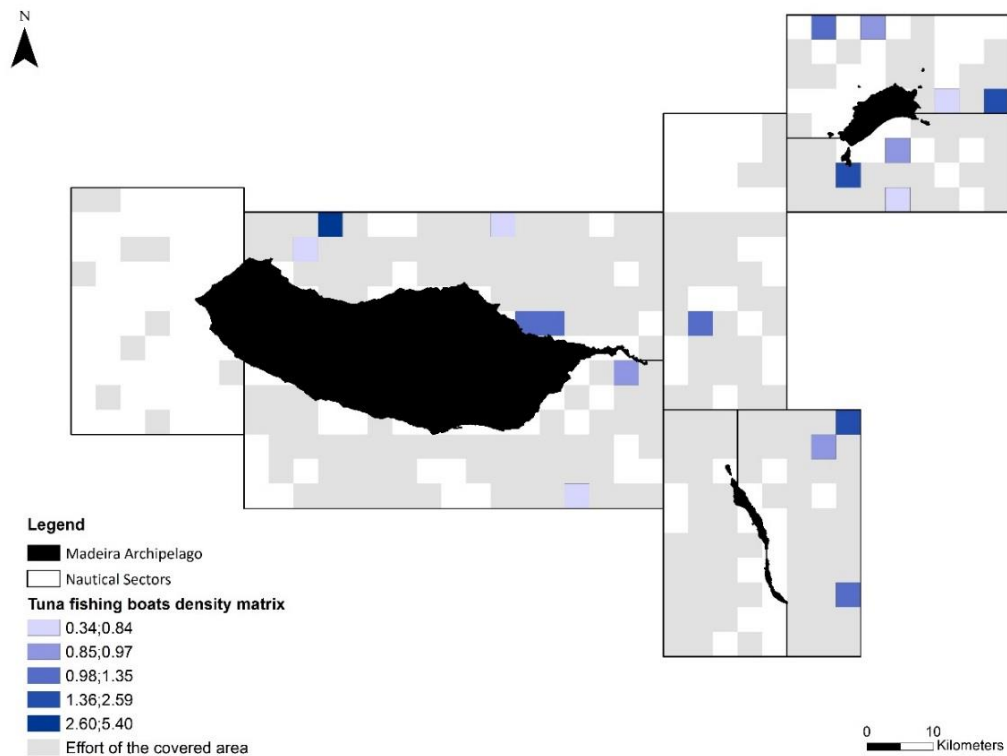


Figure 40 - Tuna fishing boats sightings distribution density matrix.

B) Black scabbard fishing boats

This fishery accounted for approximately 30% of the total fishing landings, in tonnes landings in Madeira, correspondent to 30% of the profits, in the year 2012 (Instituto Nacional de Estatística, 2013). Two species of black scabbard fish are captured in Madeira: *Aphanos carbo* and *A. intermedius*, in an approximate proportion of 80% to 20%, respectively (Direcção de Serviços de Desenvolvimento e Administração das Pescas, 2012).

The black scabbard fishing vessels can have from 9 to 18 m length. The longline gear is composed by a mainline attached to branchlines with hooks, applied between 1000 and 1200 m depth in ocean areas of depth of more than 1200 m (Direcção de Serviços de Desenvolvimento e Administração das Pescas, 2012; Silva et al., 2011).

Table 26 contains the descriptive statistics factor of the black scabbard fishing boats

density distribution (figures 41 and 42).

After applying the Kruskals-Wallis test there were found no significant differences between the sectors of the black scabbard fishing boats distribution pattern along the study area ($P > 0.05$).

The black scabbard fishing boats locations were projected over a bathymetric map in order to infer if the distribution pattern would be conditioned by the sea depth (figure 43). Even though the sample is not very numerous, many of the plots are located in the green zone, with more than 1200 m depth. Though these fisheries occur mostly off shore, they would not operate in sea depths over 2500, where some black scabbard fishing boats sighting locations can be found in the map. Thus, these vessels were probably transiting to other areas when they were sighted during the MWM nautical surveys. These fishery usually sought out sea mounts or other islands, sometimes near the Canary islands, which are rich underwater systems (Morato et al., 2008).

Table 26 - Descriptive statistics of black scabbard fish fishing boats density – number of boats per effort unit (Km) - distribution, by sector

	Mean	SD	Median	Minimum	Maximum
sector 1	0.01	0.20	0.00	0.00	0.93
sector 2	0.00	0.00	0.00	0.00	0.00
sector 3	0.10	0.40	0.00	0.00	2.69
sector 4	0.00	0.00	0.00	0.00	0.00
sector 5	0.00	0.00	0.00	0.00	0.00
sector 6	0.10	0.29	0.00	0.00	0.91
sector 7	0.00	0.00	0.00	0.00	0.00
sector 8	0.05	0.21	0.00	0.00	0.90

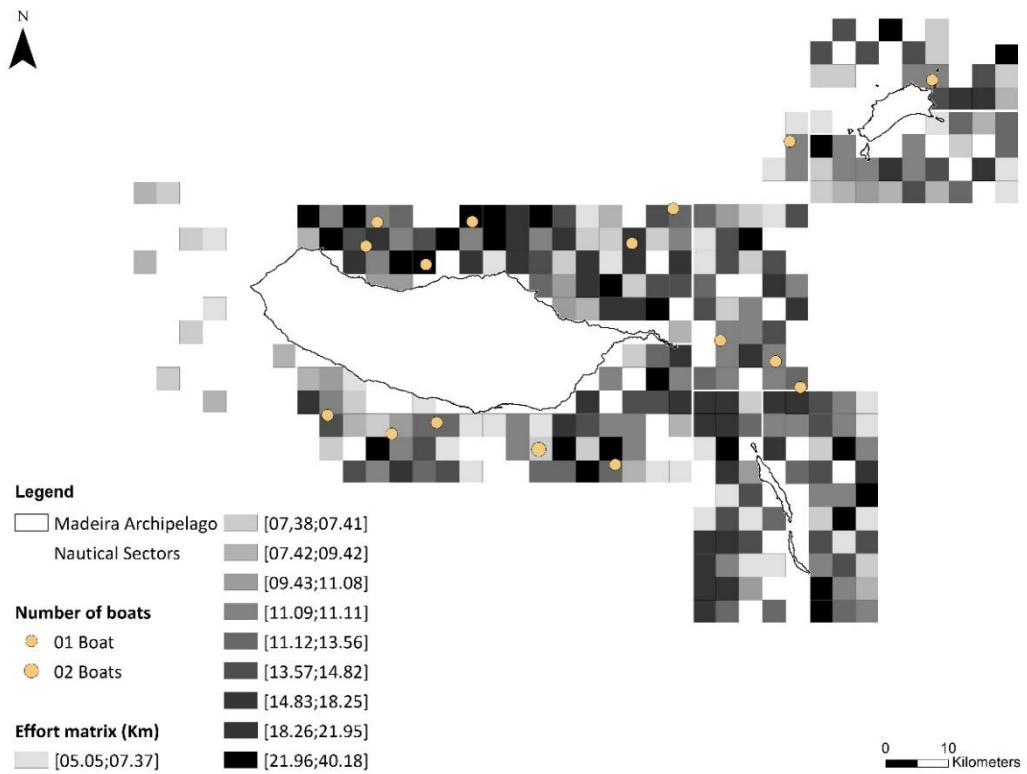


Figure 41 - Plot of black scabbard fish fishing boats sighting locations over the effort grid. Each coordinate point might correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

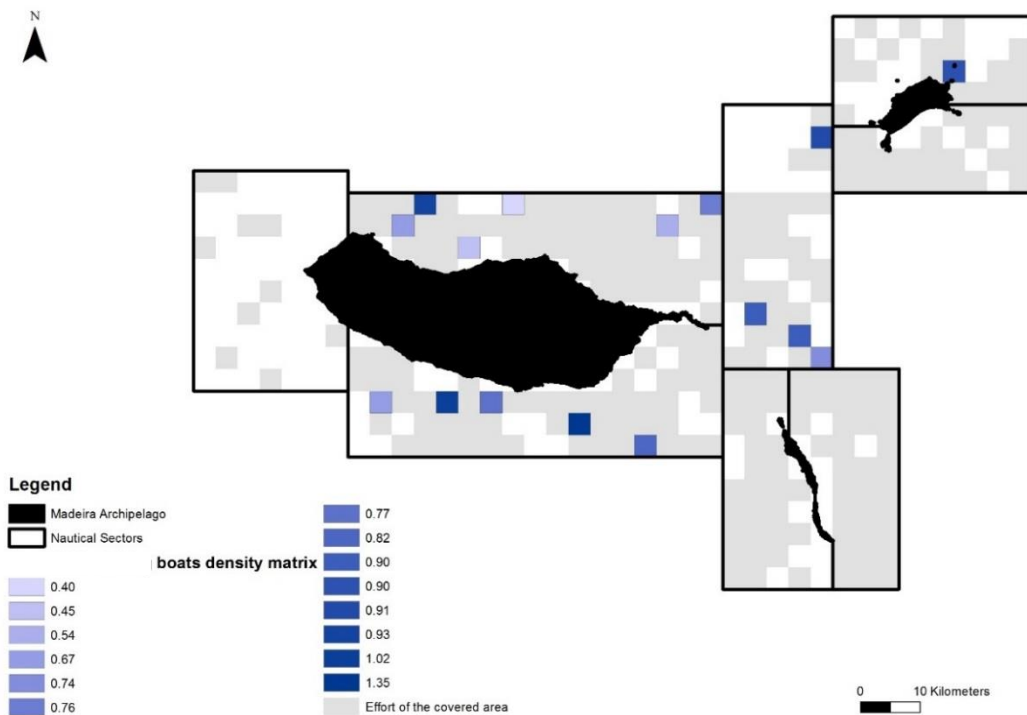


Figure 42–Black scabbard fish fishing boats distribution density matrix.

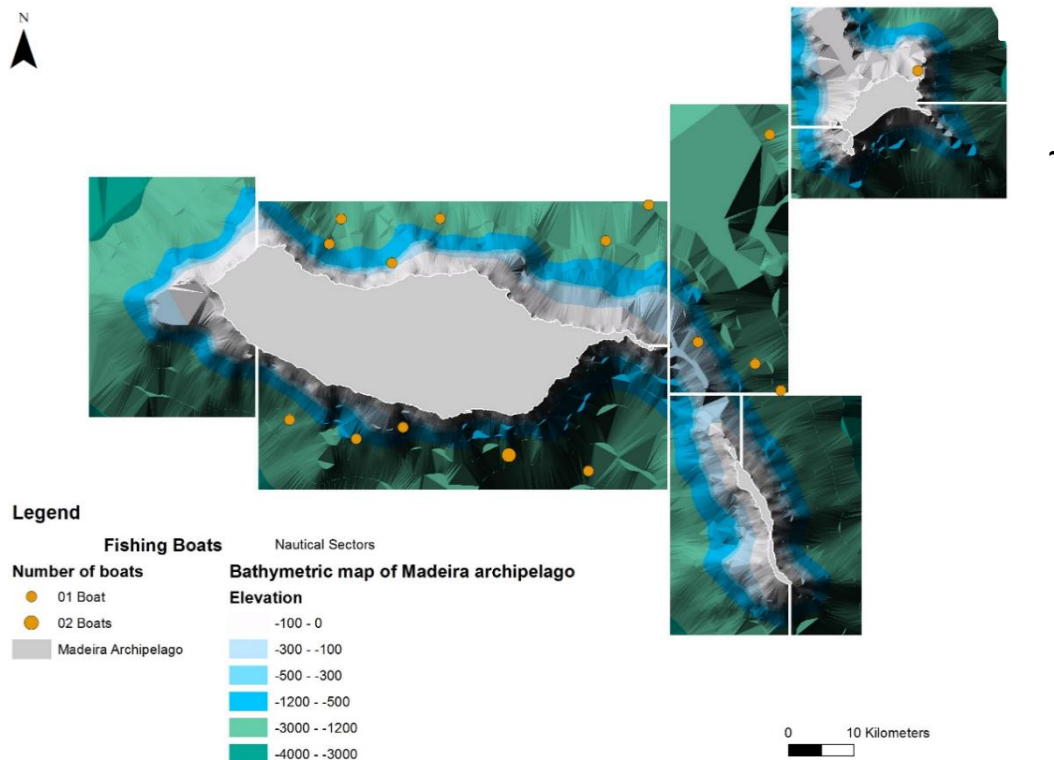


Figure 43- - Plot of black scabbard fish fishing boats sighting locations over a bathymetric map of the study area. The elevation was classified according to the depths (in meters) intervals in question.

C) Recreational demersal fishing boats

Despite the fact that recreational demersal fisheries do not contribute much for the economic input of the sector, they are very well represented in the Madeira fishing fleet, representing 89% of the group of vessels inferior to 12 m size (the majority of the fishing boats fleet in Madeira) (Direção-Geral das Pescas e Aquicultura, 2007). Demersal fisheries might use handlines (hook gears operated by hand) or bottom longlines (mainline of nylon attached with hooks) (Silva et al., 2011). Some of the target species are: wreckfish (*Polyprion americanus*), blackspot sea bream, common seabream (*Pagrus pagrus*), bluemouth rockfish (*Helycolenus dactylopterus*); conger eel (*Conger conger*), axillary sea bream (*Pagellus acarne*) and fokbeard (Instituto Nacional de Estatística, 2013).

These kind of fisheries seem to operate between 300 and 500 m (Silva et al., 2011). A bathymetric map was used to confront these information (figure 46). Even though it is a very slim strip, it is possible to see that many vessels aggregate along the band between 300 and 500 meters depth, staying close to the shore. In sectors 6, the “more intensively used” zone,

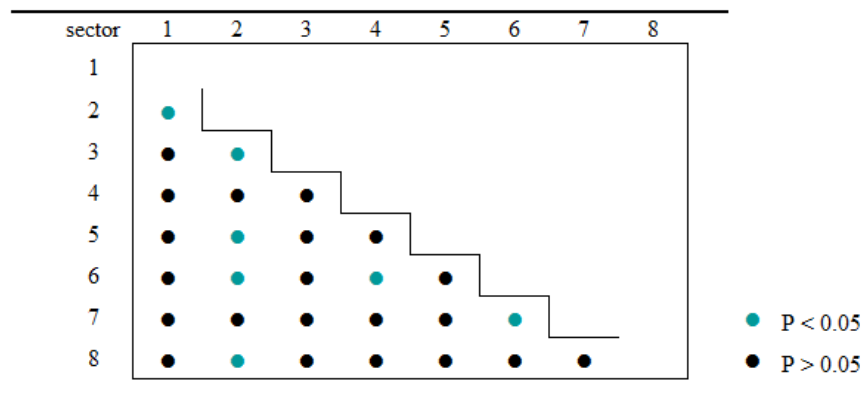
most of the plots are concentrated close to the orange line, in the lower west corner. The Passage sector comprises the platform connecting Madeira and Desertas islands, functioning like a corridor between either North or South Madeira and Desertas islands. Since recreational demersal fishing boats have a maximum length of 12 meters, the projected locations are more accurate, as the research boat had to be relatively close to sight them.

The descriptive statistics of recreational demersal fisheries general distribution (figures 44 and 45) are listed in table 27. Significant differences were detected among the different sectors pattern distribution (Kruskal-Wallis test significant for $P < 0.05$). Results can be checked in table 28. Sector 3 stand out from the sectors with the lowest averages, indicating it might be the more active sector, while sector 2, the empty sector, is significantly different from all the sectors except 4 and 7, underlining these as the low traffic zones. Sector 2 was much less frequently surveyed, which might have influenced such results.

Table 27 -Descriptive statistics of black scabbard fish fishing boats density – number of boats per effort unit (Km) - distribution, by sector.

	Mean	SD	Median	Minimum	Maximum
sector 1	0.20	0.60	0.00	0.00	2.60
sector 2	0.00	0.00	0.00	0.00	0.00
sector 3	0.60	2.60	0.00	0.00	20.25
sector 4	0.05	0.23	0.00	0.00	1.35
sector 5	0.24	0.92	0.00	0.00	5.42
sector 6	0.39	1.05	0.00	0.00	5.01
sector 7	0.02	0.12	0.00	0.00	0.68
sector 8	0.35	1.32	0.00	0.00	0.75

Table 28 - Mann-Witney tests results – Comparison of the recreational demersal fishing boats sightings general density distribution in the sectors of the study area



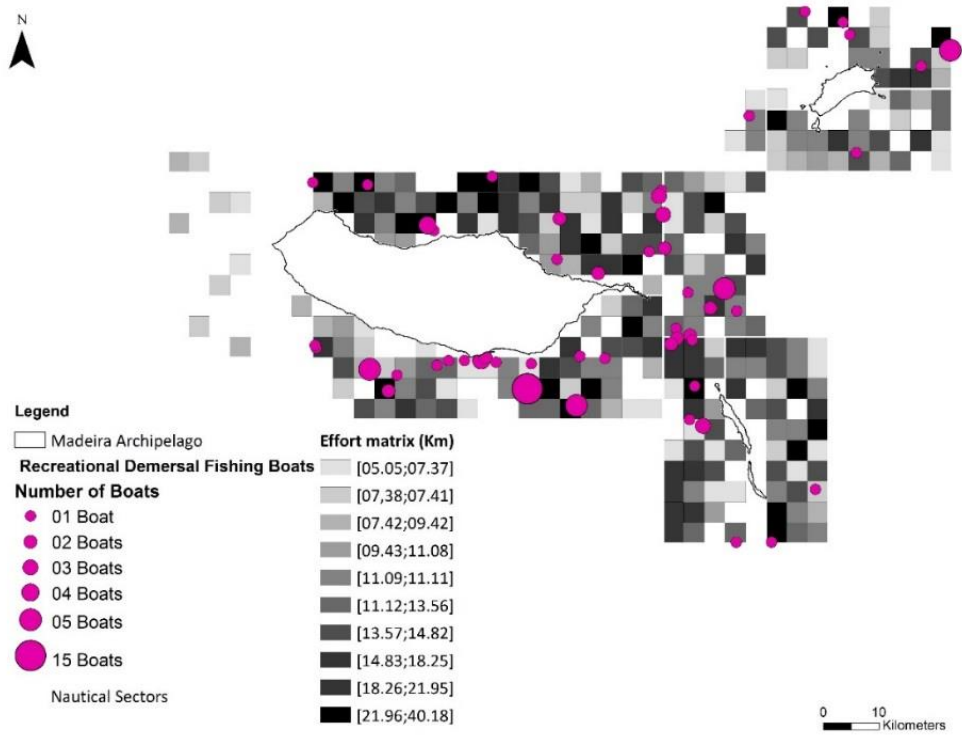


Figure 44 - Plot of recreational demersal fishing boats locations over the effort grid. Each coordinate point might correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending how much it was surveyed.

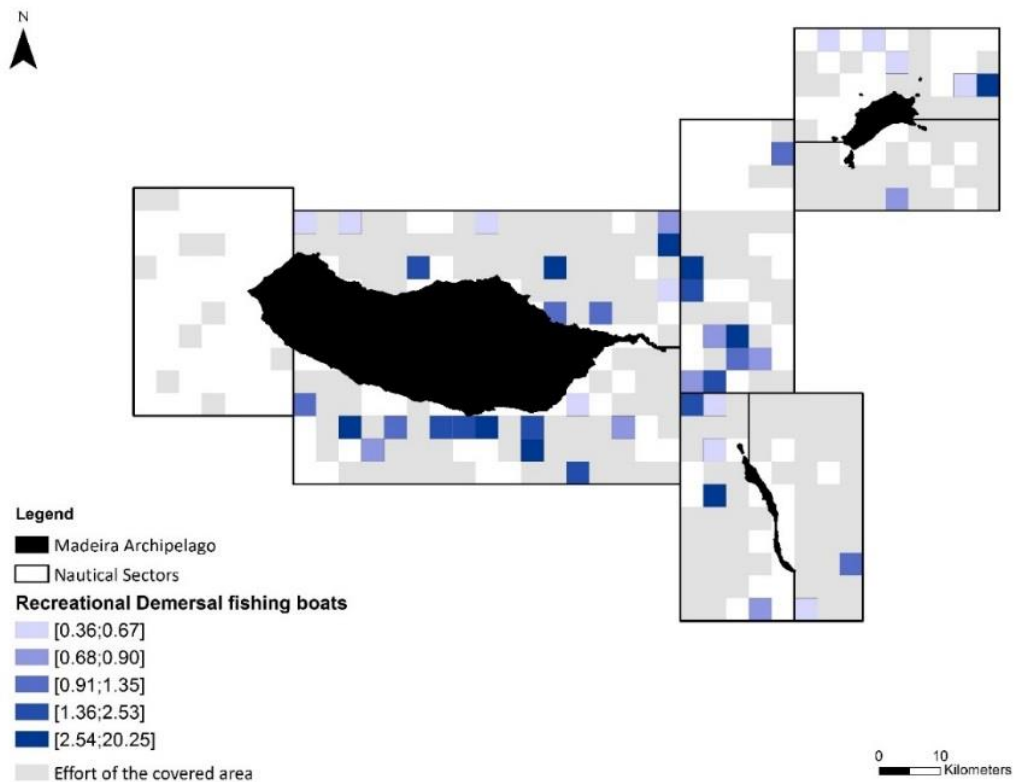


Figure 45 - Recreational demersal fishing boats sightings distribution density matrix.

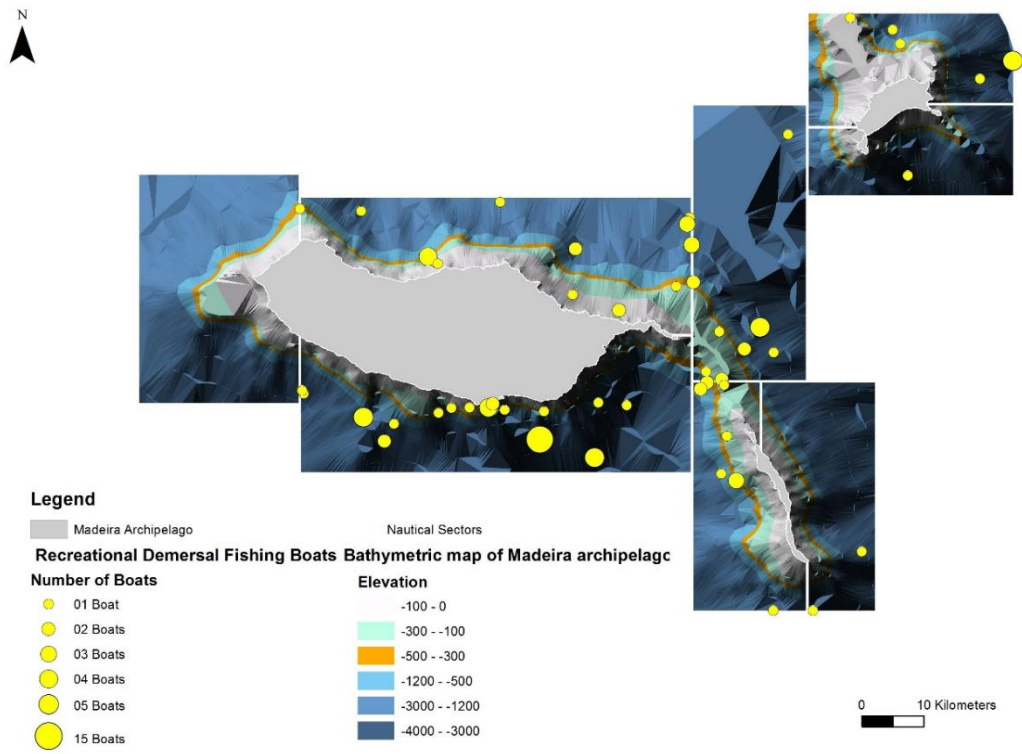


Figure 46 - Plot of recreational demersal fishing boats sighting locations over a bathymetric map of the study area. The depth (m) was classified according to the depths intervals in question

3.2.5 Big Game Fishing boats

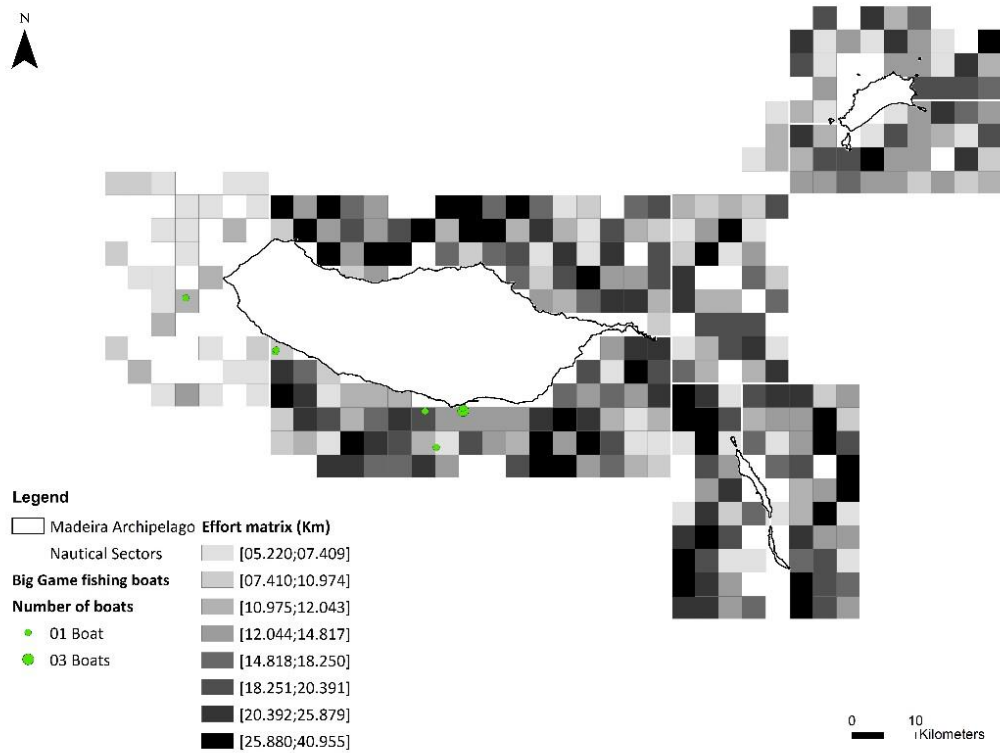


Figure 47 - Plot of big game fishing boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending on how often it was surveyed.

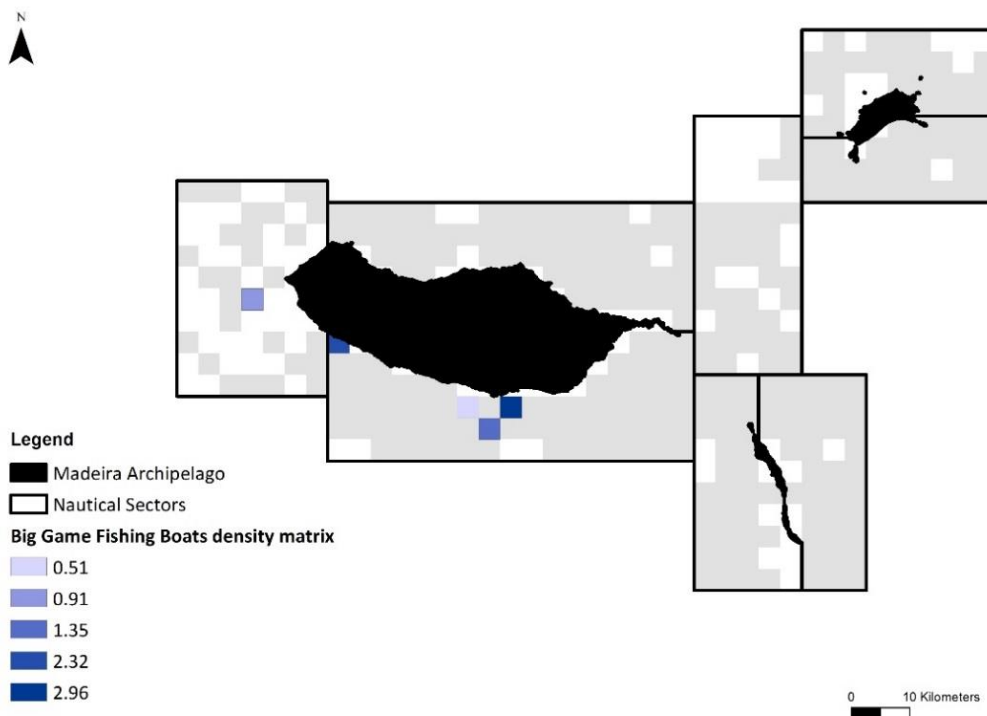


Figure 48 - Big Game Fishing Boats sightings distribution density matrix.

Big Game Fishing activities are undertaken in small vessels but they might go far from the shore (8 – 10 nautical miles). Even though the presented sample (figures 47 and 48) is not very illustrative, it is possible to see most of the big game fishing boats occupy the South Madeira sector and are positioned near the ports where these type of vessels are mostly located: Funchal and Calheta.

3.2.6. Whalewatching boats

According to previous studies, more than 10 vessels are running the business, sought out by approximately 58 thousand tourists every year, accounting for 1.5 million euros of annual revenue (Ferreira, 2007).

No statistical treatment was applied to detect significant differences between the different sectors across the whale watching boats general distribution since it was evident just attending to the respective map pattern distribution (figures 49 and 50). All the whalewatching boats records are concentrated in the South Madeira sector, except for one coordinate point/sighting location. This goes accordingly to previous MWM reports which stated that most of the maritime-touristic tours would go from Funchal to the Southwest coast of Madeira (Freitas et al., 2004a). Whalewatching boats would not go far away from the main port, since these trips usually take no more than a few hours. Sector 3 is highly frequented by cetaceans in general. Hence, makes sense that South Madeira sector would be a preferential zone for whale watching expeditions, since apparently there would be better chances of encounter with whales and dolphins when crossing this area. Considering the total sightings, only 17% (n=7) of the total whale watching boats were seen in the presence of cetaceans. These percentage does not reflect the reality though, since the cetacean observation success by the operators rounds the 80%. The fact that not many whalewatching boats were seen in the presence of cetaceans during the sea surveys might be due to the sample process and the low probability of encountering whalewatching vessels interacting with cetaceans, as there are not so many of these types of vessels.

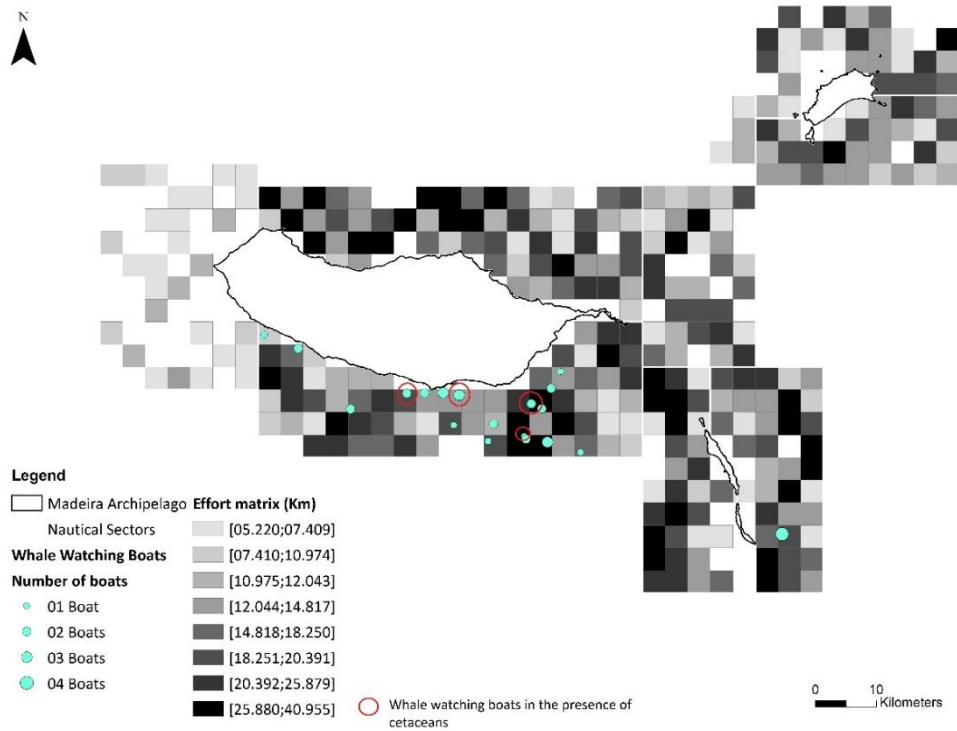


Figure 49 - Plot of whalewaching boats locations over the effort grid. Each coordinate point may correspond to more than one vessel sighting, represented through a variable diameter. Each effort grid cell presents a different gradient depending on how often it was surveyed.

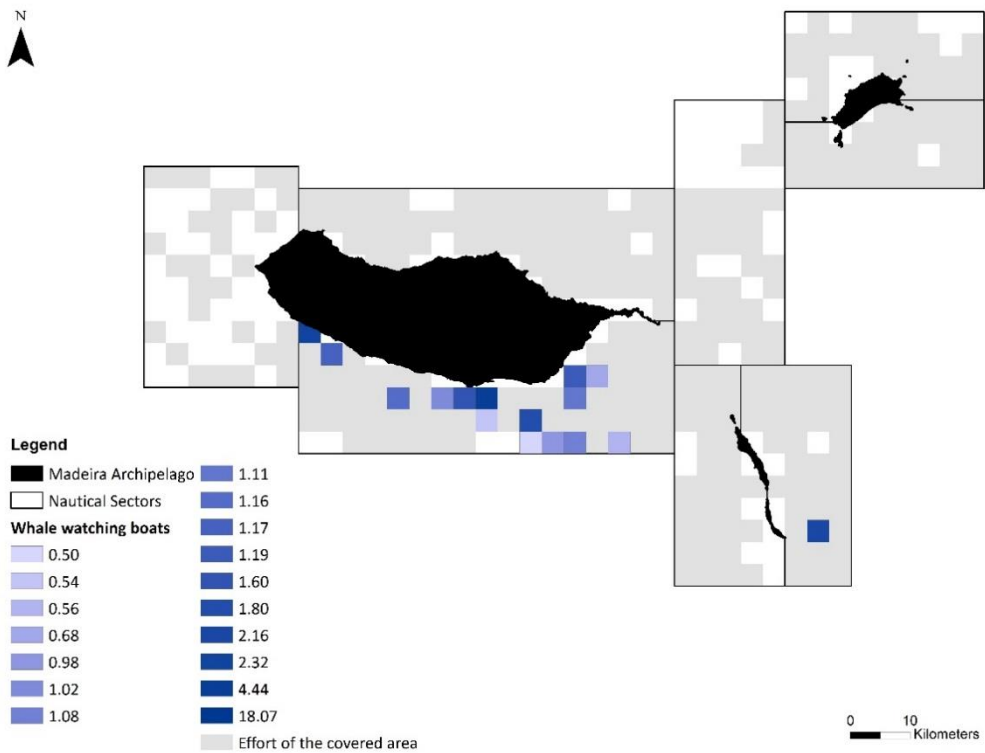
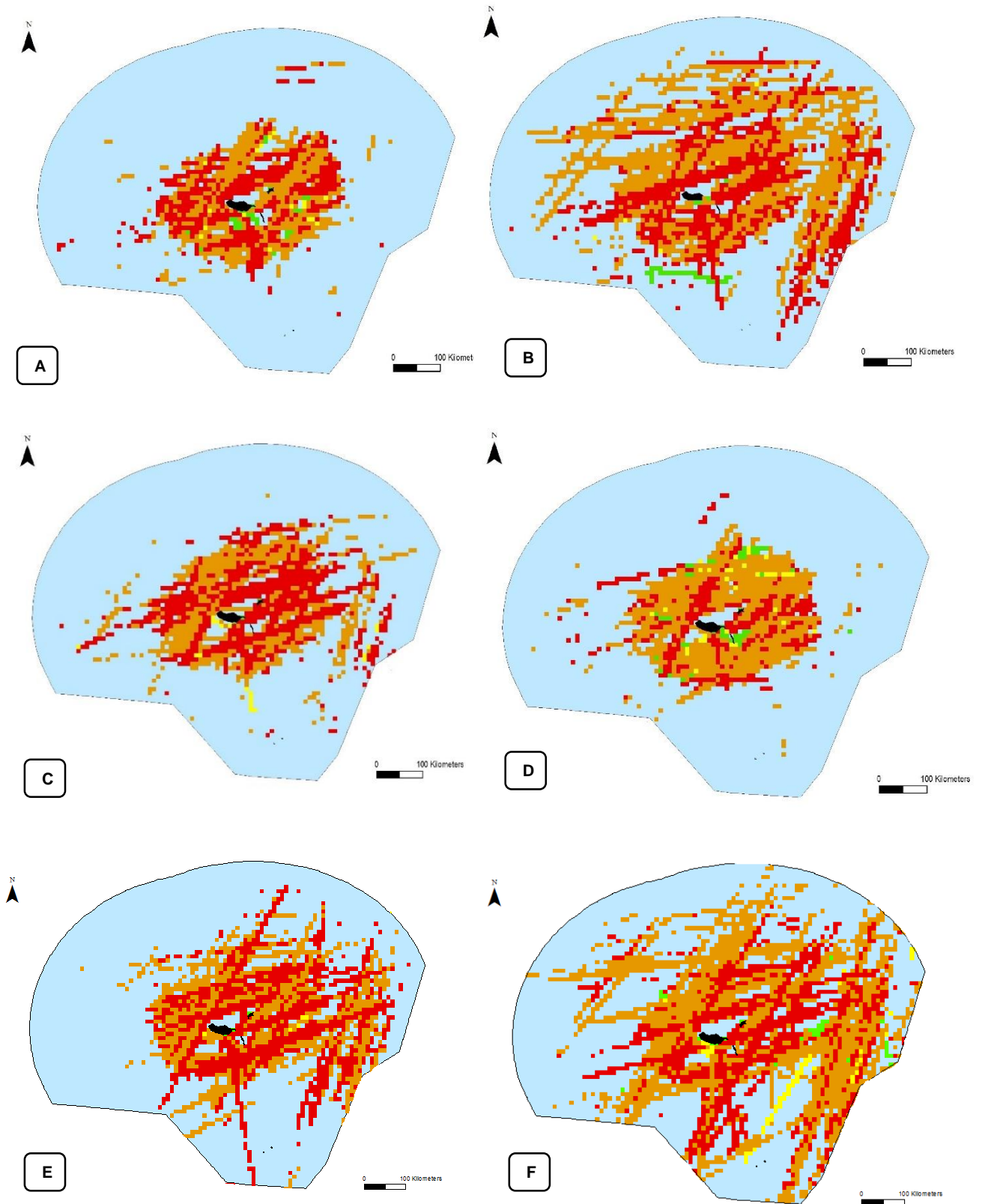


Figure 50 - Whalewaching Boats sightings distribution density matrix.

3.3. Vessel speeds

3.3.1 Offshore traffic



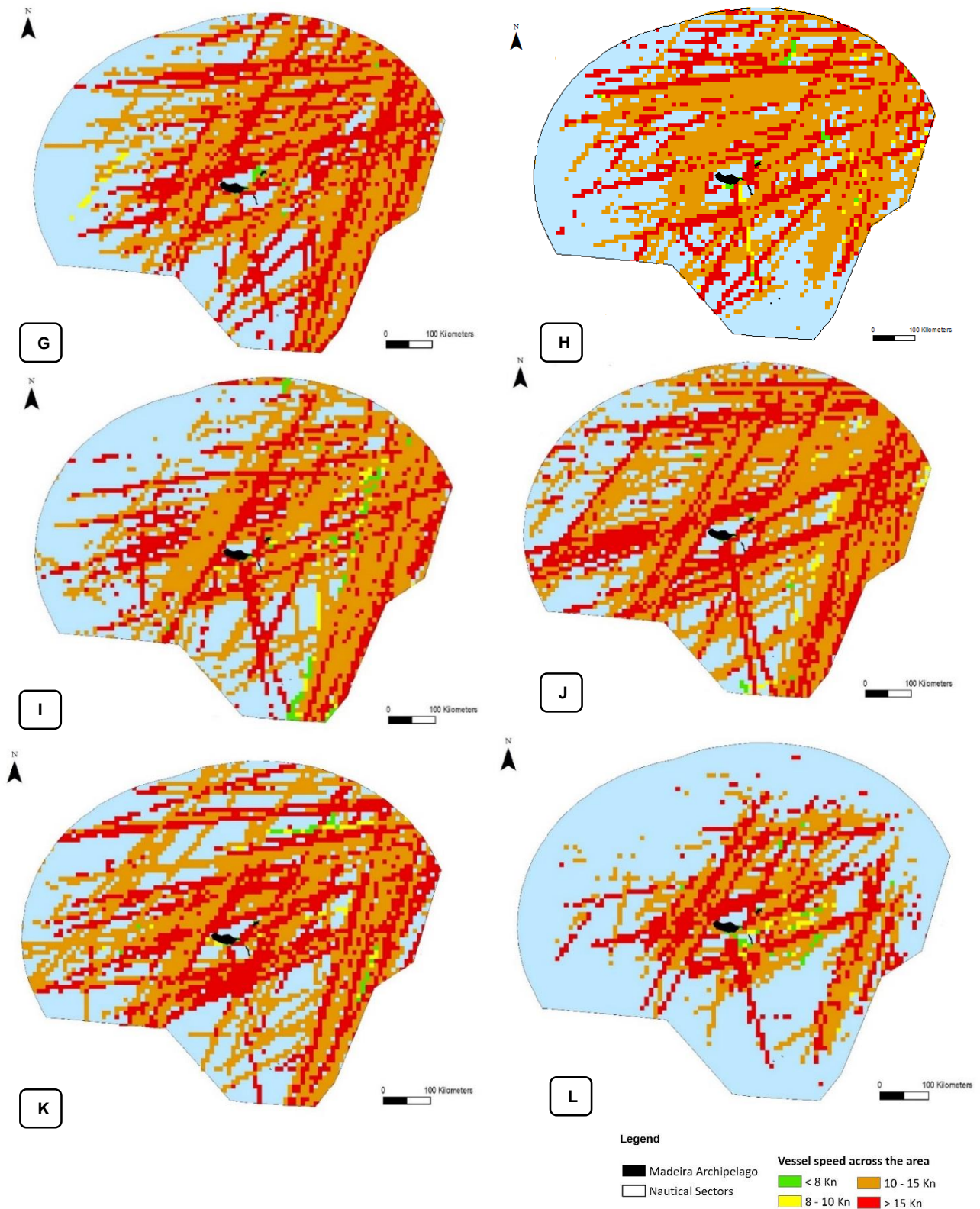
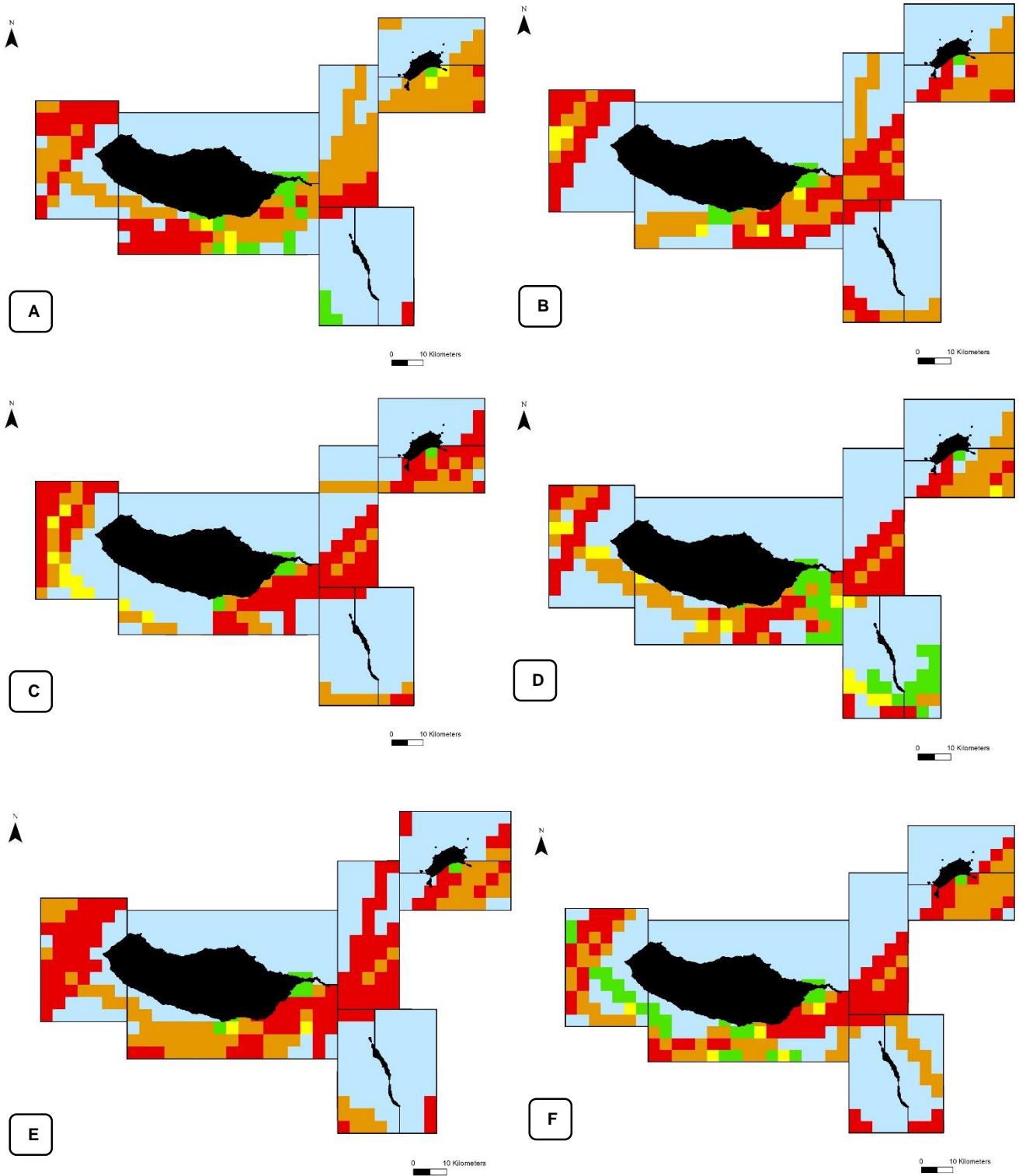


Figure 51 - Speed matrix maps displayed within Madeira ZEE area. Each pixel is associated with the vessels SOG (Sped Over Ground) average value. The maps are displayed by season: winter (A-G) and summer (H-L). For the months available in at least 2 years of data (see table 1, section 3.1), only one representative map (the one apparently displaying less coverage gaps) was displayed: A – November 2008; B- December 2008; C – January 2009; D – February 2009; E – March 2010; F – April 2010, G – May 2008; H – June 2011; I – July 2008; J – August 2008; K – September 2009; L – October 2008. . The remaining maps can be consulted in Annex IV.

3.3.2 Inshore traffic



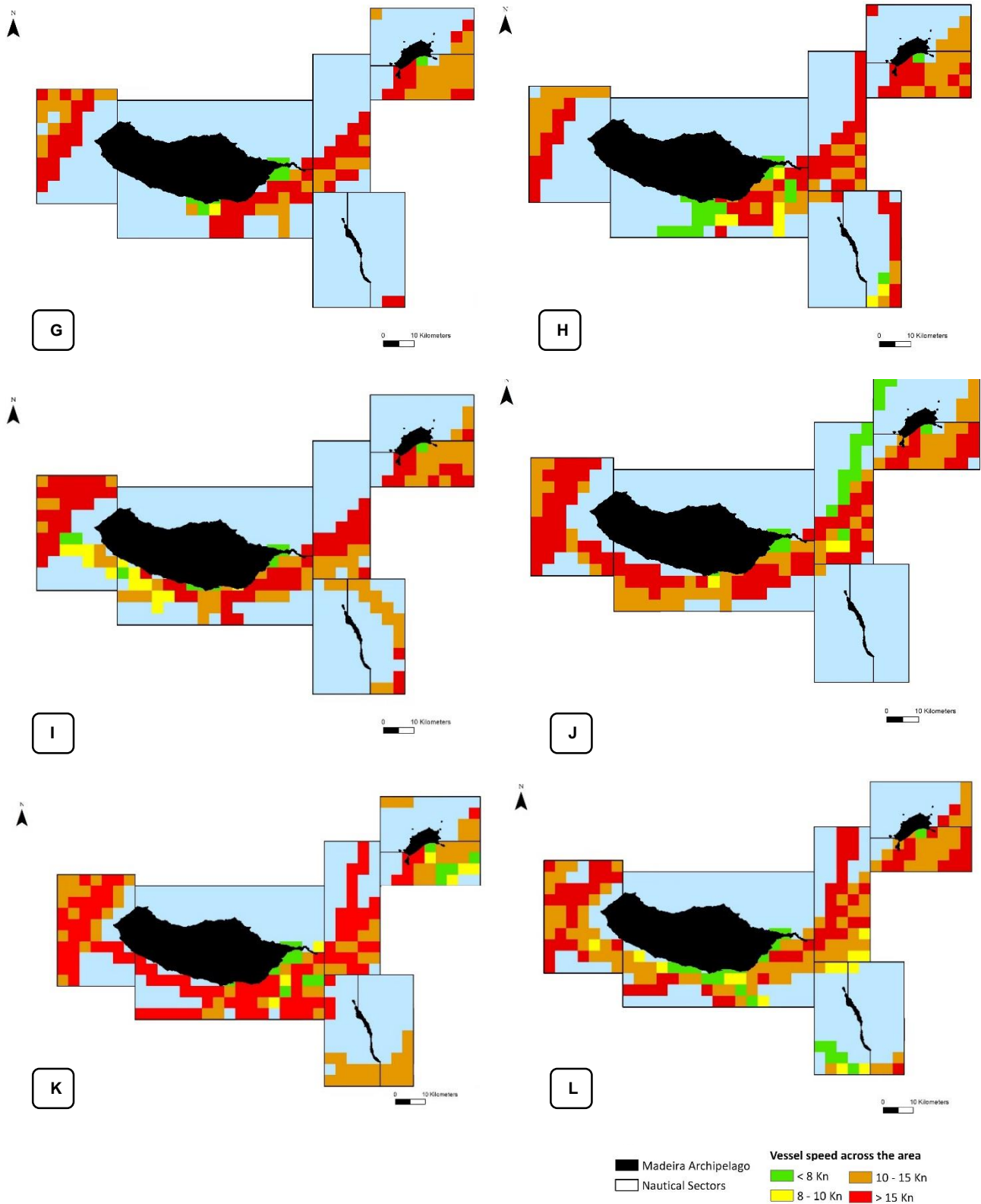


Figure 52 - Speed matrix maps displayed within the nautical sectors of the study area. Each pixel is associated with the vessels SOG (Sped Over Ground) average value. The maps are displayed by season: winter (A-G) and summer (H-L). For the months available in at least 2 years of data (see table 1, section 3.1), only one representative map (the one apparently displaying less coverage gaps) was displayed: A – November 2008; B- December 2008; C – January 2009; D – February 2009; E – March 2010; F – April 2010, G – May 2008; H – June 2011; I – July 2008; J – August 2008; K – September 2009; L – October 2008. The remaining maps can be consulted in Annex III.

The presented speed matrix maps (figures 51 and 52) were based on the same AIS data displayed in section 3.1. Even though all types of vessel were overall considered, the speed values correspond mostly to ships (including cargos and cruises), accounting for at least 70% in both offshore and inshore traffic composition correspondent to one week of each representative month.

Vessel speed is one of the conditioning factors which might determine the severity of a ship collision with a whale. According to previous studies, the probability of a whale getting lethally injured in consequent of a ship strike is above 50% if the vessel is navigating over 10 Kn speed. If the incident occurs while the ship is moving at more than 15 Kn speed, the chances of a lethal injury increases from 80 % to 100% (Vanderlaan and Taggart, 2007). Therefore, this analyses will focus on what may be considered the “lower” (< 10 kn) and “higher” (> 10 Kn) speeds colour pattern, spread across the area.

Attending to figures 51 and 52, in both offshore and inshore traffic, most cells present speed average values over 10 kn, as the matrix pattern is mostly composed by orange and red cells..

Considering the inshore traffic, green and yellow coloured cells, corresponding to lower speed values, are repeatedly present in sectors 3 and 7, frequently located close to the Madeira and Porto Santo, island main ports, Funchal, Caniçal and Porto Santo. Vessels tend to reduce speed as they approach the harbour, same way they slowly increase speed as they set off from it. Some green cells are actually coincident with the main ports location while others constitute green/yellow “bands” heading towards or away from the ports. Apart from this, by means of the observation of the matrix colour pattern. speeds over 10 Kn appear to be the most common in sectors 3 and 7.

Speeds under 10 Kn are also detectable in East and West deserts sectors. The green and yellow cells closest to the shore correspond to small vessels, as ships would not be able to moor there. Desert islands are recurrently sought out for touristic purposes. Cargos and cruises also use these sectors, passing farther from the coast.

In sector 6, the transition between Madeira and Porto Santo island, speeds under 10kn are rare.

In sector 2, mostly crossed by passing cargo, dominant speeds are also superior to 10 Kn.

3.4. Potential impact towards cetaceans

Remitting to the previous results, the inshore traffic corridor, considering overall types of boats, sector 3 stands out as the zone with the higher traffic level, used by every type of vessel, as it was predicted. Sectors 5 and 6 follow, presenting a significant level of vessel movement. Sector 5 is mostly used by fisherman while sector 6 is frequently crossed by recreational, fishing boats and ships. Sector 1 is mainly used by recreational and fishing boats. The areas with the lowest traffic level are sectors 2 (crossed by recreational, fishing boats and ships) and 8 (mostly used for fishery activities). During the summer, traffic level rises up in South Madeira (high season) while during the winter a “high used corridor” (including sectors 3, 5, 6 and 7) is clearer.

Now, attending to the cetaceans’ distribution pattern, parallel studies conducted by the Madeira Whale Museum found out that sector 3 includes a critical area for cetaceans in general, where these are more frequently sighted (Luis Freitas Comm. Pers.).

According to previous studies, the general cetacean distribution, sector 3, 6 and 7 hold the higher activity, again the “high used corridor”. These sectors present similar sighting index, i.e., number of sightings per effort unit (Km) of each sector (Freitas et al., 2004b)

Thus, it is possible to find a similar pattern distribution between the general distribution of either traffic or cetacean’s.

Comparing both density distributions of traffic and cetaceans along the inshore study area, significantly higher average density values of vessels and cetaceans are found in the “high used corridor” including sectors 3, 6 and 7, a preferential area for both, where the encounter probability is higher. Therefore, this corridor can be considered a conflict zone, frequently sought out by both vessels and cetaceans, also verified in recreational boats’ and ships’ distributions.

This spatial pattern overlapping would not be inconsequent. Even though none of these factors has been quantified in the present study, through the following pages a prediction of the potential impact resulting from the interactions of cetaceans with the marine traffic will be attempted.

Marine traffic and potential impacts towards cetaceans within the Madeira EEZ: a pioneer study

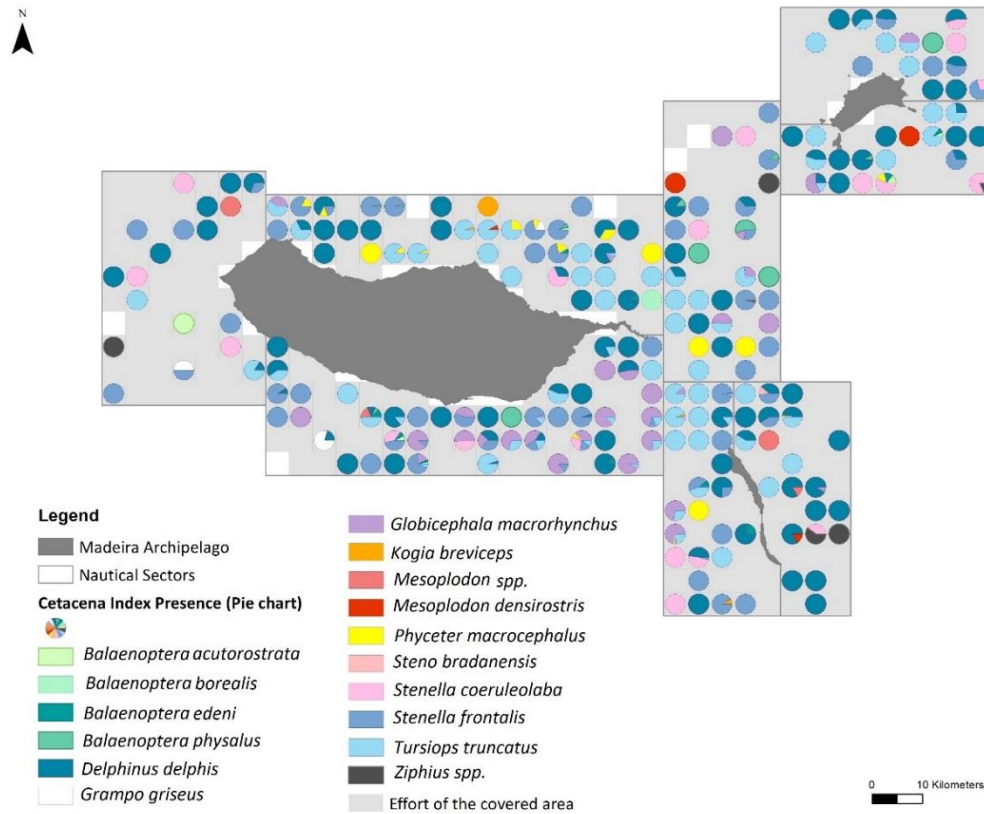


Figure 53 - Cetacean adults' pattern distribution represented through a pie chart where each pie represents the proportion of each species located within each grid cell through the period of 2001 until 2012

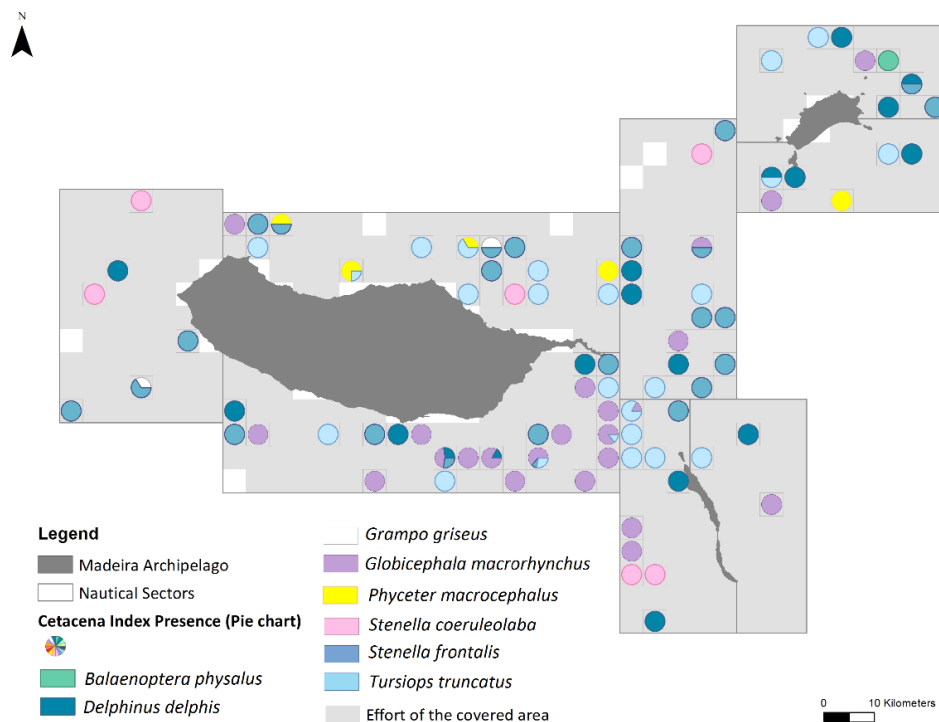


Figure 54 - Cetacean calves' pattern distribution represented through a pie chart where each pie represents the proportion of each species located within each grid cell through the period of 2001 until 201

All type of vessels might represent a threat just by contributing to the cumulative effect of the marine traffic, i.e., any type of vessel is associated with a pollution input, can cause noise disturbances, contribute to an habituation process through which cetaceans might manifest a lack of awareness towards anthropogenic disturbances or eventually collide with cetaceans (Bejder and Samuels, 2003; Laist et al., 2001; Weilgart, 2007). However, some kinds of vessels are associated with specific cetacean interactions that should be considered independently. Likewise, some species are more prone to traffic interactions than others, which will be also noted.

No cetaceans' distributions density maps are going to be displayed in the present document since a spatial and temporal distributions of these species is already being undertaken by the Madeira Whale Museum research team and is going to be presented elsewhere. Instead, the comparative analyses will be based on cetacean presence index maps (figures 63 and 64), representative of both adults and calves. Thereby, the potential impact interpretation or estimation will be based on the crossing of the traffic potential conflict zones with the areas where the species of interest were sighted, in order to highlight areas of co-occurrence of traffic and cetaceans.

Unlike the remaining type of vessels, whalewatching boats objectively look out for cetacean encounters, i.e., they represent an orientated disturbance towards these species. Thus, it would be expected that the overlapping zone between the pattern distribution of both would be coincident with a "highly used" sector of cetaceans in general, in the considered study area.

Several studies have enlightened the negative effect of this industry on individuals and populations of different cetacean species (Bejder and Samuels, 2003; Orams, 1997, 2000).

Different species present different tolerances and reactions towards the cetacean watching tours (Ritter, 2003). The interaction between cetaceans and whalewatching vessels was previously investigated in the study area and short term effects were observed among the Delphinidae, and further studies and monitoring plans were advised (Ferreira, 2007). Apparently, bottlenose dolphins are the Odontoceti more frequently subject to tourism. Even though these species are spread worldwide, they are often found in inshore populations with limited home-ranges, and so repeatedly exposed to tourism (Constantine et al., 2004; Peters et al., 2012). Bottlenose dolphins can be found year round in the Madeira shores and Photo ID studies conducted by the MWM suggest the existence of a resident group in this area (Freitas et al., 2004a). Stress responses have also been reported from pilot whales when followed by whalewatching tours (when these were not conducted accordingly) (Freitas et al.,

2004a). Whalewatching boats interaction with cetaceans may lead to more aggravating concerns when in breeding periods, since it may compromise the survival of calves (Bejder et al., 2006; Davenport and Davenport, 2006; Peters et al., 2012; Tseng et al., 2011). Bottlenose dolphin and short-finned pilot whales are two of the most frequent species in the potential conflict zone and both have been sighted with calves in the area.

During whalewatching tours, the interaction between the observer and the species of interest might be frequent and eventually extended through long periods of time, as usually tourist crave interactions with whales and dolphins (Bejder and Samuels, 2003; Jelinski et al., 2002; Tseng et al., 2011). Cumulative short term effects (interruption of breeding, social feeding or resting behaviour) may lead to long term consequences (such as decreasing of reproductive success) and some studies suggest it could result in the long-term displacement of cetaceans from preferred areas (Bejder and Samuels, 2003). However, same research also recognises that it is difficult to point human activity as the real cause of the effect, as other variables could also be involved (Bejder and Samuels, 2003).

Less than 10 years ago, this activity in the study area, was mainly opportunistic, running under a voluntary conduct protocol proposed by the Madeira Whale Museum.

The management of whalewatching varies noticeably around the world (Orams, 1997, 2000). Only recently in, the present year, a preventive law directed to the whalewatching activity was approved by the Madeira regional government. Nowadays, in the study area, the whalewatching activity is no longer opportunistic, as most of these vessels already advertise and sought out for cetacean either at land or in the sea.

Whale watching is a growing business, usually starting in small numbers and then converting into an industry based in enhanced infrastructure sought out by wildlife tourist from everywhere (Davenport and Davenport, 2006), same has been happening in Madeira,

As previously mentioned, a preferential corridor was identified common to the traffic and the cetacean population of the study area. That same overlapping zone is very clear when attending to ships pattern distribution in particular.

Ships may negatively interfere with cetacean population, mainly by means of alteration of underwater sound environment and through collision (Harris et al., 2012).

Large vessels produce rather loud and mainly low frequencies (which spreads much more efficiently through the water). The main source of shipping noise is the result of propeller cavitation (collapsing of air spaces originated by the motion of the propellers) (Southall, 2005). The utmost energy input emitted by large commercial vessels is below 1 kHz. Thus, animals that produce and receive sounds in this band are more vulnerable to these effects - mainly large whales (Weilgart, 2007; Zacharias and Gregr, 2005). It is possible to sense a 6.8 Hz tone

from a super tanker from a distance between 139 and 463 Km (sources levels estimated at 190 dB and referenced to 1 μ Pa) in the 40 – to 70-Hz (Gordon and Moscrop, 1996), i.e. , i.e., within the frequency range of sounds emitted and received by Mysticets (Southall, 2005). Generally, the power of acoustic exposure increases with the proximity of the whales towards the ship (Kipple, 2002). In the inshore study area, both whales and ships sighting locations were plotted within 12 Km from the shore, i.e., within a distance much smaller than 139 Km. Thus, the shipping noise impact should be quite relevant towards the animals.

Whales might also suffer an habituation process and consequent lacking of sensitivity towards the noise source, being struck more easily (pointed as a possible cause behind the sperm whales strandings in the Canary islands) or might just be distracted or asleep, also previously reported with sperm whales (Carrillo and Ritter, 2008; Laist et al., 2001; Miller et al., 2008).

The incidence of ship strikes in a certain area is not easy to quantify, depending on different variables, such as the level of traffic activity, the number of cetaceans and their behaviour within that area. The amount of time that whales spend underwater away from the watercraft or their ability to detect and consequently divert from them, weighs on the probability of ship strikes occurrence within a certain area.

Every type and size of vessel can hit whales, but the more aggravating or lethal cases listed happened with ships comprising 80 m length or more, traveling over 14 kn of speed (Evens et al., 2011; Laist et al., 2001), meaning cargo, ferries and cruises represent a potential menace. In previous studies focused on the collisions between vessels and Mediterranean fin whales (Panigada et al., 2006) ferries and cargos were presented as the type of vessels major responsible, accounting for 62,5% and 16.7 % strike cases, respectively.

The probability of a ship strike turn out fatal increases from 8.6 (20% of probability) to 15 Kn (80% probability). At speeds below 11.8 Kn, the likelihood of lethal injury is inferior to 50%, while at speeds over 15 Kn, chances rise up from 80% to 100% (Vanderlaan and Taggart, 2007). Even though in sector 3 ships tend to reduce speed or slowly pick up speed as they get close or away from the ports, provisionally giving time and space for whales to dodge it, the red stain, correspondent to speed levels over 15 Kn, is still well spread, specially further from the shore and higher depths where the presence of whales would be more likely, and in sectors 6 and 7, part members of the “high used corridor”, speeds over 10 kn are the most frequent. This means that if a ship strike takes place within the area just mentioned, there are highly chances of it being fatal. However, apart from that, this information adds nothing towards the probability of a ship hitting a whale. The higher number of cetaceans and whales within an area, the greater the probability of ship strike incidence. In the study area, the “high used corridor” is frequently

sought out by cetaceans and vessels and apparently most ship strikes take place over or near the continental shelf, probably due to significant concentrations of both traffic and whales (Laist et al., 2001), as also verified in the present case study. However, the inshore traffic of the study area also seems to be less intense when comparing to other areas where ship strikes reports are more frequent (consult section 3.1.2), which should also be taken into account.

Considering the identified species within the study area, fin whales, short-finned pilot whales, minke whales, Cuvier's beaked whale (*Ziphius cavirostris*) and sperm whales (*Physeter* spp). are among the group of species known to be more frequently involved in ship strikes (Carrillo and Ritter, 2008; Laist et al., 2001; Panigada et al., 2006). Some areas hold stranding archives since the 70s. In the United States, through the years of 1975 to 1996, out of the 92 fin whale stranding cases, 33% were most possibly consequent of a ship strike. Italian registries for the period of 1986 to 1997, include 12% of reported strandings caused by a ship strike, where 20% fin whale, 33% minke whale and 6% sperm whale cases were attributed to the same cause. In France, analogues records can be found, with 13% of the reports classified as ship strikes, among which 22% of the fin whales strandings were most likely caused by a ship strike, involving both ferries and tankers (Laist et al., 2001). Even closer by, Canary islands have been experiencing a considerable increasing of ship strikes (Carrillo and Ritter, 2008), on which the main target species are sperm whales (41%), pygmy sperm whales (17%), Cuvier's beaked whales, short finned pilot whales (10%) and three baleen whale species (15%) .

From the 136 MWM stranding reports, 2 % (n = 3: one fin whale, one Bryde's whale and one Gervais' beaked whale) were possibly caused by a ship strike and 0.7 % (n = 1, a Cuvier's beaked whale) was certainly caused by a ship strike. These species were previously reported has more vulnerable to traffic incidents (Freitas et al. 2004a; Laist et al., 2001 ; Waerebeel et. al., 2007).

Calves spend more time at the surface since they have not yet fully developed their diving abilities and do not need to look out for prey, as they are still being nursed. They are also more unexperienced at ships presence since they may not recognised them as a potential threat. Therefore, calves may be more exposed to this type of incidents (Carrillo and Ritter, 2008; Laist et al., 2001; Lammers et al., 2003; Panigada et al., 2006), reason why their pattern distribution was also attended separately.

All the mentioned species are present in the most intense ship traffic area and are so susceptible to all the associated risks, even though these have not been quantified so far. Apparently, by means of just a qualitative analyses, short-finned pilot whale pattern distribution seems to be of greater concern since most of the representative patch overlaps the potential conflict zone for either adults or calves. Both sperm whale and fin whale presence were also

reported in the same area, especially across sector 6. Cuvier's beaked whale presence index is not very representative and thus cannot be very conclusive, however, considering the few times this species was sighted, it was still detected in the "high used corridor". Even though these species spend a lot of time underwater while feeding, calves might spend more time at the surface.

Vessels strikes involving small cetaceans are more frequently related with small vessels and many cases showed evidence of vessel propeller hit (Waerebeek et al., 2007). By "small vessels" are being considered planning craft powered by outboard engines, where most recreational, whalewatching and big game fishing boats are included. Considering these 3 vessel types all together, they comprise almost 40% of the Madeira inshore traffic fleet sample, which is quite significant. Motorboats, when in function, represent a menace to cetaceans through wake formation, possible impact and visual or acoustic disturbances, again specially during breeding periods (Davenport and Davenport, 2006). All these types of vessels intersect the area year round.

These kind of vessels are associated with noise levels 140 dB at 50 m range and 400-4000 Hz, with a greater effect on small cetaceans, and consist on the most important source of acoustic pollution near developed areas (Gordon and Moscrop, 1996; Zacharias and Gregr, 2005).

They can also be included in nautical tourism, which presents a relatively high activity in coastal areas (Balaguer et al., 2011). Madeira and its wonders attract tourists every year, especially from United Kingdom (23.9 %) and Germany (21.6 %). Many tourist arrive by cruises and the number of passengers has been rising over the last decade, which should be reflected in an input towards the regional tourism (DREM 2012).

Whalewatching, recreational, big game fishing and recreational demersal fishing boats necessarily return to the harbour in the same day. Thus, while frequently crossing the coastal area, these type of boats may also represent a significant source of water noise, standing as a possible acoustic impact towards cetaceans, as verified in other study sites (Rako et al., 2013). Some studies also reported a possible decrease in dolphin abundance in areas of high nautical tourism activity (Bejder et al., 2006)

When subject to constant disturbances by tourist activities, cetaceans may go into a stage of habituation, which, under certain circumstances, can result in the decline of the animal natural level of alert towards anthropogenic disturbances, becoming more subjective to vessel strikes (more likely to happen due to the lack of space of escape as whale watching vessels might cross their path or approach too closely in high speed), entanglement and vandalism

(Bejder and Samuels, 2003; Peters et al., 2012; Waerebeek et al., 2007). Though in Madeira, the recent legislation and the voluntary code of conduct are oriented to avoid this situations.

Common bottlenose dolphins, atlantic spotted dolphin, stripped dolphin and short-beaked common dolphin, are some of the species reported as casualties of vessel strikes all over the globe, and they are all, adults and calves, represented in the sectors more intensively used by recreational boats (sectors 3, 6 and 7), whale watching boats (sector 3) and big game fishing boats (sector 3), and thus subject to its potential impact.

The “high used corridor” thus stand as a potential vessel strike risk area (figure 66), frequently crossed by fast ships, recreational boats and the cetacean species more susceptible to these type of impact.

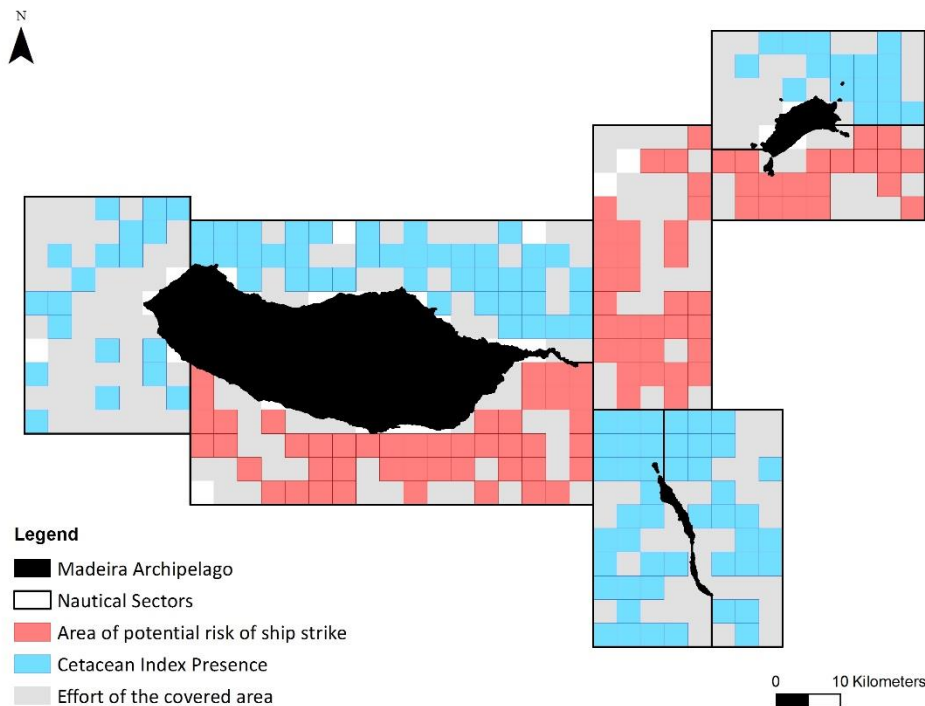


Figure 55- The potential conflict zone.. The red cells represent the cetacean index presence that intersect sectors 3, 6 or 7 the “high used corridor”, a preferential corridor for both cetaceans and ships, where the last ones often cross the area moving at speeds over 10 Kn, i.e., a potential risk of ship collision area.

The last statement might sound rather bold, since these problem was never brought out to the study area in question before, however, this also the first time that a traffic related study has been addressed to Madeira waters.

Even though not many strandings associated with these causes have been reported so far around the Madeira islands, these might have passed overlooked, since most carcass usually immediately sink instead of floating or may be drift away from the islands to the open

ocean (Gregory et al., 2012; Laist et al., 2001; Weilgart, 2007), the advanced carcass decomposition might mask possible death causes signs (Gregory et al., 2012; Laist et al., 2001) or, regarding ship strikes detections, blunt trauma impacts may not show any external signs, for instance (Evens et al., 2011; Gregory et al., 2012).

Transporting the problem to the offshore waters, even though cetaceans locations are not being contemplated, the big part of the EEZ of Madeira traffic is composed by cargos, and its traffic distribution is spread all over the area, running year round, manly travelling through fixed routes, constantly crossing the area and most of them, as they are just passing by, travel at speeds above 10 Kn. Apparently the months with higher level of traffic activity correspond to the summer period, where the presence of calves its most likely, increasing their vulnerability towards these potential impact.

There is some physical evidence that can be related with ship strikes in the present study area. Furthermore, the Madeira EEZ is a very large area with a related small coast line. Thus, the probability of a carcass of an animal victim of a ship strike in the open ocean reach the shoreline is small. Even so, considering other study areas where ship strike evidence are more alarming, as in the North sea (Evens et al., 2011), for instance, to which the offshore traffic in Madeira only corresponds to 17% (see section 3.1.2).

Nevertheless, difficulties in gathering ship strikes evidence have been reported in most of the related studies (Donavan and Leaper, 2011; International Whaling Comission, 2011; Laist et al., 2001; Waerebeek et al., 2007), even in the areas where this problem seems to be more aggravating (Carrillo and Ritter, 2008). Thus, some of the most intensive studies on the subject, especially the revision ones, had focused not only on stranding archives, but also in historical and anecdotal records, and still, only a few of the total number of ship strike occurrence was unveiled (Donavan and Leaper, 2011; Laist et al., 2001). This type of data has never been collected in the present study area,

It is too soon, however, to speculate towards the real impact of ship strikes in the area, since only now the first results are coming out. Nonetheless, this study brought up a scenario in which the factors promoters of ship collisions may be present, demanding a closer look into the matter.

4. Final conclusions

Attending to the available AIS data, the Madeira EEZ traffic is not so intensive as the areas of higher traffic level, corresponding to 22% and 17% of the Baltic and North sea, respectively. The AIS based estimations, however, are always biased, in all areas, since the considered number of vessels is usually underestimated due to coverage gaps/ signal interference and do not represent the real traffic density, and the proportion of recreational boats is not representative. For the present study area, only mostly cargo and cruises were taken into account. Yet, as presented in the inshore traffic section of the present document, though fishing boats represent about 50% of its sample composition, most of those are small vessels dedicated to recreational demersal fisheries (as verified in the second sample period, from 2010 to 2012, where recreational demersal fishing boats would represent 70% of the total fishing boats), and assuming these samples are representative of the inshore traffic of Madeira, tuna and black scabbard fish fishing boats would just account for about 15% (0.3×0.5) of the traffic fleet. Thus, only a small fishing vessel proportion would be reflected in the offshore waters, apart from other foreign fishing fleet that could cross the area.

Nevertheless, marine traffic in Madeira shores is still relevant and may inflict an important impact in the surrounding environment which should not be ignored.

Minding the inshore traffic corridor, the level of traffic is not easy to infer, as comparable areas with similar dimension and traffic features are not easy to find. Attending to the considered confrontations, the level of traffic is also inferior when comparing to some of the most “busiest” traffic areas, representing 1.17 % of the strait of Gibraltar’s. The major difference between the level of the inshore traffic of the study area and the strait of Gibraltar’s was expected, since the last one is the only connection between the Atlantic Ocean and the Mediterranean Sea, constantly crossed by many shipping trade routes.

Overlapping zones where detected, i.e., areas of higher level of traffic coincide with areas frequently used by cetaceans, which can be perceived as conflict zones.

South Madeira is the most frequently crossed sector for every type of boat, standing out as the inshore traffic “busy zone”. Which means all the possible mentioned effects are clumping there and synergistically amplifying the frequency and impacts towards the cetaceans’ population.

This is also the most sought out sector by cetaceans and presents an important site for these species.

A common “high used corridor” by both vessels and cetaceans was identified, standing

as a potential ship strike risk zone.

Even if the problem does not seem to be so aggravating when comparing with the more problematic areas, it does not make it any less relevant and should not be ignored.

Therefore, the traffic spatial temporal characterization should be carried on and improved by defining specific routes and constructing vessel density matrix for the entire Madeira EEZ. The AIS analyses could be coordinate with the analyses of the WMO Voluntary Observing Ships (VOS) Scheme, following the example of previous studies (Evens et al., 2011). The VOS program (see: http://www.vos.noaa.gov/vos_scheme.shtml) is in motion since 1953 and is based on the meteorological and oceanographic voluntary data collection by vessels all over the world. This information is also used for shipping traffic purposes, even though it is conditioned to the type of vessels engaged in the program, consequently commercial vessels are not very well represented. Nevertheless, this information could work as a complement, partially compensating the coverage flaws associated with the AIS data.

Even though this study has pointed out possible traffic impact towards whales or dolphins, apart from by-catch and whale watching effects, none of these has been quantified so far, so an attempt to do so should be undertaken in a near future.

Whalewatching activities should be monitored to infer if the voluntary conduct code is being followed, as these vessels specifically circulate in the cetaceans' critical zone, and previous studies already concluded that these activities were not indifferent towards whales or dolphins in the study area, and this is not expected to decrease over the years.

The potential impact regarding ship strike and water noise on cetaceans should be quantified for the present study area.

The probability of a ship strike depends on the level of traffic activity and the incidence and cetacean population species composition and how they use the area (if they use it to rest, for instance, they may be more vulnerable to these potential impacts). Thus, in order to infer the probability of ship strike around the study area, recommendations by ASCOBANS (International Whaling Commission, 2011) on the subject could be followed. Thus, a dedicated trained observer should be placed on board of cargo or cruises and register cetacean presence and interactions/ behaviour towards the traffic in the close/ near surrounding area and, in the eventual direct observation of a collision, correspondent vessel speed and time should be noted down. A workshop could also be proposed to crew members, rising the awareness towards the problem and training them to identify marine species, which could eventually help

in preventive ship manoeuvres when a whale would be at sight (despite these strategy efficiency is still questionable). These program could be useful in many ways, since it could also work as a platform of opportunity for different research purposes, such as the collection of cetacean and traffic sighting locations (estimations of abundance) along the whole Madeira EEZ. A similar project is already running in the same study area and has, proving it is actually doable (Correia, 2013).

The available photo-ID catalogue should also be used to detected possible signs of blunt trauma, such as propeller cuts, in either adults or small cetaceans.

These should be reinforced by historical and anecdotal reports gathered by means of consult of old books, documents or archives related to the subject, and interviews, to the locals and sailors man, about possible whale or dolphin boat collisions or incidents experiences throughout their time at sea, that they would be willing to share. Though these kind of information might be hard to obtain, it would be helpful in identifying potential risk areas of ship collisions along the study area.

Vessel numbers along the coastal areas are expected to increase in either a domestic or international level, as new routes are emerging, and simultaneously old ports are developing (Southall, 2005). Therefore, it is important to keep track with the traffic expansion and ascertain how it is being reflected in the cetacean population so that, if required, mitigation measures might be implemented in time.

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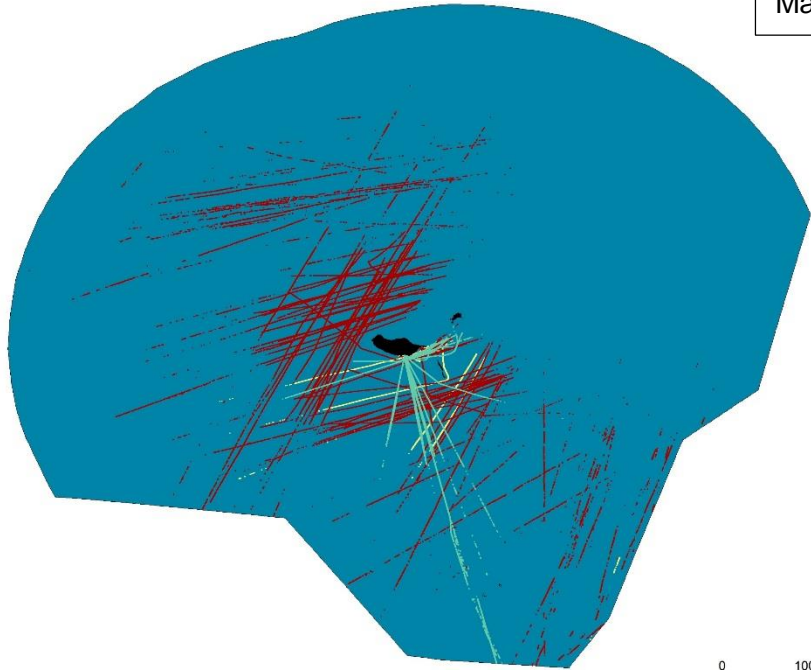
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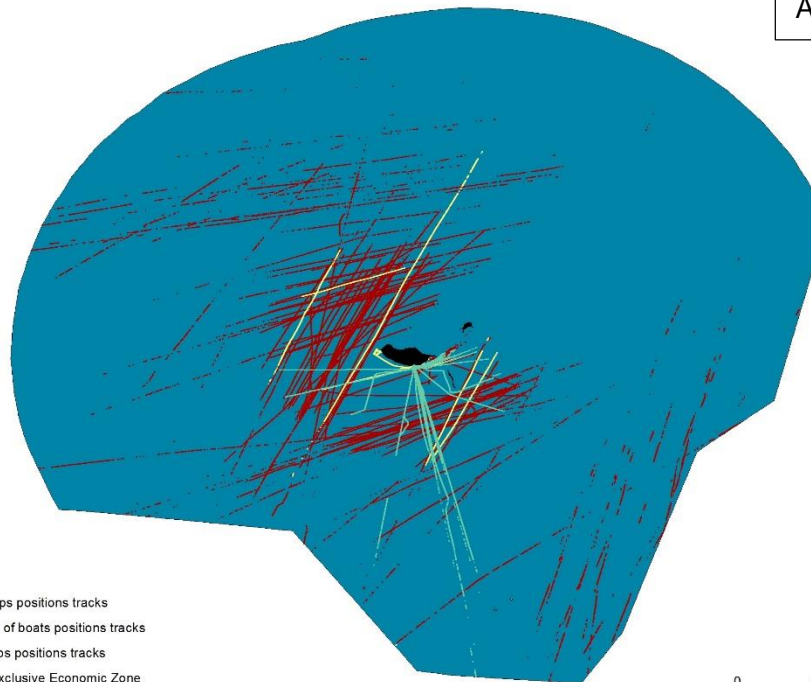
Annex I

March 2011



0 100 Kilometers

April 2011

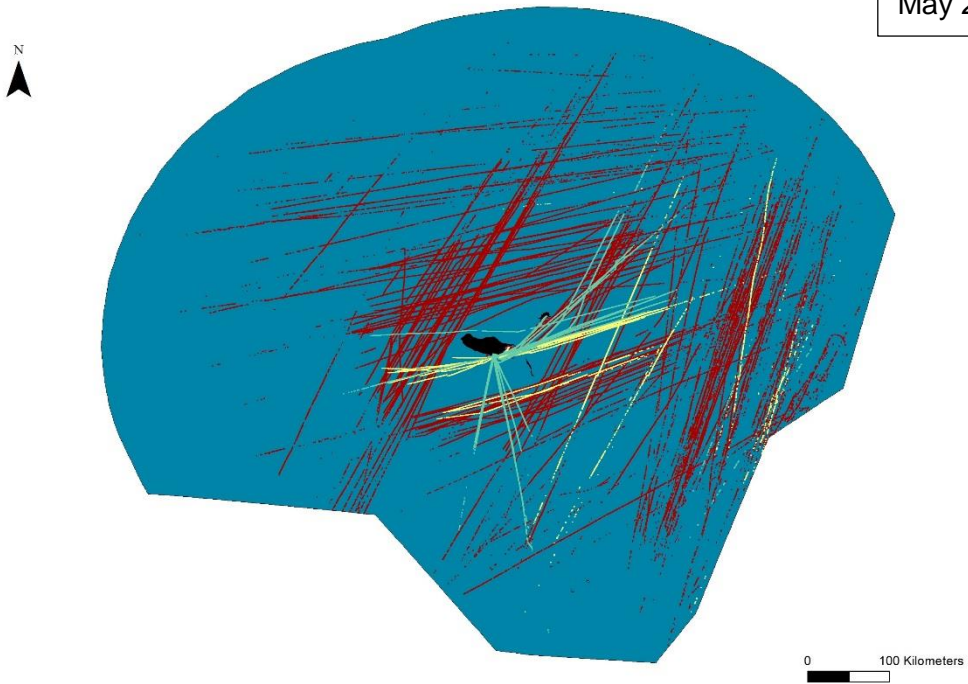


0 100 Kilometers

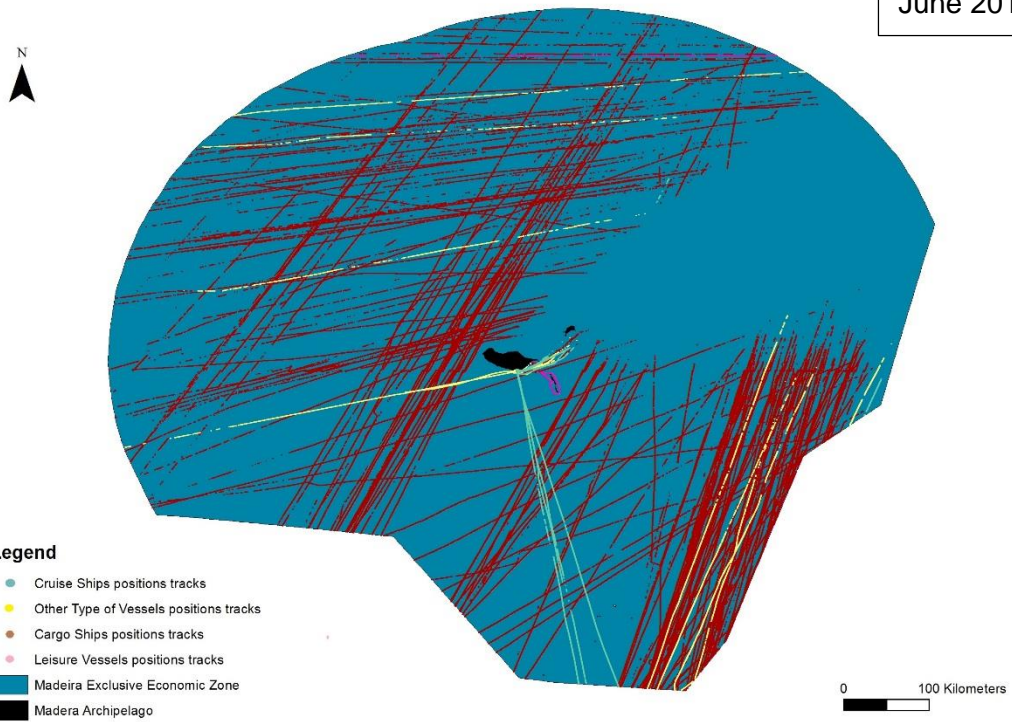
Legend

- Cruise Ships positions tracks
- Other type of boats positions tracks
- Cargo Ships positions tracks
- Madeira Exclusive Economic Zone
- Madera Archipelago

May 2010

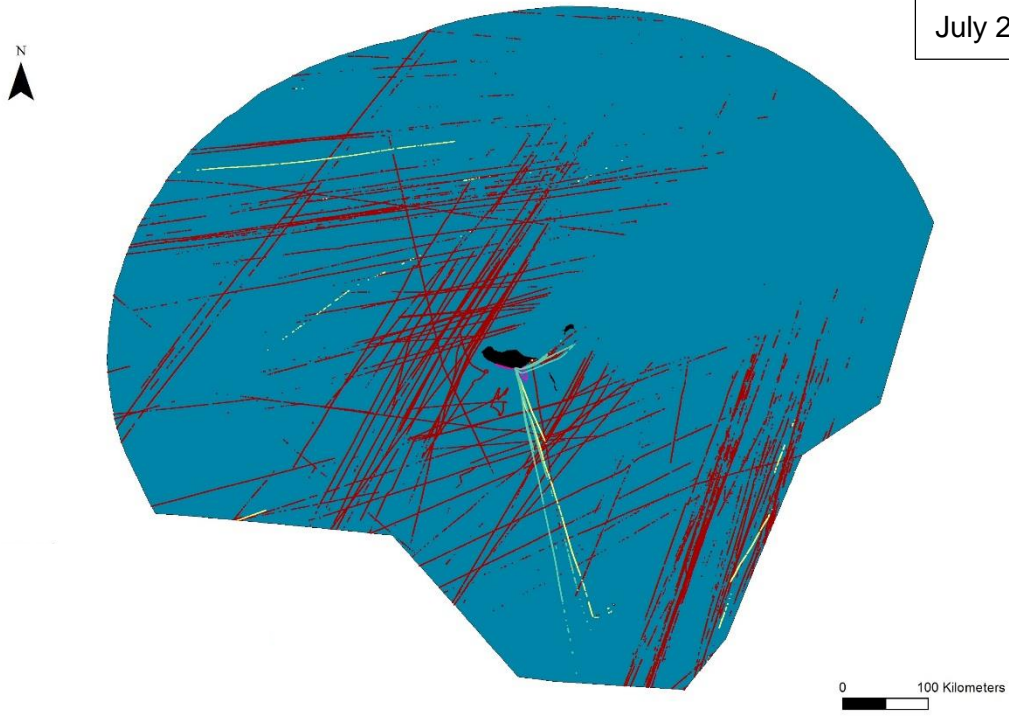


June 2010

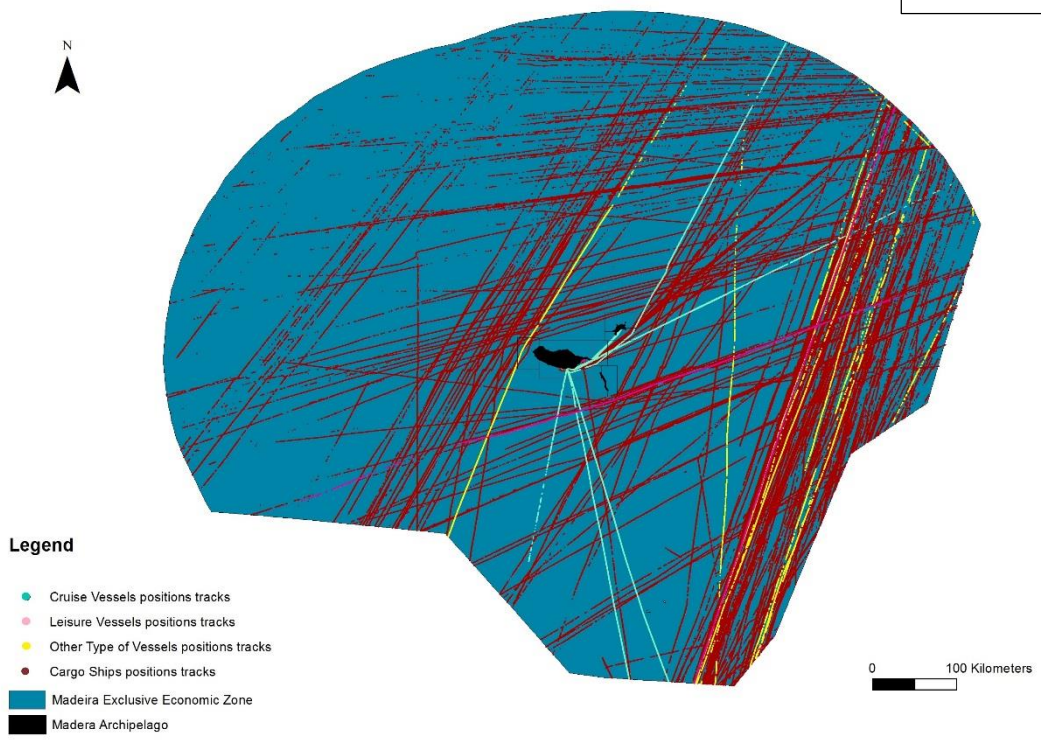


- Legend**
- Cruise Ships positions tracks
 - Other Type of Vessels positions tracks
 - Cargo Ships positions tracks
 - Leisure Vessels positions tracks
 - Madeira Exclusive Economic Zone
 - Madera Archipelago

July 2010

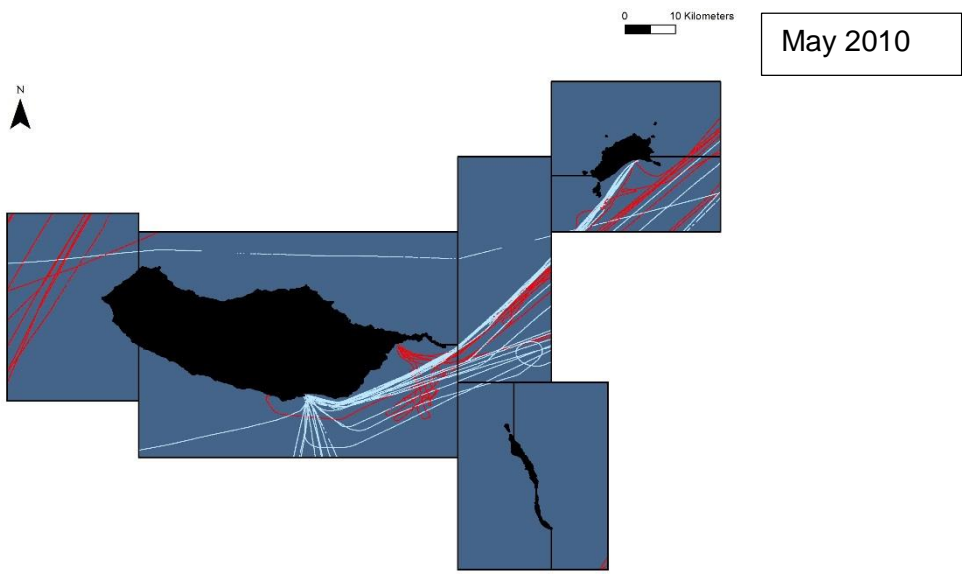
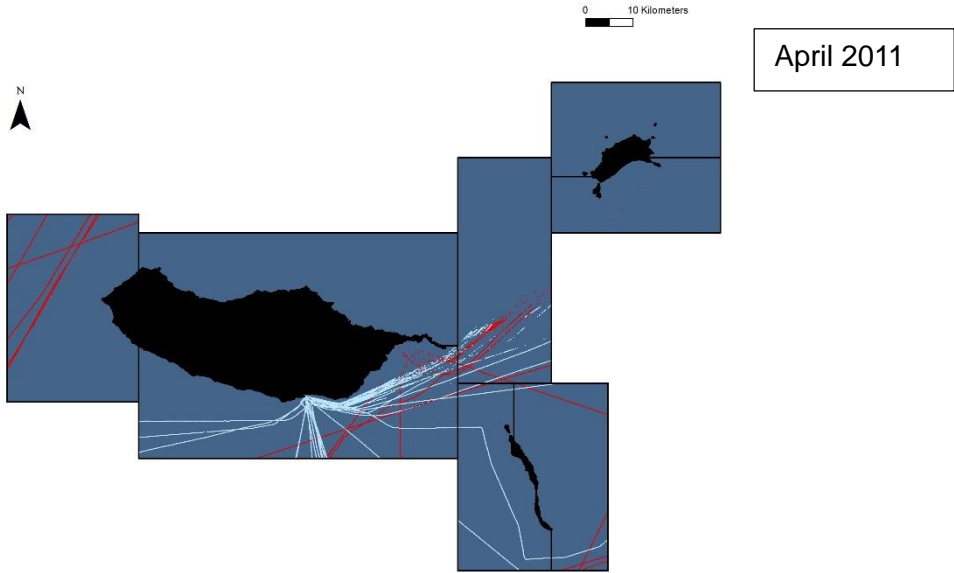
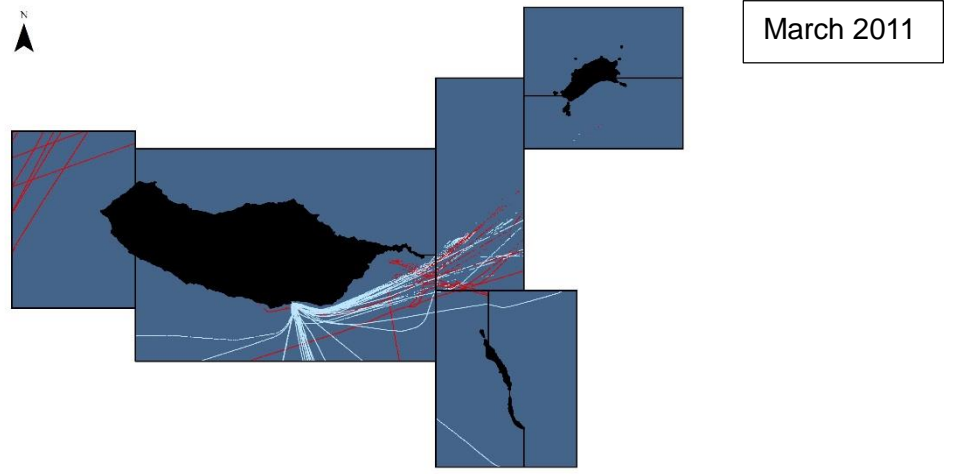


August 2010

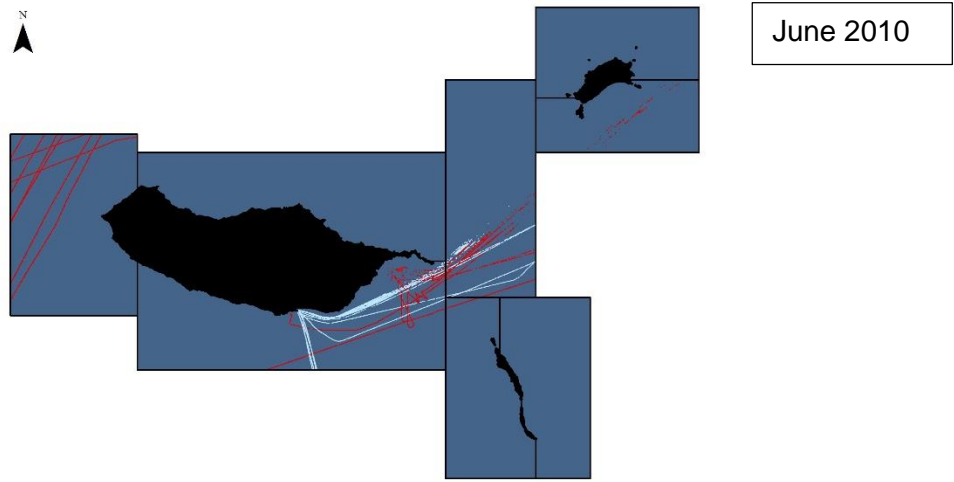


- Legend**
- Cruise Vessels positions tracks
 - Leisure Vessels positions tracks
 - Other Type of Vessels positions tracks
 - Cargo Ships positions tracks
 - Madeira Exclusive Economic Zone
 - Madera Archipelago

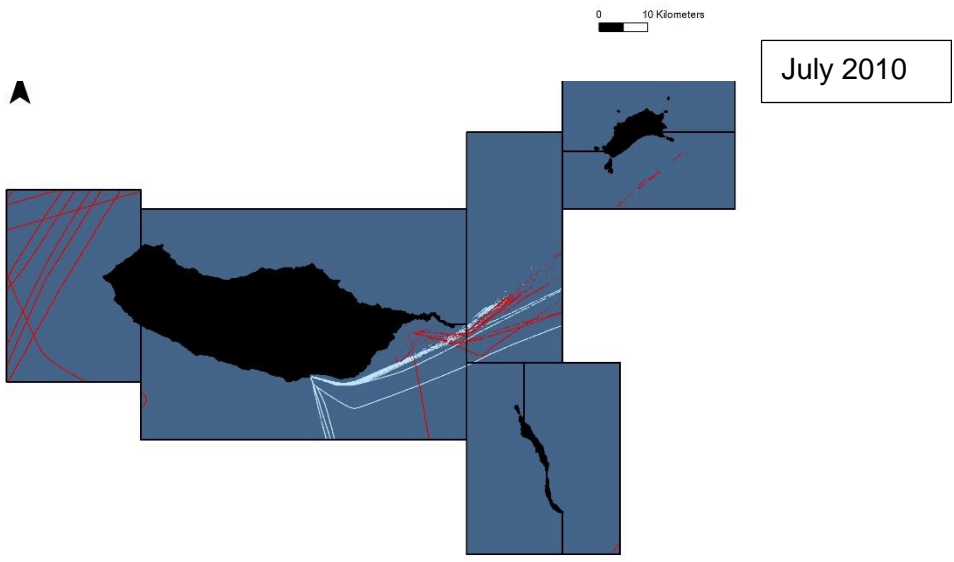
Annex II



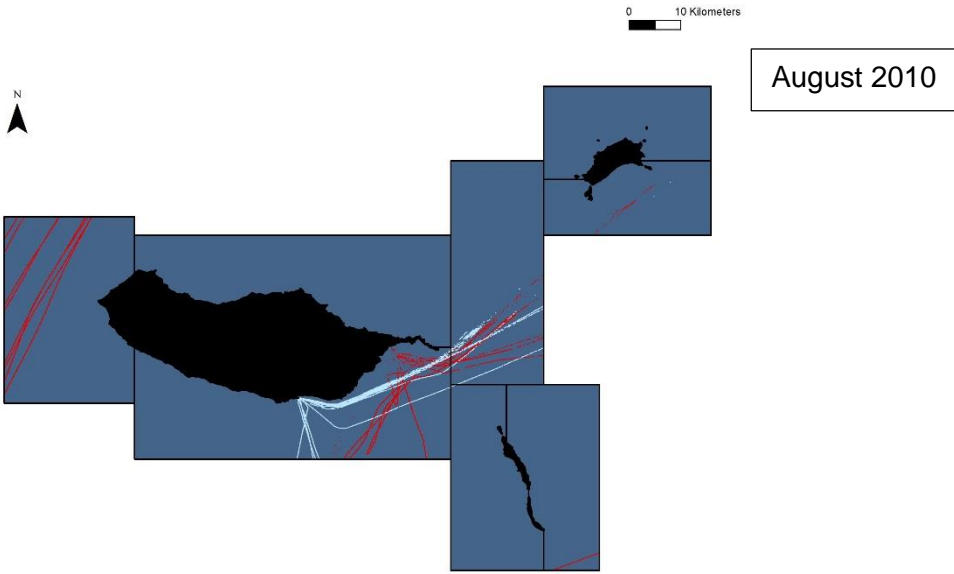
- Legend**
- Madeira Archipelago
 - Nautical Sectors
 - Cargo ships position tracks
 - Cruises or ferrys position tracks



June 2010



July 2010

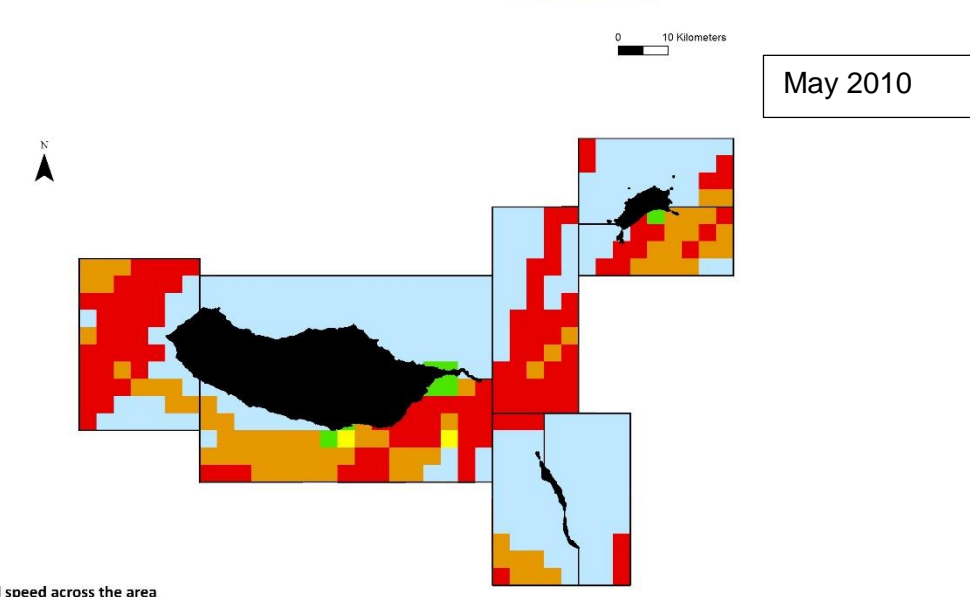
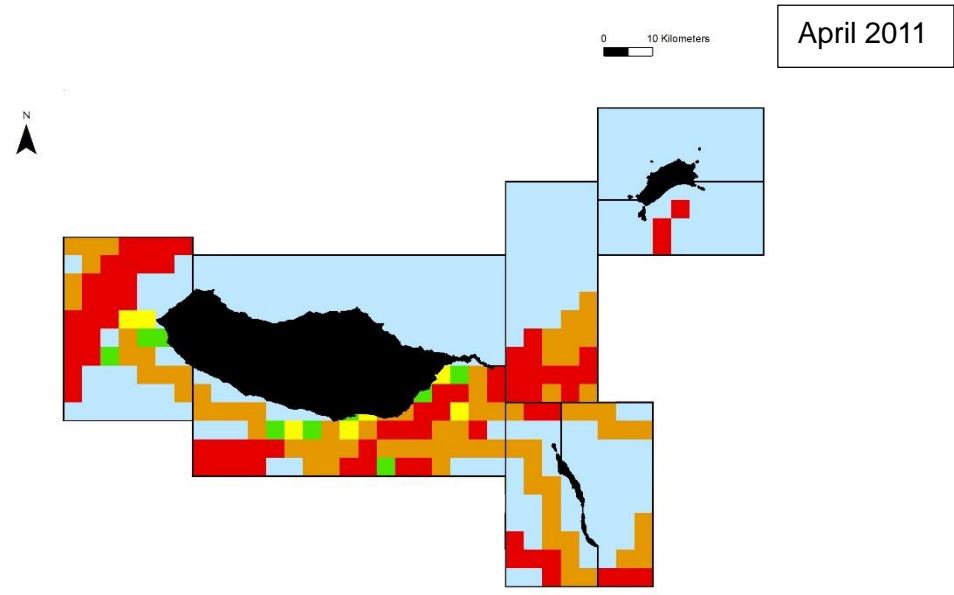
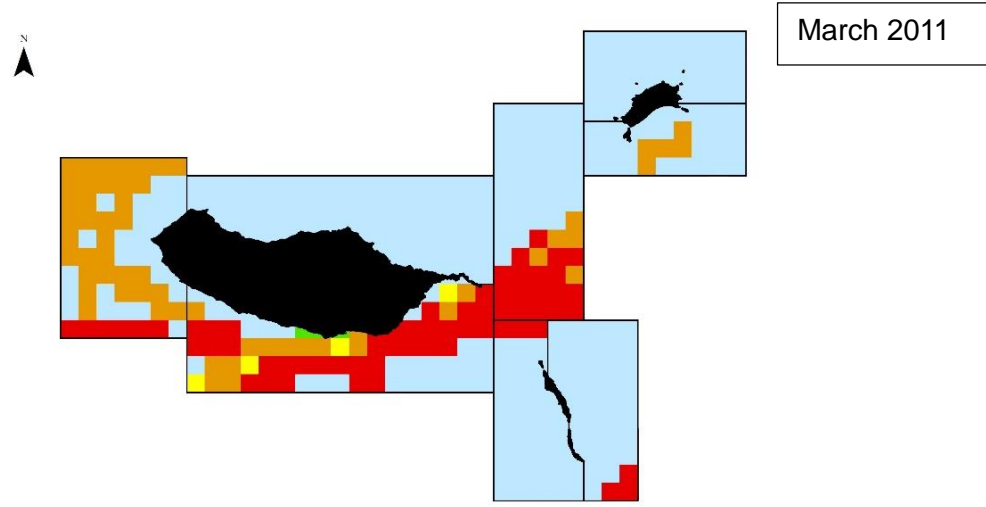


August 2010

- Legend**
- Madeira Archipelago
 - Nautical Sectors
 - Cargo ships position tracks
 - Cruises or ferrys position tracks

0 10 Kilometers

Annex III



Legend

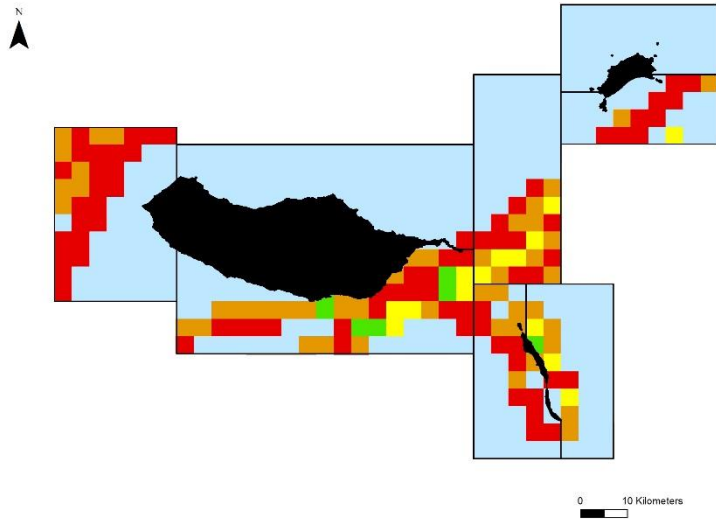
Madeira Archipelago
 Nautical Sectors

Vessel speed across the area

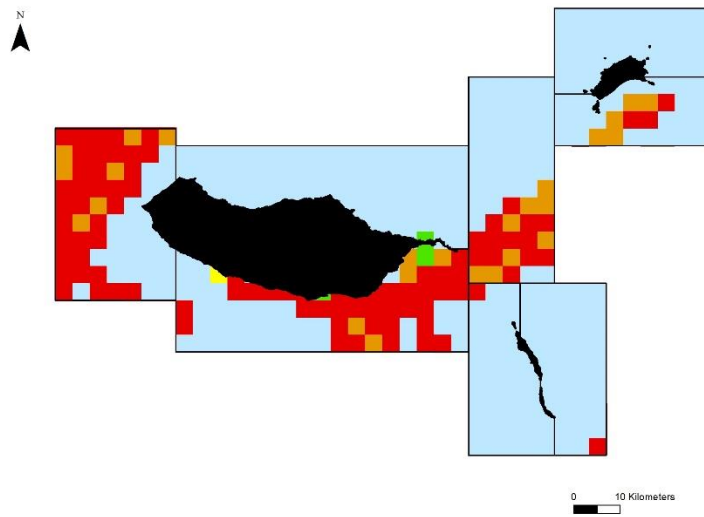
< 8 Kn	8 - 10 Kn	10 - 15 Kn	> 15 Kn

0 10 Kilometers

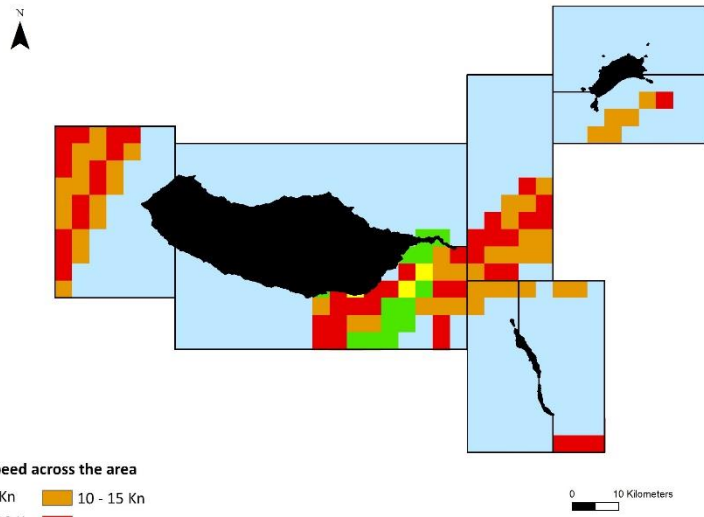
June 2010



July 2010



August 2010



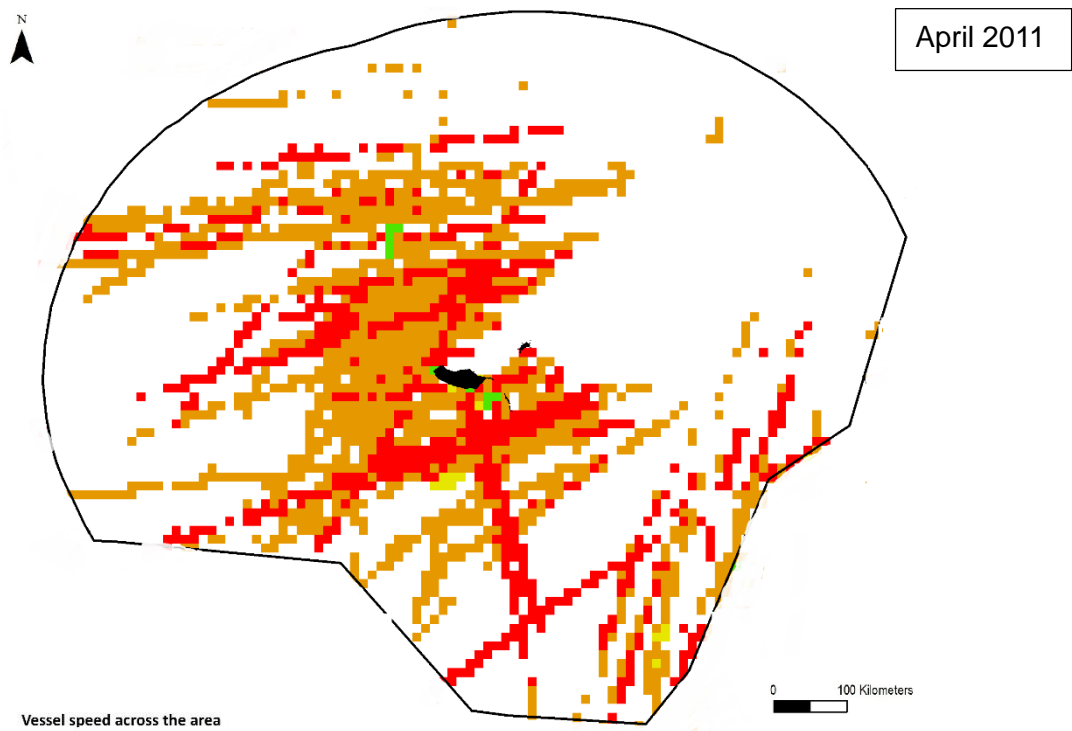
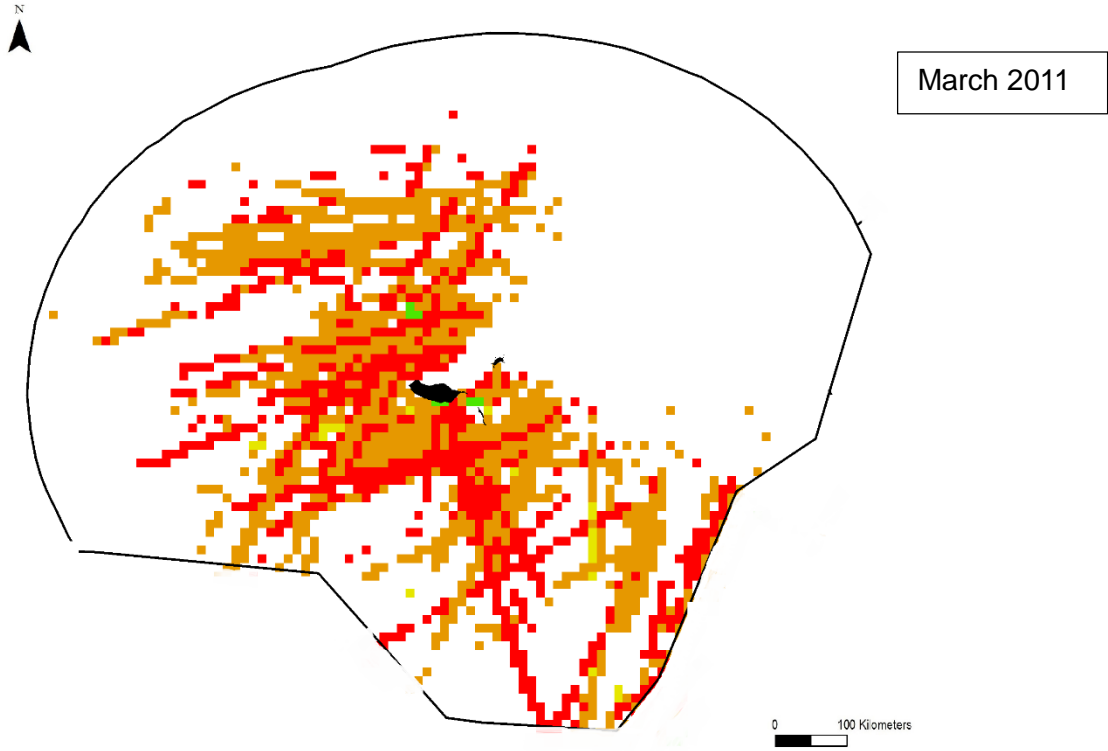
Legend

- Madeira Archipelago
- Nautical Sectors

- Vessel speed across the area**
- < 8 Kn
 - 8 - 10 Kn
 - 10 - 15 Kn
 - > 15 Kn

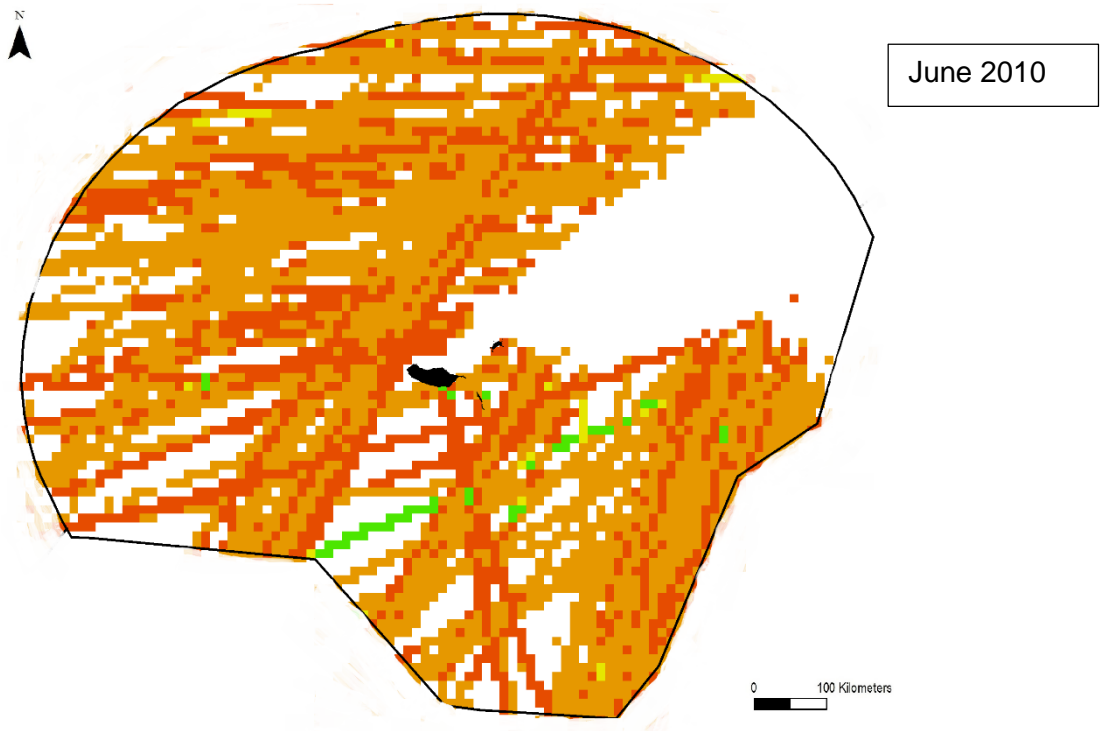
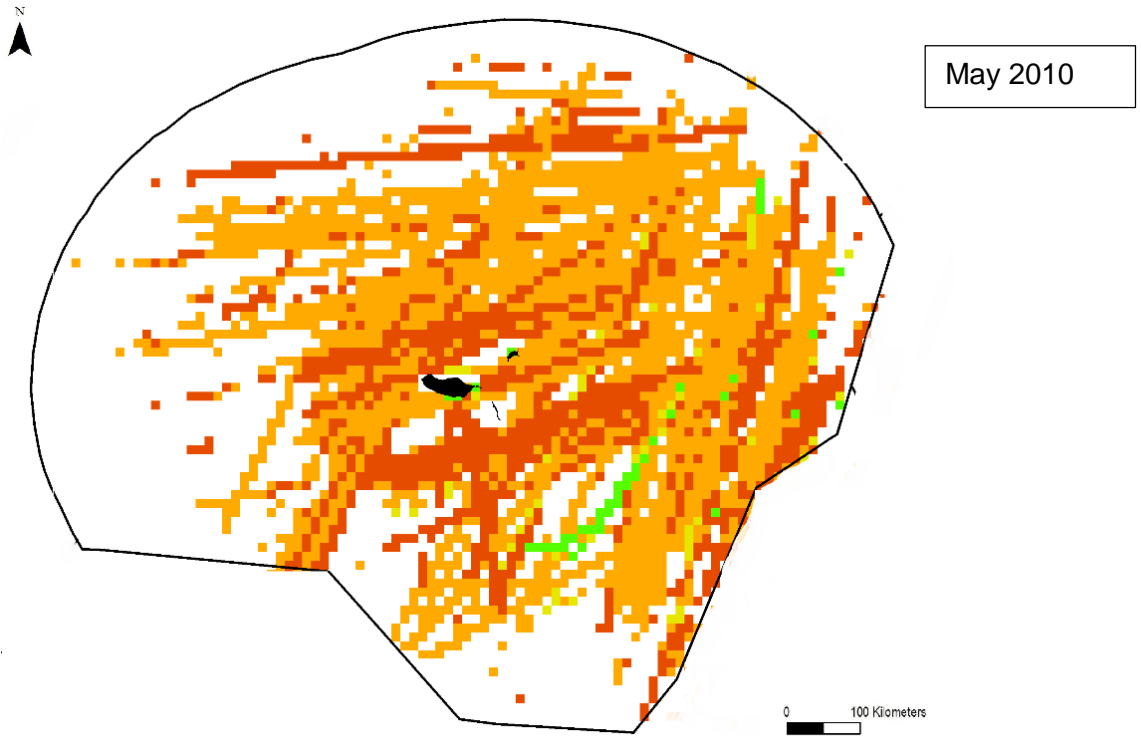
0 10 Kilometers

Annex IV



Legend

Madeira Archipelago	< 8 Kn	10 - 15 Kn
Madeira EEZ	8 - 10 Kn	> 15 Kn

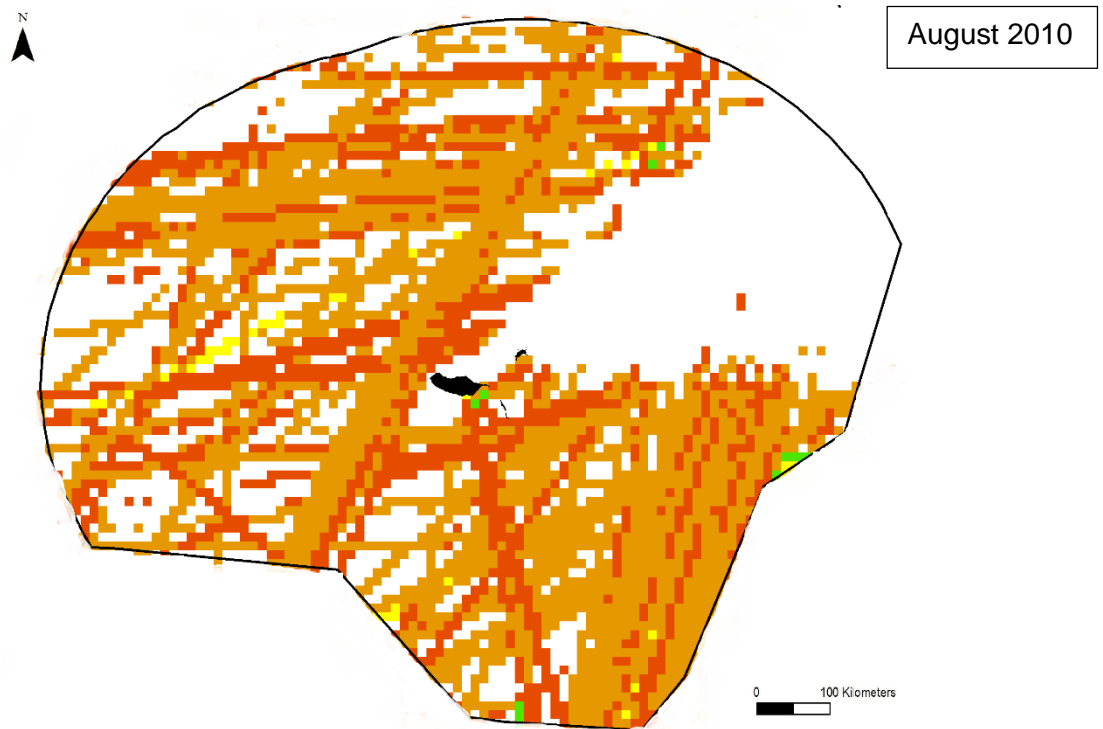
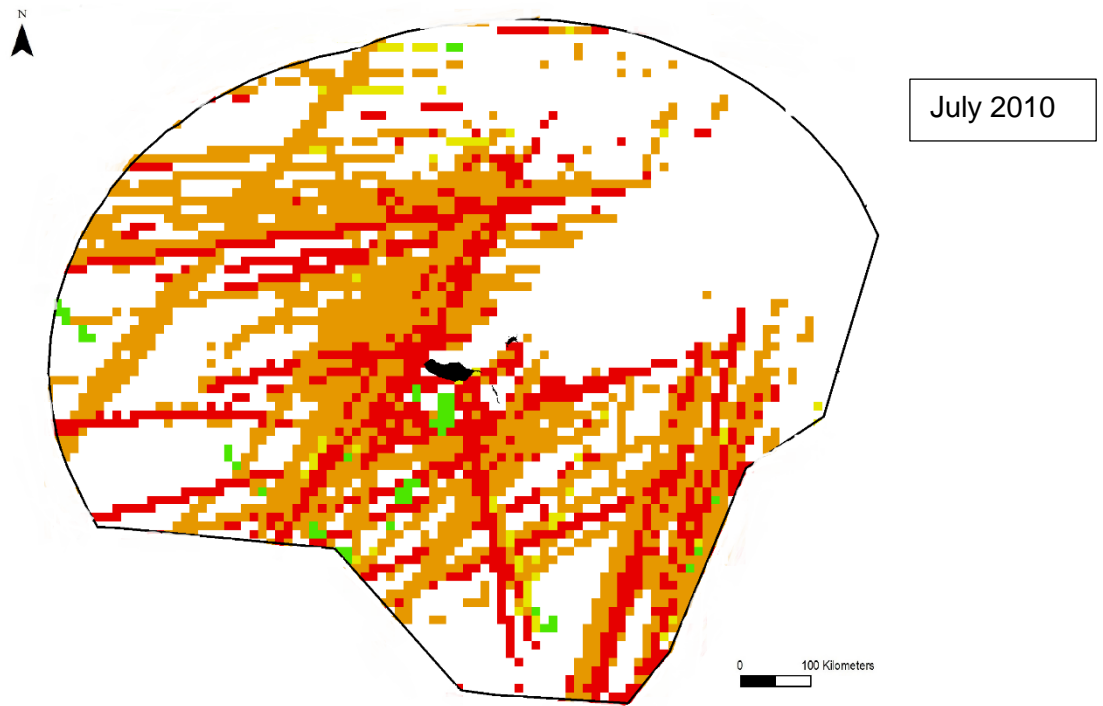


Legend

- Madeira Archipelago
- Madeira EEZ

Vessel speed across the area

■ < 8 Kn	■ 10 - 15 Kn
■ 8 - 10 Kn	■ > 15 Kn



Legend

- Madeira Archipelago
- Madeira EEZ

Vessel speed across the area

- < 8 Kn
- 8 - 10 Kn
- 10 - 15 Kn
- > 15 Kn

