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Mapping vessel tracks in whale habitat Comodoro Rivadavia, Argentina

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Foreword

In the summer of 2018, I sailed with my family from Palamos (Spain) to Majorca. During this crossing, we came across a sperm whale (Physeter macrocephalus). It was the first time I saw a whale in the wild, an unforgettable experience. The underwater world has fascinated me since I was little, so I hesitated for a long time to study biology. Choosing to study Nautical Sciences took me in a completely different direction. However, during my internship on the sailing ship Dar Mlodziezy, one of the instructors gave a presentation on the Great Whale Conservancy. This organisation aims to protect whales, especially the blue whale. They do this, for example, by changing the TSS in several places so that the animals' route is avoided. I was hugely impressed by the Great Whale Conservancy and saw an opportunity to combine my two interests, ships and the underwater world.

I would like to thank my supervisor Dr Geert Potters because I sincerely could not have completed this thesis without his cooperation. I also want to thank Captain Michael Barbaix to get me in contact with the Great Whale Conservancy and to help me with his professional and experienced look at the AIS data. And as last I want to thank Michael Fishbach for giving me the opportunity to help with a project of the Great Whale conservancy.

Samenvatting

Deze scriptie markeert een belangrijke mijlpaal in het bevorderen van het voortbestaan van walvisachtigen in de Golf van San Jorge. Het biedt een universeel toepasbaar sjabloon voor het in kaart brengen van AIS-gegevens van schepen. Deze gegevens leveren waardevolle inzichten op in gebieden met een hoog risico op aanvaringen met walvisachtigen. Op basis van deze geïdentificeerde zones kunnen vervolgens onderzoeken worden uitgevoerd om methoden te vinden om het aantal schepen in deze gebieden te verminderen, wat zou moeten resulteren in een afname van botsingen tussen schepen en zeedieren.

De literatuurstudie behandelt verschillende walvissoorten en presenteert hun wereldwijde populatiegegevens. De walvisjacht heeft een aanzienlijke impact gehad op deze populaties. In de afgelopen 150 jaar is het aantal walvissen in de noordelijke Stille Oceaan met 62.858 individuen afgenomen. Walvisachtigen spelen een essentiële rol bij het voeden van het plankton en indirect bij het absorberen van CO2. Ondanks hun positieve bijdrage aan het ecosysteem, hebben menselijke activiteiten twee aanzienlijke negatieve effecten op zeedieren, namelijk geluidsoverlast en het risico op aanvaringen. Enkele van de meest risicovolle gebieden voor zeedieren zijn de Helleense Trog, het leefgebied van de potvis, en de kust van Florida en Georgia, waar de noordkaper voorkomt.

Een mogelijke oplossing voor dit probleem is het scheiden van scheepsroutes en walvisgebieden. Hiervoor is gedetailleerde kennis vereist over de locaties van zowel walvissen als schepen. In deze scriptie wordt een uitgebreid stappenplan gepresenteerd voor het in kaart brengen van scheepsroutes op basis van historische AIS-gegevens van Spire Global, met behulp van het programma QGIS.

De schepen in de verzamelde gegevens zijn gecategoriseerd in negen verschillende types: onbekende schepen, andere schepen, tankers, sleepboten, vissersschepen, vrachtschepen, wetshandhavingsvaartuigen, loodsboten en schepen met anti-vervuilingsapparatuur. Na het in kaart brengen van deze diverse scheepscategorieën kan geconcludeerd worden dat de Golf van San Jorge wordt overspoeld door vissersschepen en tankers. Dit komt overeen met de verwachting, gezien de aanwezigheid van twee Single Point Mooring-boeien bij Comodoro Rivadavia en Caleta Olivia, waar olie wordt overgeladen van en naar schepen.

Aangezien de walvisgegevens ten tijde van het schrijven van deze scriptie nog niet beschikbaar waren, is het nog niet mogelijk om een definitief resultaat te presenteren. Het gedrag van de schepen is echter geanalyseerd en in kaart gebracht. De kaarten die in deze thesis worden gepresenteerd, vormen een eerste stap in de richting van de bescherming van walvisachtigen in het gebied van Comodoro Rivadavia, Argentinië. Dit project kan dienen als een waardevol model voor toepassing in andere regio's wereldwijd.

Abstract

This thesis represents a crucial step towards aiding the survival of marine life in the Gulf of San Jorge. It provides a comprehensive template for mapping vessel Automatic Identification System (AIS) data, applicable worldwide. By harnessing this information, a more accurate assessment of areas posing high risks to cetaceans can be obtained. Once these areas are identified, further research can be conducted to devise strategies for reducing vessel traffic in these zones, thereby mitigating ship and marine animal collisions.

The literature review encompasses various whale species, along with their global populations. It is evident that whale hunting has exerted a substantial impact on these populations. Over the past 150 years, the northern Pacific whale population has witnessed a decline of 62,858 individuals. Cetaceans play a pivotal role in providing food for plankton and indirectly sequestering CO2. Despite their positive impact on humans, humans themselves contribute two significant negative effects on marine animals: underwater noise pollution and the threat of vessel collisions. Among the most perilous areas for marine life are the Hellenic Trench, the habitat of sperm whales, and the coasts of Florida and Georgia, where the North Atlantic right whale resides.

One potential solution to this problem is the segregation of ships and whales, necessitating a comprehensive understanding of whale and vessel locations. This thesis outlines a comprehensive procedural framework for mapping shipping routes using historical AIS data obtained from Spire Global, employing the QGIS software program.

The vessels within the dataset were categorized into nine groups: unknown vessels, miscellaneous vessels, tankers, tugboats, fishing vessels, cargo ships, law enforcement vessels, pilot boats, and pollution control vessels. Following the mapping of these diverse vessel types, it is evident that the Gulf of San Jorge is inundated with fishing vessels and tankers. This observation is expected, given the presence of two Single Point Mooring buoys near Comodoro Rivadavia and Caleta Olivia. These buoys serve as terminals for the transfer of oil to and from ships.

Since the whale data was not available at the time of writing this thesis, a final outcome cannot be presented yet. However, the behaviour of the ships has been explained and mapped out. The maps presented in this thesis serve as a starting point for the protection of cetaceans in the area of Comodoro Rivadavia, Argentina. This project can be used as a model in other regions worldwide.

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1 Literature study

1.1 Introduction

Since the advent of whaling in the 17th century, the global whale population has suffered a profound decline. The extent of human-induced damage over the centuries is staggering. Historical accounts and visual depictions of ships returning to port with whales adorning their bows have been widely documented. Whales hold significant importance for humanity, serving as vital ecosystem contributors that directly influence the well-being and prosperity of our species. Furthermore, their species diversity holds immense ecological significance for our planet.

Marine mammals endure substantial disruptions caused by ships, both through collisions and the pervasive issue of noise pollution. The actual decibel levels produced by shipping activities and the consequential impact on cetaceans warrant further exploration. In addition to noise, ships pose a threat due to their speed and the sheer volume of vessels traversing our oceans and seas. The proliferation of ships raises the likelihood of potentially catastrophic collisions between these magnificent animals and maritime traffic. The speed at which a ship is traveling plays a significant role in determining the severity of consequences resulting from such collisions.

Furthermore, acquiring precise knowledge of the habitats and migration patterns of marine animals is of utmost importance. Equally vital is comprehending the positions and movements of ships to attain a comprehensive understanding of the overall picture. By integrating these two pieces of information, we can deduce the most hazardous locations for specific whale species.

Numerous individuals and organizations are actively engaged in efforts to mitigate harm to cetaceans and seek effective solutions. It is crucial to identify and evaluate the most efficient and successful strategies implemented thus far in order to minimize damage and promote the well-being of these magnificent creatures.

1.2 Cetaceans in marine environments

1.2.1 The state of cetaceans in oceans

This thesis deals with the entire group of cetaceans. This group consists of mammals that live underwater such as the whales, dolphins and porpoises. A total of 81 species live in 14 families, divided into the two main groups: the Mysticeti (baleen whales) and the Odontoceti (toothed whales, dolphins and porpoises). The difference between these two main groups is that the Mysticeti have no teeth, but baleen plates that can filter plankton from the water. Their size can range from smaller than two metres to larger than 25 metres and their mass varies from smaller than 100 kg to larger than 100 000 kg (Fordyce & de Muizon, 2001).

The sperm whale (Physeter macrocephalus) is a first example of the Mysticeti group. This species can grow up to 16 metres long in males and up to 11 metres long in females. The sperm whale has the largest brain on earth. The most remarkable feature is the spermaceti organ, which is a huge nasal complex. This nasal complex allows the animals to produce very loud clicks for echolocation. The sperm whale can dive up to 600 metres deep and will therefore live mainly in deeper ocean waters. Another remarkable feature of the sperm whale is that it consumes up to ten million tonnes of food per year (Whitehead, 2018).

Figure 1 Spermwhale
Source: ('Sperm whale', 2022)

Another species of the Mysticeti group is the humpback whale (Megaptera novaeangliae). This specie could be studied more easily than others because their habitat is closer to coasts. During summer, these animals migrate to higher latitudes. When the humpback whale wants to mate or breed, usually during winter, it will migrate to subtropical waters. The humpback whale can grow up to 17 metres long, and in this specie it are the females that grow on average 1-1.5 metres longer than the males (Mann, Connor, Tyack, & Whitehead, 2000).

Figure 2 Humback whale
Source: ('Humpback whale', 2022)

The common whale (Balaenoptera physalus) is the second largest of the Cetaceae, the blue whale being the largest. Humans hunted this whale enormously during the 20th century, but it is still scattered all over the world (Aguilar & García-Vernet, 2018). The common fin whale can grow up to 27 metres long. They are usually grey on top and white underneath. Usually alone, but sometimes in small groups, these animals migrate north for food and south during the winter months (High, 1984).

Figure 3 Fin whale
Source: ('Fin whale', 2022)

An example of the group Odontoceti is the orca (Orcinus orca). The orca is a predator. The animal is hugely distributed around the world, but especially in the Pacific Northwest, the Northeast Atlantic, around New Zealand and Antarctica (Bolaños-Jiménez et al., 2014). There is no single type of orca, although this is often thought. The orca is divided into several ecotypes, with their own characteristics. These different ecotypes will not interact with each other and differ genetically. The orca lives together in large groups of five to 40 individuals. The diet of an orca consists of different species of fish and seals (Emmons, Hard, Dahlheim, & Waite, 2019).

Figure 4 Killer whale
Source:('Orka', 2022)

In recent years, the population of whales has declined dramatically. In the North Pacific, during the last 150 years, the population of whales has declined by 62,858 individuals (Estes, DeMaster, Doak, Williams, & Brownell, 2006). The sperm whale's collection has declined the most during whale hunting. As a result, the population decreased from 1 100,000 individuals to 360,000 (Whitehead, 2018). Since 2010, the sperm whale population has experienced a negative decline of 4.5% per year (Gero & Whitehead, 2016).

The northern right whale (Eubalaena japonica) is thought to have the smallest population. After research, it was found that about 30 Northern right whales were thought to live in the Bering Sea (visual: 30 and genetic:28). Estimatations suggest that the population of this species in the North Pacific is not much more (Wade et al, 2011).

1.2.2 Importance of the whale for humans

The precarious situation of cetaceans in Earth's oceans does not only have direct consequences for the animals themselves. As part of a global marine ecosystem, they also play a role in the well-being and prosperity of the human species. This concept is referred to as "ecosystem services".

After eating fish and krill, whales will return to the photic zone. In the photic zone there is enough light to engage in photosynthesis, this zone is located in the upper layer of the water. Here the whales will unload plumes of liquid excrement, these contain iron and nitrogen. These nutrients will fertilise the plant plankton that live only in the photic zone. The up-and-down movement of marine animals keeps the plankton in the photic zone longer to grow. The more plant plankton, the more animal plankton, so the more food for marine animals. Another positive story of the whale is that the plant plankton absorbs CO_2 from the atmosphere. When this plankton eventually sinks to the bottom, it disappears there for thousands of years. So the more whales, the more plankton and the more plankton, the more food for the animals and the less CO_2 in the atmosphere (How whales are changing the climate, 2014).

Whales have a clear regulatory function in our ecosystems, e.g. in keeping the planet's carbon balances in balance. A large whale, such as the blue whale (Balaenoptera musculus), stores around 33 tonnes of CO_2 in its body during its lifetime. This CO_2 is not released into the atmosphere when the dead animal sinks to the bottom when it dies, but will instead feed organisms at lower depths. In comparison, during the average life span of a whale, about 70 years, a new tree can only capture 1.5 tonnes of CO_2 (Schoukens & Willaert, 2021).

Another importance of the whale for humans concerns ecotourism. Every day there are whale watchers all over the world earning billions from whale watching. This is a positive story for many people, who depend on tourism. Not only does the tourism industry benefit from whales, but researchers also go whale watching to better understand the animals. There are of course two sides to this story, by better understanding the animals one can better protect them, but approaching so close to whales is not without danger. There is always a chance that these animals could be harmed by collisions (Parsons, 2012). Moreover, it has already been found that whales behave differently when watched; whether spotting the animals has a long-term impact is not known (New et al., 2015).

1.3 Damage to cetaceans from shipping

As previously explained, cetaceans are important to humans. It is therefore logical to want to create a safe environment to protect these animals. Nevertheless, cetaceans still face many dangers coming from humans. The most obvious damage comes from ships. With ships getting bigger and faster, the cetaceans experience more collisions with ships, resulting in injury or death. In addition to collisions, the animals also suffer from noise pollution. The following gives a closer look at these different forms in which shipping impacts on these animals.

1.3.1 Noise pollution

1.3.1.1 Whale sounds

Whales use their voices for various reasons, such as communicating and hunting. If their transmitted sounds are disturbed by noise pollution, certain communications may be lost or diminished.

Light propagates relatively poorly in water, whereas on land humans can see for kilometres you will be able to see 20 metres far under water in good conditions. In contrast, sound propagates much better in water than in air. This makes hearing more important to animals underwater than their sight, which can be seen in the evolution of the auditory nerve compared to the optic nerve. In land animals, the auditory nerve has evolved much less than in marine animals, so marine animals will 'see' by sound and communicate at much greater distances. The calls of whales can thus be detected up to hundreds of kilometres away (Tyack & Clark, 2000).

Fin whales exhibit sounds at a low frequency, it is suspected that this was used when the animal was surprised or showed agonistic behaviour (Watkins, 1981).

Another important phenomenon of the whale is its song. This consists of a series of sounds that the whale repeats over and over again. This song can last for hours and can reach for miles. People do not know the function of the song of whales. Moreover, each species of whale also has its own sounds and differences even occur within the same species, depending on the region where the marine mammal lives (Payne & McVay, 1971). For example, the song of the humpback whale living in Pacific Ocean on the east coast of Australia is different from the song of the humpback whale living in the Indian Ocean on the west coast of Australia (Noad, Cato, Bryden, Jenner, & Jenner, 2000). One function of the humpback whale's song is thought to be related to mating. Only male humpback whales produce the lilting sounds, either to scare away other males or to woo female humpback whales. However, this is only speculation (Español-Jiménez & van der Schaar, 2018). In addition, fin whales also emit 20 Hz pulses in patterns, these are said to be intended for decorating female fin whales (Watkins, 1981).

A second way marine mammals deploy sound is when hunting for their food. For example, the diet of the orca (Orcinus orca) consists mainly of herring, a fish that moves in schools. First, the orca will force the school of herring to swim to the surface. Then the animal emits a call to manipulate the shoaling of the herring, which will cause the herring to swim closer together (Simon, Ugarte, Wahlberg, & Miller, 2006).

This prevents them from manoeuvring properly, making them extra vulnerable. When some herrings swim out of the shoal formation, the orca will give them a near death blow with its tail so that it can eat them. This hunt can last up to 2 hours (Orcas Hunt For Herrings | World's Deadliest Whale | National Geographic Wild UK, 2020).

Besides singing, a whale will also make other sounds, performed by males and females. These sounds are used for communication in a group or between groups. The social sounds may include clapping on the water or breaking the water by dropping onto the water. Whales mainly use these phenomena among themselves in the group. Communication between two competitive groups mainly consists of blowing underwater and weeping sounds. It is a possibility that all these sounds contribute to group composition, mutual communication and mediate interaction between different social groups (Dunlop, Cato, & Noad, 2008). With the common fin whale (*Balaena physalus*), it was investigated when they would use certain frequencies. It appears that higher frequencies are used for communication with other fin whales in the environment. The fin whale also emits a single 20Hz pulse, which is used for communication with nearby fin whales as well as with more distant animals (Watkins, 1981).
Because sound propagates so well in water, a baleen whale (Mysticeti or Mystacoceti) can use it to orientate itself. When one encounters a whale in the middle of the ocean, it appears to be travelling alone. This animal may be visually alone, but may be in contact via hearing with other whale miles away (Payne & Webb, 1971).

Next, the sperm whale (Physeter macrocephalus) was found to make clicking sounds underwater. The sperm whale is believed to use these sounds for echolocation. Echolocation is used by animals to determine their surroundings when visibility is poor. Sound signals are emitted by the animals, these are echoed by objects in the environment. The reflected echoes are compared with the emitted pulses. The brain converts these pulses into images so that the animals get a picture of their surroundings without using their eyes. With echolocation, animals can know the distance to an object by measuring the time difference of transmitting and receiving the transmitted pulses (Jones, 2005). Each sperm whale makes different click sounds, so each individual can distinguish its own click sounds from the others. The click sounds produced by sperm whales are not random; each series of sounds belongs to a particular sperm whale (André & Kamminga, 2000).

1.3.1.2 How loud are ships and where does this nuisance come from?

The number of ships on water is increasing tremendously during the last few years. This creates more noise pollution for marine animals. From 1972 to 1999, underwater noise between 20 and 80 Hz increased by 10 decibels. This is not unusual when in this period the number of ships increased from 57,000 to 87,000 in the merchant fleet (Andrew, Howe, Mercer, & Dzieciuch, 2002).

Noise pollution from ships is a fact of life. Over the past 4 decades, ship noise has generally increased by 2.5-3 dB per decade (Chen et al., 2017). For frequencies below 300 Hz, only cavitation causes noise pollution. (Wittekind & Schuster, 2016) Besides cavitation, other important sources that cause noise at ships are the engine, auxiliary generator and propeller. They each have a greater impact at different speeds of the ship. At low speeds, the ship's auxiliary generator in particular will cause noise. When the ship accelerates to a medium speed, the propulsion engine takes over this role (Kozaczka & Grelowska, 2004).

Cavitation is a major cause of noise pollution. There are bubbles on the propeller that explode, when this happens the radial velocity becomes infinite and an infinite pressure is created. The transient pressure pulse along with the explosion of the bubble on the propeller cause the noise. (Harrison, 1952) For most ships, most noise is experienced around 50 Hz. (Wittekind & Schuster, 2016).

When sonar and seismic surveys are carried out, a short intense pulse of sound is released and repeated over and over again. These pulses are used to survey the seabed, detect shipwrecks and shoals of fish. Another function of these surveys is to detect gas and oil in the seabed. Pulses ranging from 20Hz to 500Hz are used to conduct these surveys. Besides survey vessels, there is also the offshore sector. Sounds between 100Hz and 1kHz are generated when oil and gas platforms, bridges and wind turbines are constructed.

The energy peak in this research is in the low (20 Hz) to very high frequency range (500 kHz), depending on the type of survey and bottom depth. Military personnel detect enemy submarines with sonar devices that produce sound with very high intensity at low to medium frequencies. And during pile driving in the construction of bridges, offshore oil and gas platforms and offshore wind turbines, the energy peak is in the lower frequencies, between 100 Hz and 1 kHz. Due to the high intensity of the sound, the lowest frequencies are detectable underwater up to 70 km away. Underwater explosions produce an even higher sound pressure (Doom, Cornillie & Haelters, 2013).

1.3.1.3 The effects of noise pollution on whales

How is the behaviour of Cetaceae now affected by ship noise pollution. In the long run, these marine mammals will avoid certain environments with too much nuisance. This forces the animals to look for a new habitat, this habitat is a second choice and therefore not the most optimal one. Here the habitat will be less favourable, due to less food choice, for example. Another consequence of human noise is the disruption of communication. This has the consequence that mothers may get separated from their young. This may also disrupt the echolocation of the whales. There are also short-term consequences of sound pollution. 36 hours after a routine US Navy training session, 17 beaked whales were stranded (Ziphiidae). The training consisted of testing and training with a particular type of active SONAR, MFAS. After the autopsy, the animals were found to have died from the stranding and not from the SONAR. However, they also found haemorrhages near the ear, brain and fat pads alongside the lower jaw through which the sound waves are transported. The exact significance of these lesions remains unknown. (Doom, Cornillie, Gielen, & Haelters, 2013)

1.3.2 Collisions with vessels

This chapter lists some collisions that have happened in the past. Several species of whales have already been victims of collisions with ships. These collisions can be fatal to the animal, but sometimes the animal survives. This way many collisions have gone unnoticed. Due to the large size of the ship, the crew does not always feel a collision with a whale, and the animal may not have been noticed during the lookout. In many cases, it is only when the ship is in port that one notices a whale on the bow. Usually the animal is collided with and left in the water with injuries; it may then be stranded on the shore (Jensen, Aleria, Silber, Gregory, Calambokidis, 2003).

The National Oceanic and atmospheric administration (NOAA) has created a database compiling all known accidents between ship and whale. Although many accidents are noticed, there are still a huge number of collisions that go unnoticed. When the animal is collided with, the injuries are not necessarily fatal and the animal can still swim on unnoticed. The database goes up to the year 2002, which does not make it up to date. The database starts from the first known collision, which was back in 1930. In 1930, a whale was struck by a stomer in the Pacific Ocean, close to Raratonga. NOAA's database confirmed a total of 292 accidents from ship collisions (Jensen, Aleria, Silber, Gregory, Calambokidis, 2003). It is suspected that from the 1800s, ships were capable of inflicting injuries on marine animals because ships sailed faster from then on. From the time a ship can travel 13-15 knots, it can cause serious injuries to marine mammals, up to even killing them. Ships continued to sail faster and faster, this resulted in more frequent collisions (Laist, Knowlton, Mead, Collet, & Podesta, 2001).

Figure 5: Collision in port Mizushima
Source: (Browne, 2021)

Images of whales lying dead over the bulb of ships are increasingly common in the media. In September 2021, an article came out about a collision at Mizushima port in Kurashiki. According to the article, no one knows how the animal ended up on the bulb and whether the animal was already dead before the collision. It was a Japanese tanker and the crew had not noticed anything while travelling through the Pacific. The animal involved in this case was a species of fin whale. The common fin whale is the most frequently attacked by ships (Browne, 2021).

Figure 6: Beaching of whale in Texel
Source: (Ruiter, 2017)

Stranded whales also occur closer to home. On the Dutch coast, Texel, a whale stranded in 2017. It was a female fin whale that was 23 metres long. The animal was beached in very poor condition, so it must have been dead in the water for a long time. The body was examined and it was found to have died after a collision. Later, reconstruction of the skeleton revealed that eight vertebrae were missing; these would have gone out during a second collision with a ship. This reflects that a collision is not noticed by ships every time and the dead animal may not be discovered until much later ('Fin whale stranded on Texel in 2017 is largest animal on Dutch coast ever', 2022).

1.4 In which locations whales are most affected by ships

It is important to know exactly where Cetaceans are at risk from ships. To do this, the routes of ships must be compared with the routes of the whales.

It stands to reason that the more ships there are in a given place, the more noise is recorded. That is why harbours and straits are locations with a huge amount of underwater noise. A strait is often the passage for many ships in a relatively small area, resulting in a high concentration of ships. A first large-scale noise map was created, representing the underwater noise of the North Sea. This map was made using AIS to determine the amount of ships sailing around and by measuring underwater noise at four different locations. The AIS info and measurements were then compared, creating a map showing the different levels of noise at different locations (Farcas, Powell, Brookes, & Merchant, 2020).

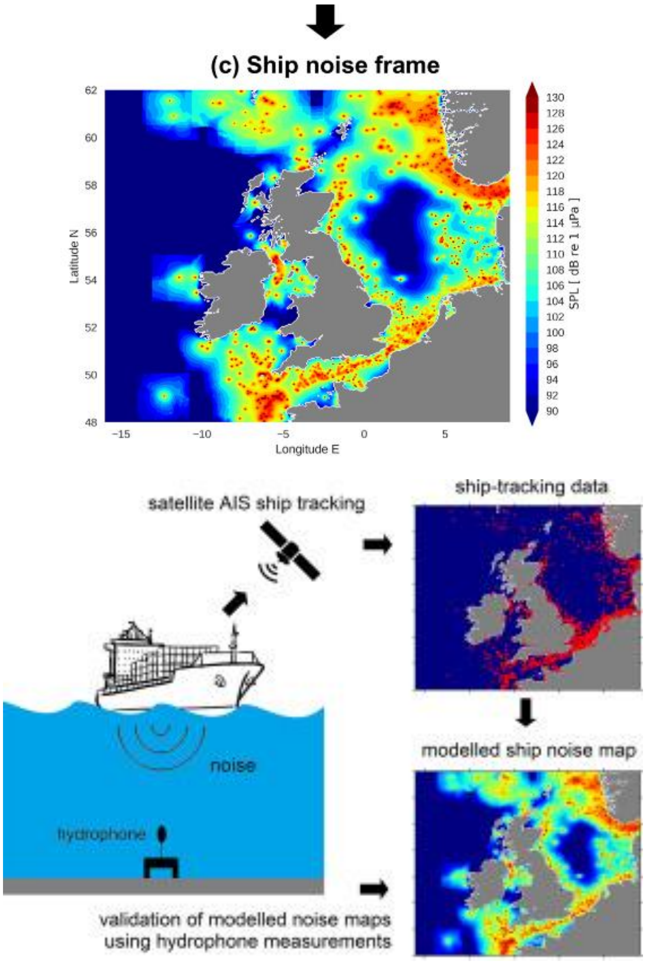


Figure 7: Folder with ship noise level displayed
Source: (Farcas e.a., 2020)

Off the coast of Canada, Seattle, Vancouver and Prince Rupert, underwater noise has been investigated. This zone is Canada's Pacific Exclusive Economic Zone (EEZ). In this study, vessel routes were determined by a geo-referenced database provided by the Canadian Coast Guard's vessel traffic operation support system (VTOSS). The figure shows the accumulated hours of vessel traffic in Canada's EEZ. When two vessels, travelling at the same speed, are navigating the same route at the same time, the time they take to cross a cell will be the same length. The total time of traffic will then be 60 minutes (30 min x 2 ships). This map was made in 2008 and counted a total of 8784 hours of traffic. The cell with the most accumulated hours of traffic had an average of 3 ships for every hour of the year.

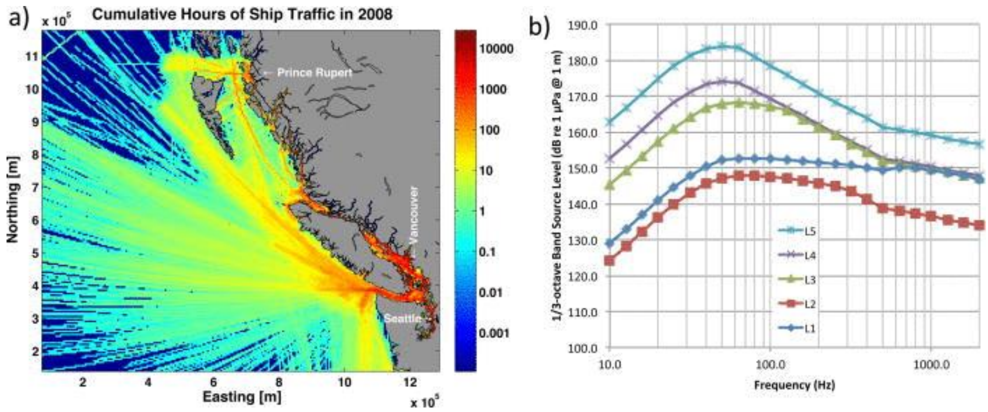


Figure 8: Display of hours of ship noise per area
Source: (Erbe, MacGillivray, & Williams, 2012)

The level of noise coming from the ship depends mainly on the ship's length and speed. As a result, vessels were divided into different groups and the noise map was corrected for each category of vessel (Erbe et al., 2012).

Sperm whales mainly live in the Mediterranean Sea. These animals face the greatest danger in the Hellenic Gorge, near Greece. This underwater valley extends over 50,000 square kilometres along the Greek coast and reaches a maximum depth of 5,267 metres, which is also the deepest point in the Mediterranean Sea (OceanCare, 2019). The Mediterranean sperm whale is an endangered species according to IUCN and is mainly threatened by fishing nets and ship collisions. Between 1992 and 2014, 28 sperm whales stranded on the coast of Greece, of these, 23 were investigated. 12 of these deaths were caused by ship collisions. Three sperm whales were also reported to have died due to collision, but this is in doubt (Frantzis, Leaper, Alexiadou, & Lekkas, 2015).

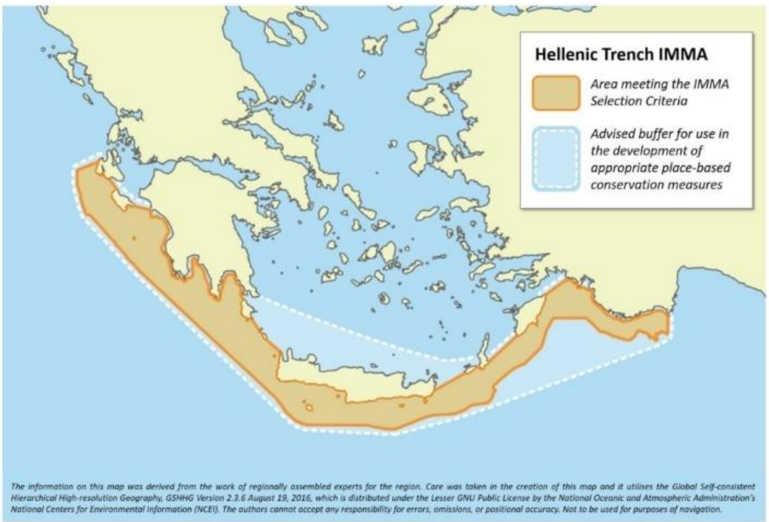


Figure 9: Hellenic trench
Source: ('Hellenic Trench', z.d.)

The whale's route along the Hellenic Valley largely extends over the 1,000-metre draft. Along the island of Zakynthos, many ships sail along the line of this depth, so there is a high possibility of whales encountering ships on their route. This has been investigated and shown on maps. To obtain data from the sperm whales, researchers went on daily departures from a port on sick for sounds and or visible signs of the whales. With the data obtained, a map was made with hotspots of the whales, see image. The coloured circles on the map indicate the amount of sperm whales, red represents more than 20 sperm whales per kilometre, green for 5-20 sperm whales per kilometre and yellow for less than five sperm whales per kilometre. On the map are black circles, these indicate more specific areas; A, B, C and D. To map the density of vessels, AIS data was used. Since AIS is mandatory for ships larger than 300 GT, it is possible to track the largest ships. To display the density of ships on map, the study area was divided into two pieces; north and south. Bringing together vessel density and whale hotspots gives a picture of where sperm whales are most at risk around the Hellenic Valley. For the same purpose, a map was also made with blue spheres indicating the whales' hotspots and the black line of the ships' main route. On this map, it is clearly visible that the routes of whales and ships partially overlap (Frantzis, Leaper, Alexiadou, & Lekkas, 2014).

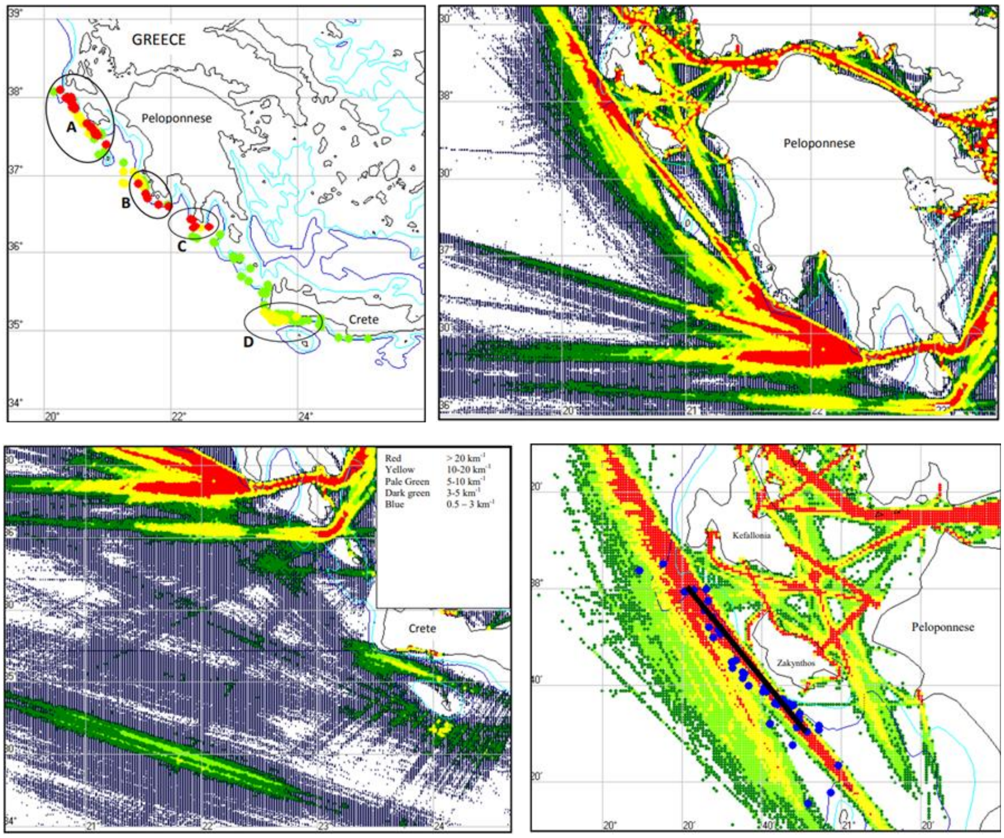


Figure 10: Traffic in the Hellenic traffic
Red >20 km ships sailing per square km per month
Yellow 10-20 km ships sailing per square km per month
Light green 5-10 km ships sailing per square km per month
Dark green 3-5 km ships sailing per square km per month
Blue 0.5-3 km ships sailing per square km per month
Source: (Frantzis, Leaper, Alexiadou, & Lekkas, 2014).

Another highly endangered whale species is the northern right whale (Eubalaena glacialis). This whale has been found in the oceans for more than 1,000 years. By 1900, this whale species was almost extinct due to human hunting during the 16th and 17th centuries. Not only the North Cape was the target of hunters, but also other whale species such as the bowhead whale (Balaena mysticetus).The hunting of whales was done with harpoons, with the purpose to use the oil from the whales in daily human life (Morais et al, 2017).

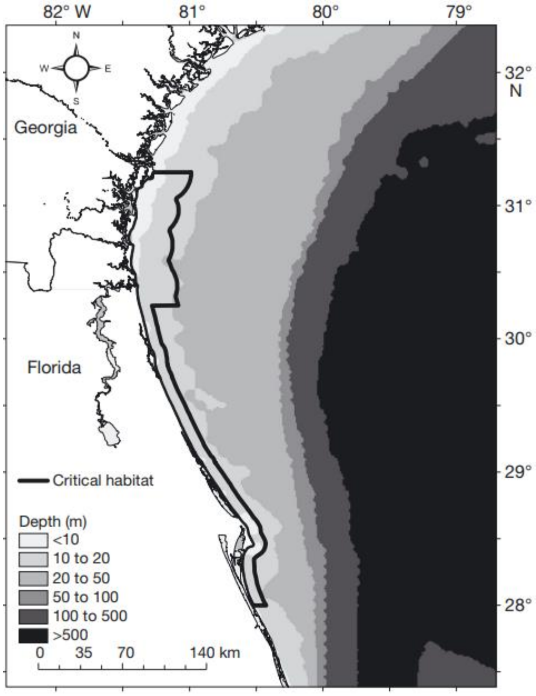


Figure 11: North Cape habitat designation
Source: (Keller, Garrison, Baumstark, Ward-Geiger, & Hines, 2012)

The Northern Cape is mainly located along the coast of the states of Georgia and Florida. At this spot flows the Gulf Stream that comes from the eastern side of the Atlantic Ocean. With the current comes warm water, creating an ideal temperature at this spot for the whale to give birth. The best environment for a whale calf's first years is in water of 13 to 15 degrees at a depth of 10 to 20 metres. Therefore, whales migrate to this environment from December to March (Keller et al., 2012).

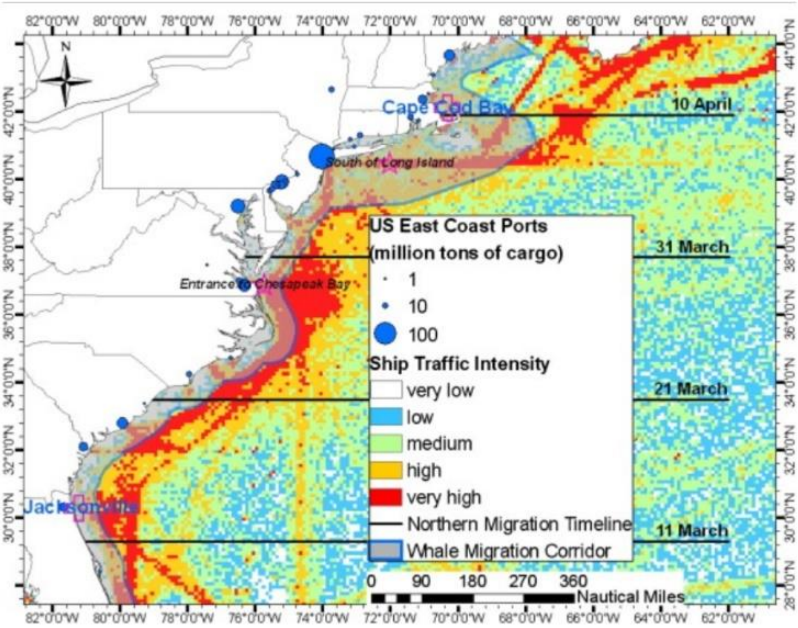


Figure 12: Display ship traffic along the coast of Georgia and FLorida
Source: (Firestone, Lyons, Wang, & Corbett, 2008)

The North Cape migration starts in mid/late March from the coast of Jacksonville to the tip of Long Island (New York). Whales with calves start the migration north several days later than those without calves. During this migration, the whales encounter several major ports, such as Jacksonville, Savannah and Charleston. All these ports create a lot of vessel traffic and thus a lot of inconvenience for the animals. The busiest spots of traffic were mapped as shown in the image. In the image, you can also see the area where the Northern Cape is mainly located during migration. This shows that there are several overlaps between the route of the ships and of the whales (Firestone et al., 2008).

1.5 Solutions for the whales

1.5.1 Potential measures

The easiest measure that can be taken is to reduce the speed of ships. This gives marine mammals more time to swim away. The probability of an animal dying after a collision when the speed is less than 15 knots is less than 70%. This adaptation by ship owners is still proving difficult; this may be due to ship owners' profit mindset. The faster the ships sail, the more trade there is and the more money is made. Although that when ships sail slower there is also less consumption of oil. This will also greatly reduce the cost of the ship and reduce emissions (Ronen, 2011).

Another solution is to divert ships' busiest routes. In the previous chapter, it becomes clear that certain routes of ships overlap with the routes of migrating whales or with the habitat of whales. The North Cape migration period is largely known and this can therefore be anticipated by humans. A TSS can be introduced or shifted to avoid the whales' hotspots, such as the North Cape and the sperm whale, with ships.

1.5.2 Actions already taken

Before solutions can be found to reduce collisions with whales, research needs to be done to know where the problem is. IBM, in collaboration with ProMare, recently released the Mayflower, which is an autonomous research vessel. The goal is for the Mayflower to depart soon from Europe to the United States. During this ocean crossing, the ship will measure the quality of the water and the amount of plastic, among other things. It will also listen to whale sounds (Mayflower, 2021). This may allow us to have a better view of the whales' route, so that this information can be correlated with AIS data showing ships' routes (IBM, 2022).

Some measures have already been taken to decrease whale collisions. For example, the IMO has introduced FSA (formal safety assessment). This is a step-by-step plan to assess the risk to the marine environment and check the costs and benefits of the implied measures. First, the hazard is determined and a risk assessment is made with this. Next, the risk control options are considered and the costs and benefits of the measures are assessed. Finally, IMO gives its recommendations of the findings to the companies. All the measures found during the study using FSA are not mandatorily imposed on the companies. So there is no legislation only suggestions and recommendations. This makes the rules less efficient (Sèbe, Kontovas, & Pendleton, 2019).

Next, speed reduction is a commonly used measure that brings significant impacts. Collisions with whales are not avoided by reducing speed, but the injuries sustained by whales are of lesser magnitude. Whale deaths from collisions are 80-90% less when a speed limit is imposed. In 2008, the U.S. National Oceanic and Atmospheric Administration introduced a speed limit during certain periods to reduce collisions between whales and ships. Ships with a size of 65 feet or larger are imposed a speed limit of 10 knots (Conn & Silber, 2013). This speed limit is most effective at a maximum speed of 15 knots, meaning that the probability of a non-fatal collision accident is minimal at that speed. If the vessel is travelling 15 knots fast, the probability of a fatal accident will be 79 per cent. When a vessel is travelling faster than 15 knots, the probability of a fatal accident will increase rapidly to sit close to 100 per cent (Vanderlaan & Taggart, 2007).

An example of the implementation of rules benefiting whales provides Euronav, the Belgian tanker shipping company. Euronav mandates the implementation of the voluntary rules of the East Coast of Canada, the waters around California and the Hellenic Valley in the 2022 captain's instructions. This requires the captain to follow the measures while travelling through these waters (Euronav, 2022).

Transport Canada is a government agency responsible for Canada's transport policy (Canada, 2021). This organisation has implemented certain rules with the aim of protecting and conserving the endangered North Atlantic whale. As you can see from the image, Canadian waters are divided into different zones, each zone has different rules. For example, there is a fixed speed limit for the static zone for vessels larger or equal to 13 metres during the period from 15 April to 20 October. These vessels are then allowed to travel up to a maximum of 10 knots (Canada, 2022).

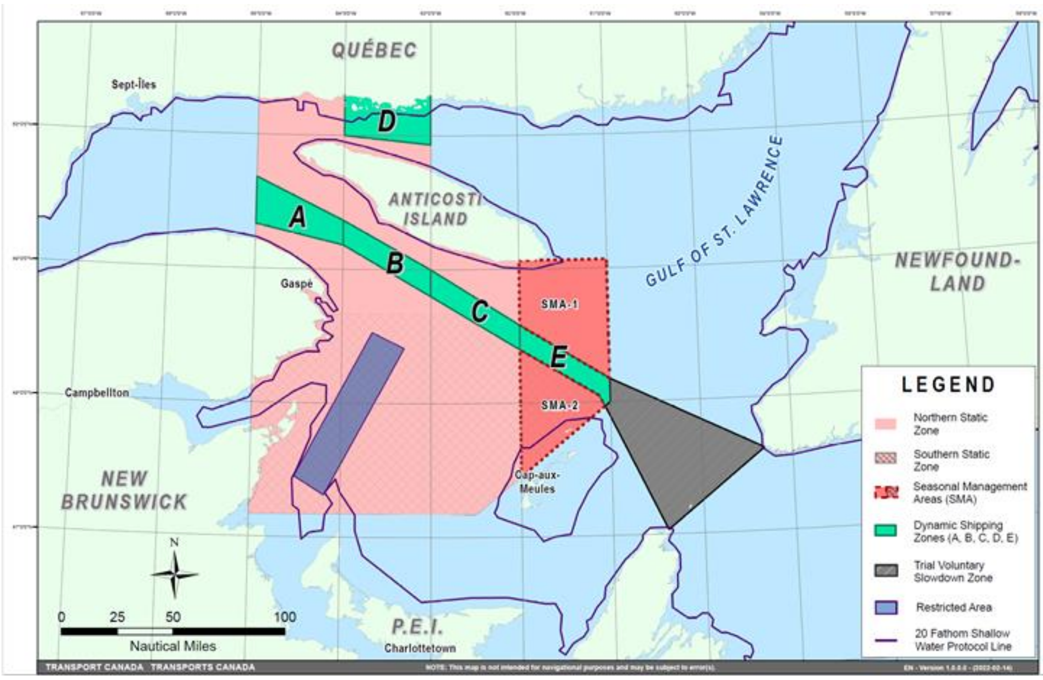


Figure 13: Zones in the Canadian waters
Source: (Canada, 2022)

In the Mediterranean, the focus is on protecting sperm whales (Physeter macrocephalus). These are endangered here, especially around the Hellenic trench is a hotspot for sperm whales. The Greek government is now sending official notices alerting seafarers to the presence of the marine animals. A warning is issued via Navtex, so that a lookout is provided to protect these marine animals and so that one will avoid a collision. This measure by Greece is very recent, since 21 February 2021, with this a first official step has been taken to protect marine animals around the Hellenic Valley ('Greece takes first measures to protect sperm whales from ship collision', 2021).

The Mediterrean Shipping Company (MSC), a major shipping company for container ships in the Mediterranean with a high impact on marine mammals, has decided to modify the route of its ships off the west coast of Greece so that sperm whale habitat would be better protected. This is a huge investment by such a large-scale shipping company that may give other shipowners the same ideas ('MSC Takes Action to Save Endangered Whales in the Mediterranean', 2022).

IMO has established guidelines to reduce underwater noise to a minimum. They are guidelines and therefore not mandatory to implement, these guidelines apply neither to military ships nor to ships that intentionally emit sounds for sonar or seismic activity detection. When designing a new ship, one can have the most influence on a ship's underwater sound. The shape of the hull determines how water flows to the propeller, resulting in less/more underwater noise. In addition, when determining the propeller, one can also look at its effect on underwater noise and thus cavitation formation. Whether the propeller causes much cavitation can be tested at scale in tunnels, thus the propeller can be optimised to cause as little cavitation as possible. The ship should be designed to have as homogeneous a wake-field as possible, the more homogeneous the less cavitation and thus the less noise. Next, the IMO recommends keeping noise caused by machinery on board as low as possible, possibly by vibration isolators. Keeping the ship, hull and propeller generally clean will also reduce underwater noise. Finally, the IMO recommends following different routes and reducing the ship's speed so that the ship will have less impact on the underwater fauna ('Ship noise', 2019).

Many non-profit organization are doing research about the cetaceans to understand these animals better and find a way to help them survive. One of this non-profit organization is the Great Whale Conservancy (GWC). The goal of the GWC is to protect the marine mammals and their habitat, with the emphasis on the blue whale. The organization aims to promote the conservation of whale populations and their habitats through research, scientific studies, and data collection. By understanding the biology, behaviour, and ecology of whales, they work towards effective conservation strategies. The GWC advocates for the protection of whales through public outreach, education, and awareness campaigns. They strive to promote understanding and appreciation of whales and the importance of their conservation among communities, policymakers, and the general public. Furthermore, the organisation actively opposes commercial whaling and advocates for the enforcement of international regulations and laws that protect whales from hunting and exploitation. They work to raise awareness about the ongoing threats faced by whales due to whaling activities. Moreover, the GWC recognizes the significance of preserving and restoring healthy whale habitats. They support efforts to establish protected areas, promote sustainable marine practices, and reduce the impacts of human activities that can harm whales and their ecosystems.

2 Research aim

One of the biggest problems for whales in general is a collision with a vessel. Since humans cannot communicate to the animals to not swim at certain places, the vessels will need to move. For knowing where best the vessels need to sail, an investigation on the routes of the ships and the animals is necessary.

The goal of the broader research is to protect the sea mammals from ship collisions and other disturbances from ships. Looking at the broader picture, this research is meant to save more cetaceans from injuries and dying. When looking further in the future the ultimate goal is to help fight extinction of the sea animals. The extinction is not only the consequence of collisions with ships, but this plays a big part in it. In order to avoid unnecessary interaction between animals and ships, this is necessary to analyse the shipping routes that interact with the whale habitat. This thesis will therefor use a QGIS application to represent the obtained AIS data from Spire Global on a map. After putting all the data on a map, the densest routes will be compared with the data of the routes of the living whales in these areas. These routes of the whales will be obtained by the Great Whale Conservancy.

3 Material and methodology

3.1 Defining the research area

Before starting the research, the investigated area must be defined. The Great Whale Conservancy is monitoring whales in different regions around the world, such as around the ports of Ensenada (in the Northwest of Mexico) and Comodoro Rivadavia (at the east coast of Argentina).

For this research, the area around the port of Comodoro Rivadavia will be investigated. This area is located in the Gulf of San Jorge, Argentina. There are two ports in this area, Comodoro Rivadavia and Caleta Olivia. This first harbour is a medium-sized port with mostly fishing vessels and oil/chemical tankers going in and out. The restrictions of this port are a maximum draught of 10 meters and a maximum length over all of 180 meters ('Comodoro Rivadavia Port', 2023). However, the maximum length of a vessel that has called the port is 146 meters and the maximum draught of a vessel in this port recorded is 8.2 meters. The location of the port of Comodoro Rivadavia is found at coordinates S 45° 51' 21.61" - W 067° 27' 53.98" (MarineTraffic, 2023a).

The second port in this area, the harbour of Caleta Olivia, is also classified as a medium-sized port. The most frequent types of vessels entering this port are fishing vessels and offshore supply vessels. The restrictions of this port are a maximum draught of 20 meters and a maximum deadweight of 160,000 tons ('Caleta Olivia Port', n.d.). However, the recorded maximum draught and deadweight of ships that have entered the port, are respectively 7.8 meters and 74402 tons. Caleta Olivia is located at coordinates S 46° 25' 36.90" - W 067° 28' 31.61 (MarineTraffic, 2023b).

Close to these harbours there are 2 single point mooring (SPM) buoys. Each buoy is connected with an underwater laying pipe to the mainland. These buoys are interesting to investigate as well, as most of the tankers will charge or discharge their fuel/cargo here. Due to this, many of the ship traffic is expected to be centred around these buoys.

The area under consideration has been delineated with the coordinates in Table 1, as represented in the graph of Figure 14 The SPM buoy close to Comodoro is indicated with the red letter A and the SPM buoy close to Caleta Olivia is indicated with a red letter B.

Table 1 Coordinates research area Comodoro Rivadavia
Source: Own work

Coordinates in the Gulf of San Jorge		
Points	**longitude**	**latitude**
Point 1	66.580166 W	46.7122941 S
Point 2	67.5568567 W	46.620971 S
Point 3	67.7015082 W	46.1451224 S
Point 4	67.57163 W	45.43552 S
Point 5	66.610272 W	45.435528 S
SPM buoy Comodoro	67.320278 W	45.774444 S
SPM buoy Caleta Olivia	67.4756412 W	46.4265426 S

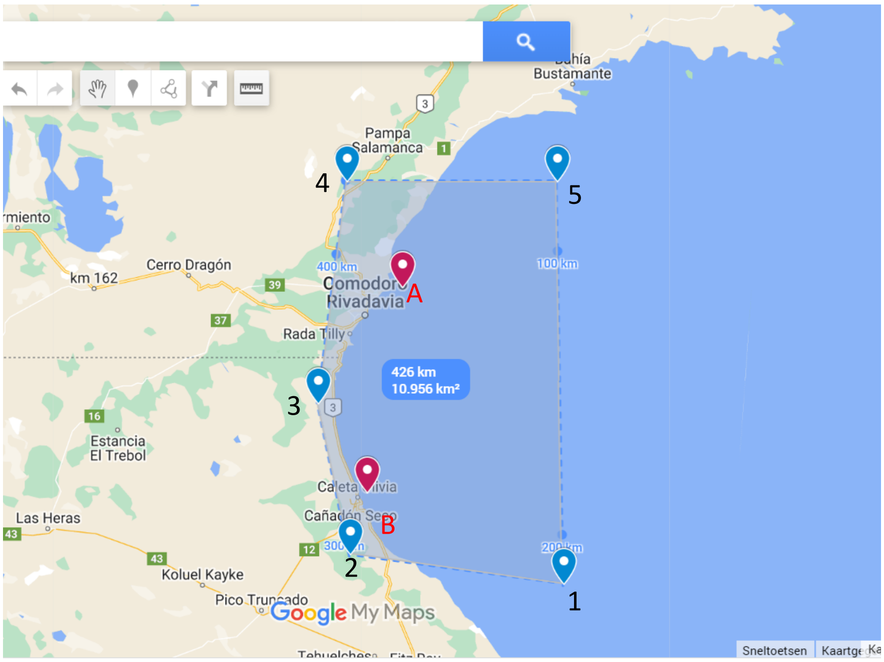


Figure 14 Research area Comodoro Rivadavia
The SPM buoy close to Comodoro is indicated with a red letter A and the SPM buoy close to Caleta Olivia is indicated with a red letter B.
Source: own work

3.2 Presence of whale species around the research area

South America counts almost 30,000 km of coastline and stretches through three different oceans, the Caribbean, the Pacific and the Atlantic Ocean. The area of this research is located along this coastline, at the Patagonian shelf. The waters along this shelf are known for its rich marine biodiversity. In total 44 species of marine animals, including seven species of whales, are living in the waters of the Southwest Atlantic Ocean. This makes the waters a perfect habitat for many animals, but also a perfect location for tourists (Miloslavich et al., 2011). There has been made a list of the cetaceans that were sighted or stranded in the region from Punta Tombo (44° 02' S, 65° 11' W) in Chubut Province, to Caleta Olivia (46° 06' S, 67° 37' W). In total thirteen species, including ten odontocetes and three mysticetes were reported in the area (Reyes, 2006). Next are some examples of the cetaceans that are inhabiting the research area.

3.2.1 Odontocetes

3.2.1.1 Commerson's dolphin

The Commerson's dolphin (*Cephalorhynchus commersonii*) is mostly seen in the area of Patagonia, Tierra del Fuego, Cape Horn and the Falklands Islands. They live in shallow coastal waters at a maximum depth of 200 meters (Garaffo et al., 2011). Figure 15 shows an example of a commerson's dolphin.

Figure 15: Commerson's dolphin
Source:(Wikimedia Commons contributors, 2023a)

3.2.1.2 Dusky dolphin and Peale's dolphin

The Dusky dolphin (*Lagenorhynchus obscurus*) lives in the polar regions of the Southern Hemisphere. The dusky dolphin has been a victim of accidental catches in the coastal and offshore fishery of Argentina (Koen, Alberto, Aníbal, Noemí, & Alberto, 1997).

The Peale's dolphin (*Lagenorhynchus australis*) is mostly seen around the continental shelf of Patagonia, Tierra del Fuego and Chile and also in the deeper waters of channels and protected bays of South Chile. Peale's dolphins are mostly found in forests of kelp, seeking for protection (Goodall & Natalie, 2009).

Figure 16: The Dusky dolphin and Peale's dolphin
(A): Dusky dolphin Source: (Wikimedia Commons contributors, 2020a)
(B): Peale's dolphin Source: (Wikimedia Commons contributors, 2022a)

3.2.1.3 Long-finned Pilot whale

The Long-finned Pilot whale (*Globicephala melas*) occurs in two separated areas, one in the North Atlantic Ocean and the other in the polar waters of the Southern Hemisphere. There have been strandings and sightings of this specie in the Gulf of San Jorge, Isla Tova and Punta Tafor (Reyes, 2006).

Figure 17: Long-finned Pilot whales
Source: (Wikimedia Commons contributors, 2020b)

3.2.1.4 Risso's dolphin

Normally the Risso's dolphin (*Grampus griseus*) will be seen in more warmer and tropical waters, but they are also found along the coast of Argentina, south of the Península Valdés. The habitat of these animals is more offshore in deeper waters, but they inhabit coastal waters as well (Jefferson et al., 2014).

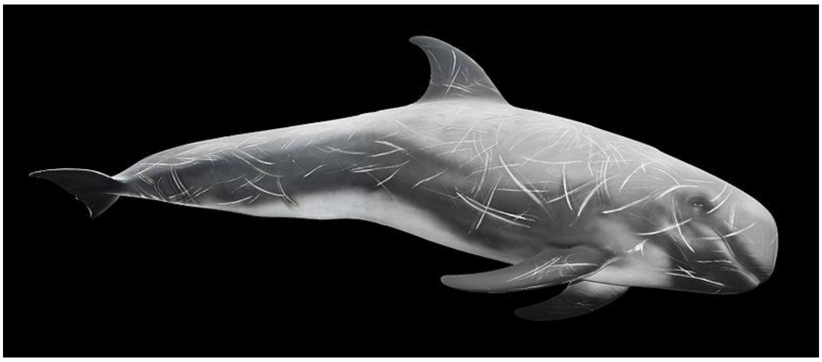


Figure 18: Risso's dolphin
Source: (Wikimedia Commons contributors, 2020c)

3.2.1.5 Mesoplodon grayi and Mesoplodon layardii

The Gray's beaked whale (*Mesoplodon grayi*) is a species of beaked whale found in the Southern Hemisphere. Gray's beaked whales have a circumpolar distribution in the Southern Ocean, mainly occurring in sub-Antarctic and Antarctic waters. They are thought to primarily feed on squid and deep-water fish, diving to great depths in search of prey (Westbury et al., 2021).

Layard's beaked whale *(Mesoplodon layardii*) is another species of beaked whale. Layard's beaked whales have a widespread but patchy distribution, primarily found in the Southern Hemisphere. They are often associated with deeper offshore waters. Similar to other beaked whales, Layard's beaked whales are deep-diving species that spend most of their time in deep oceanic waters (Pinedo, Barreto, Lammardo, Andrade, & Geracitano, 2002).

Figure 19: Stranded Gray's beaked whale
Source: (Wikimedia Commons contributors, 2022b)

3.2.1.6 Killer whale

At the coast of Argentina, the Killer whale (*Orcinus Orca*) can be seen from the most Southern point until Punta Norte. This habitat also includes the research area of this thesis. One of its main feeds is the sea lion (*Otaria flavescens*). This is why many killer whales are seen at Punta Norta, during the breeding season of the sea lions (Otaria flavescens) (Iñíguez, 2001).

3.2.2 Mysticetes

3.2.2.1 Eubalaena australis

The Southern right whale (*Eubalaena australis*) lives around approximately 20 degrees South to 65 degrees South. Península Valdés, located at the coast of Argentina, is a very famous nursing area for these animals. In the winter of the Southern Hemisphere, the Southern Right whale will be breeding in more low latitude regions like Península Valdés (Rowntree, Payne, & Schell, 2020). During the summer of the Southern Hemisphere these animals will travel to feeding areas, located at higher latitudes (Best & Schell, 1996).

Figure 20: Southern right whale
Source: (Wikimedia Commons contributors, 2022c)

3.2.2.2 Antarctic minke whale

The Antarctic minke whale (*Balaenoptera bonaerensis*) occurs only on the Southern Hemisphere. As their name suggests, Antarctic minke whales are found in the waters surrounding Antarctica. They are known to migrate between the colder, polar regions during the summer feeding season and the warmer, more temperate waters during the winter breeding season (Tamura & Konishi, 2009).

3.2.2.3 Sei whale

Sei whales (*Balaenoptera borealis*) have a widespread distribution and can be found in various oceans around the world. They typically inhabit deep offshore waters but may come closer to shore during feeding periods. Their range includes temperate and subtropical regions, although they can also be found in some polar waters (Horwood, 2009). Sei whales are primarily krill feeders, but they also consume small schooling fish, such as herring and sand lance. They use a feeding technique called "lunge feeding" in which they engulf large volumes of prey and water by accelerating forward with their mouths wide open. They then filter the water through their baleen plates, retaining the prey for consumption (Prieto, Janiger, Silva, Waring, & Gonçalves, 2012).

Figure 21: Sei whale
Source: (Wikimedia Commons contributors, 2022d)

3.3 Gathering data

3.3.1 Period of the data

The data were obtained from Spire Global, a commercial company in possession of global AIS data from 2009.

An important factor to consider is the period of the AIS data to collect. The past years have had a big influence on the marine traffic around the world. Because of the Covid pandemic, many cruise vessels could not sail. In the research area of Comodoro Rivadavia there are mostly tankers sailing. The COVID pandemic did not have a significant influence on the tanker industry. This is why the year 2022 was chosen for this area, to obtain the most recent data.

3.3.2 Data content

The data of Spire Global holds a lot of info, although not all the given information is useful for this research. An example of a data set is given in Annex 1.

Firstly, the data consists of identification information from the different vessels. Starting with the Maritime Mobile Service Identity (MMSI), a nine-digit number, and the IMO number, three letters followed by a seven-digit number of every vessel from the data. These two numbers are unique for every vessel and with these numbers of unknown vessels from the data can be found. Other identification information received from the vessels are the name and callsign. Other details about the identity of the ship are collected as the country of the flag the ship is sailing, with other words the country of registration, and the flag code.

Furthermore, the vessels' type is important for this research and can also be gathered from the dataset. The vessels' type is subdivided in five categories: the vessel type, vessel type code, vessel type cargo, main vessel type and sub vessel type. The class of the vessels is specified in the data set as well.

Information about the dimensions of the collected data was obtained in the form of length, width and draught. The length is measured of the bow to the main tower and from the main tower to the stern. The width is the length from the port side of the vessel to the main tower and from the main tower to the starboard side of the ship. The length, width and draught are all given in meters. This information is useful to have an idea how big the influences are from the vessel navigating these waters.

Also, the position and time of every vessel in the data set is given. For the longitude and the latitude, the WGS84 system was used as reference coordinate system. Both longitude and latitude are expressed in decimal degrees. Also, date and time of the last static AIS message in UTC is given in two different ways; YYYYMMDDHHmmSS and YYYY-MM-DD HH24:MI:SS.

Subsequently, figures about the status of the vessel are listed. The speed over ground, course over ground, rate of turn, heading, navigational status and navigational status code. The speed over ground is expressed in knots, the course over ground is given in degrees, the rate of turn is given in degrees/minutes and the heading is given in degrees. The navigational status is expressed by a text, for example, at anchor. Every navigational status has an own navigational status code, given as a number.

Details about the destination and the estimated time of arrival are also found in the data set. The port of destination is defined as a text and the estimated time of arrival as month, day, hour and minute; MMDDHHmm.

As last the source contains more information on how the data is gathered. This is by means of a satellite AIS (S-AIS), terrestrial AIS (T-AIS), or vessel AIS (V-AIS).

3.4 Input of data into QGIS

3.4.1 Import of a map

For this investigation the map did not need to be very advanced. A simple map of the world with clear contours should be sufficient. That is why a map which was already in the QGIS program was adequate. Via the QGIS program there is a world map available of Open Street Map, without installing anything extra. This map was created by replacing the coordinates by the word ‘world’. The box of the coordinates is indicated by a red rectangle on Figure 22. After this, only the contours of the world are shown.

More details can be added to the map through a connection with an Open Street map of the area. A plugin of Open Street Maps is already installed in the QGIS program and can be found in the browser. The browser tab named *XYZ Tiles* provides a connection with the Open Street map, as indicated with a green rectangular on Figure 22. After opening the open street map, a simple map of the world will appear, as seen on Figure 22.

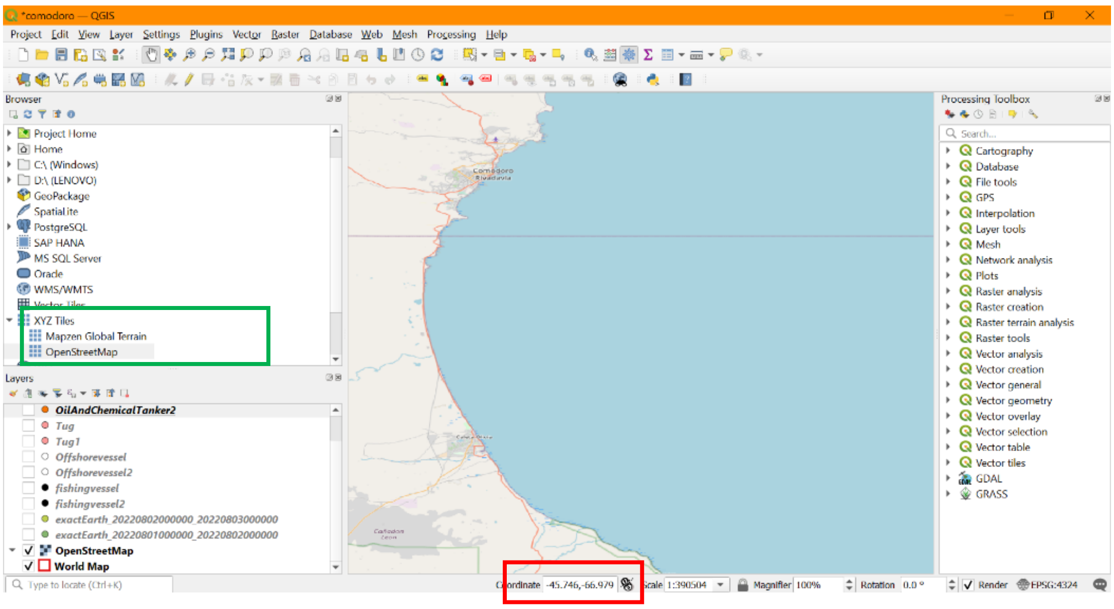


Figure 22 Result after imputing the world map and open street map Example map Comodoro Rivadavia
The red rectangular indicates where the coordinates are in the QGIS program. The green rectangular indicates where the open street map is located.
Source: Own work

3.4.2 Importing data

For importing the AIS data from Global Spire, the data needed to be in the form of a csv file. Adding these files was done by selecting 'layer', 'add layer' and then 'add delimited text layer'. When selecting add delimited text layer an extra tab will open, like in Figure 23. After selecting the file in this tab, some settings needed to be changed. Firstly, at the file format, the correct separating value was set to have a comma as separating sign. Secondly, record and fields options were selected. For the files of this research 'First record has field names', 'detect field types' and 'Decimal separator is comma' were selected and 'Number of header lines to discard' was set to zero. For the Geometry Definition, point coordinates have been selected with the X field corresponding to longitude and the Y field to latitude. For the Geometry CRS, 'EPSG: 4326 – WGS 84' was selected. For the layer settings, nothing was selected. A check of whether all settings were correctly adapted was always performed using the data sample shown by the QGIS programme itself. All these steps are illustrated in Figure 23.

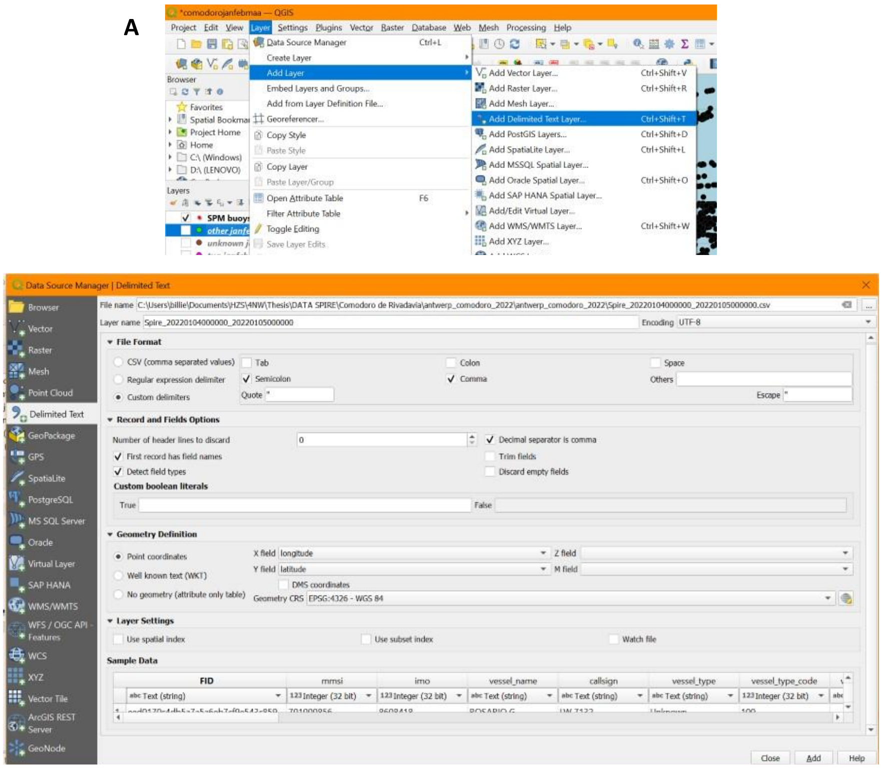


Figure 23 Procedure to import a csv file into the QGIS programme.
(A): Instructions for opening the Data source manager
(B): Selections for importing the delimited text file
Details are explained in the main text.
Source: Own work

Using the same method, a small csv file with the coordinates of the two single point buoys was added to the QGIS. On the map these two SPM buoys are indicated with a red star ().

3.4.3 Making different maps per category

To have a clearer view of which type of ships are causing the most problems for the animals, the maps were divided into different maps for every type of vessel. For making all maps clearer different colours were used for every type, as in Table 2. The Great Whale Conservancy uses their own standard set of colours for different species of whales. The remaining colours such as orange, pink, black, brown and white were therefore chosen for ships that occur a lot. Purple, green and yellow were chosen for ships that do not occur a lot in the data set.

Table 2 Legend type of vessels
Source: Own work

Type vessel	**Colour**
Tanker	Orange
Tug	Pink
Fishing vessel	Black
Pilot	White
Other	Green
Unknown	Brown
Vessel with anti-pollution equipment	Yellow
Law enforcement	Purple

When the data set had been imported into the QGIS system, different maps were plotted. Firstly, the attribute table of the layer of the imported data was opened by a right click on the layer. When the attribute table is opened, a field filter must be put on the column of the vessel's type. When selected one filter, for example 'tug', only the tugs will be shown in the attribute table. When closing the attribute table, all the tugs will be highlighted by yellow dots. Now these tugs have been saved as a different layer. This has been done for every type of vessel, which results in different layers per type of vessel, per month. As a result, a map with different colours per type of vessel is created.

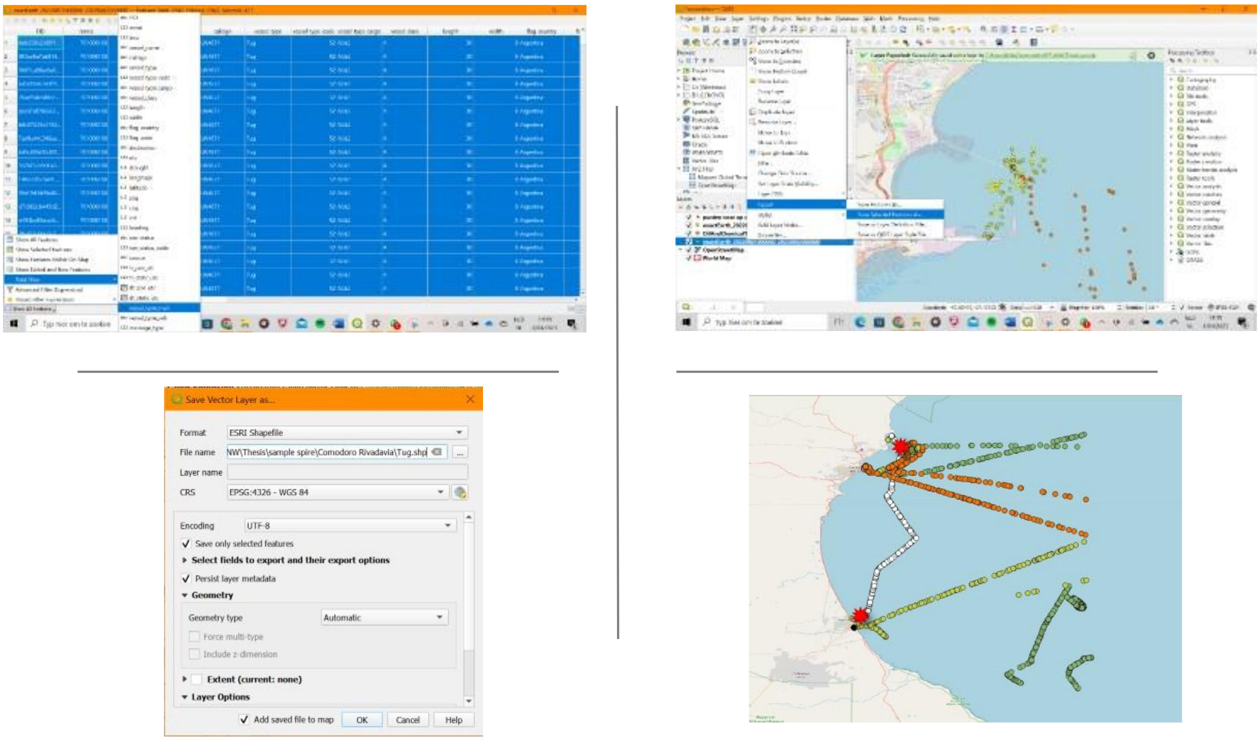


Figure 24: QGIS examples
Source: Own work

3.5 Help with interpretation of the data

To have the best interpretation of the data possible, there were discussions with Michael Fishbach, the founder of the GWC and an interview with César Augusto Gribaudo. César lives in Caleta Olivia, which is located in the research area.

Michael Fishbach is a passionate advocate for the protection of large whales, particularly blue whales. He began his career as a professional tennis player before shifting his focus to conservation efforts. Fishbach founded Vermont hiking tours and later sold the company, after which he started studying Beluga whales with a research group called GREMM. This led him to study blue whales with Richard Sears at the Mingan Island Cetacean Study.

For the past twenty years, Fishbach has been leading eco-tour research trips to the Sea of Cortez in January to March to study blue whales. In 2010, he co-founded the Great Whale Conservancy (GWC), a non-profit organization committed to preventing unintentional whale deaths caused by marine shipping and traffic. Fishbach believes that ship strikes pose the most urgent threat to large whales and advocates for practical solutions to reduce whale mortality.

César Augusto Gribaudo is a museologist that lives in Caleta Olivia. He is doing research about the cetaceans in the Gulf of San Jorge. Because César lives in Caleta Olivia, he knows the structure of the ports and the most recent situation of the cetaceans and the vessel traffic.

4 Results and discussion

4.1 Overview of the ships around Comodoro Rivadavia

4.1.1 Unknown vessels

The first group of vessels that were studied were the ones labelled as “unknown”, in order to add them to other categories where possible.

The unknown vessels are vessels that had not been characterised in the received dataset. However, because the data contained also the IMO number and the MMSI number of every ship, the types of these unknown vessels could be identified. This could be easily done by searching for the vessels on the site of Marine Traffic.

On Figure 25(A), there are five different unknown vessels, named: Calandria, Rigel 1, Alondra, Orion 2. Rosario. Calandria, Rigel 1 and Alondra are all pilot vessels, while Orion 2 and Rosario are fishing vessels.

On Figure 25(B) are 11 different vessels of type unknown, named: Calandria, Baffetta, El Chalten, Sagrario, Rigel 1, Altar, Alvarez Entrena 1, Trabajamos, Don Augustin, Misal and Pensacola 14H. Calandria and Rigel 1 are pilot vessels. El Chalten is an offshore tug supply vessel and is categorised as ‘other’ in this research. Sagrario, Altar, Alvarez Entra 1, Trabajamos, Don Augustin, Misal and Pensacola are all fishing vessels. The type of Baffetta was not found on Marine Traffic, or any other website. After looking at the pattern of the ship, it seemed to be a fishing vessel. Another reason to assume Baffetta is a fishing vessel is by looking at the destination of this ship. The destination was always ‘pto. Cro. Riuadovia’ or ‘zona de pesca’, which means fishing zone.

On Figure 25(C) are only three different unknown vessels, named: Calandria, Baffetta and Rigel 1. As seen before, Calandria and Rigel 1 are pilot vessels. Baffetta is, as described above, most likely a fishing vessel.

On Figure 25(D) four different vessels, categorized as unknown were found, named: Altar, Baffetta, Calandria and Rigel 1. Rigel 1 and Calandria were found to be pilot vessels. Altar a fishing vessel and Baffetta, again, also most likely a fishing vessel.

After defining all the unknown vessels, this category can be eliminated. The following categories are modified to the last version, included with all the ships from the group ‘unknown’.

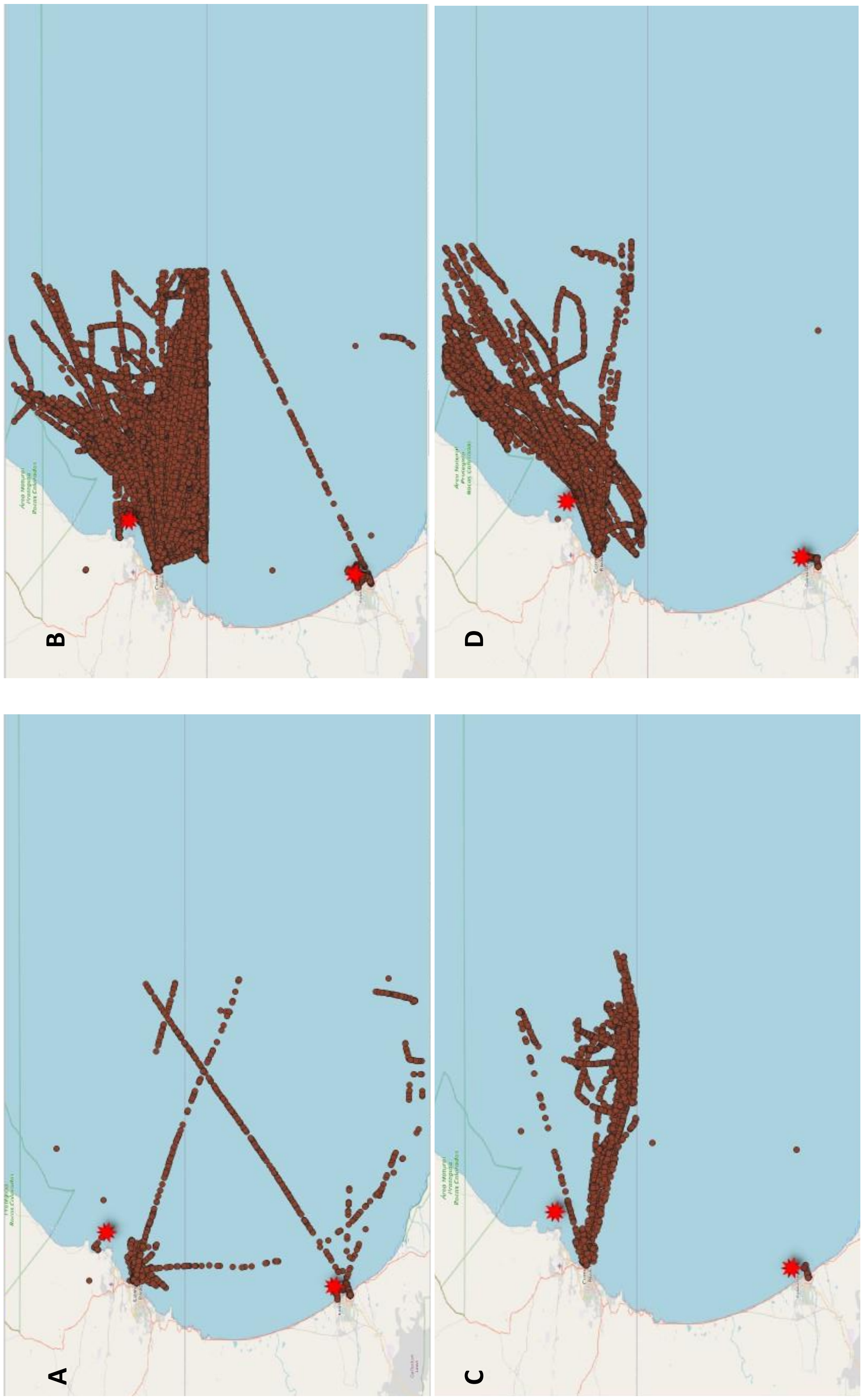


Figure 25: Distribution of the unknown vessels in the area of Comodoro Rivadavia of the year of 2022, per three months. All four maps are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of all unknown vessels during the months January, February and March.
(B): Distribution of all unknown vessels during the months April, May and June.
(C): Distribution of all unknown vessels during the months July, August and September.
(D): Distribution of all unknown vessels during the months October, November and December.
Source: Own work

4.1.2 Other vessels

After investigating the section *other*, the ships could be divided in fishing vessels, Offshore Tug Supply Ship and fishery patrol vessels. For the whole year of 2022 only three different ships were combined in the category 'other'. The first vessel in this category was El Chalten. Because the MMSI number is also part of the data, the details of this ship could be found on the internet, which led to the identification of El Chalten as an Offshore Tug Supply Ship. The second vessel is named Mar Argentino. This ship is a fishery patrol vessel. The last one is named Alvarez Entrena 3, which is a fishing vessel.

This explains the somewhat weird pattern of the vessels on Figure 26(C,D). The fishery patrol vessel has a very irregular route, because it sails through the fishing zones, without actually fishing. Subsequently, the fishing vessel was added to the other fishing vessels and the fishery patrol vessel received its own category.

In the end, the category 'other' only content offshore tug supply ships. Offshore supply ships are seagoing tugs. These types of vessels can be used for multiple reasons, for example salvaging, towing, anchor handling in the offshore, environmental service and assisting ships with engine trouble. After taking a closer look at the SPM buoys, it is clear that the offshore tug supply ships are handling around these buoys, an explanation for this is that the seagoing tugs are helping the arriving and departing tankers to make a connection with the SPM buoys. Since there are multiple tracks from one SPM buoy to the other, it seems that the same offshore tug supply ship is used for both buoys.

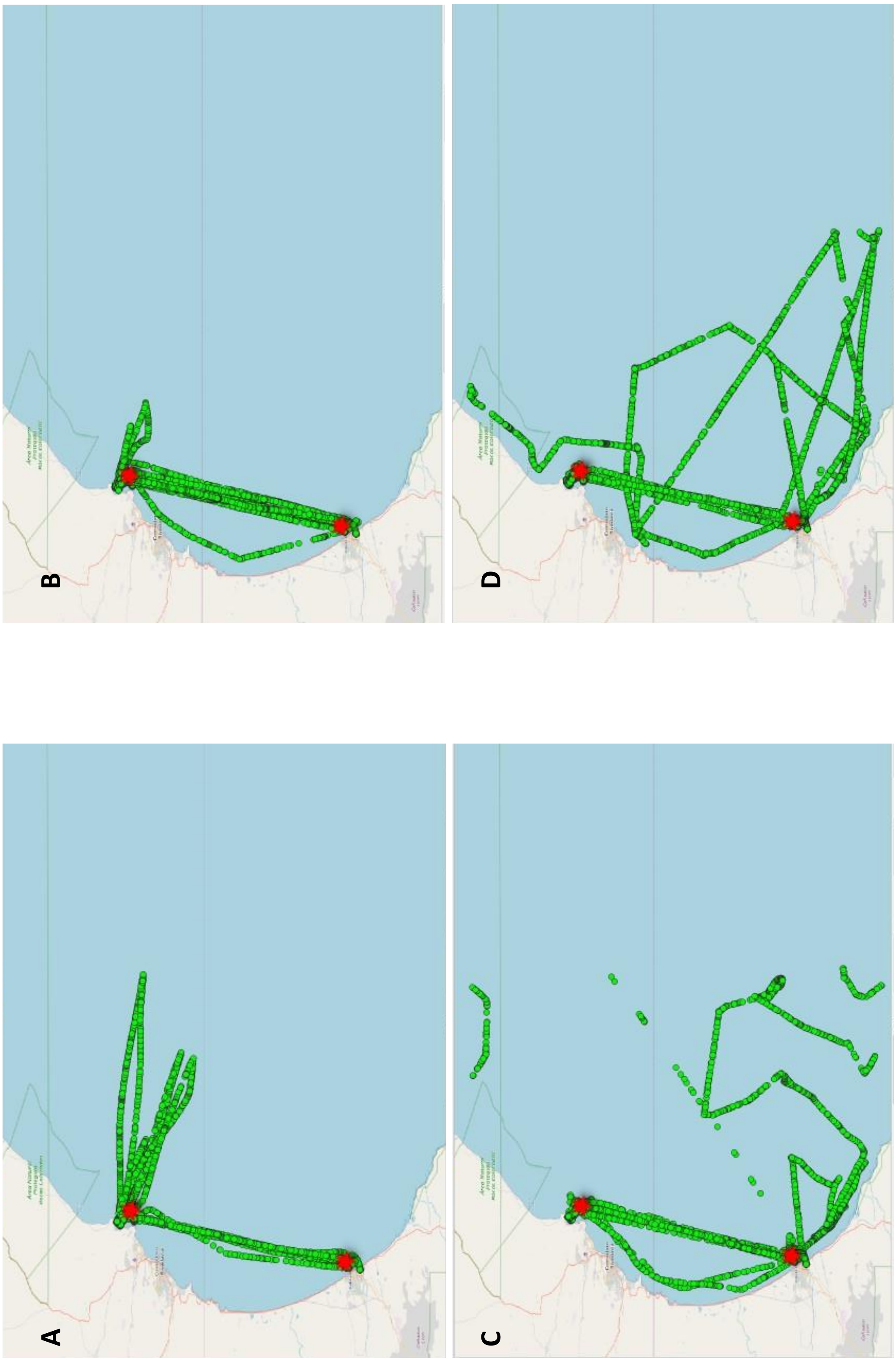


Figure 26: Distribution of the other vessels in the area of Comodoro Rivadavia of the year of 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of all other vessels during the months January, February and March.
(B): Distribution of all other vessels during the months April, May and June.
(C): Distribution of all other vessels during the months July, August and September.
(D): Distribution of all other vessels during the months October, November and December.
Source: Own work

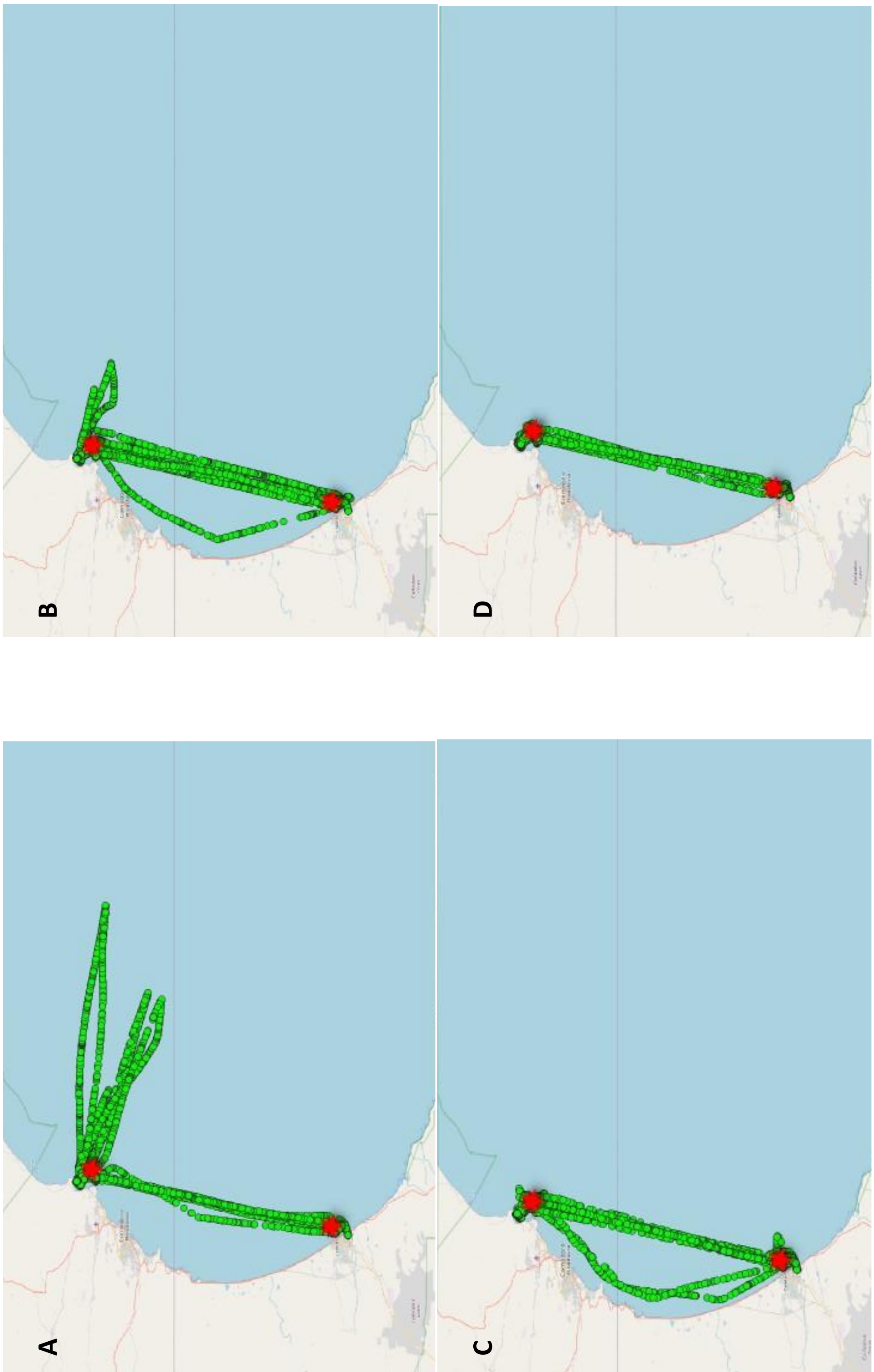


Figure 27: Distribution of the other vessels in the area of Comodoro Rivadavia of the year of 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of all other vessels during the months January, February and March.
(B): Distribution of all other vessels during the months April, May and June.
(C): Distribution of all other vessels during the months July, August and September.
(D): Distribution of all other vessels during the months October, November and December.
Source: Own work

4.1.3 Tankers

Looking at Figure 28, it can be concluded that during the whole year many tanker vessels are traveling in the area of Comodoro Rivadavia. The majority of the tankers is navigating these waters during the months July, August and September. According to César Augusto Gribaudo the average arriving and departing tankers is about the same all year.

The two red stars represent the two SPM buoys laying in front of the coast. As expected, the majority of the tanker vessels sail to these buoys. Another remarkable phenomenon is that almost no tanker sails from one buoy to another. The ships sail only to one of the two SPM buoys.

A Single Point Mooring (SPM) buoy is a floating device used in offshore oil and gas operations to facilitate the transfer of crude oil or other petroleum products between a tanker vessel and an onshore facility. It serves as a secure and flexible connection point for the vessel during the loading or unloading process. An SPM is usually present at ports that are not equipped to receive large tankers. The SPM buoy is anchored to the seabed using mooring lines, which provide stability and keep the buoy in position. The buoy itself consists of a buoyant structure on the surface, often with a turret system that allows it to rotate with changing wind and current conditions. The buoy is equipped with various systems and equipment to handle the transfer of fluids. These typically include flexible hoses or subsea pipelines that are connected to the submerged parts of the buoy. These connections allow for the flow of oil or gas between the vessel and the onshore facility. Mooring lines are attached to the buoy and are secured to anchors on the seabed. These mooring lines provide the necessary tension and stability to keep the buoy in position despite external forces such as waves, currents, and wind. When a tanker or vessel arrives at the SPM buoy, it approaches the buoy's mooring point. The vessel's bow is typically connected to the buoy via a hawser or a mooring line. This connection keeps the vessel in place relative to the buoy, allowing for safe and controlled fluid transfer. Once the vessel is securely moored to the buoy, the fluid transfer operations can begin. Oil or gas is pumped from the vessel's storage tanks through the hoses or pipelines connected to the buoy. The fluid flows to the onshore facility or vice versa, depending on whether it is loading or unloading operations (Wichers, 2013).

Besides the two buoys as destination, many tankers are concentrated in front of the port of Comodoro Rivadavia. César Augusto Gribaudo explained in the interview that this area is served as a waiting area for the tankers, before they can make a connection to the SPM buoy. This area can have a big effect on the cetaceans if this same area is inhabited by them. These waiting areas are clearer on Figure 29 and on Figure 30.

The biggest tanker that came into the research area is named Kanaris 21 and is 277 meters long and 48 meters wide. At least one ship of more than 270 meters entered the research area every trimester of the year at.

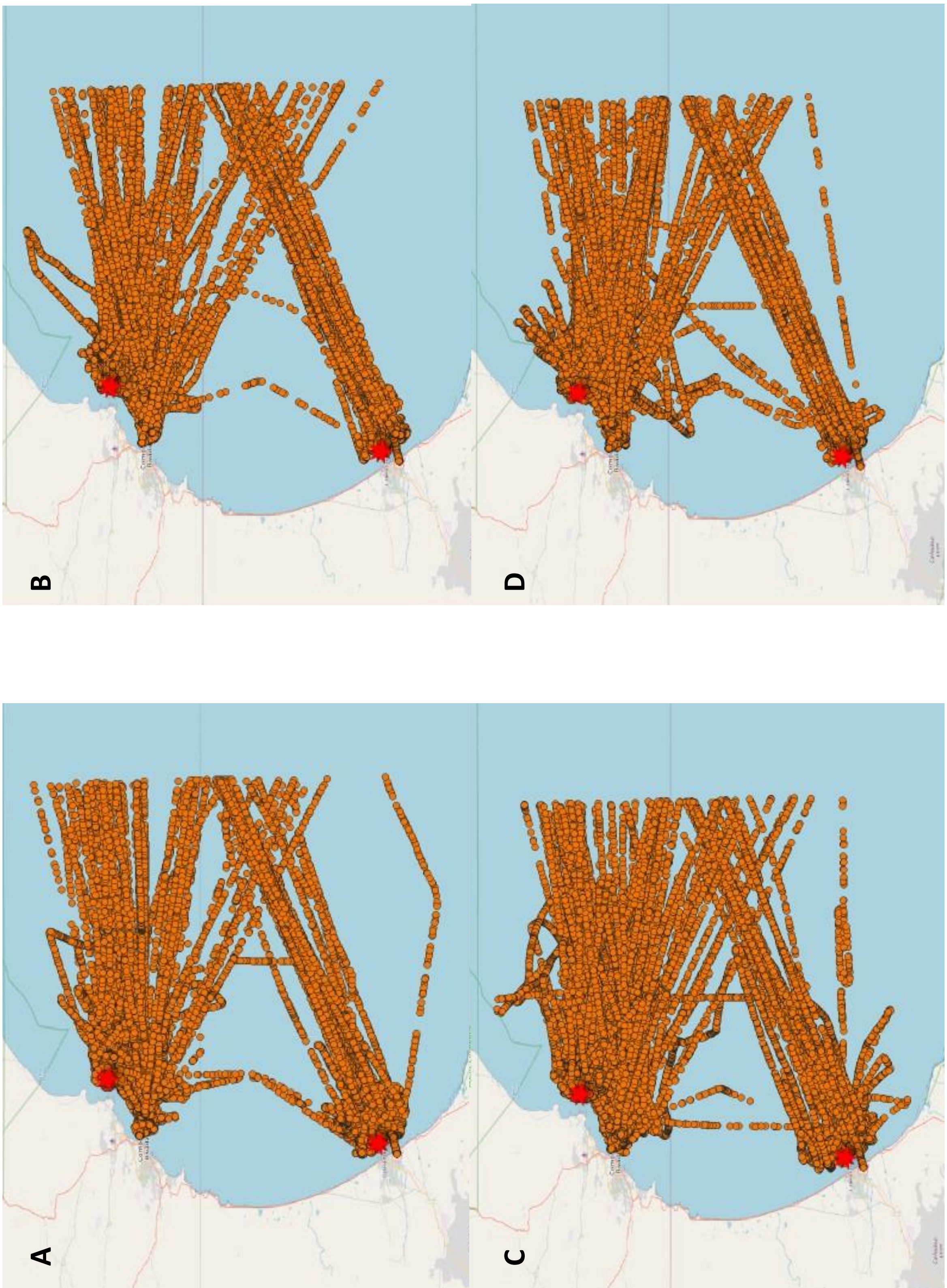


Figure 28: Distribution of tanker vessels in the area of Comodoro Rivadavia of the year 2022, divided per three months. All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of all tankers during the months January, February and March.
(B): Distribution of all tankers during the months April, May and June.
(C): Distribution of all tankers during the months July, August and September.
(D): Distribution of all tankers during the months October, November and December.
Source: Own work

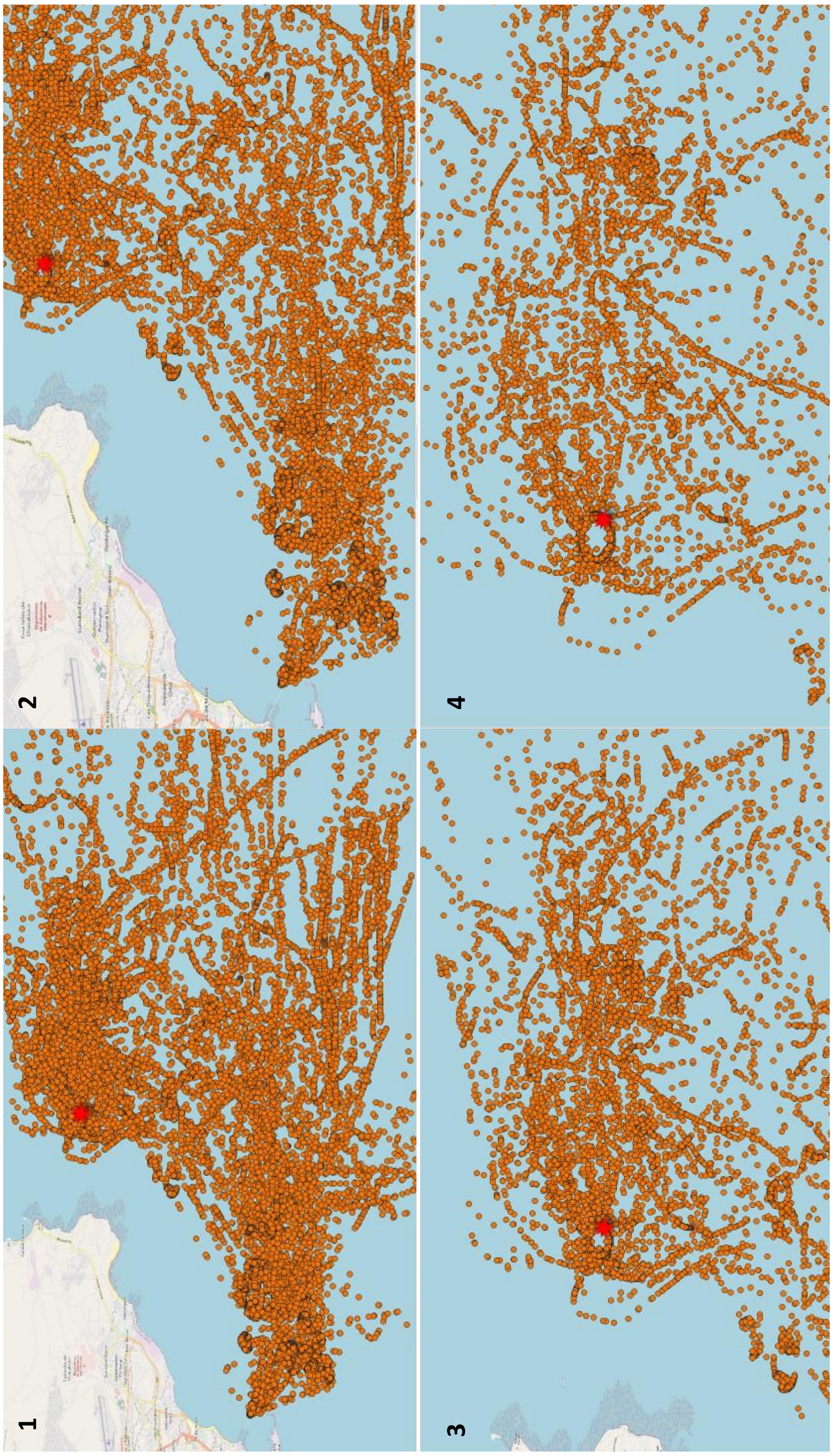


Figure 29: Closer look at the distribution of tanker vessels in the area of Comodoro Rivadavia of January, February and March.

The two red stars represents the SPM buoys.

(A): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia during the months January, February and March at scale 1:70 000

(B): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia during the months January, February and March at scale 1:50 000.

(C): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia during the months January, February and March at scale 1:35 000.

(D): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia during the months January, February and March at scale 1:25 000.

Source: Own work

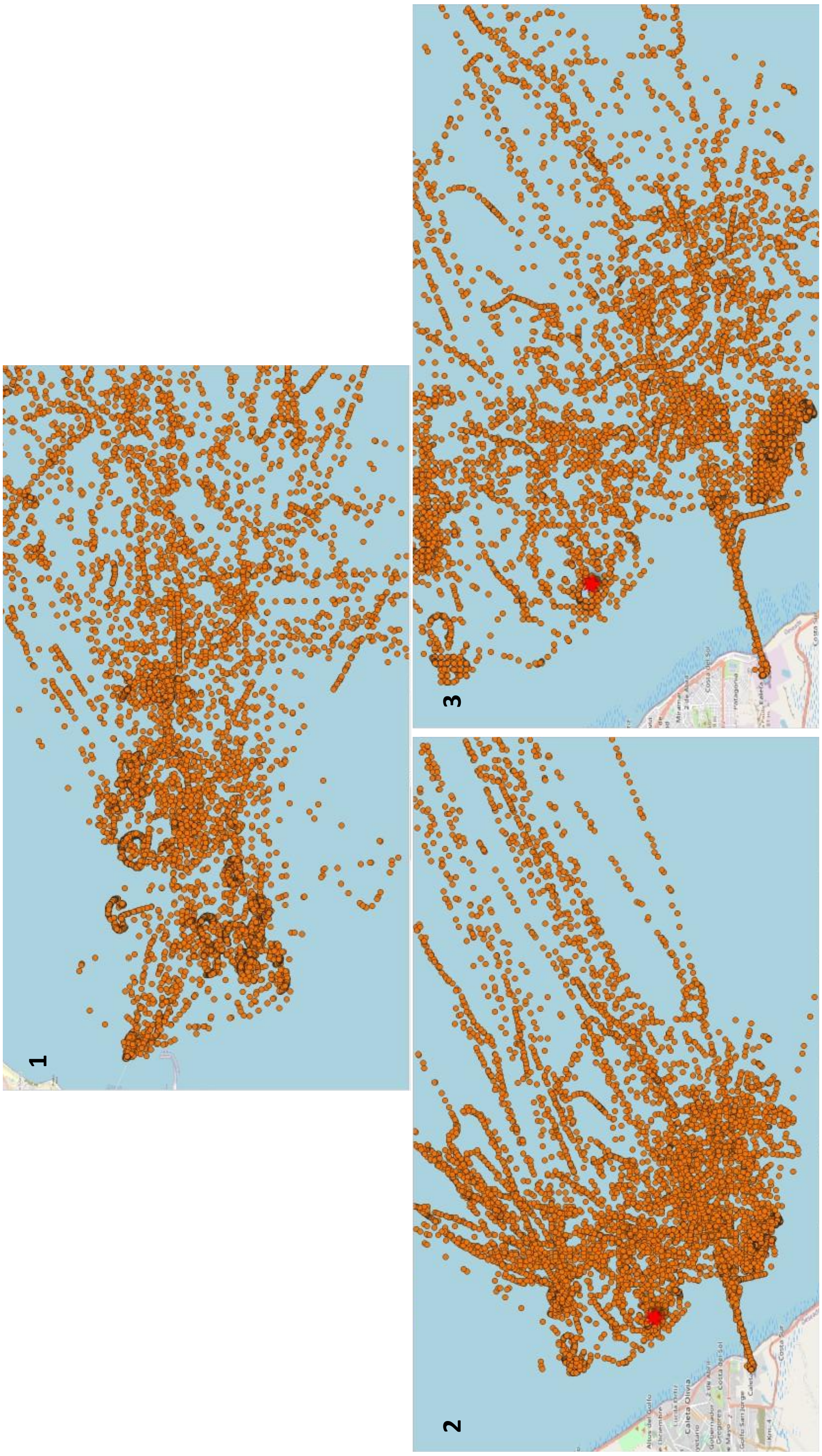


Figure 30: Closer look at the distribution of tanker vessels in the area of Comodoro Rivadavia of January, February and March.
The two red stars represents the SPM buoys.
(A): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia at scale 1:70 000
(B): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia at scale 1:50 000.
(C): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia at scale 1:35 000.
(D): Distribution of the tankers in the area of the port and SPM buoy of Comodoro Rivadavia at scale 1:25 000.
Source: Own work

4.1.4 Tugs

When observing Figure 31, it seems that during the winter of the Southern Hemisphere, there are more tugs than during the summer. A possible explanation is, that during wintertime the weather can be very harsh, resulting in a rough sea state. When the sea is turbulent, more tugs are needed to handle the ships and to handle the connection pipeline.

In addition, when the weather is too violent, the tankers need to wait before they can be connected to the SPM buoys, so the tankers need to go to an anchorage. In this case a seagoing tug can be used for assistance.

Another observation is that the tugs travel from one port to another, this can be the result of using the same tugs for both ports.

On Figure 31(B,D) are tracks of tugs that seem to go or come from the open ocean.

On Figure 32 the highlighted dots are the tracks of tugs that enter or leave the area of Comodoro Rivadavia. On Figure 32(A) this is the tug called 'Tauro'. In April this tug entered the port of Comodoro Rivadavia and in June it left again. This could be concluded by looking at the destination of this tug. The port of destination in June was Puerto Deseado. Puerto Deseado is located around ten degrees more South than Comodoro Rivadavia.

On Figure 32(B) the highlighted dots are from another tug called 'Ram Mapuche 1'. This tug entered and left the harbour in the same month, October. This tug had as destination the port of Ushuaia. Ushuaia is located in the South tip of Argentina. It seems that this tug just came for one night to cover the long journey.

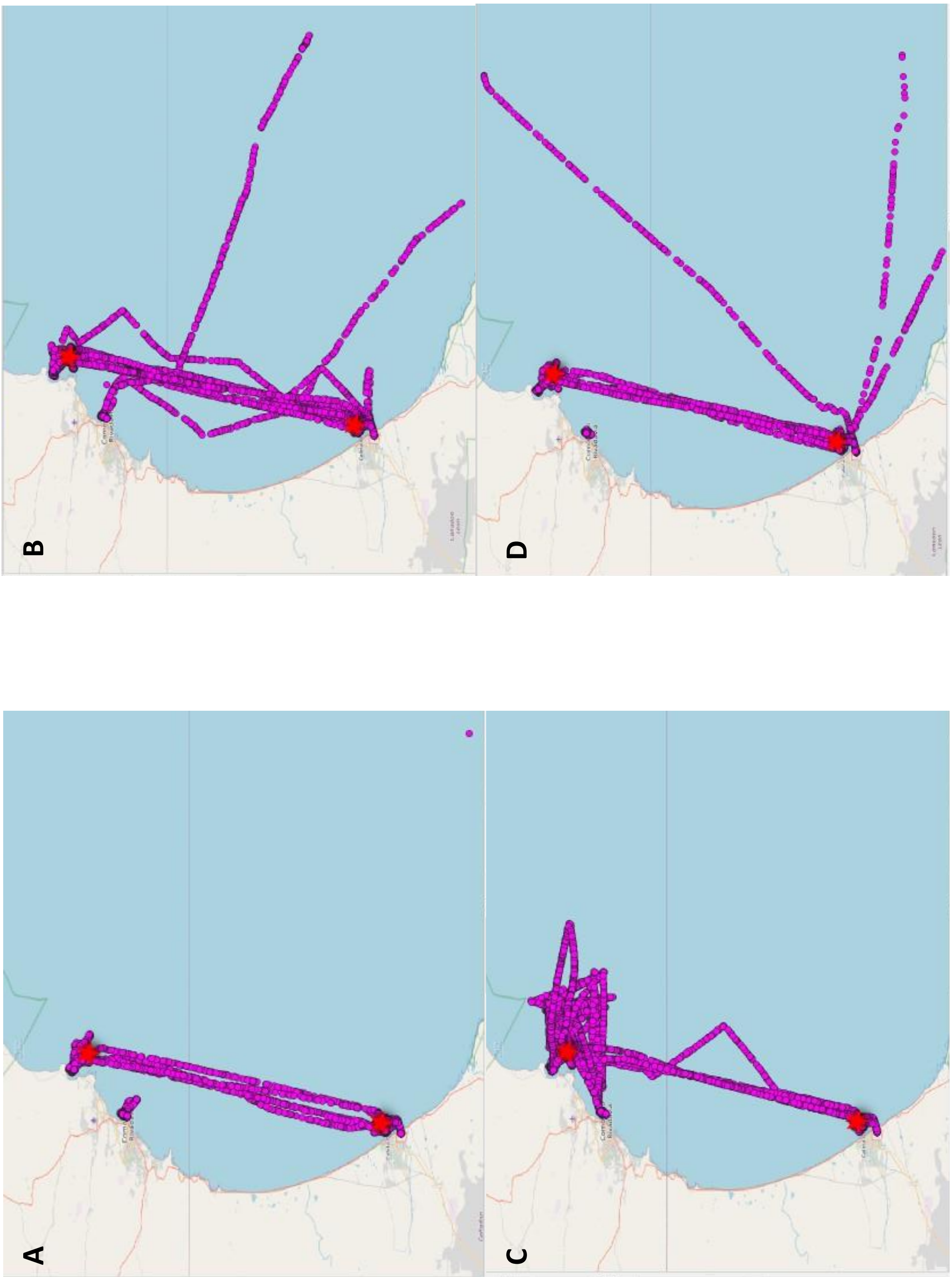


Figure 31: Distribution of tugs in the area of Comodoro Rivadavia of the year of 2022, divided per three months. All four pictures are at scale 1:400 000. The two red stars represents the SPM buoys.
(A): Distribution of all tugs during the months January, February and March.
(B): Distribution of all tugs during the months April, May and June.
(C): Distribution of all tugs during the months July, August and September.
(D): Distribution of all tugs during the months October, November and December.
Source: Own work

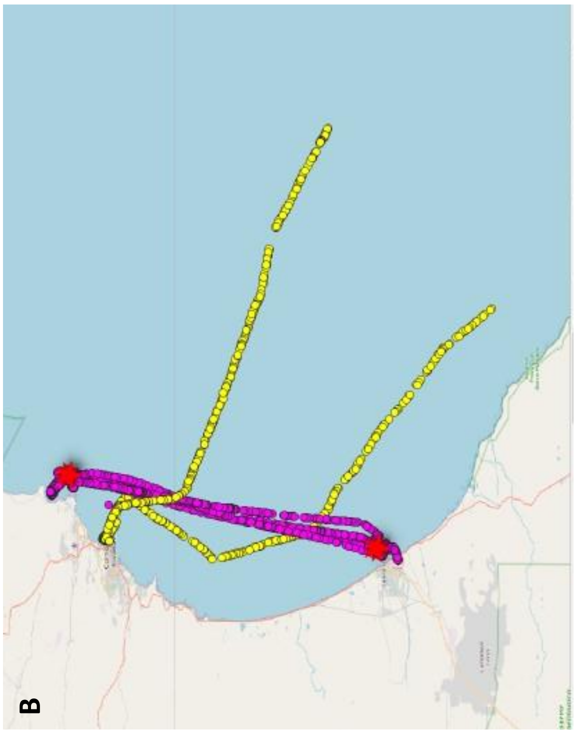


Figure 32: More detailed look to the distribution of tugs in the area of Comodoro Rivadavia during the months April, May, June, October, November and December of the year 2022.
The two red stars represents the SPM buoys. Both pictures are at scale 1:450 000.
(A): Distribution of tugs during the months April, May and June. The highlighted tracks are from a tug called 'Tauro'.
(B): Distribution of tugs during the months October, November and December. The highlighted tracks are from a tug called 'Ram Mapuche 1'.
Source: Own work

4.1.5 Fishing vessels

As can be seen on Figure 33, many fishing vessels are active in the waters of Comodoro Rivadavia. A lot of fish is being processed in different plants located in Comodoro Rivadavia. These plants are positioned close to the seaport, to have a direct connection with the fishing vessels (Yorio & Caille, 2004).

On Figure 33(A,B) it seems that there are more fishing vessels active than on Figure 33(C,D). During the months January until June, there are therefore more fishing vessels in the research area than during the months July through December. An explanation for this phenomenon can be found in the difference of weather conditions during the different seasons. Maybe one season there are more fish present than other seasons.

The maximum length of all fishing vessels from the dataset of Spire Wire was 55 meters. In comparison with a tanker vessel of 200 meters a fishing vessel can be regarded as negligible. But in comparison with a whale of 10 meters, these fishing vessels still have an impact on the cetaceans. Not only when a collision happens, but also when fishing and sailing in an area where sea animals are swimming. Ships create a lot of noise pollution when sailing and with the fishing gear during fishing operations, that can have an effect on these sea animals.

To have a clearer image of where exactly the fishing vessels are fishing, a filter on the data was put. The speed of the fishing vessels was filtered so only vessels with a sog of maximum five knots are shown on Figure 34. The highly concentrated areas should be the areas where most vessels are fishing. This is important to know, because ships that are fishing cannot be regulated into one route. When fishing, the ships will make very irregular movements through the area.

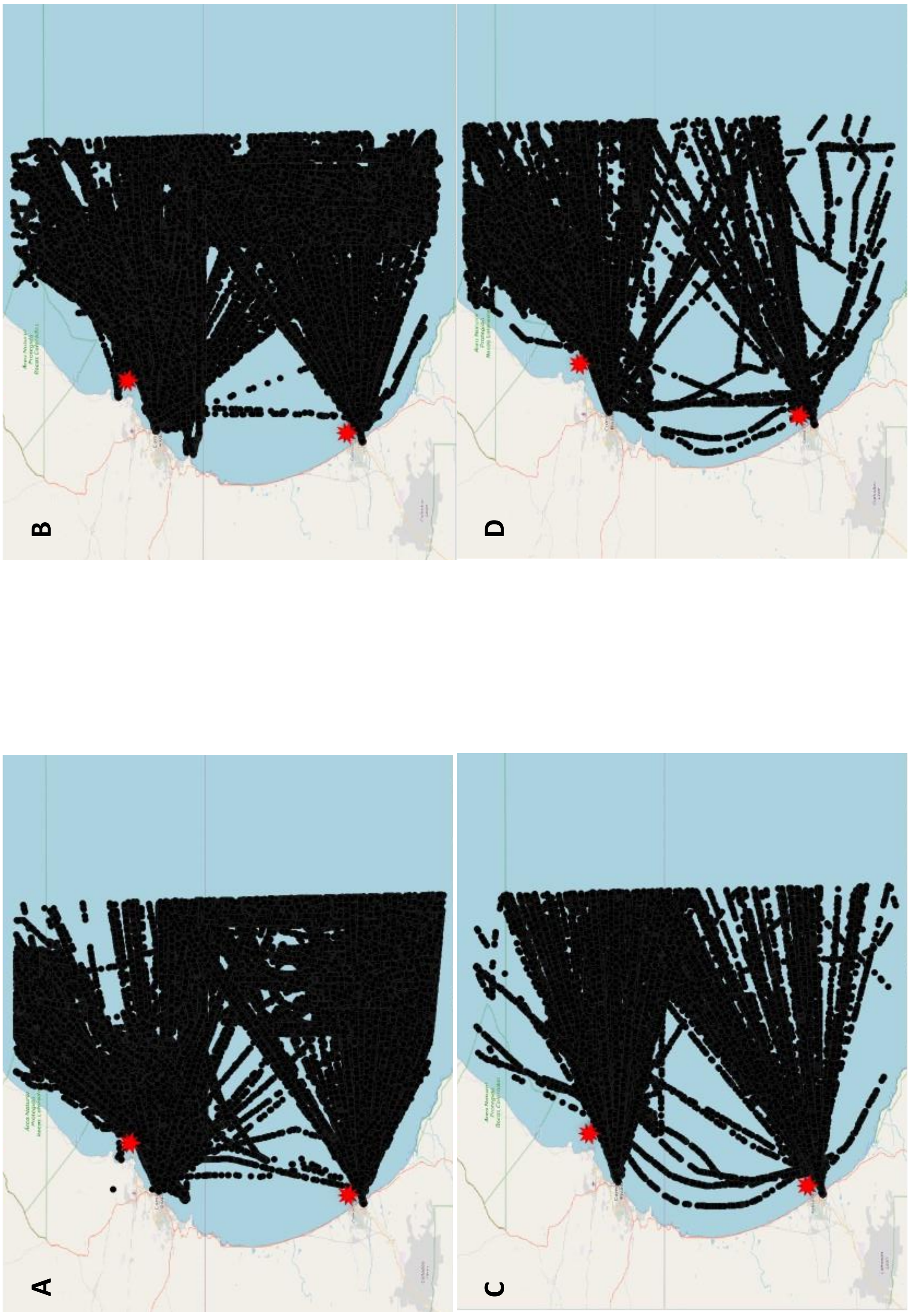


Figure 33: Distribution of the fishing vessels in the area of Comodoro Rivadavia of the year 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of all fishing vessels during the months January, February and March.
(B): Distribution of all fishing vessels during the months April, May and June.
(C): Distribution of all fishing vessels during the months July, August and September.
(D): Distribution of all fishing vessels during the months October, November and December.
Source: Own work

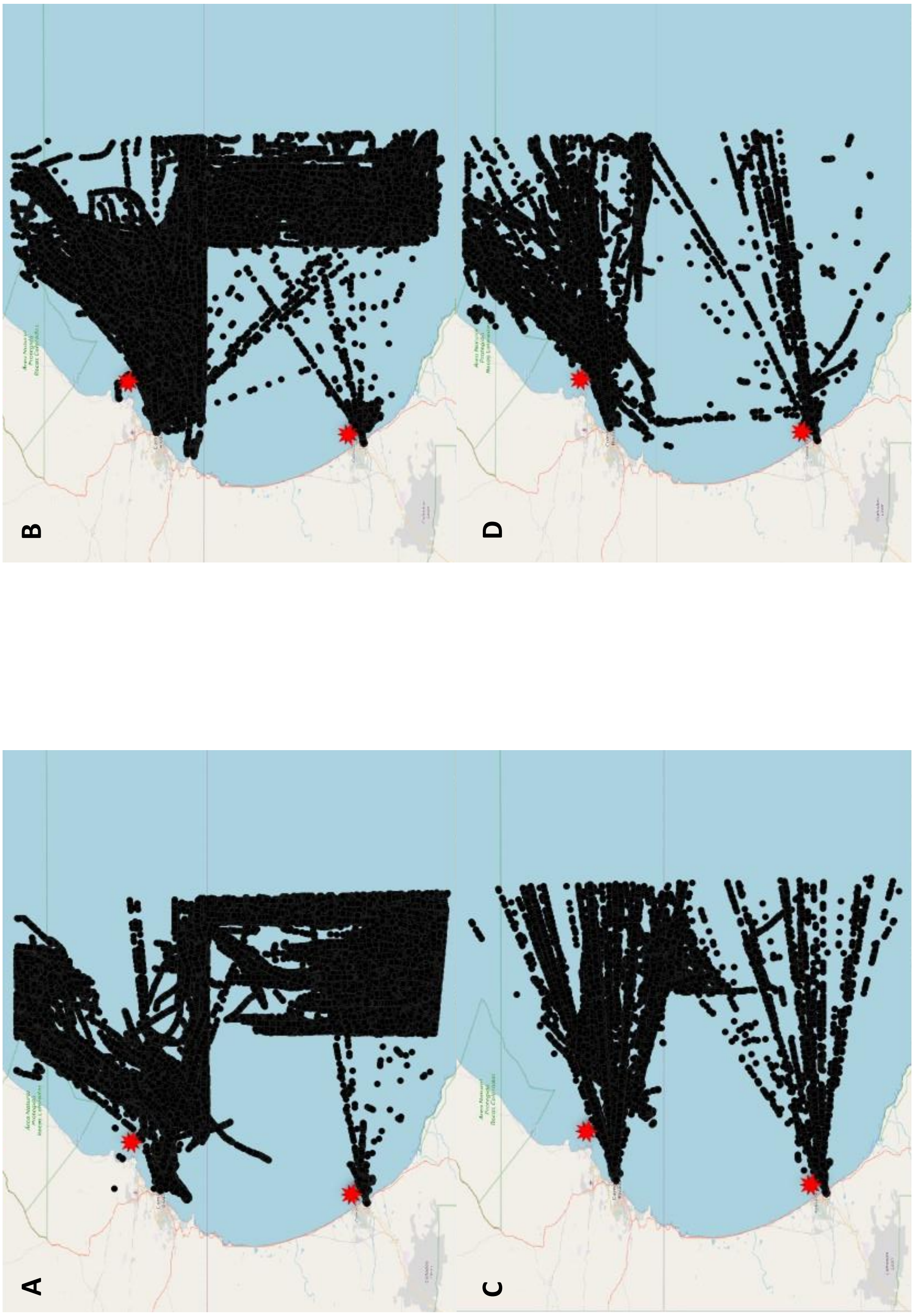


Figure 34: Distribution of fishing vessels with a speed less than 5 knots in the area of Comodoro Rivadavia of 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of fishing vessels with a speed< 5knots during the months January, February and March.
(B): Distribution of all fishing vessels with a speed< 5knots during the months April, May and June.
(C): Distribution of all fishing vessels with a speed< 5knots during the months July, August and September.
(D): Distribution of all fishing vessels with a speed< 5knots during the months October, November and December.
Source: Own work

4.1.6 Cargo vessels

Next type of vessel that was found in the data set is cargo vessels. This type of vessel was less expected than the tankers. This is because the ports of Caleta Oliva and Comodoro Rivadavia are very small, and not very good prepared for big cargo vessels. As for the tanker vessels this is not a problem because these vessels do not need to enter the harbours but stay around the SPM buoys.

Figure 35(A) shows all the cargo vessels during the months April, May and June and Figure 35(B) shows all the cargo vessels in the month July. During all the other months of the year 2022 there were no cargo vessels found. During April, May, June and July there were found three different cargo ships. Firstly, a ship named Arbumasa XVI was found as a cargo vessel in the dataset. After researching this ship on the internet, it seemed that Arbumasa XVI is not a cargo vessel but a fishing vessel. The second ship categorised as a cargo vessel is named Donia Alfa. Also, on the internet with the IMO number of the ship, it was defined as a cargo vessel. But when looking at the size of this vessel and the pattern on Figure 35(C), it seemed not so evident to be a cargo vessel. Donia Alfa is a vessel with a length of 20 meters and a width of 6 meters. This ship resembles more like a fishing vessel than a cargo vessel. The third vessel defined as cargo vessel in the dataset is named London Trader. This ship is a container vessel of 171 meters long. But when looking at the track of this vessel, this ship apparently does not enter the port of Comodoro Rivadavia, it just enters the research area and leaves again. In the dataset, the destination of every vessel is given as well, and the destination of London Trader was never Comodoro Rivadavia but Puerto Deseado. The reason of this manoeuvre is unknown.

After having a better look at the cargo vessels, the only cargo vessel that sailed in the research area in the year 2022 was London Trader.

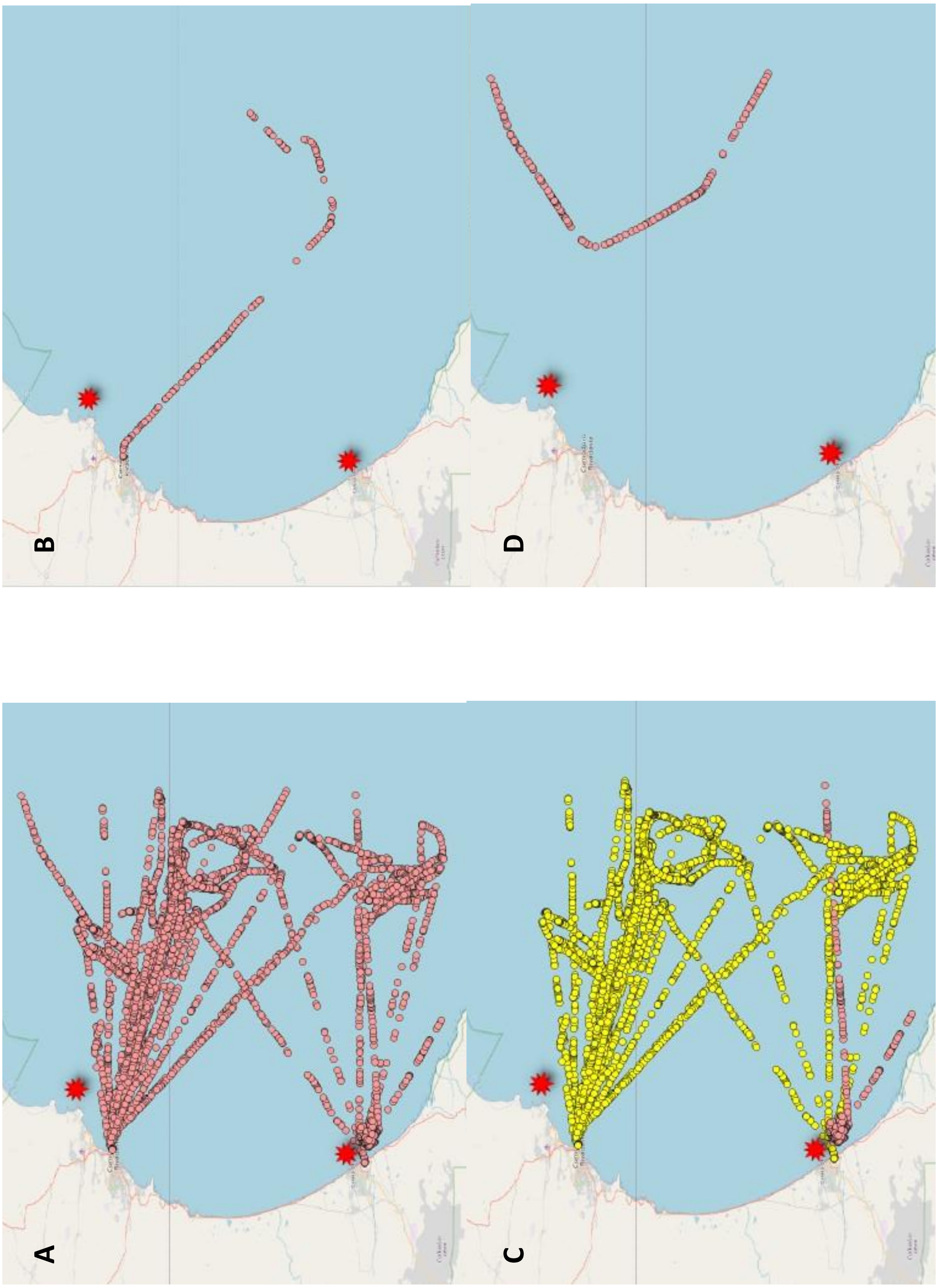


Figure 35: Distribution of cargo vessels in the area of Comodoro Rivadavia of 2022.
(A): Distribution of all cargo vessels during the months April, May and June.
(B): Distribution of all cargo vessels during the month July.
(C): Ship Donia Alfa highlighted during the months April, May and June.
(D): Track of the ship named London Trader.
Source: Own work

4.1.7 Law enforcement

The next category is the law enforcement vessels. As can be seen on Figure 36 the law enforcement is active through the whole year.

The law enforcement vessels are not concentrated around the SPM buoys as can be seen on Figure 37. A more detailed look on the area surrounding the SPM buoys is showed on Figure 37(A,B). The vessels keep a short distance to the coastline. In the interview César Augusto Gribaudo said that these vessels of the law enforcement are checking the fishing vessels.

On Figure 36(B) there is a prominent pattern of the law enforcement vessels during the month April. The tracks go very close to the nature reserve. Maybe one or more ships were protecting the nature reserve of a ship that was not permitted to go in this protected area.

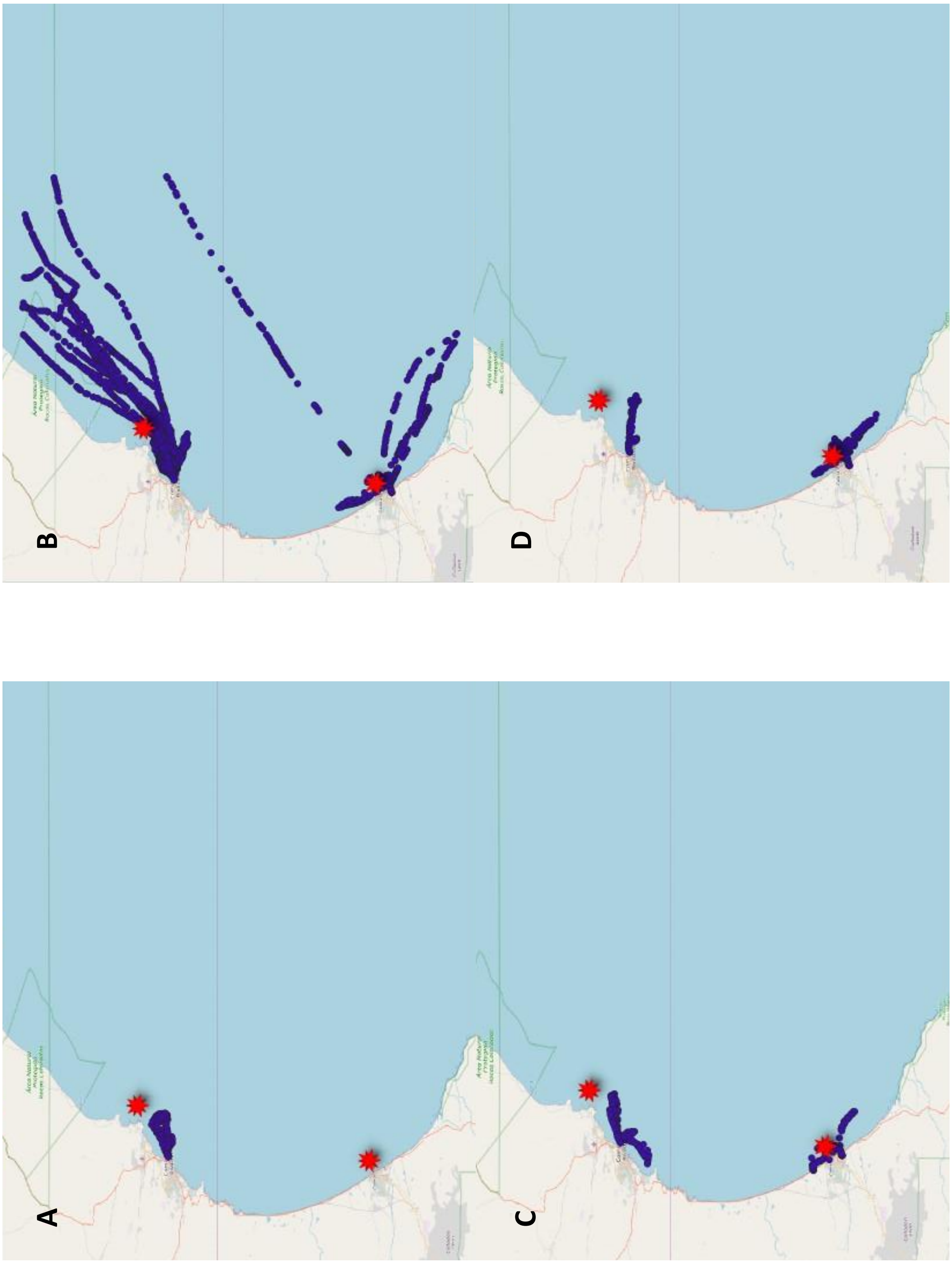


Figure 36: Distribution of law enforcement vessels in the area of Comodoro Rivadavia of the year of 2022, divided per three months.
All four pictures are at scale 1:500 000. The two red stars represents the SPM buoys.
(A): Distribution of all law enforcement vessels during the months January, February and March.
(B): Distribution of all law enforcement vessels during the months April, May and June.
(C): Distribution of all law enforcement vessels during the months July, August and September.
(D): Distribution of all law enforcement vessels during the months October, November and December.
Source: Own work

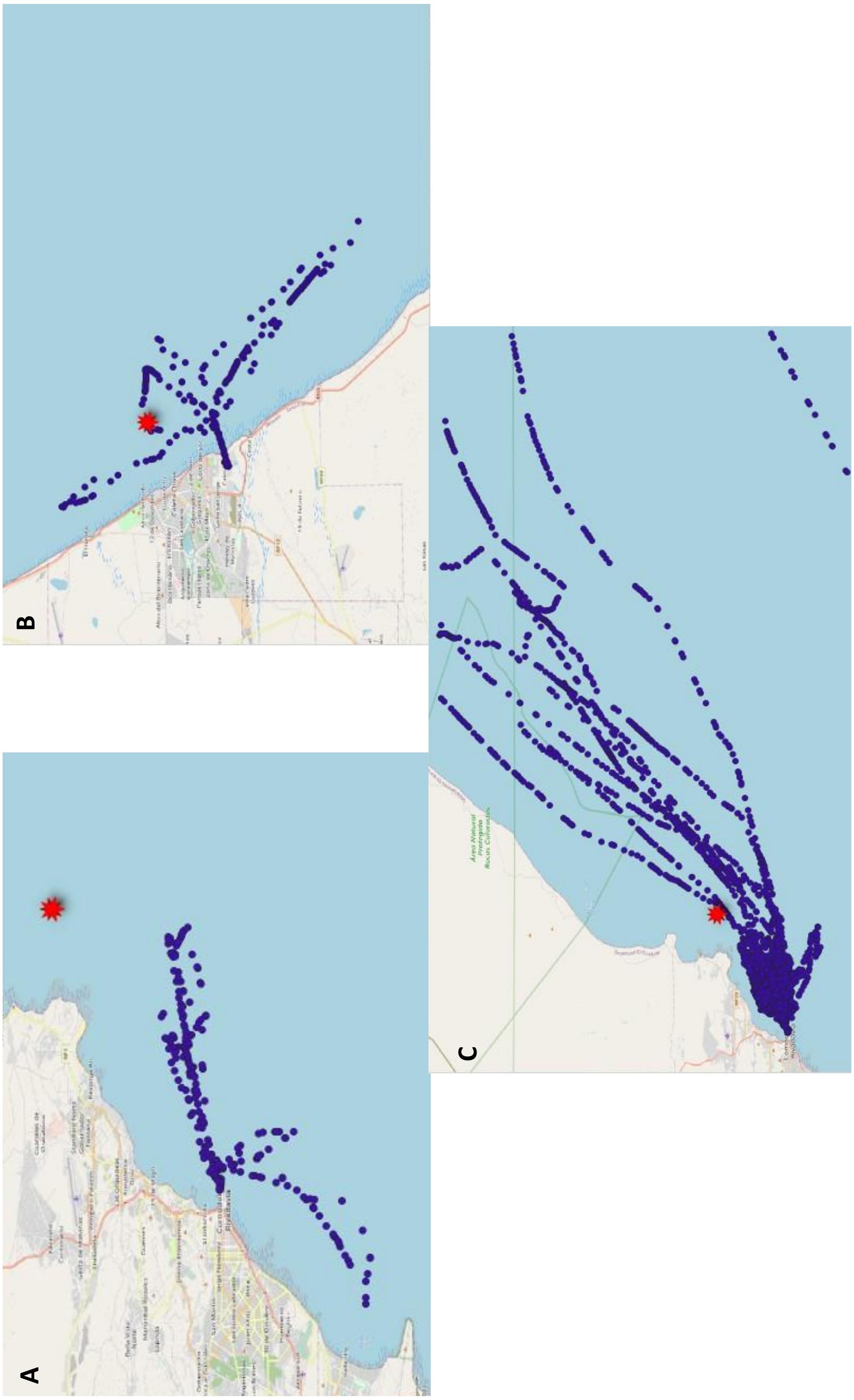


Figure 37: Distribution of law enforcement vessels in the area of Comodoro Rivadavia of the year of 2022, divided per three months.
The red stars represent the SPM buoys.
(A): Distribution of law enforcement vessels around the Northern SPM buoy of Comodoro Rivadavia.
(B): Distribution of law enforcement vessels around the Southern SPM buoy of Caleta Olivia.
(C): Distribution of law enforcement vessels around the protected nature area.
Source: Own work

4.1.8 Pilot Vessels

The details in Figure 38 show four berthing places for pilot vessels. On Figure 39 is a more detailed look of the pilot ships' hotspots. The northernmost on Figure 39(A) is close to the north SPM buoy, these pilot vessels are laying in the port of Caleta Cordova. The pilot ships leaving from Caleta Cordova have as destination the vessels that need to make a connection with the northern SPM buoy. The second berthing place of the pilots on in this area Figure 39(B) is the port of Comodoro Rivadavia. From this port the pilot ships leave to embark a pilot on the ships entering the port of Comodoro Rivadavia. Around the Southern SPM buoy there are two other berthing places for the ships. One in Caleta Olivia on Figure 39(C) and the other in Caleta Paula on Figure 39(D). The first one is for the vessels that have the SPM buoy as destination. Caleta Paula can be entered by tankers, for this manoeuvre a pilot is required. That is why also here many pilot vessels are found.

The tracks of the pilot vessels are all very close to the mainland. It is normal for a pilot vessel to not sail on open sea. This pattern was therefore to be expected. Because the waters close to the ports and coast are not too deep and contain many noises, whales will not have many nuisances of these ships.

On Figure 38(B,C) there are ships that travel from one port to another. This can be because one port was in need of an extra pilot vessel. Since the distance between the ports is not too long, the same ships can be used for both ports.

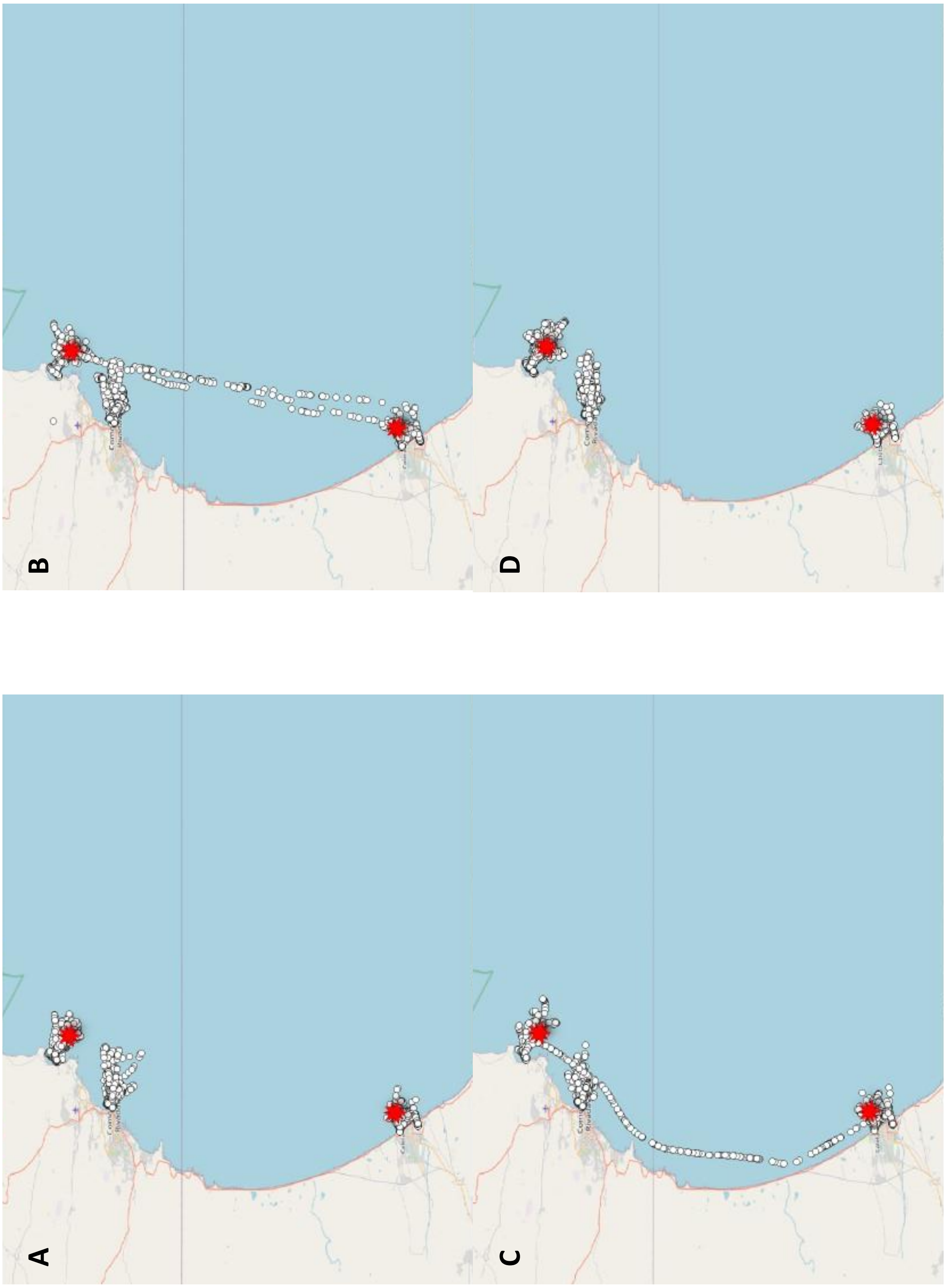


Figure 38: Distribution of pilot vessels in the area of Comodoro Rivadavia of the year of 2022, divided per three months. All four pictures are at scale 1:350 000. The two red stars represents the SPM buoys.
(A): Distribution of all pilot vessels during the months January, February and March.
(B): Distribution of all pilot vessels during the months April, May and June.
(C): Distribution of all pilot vessels during the months July, August and September.
(D): Distribution of all pilot vessels during the months October, November and December.
Source: Own work

Figure 39: Distribution of tankers and pilot vessels during January, February and March 2022.
The scale of A and B is 1:20 000. The scale of picture C and D is 1:15 000. The two red stars represents the SPM buoys
(A): Distribution of tankers and pilot vessels around the port of Comodoro Rivadavia.
(B): Distribution of tankers and pilot vessels around Caleta Cordova.
(C): Distribution of tankers and pilot vessels around Caleta Olivia.
(D): Distribution of tankers and pilot vessels around Caleta Paula.

4.1.9 Vessel With Anti-Pollution Equipment

The last type of vessel that was found in the dataset is the vessel carrying anti-pollution equipment on board. The ship only sailed in the research area during September.

The ship is called DR E Holmberg with 7918189 as IMO number, with this information more details about the type of vessel were found on the internet. It seemed that this ship is actually a fishery patrol vessel with anti-pollution equipment on board. It is difficult to know if this ship was doing anti-pollution activities in the area during the month September.

To have ships in this area with anti-pollution equipment on board is not very surprising, since this area is overrun by tankers. If there is an incident with a tanker, filled with oil, oil spill equipment is needed very fast. However César Augusto Gribaudo said in the interview that in over 30 years no spills have been made in this area. 30 years ago the SPM buoys were changed by buoys with newer technology. With this new technology, no spills happened while loading or unloading oil.

Figure 40: Distribution of the vessels carrying anti-pollution equipment in the year 2022. The picture is at scale 1:500 000. The two red stars represent the SPM buoys. Source: Own work

4.2 Velocity of the tanker vessels

When a collision happens between a whale and a ship, the speed of the vessel at the moment of collision will have an influence on the results of that collision. The chance of a lethal injury will be 21 percent when the ship sails with a speed of 8,6 knots. When the ships accelerate to 11,8 knots, this percentage increase to 50 percent. When the velocity of the ship reaches 15 knots, the percentage of a lethal injury may reach a percentage of 79 (A. Vanderlaan & Taggart, 2007).

This is why it is important to take a look at the different velocities. Because tankers are the biggest vessels with the most influence on the cetaceans and navigate most in open sea, only this category was selected to filter on speed over ground. The velocity was divided into four categories as shown in Table 3.

Table 3: Categories of velocity for tanker vessels.
Source: Own work based on data in (A. S. M. Vanderlaan & Taggart, 2007)

Velocity	**Percentage of lethal injury**
0-8.6 knots	< 21 %
8.6-11.8 knots	21 %- 50 %
11.8-15 knots	50 %- 79 %
>= 15 knots	> 75 %

4.2.1 A velocity of less than 8.6 knots

At this speed the chance of having a lethal injury after a collision between a ship and a whale is not too high, with a maximum of 21 percent. It can be said that below this speed the ships can sail almost safely through the same waters as whales. Reducing the speed to 8.6 knots is still no definite solutions to prevent the death and injuries of whales.

On Figure 41 the distribution of tankers with a speed less than 8,6 knots is shown. As expected, ships with such a slow speed are located around the SPM buoys and the harbours. When arriving at the destination, ships will slow down gradually to start their manoeuvre.

4.2.2 A velocity between 8.6 and 11.8 knots

Because the chance on a lethal injury is 50 percent at a speed of 11.8 knots, this boundary was chosen for a second category. Fifty percent is the limit between more chance of occurrence of a lethal collision than not occurring.

Figure 32 shows the distribution of tankers with a velocity below 8.6 knots, while Figure 42 shows the tankers travelling at a velocity between 8.6 and 11.8 knots. The ships at these higher speeds are not as concentrated in the neighbourhood of the harbours and SPM buoys as those at lower speeds, as seen on Figure 41. The ships at these speeds still are close to the ports and buoys but are also more present in open sea.

4.2.3 A velocity between 11.8 and 15 knots

Starting from 11.8 knots the chance of a lethal injury is 50 percent and reaches 79 percent when sailing 15 knots.

On Figure 43 the distribution of tankers with a speed between 11.8 and 15 knots is shown. These maps are very similar to the maps Figure 42. The biggest difference is that with a speed between 11.8 and 15 knots, the vessels are not sailing around the SPM buoys anymore.

4.2.4 A velocity of more than 15 knots

When sailing more than 15 knots the chances of killing a whale when colliding with it, becomes more than 79 percent. This percentage is very high, thus sailing at this speed is best to prevent. But again, only slowing down the vessels will not solve the deaths and injuries of the cetaceans.

Figure 44 shows the distribution of tankers with a velocity of more than 15 knots. As can be seen, almost no ships are sailing at these speeds in the research area. When these ships are in a collision with a cetacean, this animal would not have a lot of chance to survive the collision.

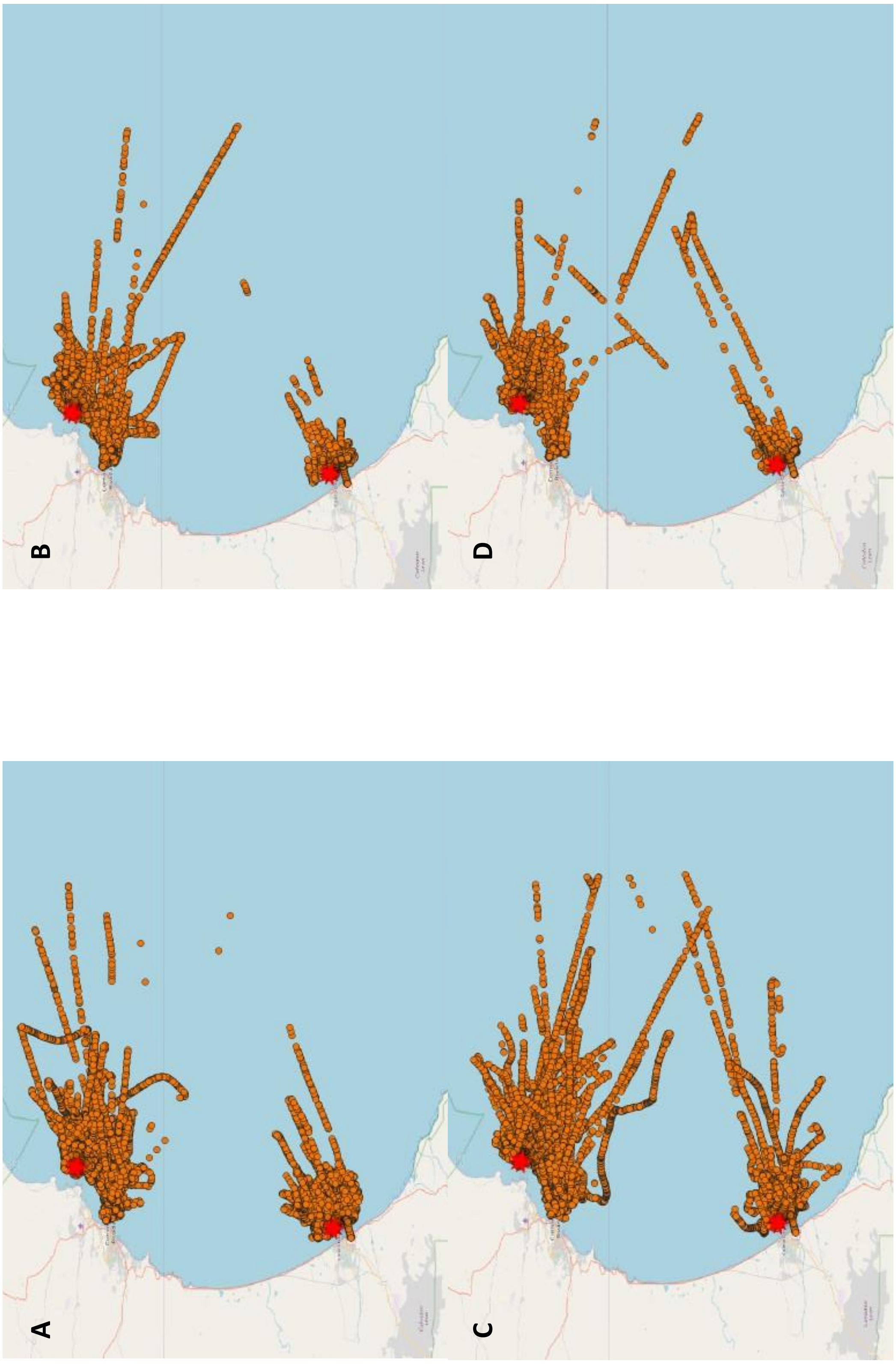


Figure 41: Distribution of tanker vessels with a speed smaller than 8.6 knots in the area of Comodoro Rivadavia of the year 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of tankers with a speed < 8.6 knots during the months January, February and March.
(B): Distribution of tankers with a speed < 8.6 knots during the months April, May and June.
(C): Distribution of tankers with a speed < 8.6 knots during the months July, August and September.
(D): Distribution of tankers with a speed < 8.6 knots during the months October, November and December.
Source: Own work

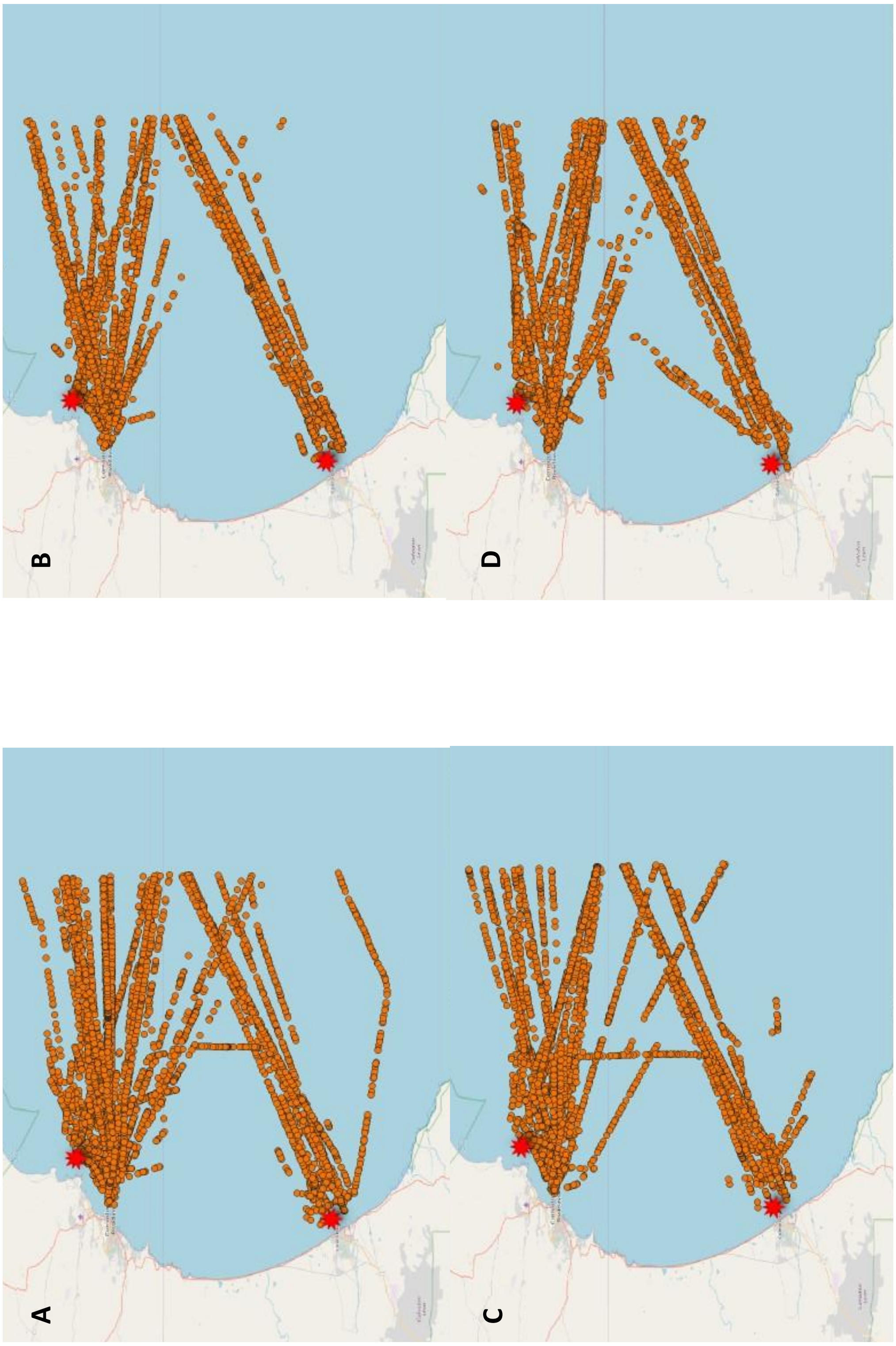


Figure 42: Distribution of tanker vessels with a speed between 8.6 and 11.8 knots in the area of Comodoro Rivadavia of the year 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of tankers with a speed between 8.6 and 11.8 knots during the months January, February and March.
(B): Distribution of tankers with a speed between 8.6 and 11.8 knots during the months April, May and June.
(C): Distribution of tankers with a speed between 8.6 and 11.8 knots during the months July, August and September.
(D): Distribution of tankers with a speed between 8.6 and 11.8 knots during the months October, November and December.
Source: Own work

Figure 43: Distribution of tanker vessels with a speed between 11.8 and 15 knots in the area of Comodoro Rivadavia of the year 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of tankers with a speed between 11.8 and 15 knots during the months January, February and March.
(B): Distribution of tankers with a speed between 11.8 and 15 knots during the months April, May and June.
(C): Distribution of tankers with a speed between 11.8 and 15 knots during the months July, August and September.
(D): Distribution of tankers with a speed between 11.8 and 15 knots during the months October, November and December.
Source: Own work

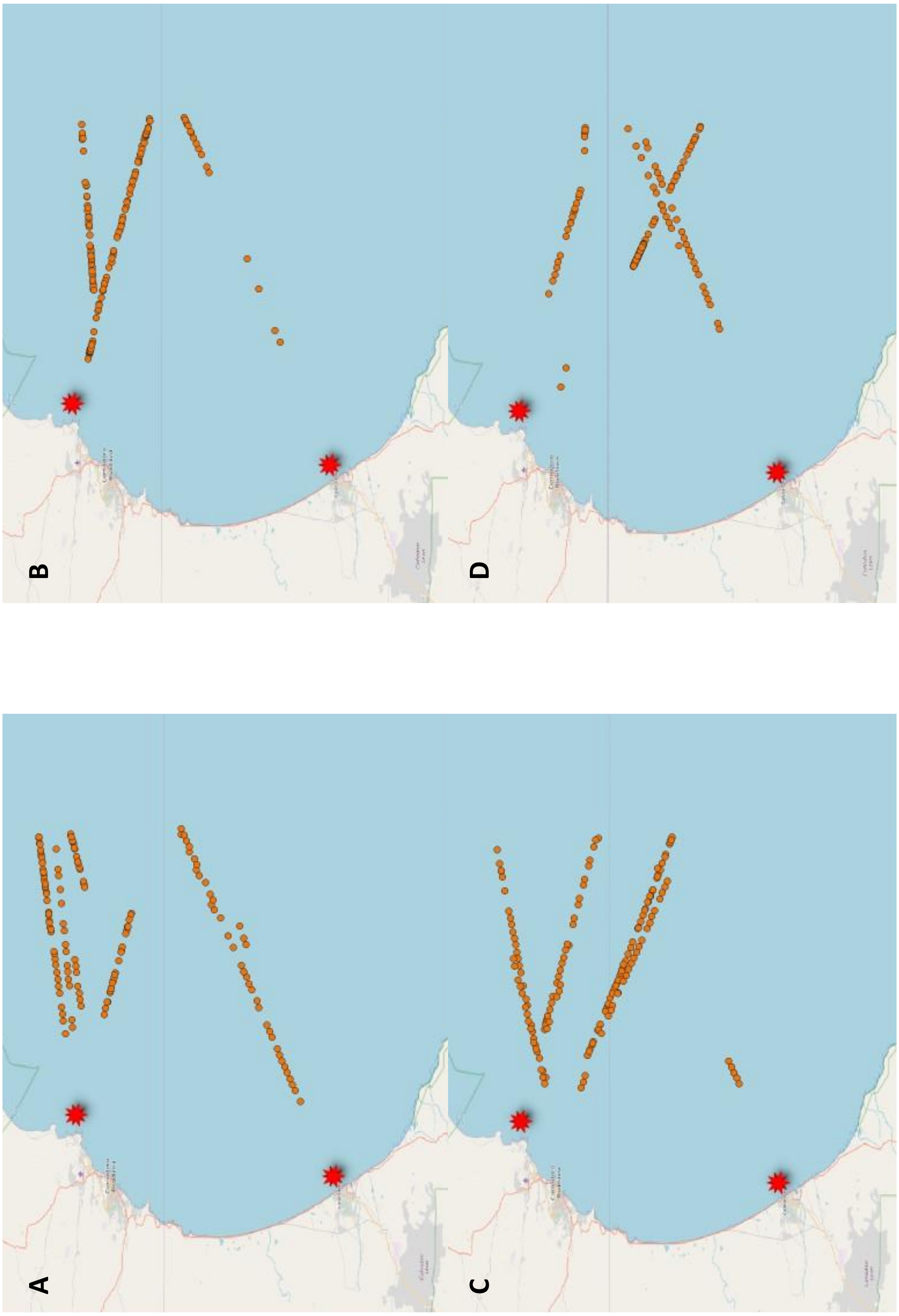


Figure 44: Distribution of tanker vessels with a speed of more than 15 knots in the area of Comodoro Rivadavia of the year 2022, divided per three months.
All four pictures are at scale 1:450 000. The two red stars represents the SPM buoys.
(A): Distribution of tankers with a speed of more than 15 knots during the months January, February and March.
(B): Distribution of tankers with a speed of more than 15 knots during the months April, May and June.
(C): Distribution of tankers with a speed of more than 15 knots during the months July, August and September.
(D): Distribution of tankers with a speed of more than 15 knots during the months October, November and December.
Source: Own work

5 Future for the collected data

5.1 Comparing hotspots of whales to routes of vessels

The next step would be to collect and show the data of the whales. The data containing the locations where the cetaceans are most spotted in the Gulf of San Jorge. This is not possible yet, since the Great Whale Conservancy was going to provide us with this data, and they had some delays. The research should be starting this summer, during the months of July and August. When the whale data is collected, this can be compared with the maps of the vessels.

5.2 What to do in Comodoro Rivadavia

Now that the routes of the vessels are mapped it gives a very detailed image of where exactly most ships are sailing. After research has been done in this area for the habitats of the cetaceans, these can be compared with the maps from this research. The tanker vessels and fishing vessels are causing the most problems. These vessels are spread throughout the whole area. Not only are they a danger for collisions, but these ships cause a lot of noise pollution as well. The smaller vessels, such as the tugs, pilot vessels and offshore tug supply vessels, are staying close to the SPM buoys or are sometimes travelling from one SPM buoy to the other. Travelling between the two buoys is done by following the shortest route. It may be necessary to modify this route to ensure greater protection for the whales.

5.2.1 Areas with no overlap

When there is an area with not both animals and ships, there should not be made any changes. The vessels can keep sailing as before, without disturbing the cetaceans. These ships can be relocated, to make a possible alternative route smoother.

5.2.2 Areas with overlap

If the vessels are sailing in an area where cetaceans are spotted regularly, then there should be a solution. An example of this are recommendations for the implementation of a traffic separating scheme (TSS). When introducing a traffic separation scheme, care should be made for not causing too big detours or extra sailing time, because this will have enormous economic effects. To implement a new TSS the experts can take into account this research to find the most suited rerouting. The percentage of vessels that need to make adaptions of their normal route can be calculated with the help of this research.

5.3 Future projects of the Great Whale Conservancy

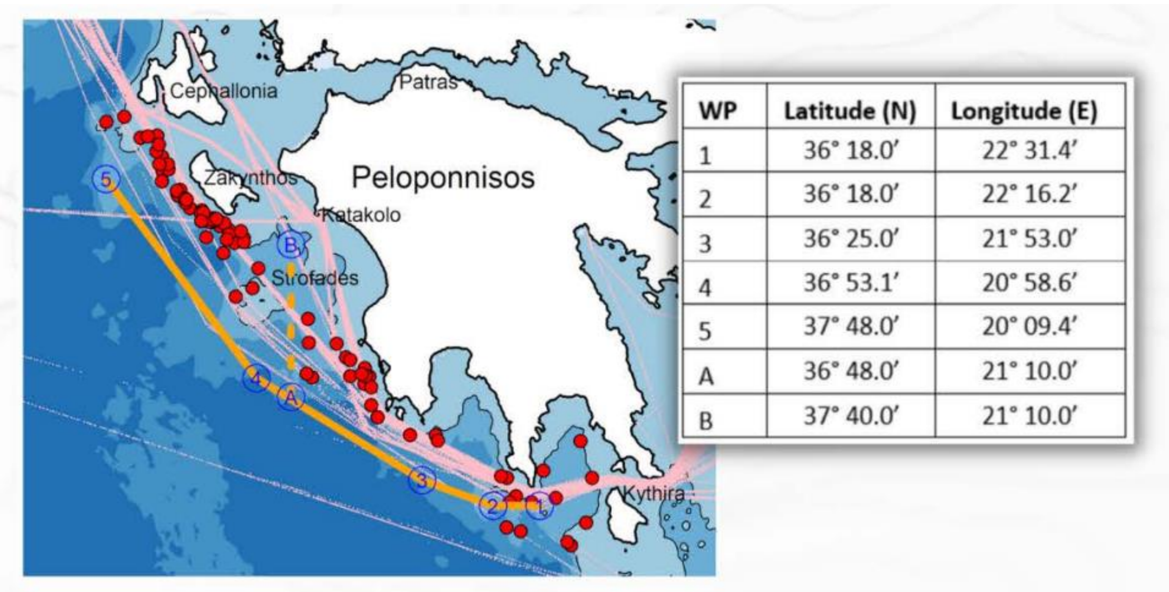
After collecting all the required info from the Gulf of San Jorge, the same will be done in the area of Ensenada. Ensenada is located on the west coast of Mexico at the North Pacific Ocean. The problem in this area is created by the many cruise vessels that are navigating these waters. Besides cruise vessels, container vessels and pleasure crafts are sailing in this area as well. This has as consequence that a lot of traffic is concentrated in this area.

The Great Whale Conservancy will focus on the humpback whales (*Megaptera novaeangliae*) and the blue whales (*Balaenoptera musculus*) in this area. The port of Ensenada is located in a bay. Before the entrance of this bay the depth decreases a lot on a small distance. This is the perfect structure for the whales to force their prey to swim to this underwater wall and trap them between the wall and themselves.

5.4 Previous projects of the Great Whale Conservancy

In the Hellenic trench multiple ship strikes with whales have been reported. Therefor has the Great Whale Conservancy already been investigating this area to find a solution.

In March 2022 the GWC, in collaboration with The Hellenic Centre for Marine Research (HCMR), International fund for Animal Welfare (IFAW), OceanCare, The Pelagos Cetacean Research Institute and the World Wide Fund for Nature (WWF) published recommended routing guidelines for the Hellenic Trench in Greece. This article was published to reduce the collisions with the Sperm whales, that are living in the Mediterranean Sea and mostly around the Hellenic trench. For these recommendations they used information about the densest routes taken by ships and data where most whales are being spotted. Both ships and whales came very close to the coast. An example is shown on Figure 45. (Whale Guardians et al., 2022)



WP	Latitude (N)	Longitude (E)
1	36° 18.0′	22° 31.4′
2	36° 18.0′	22° 16.2′
3	36° 25.0′	21° 53.0′
4	36° 53.1′	20° 58.6′
5	37° 48.0′	20° 09.4′
A	36° 48.0′	21° 10.0′
B	37° 40.0′	21° 10.0′

Figure 45: Recommended routing guidelines from Whale Guardians
The pink lines are the tracks of cruise vessels. The red spots are the sperm whale sightings. The orange line is the recommended low risk route.
Source: (Whale Guardians et al., 2022)

The pink lines on Figure 45 are the tracks of the cruise vessels in this area and the red dots represent sperm whale sightings. At many places on the map these red dots and pink lines overlap. To prevent this an alternative route is recommended to follow. This route is highlighted by the yellow track on Figure 45.

6 Conclusion

The primary objective of the broader research initiative was to mitigate ship collisions and other disturbances caused by vessels in order to protect sea mammals. To accomplish this goal, it was essential to obtain a comprehensive understanding of the prevailing conditions in various areas. As part of this thesis, a template was developed to map the locations of ships in different regions. In the future, this thesis can serve as a blueprint for creating similar maps in other areas, enabling the generation of more precise and comprehensive insights. These insights can then facilitate informed decision-making and necessary adjustments.

In the specific research area of the Gulf of San Jorge, the most significant challenges for cetaceans arise from fishing vessels and tanker vessels, which are present throughout the region. However, concentrating fishing vessels within specific zones proves difficult due to their irregular and dispersed patterns. Conversely, guiding tanker vessels towards designated areas, such as Traffic Separation Schemes (TSS), is comparatively more manageable.

In addition to tanker vessels and fishing vessels, other types of ships encountered in the Gulf of San Jorge include offshore supply vessels, tugs, pilot vessels, fishery patrol vessels, law enforcement vessels and a solitary cargo vessel. The cargo vessel merely transits the area without approaching ports or coastlines.

The offshore supply vessels, tugs, and pilot vessels generally follow similar routes, which primarily involve operating in proximity to ports and Single Point Mooring (SPM) buoys. Occasionally, these ships travel between SPM buoys by taking the shortest route. However, this route can pose challenges for cetaceans and may necessitate reconsideration.

Fishery patrol vessels exhibit a highly irregular pattern as they navigate throughout the area to monitor various ships. This extensive coverage results in a significant degree of unpredictability.

Noteworthy areas within the Gulf of San Jorge are the waiting zones for tankers. These zones serve as holding areas where tanker vessels await authorization before connecting to the SPM buoys. These areas also witness substantial traffic from pilot vessels and tugs. Consequently, these zones harbour increased maritime activity, leading to heightened disturbances for cetaceans. If cetaceans inhabit these same areas, relocating the waiting zones could be a potential solution.

Due to the unavailability of whale data, a comprehensive plan for protecting cetaceans in the Gulf of San Jorge could not be fully developed within this thesis. However, the initial steps outlined in this thesis, mark the starting point for conserving cetaceans in the Gulf of San Jorge and worldwide.

7 Bibliograph

Aguilar, A., & García-Vernet, R. (2018). Fin Whale. *Encyclopedia of Marine Mammals* (pp. 368–371). Elsevier. doi:10.1016/B978-0-12-804327-1.00128-X

André, M., & Kamminga, C. (2000). Rhythmic dimension in the echolocation click trains of sperm whales: A possible function of identification and communication. *Journal of the Marine Biological Association of the United Kingdom*, *80*(1), 163–169. doi:10.1017/S002531549900168X

Andrew, R. K., Howe, B. M., Mercer, J. A., & Dzieciuch, M. A. (2002). Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast. *Acoustics Research Letters Online*, *3*(2), 65–70. doi:10.1121/1.1461915

Best, P. B., & Schell, D. M. (1996). Stable isotopes in southern right whale (Eubalaena australis) baleen as indicators of seasonal movements, feeding and growth. *Marine Biology*, *124*(4), 483–494. doi:10.1007/BF00351030

Bolaños-Jiménez, J., Mignucci-Giannoni, A. A., Blumenthal, J., Bogomolni, A., Casas, J. J., Henríquez, A., Iñíguez Bessega, M., e.a. (2014). Distribution, feeding habits and morphology of killer whales *O rcinus orca* in the Caribbean Sea: Killer whales of the Caribbean Sea. *Mammal Review*, *44*(3–4), 177–189. doi:10.1111/mam.12021

Browne, E. (2021, 27 September). Heartbreaking photos show dead whale lodged on hull of tanker ship. *Newsweek*. Accessed 28 August 2022, from https://www.newsweek.com/mizushima-whale-death-photos-japan-ship-strike-1632925

Caleta Olivia Port. (n.d.).*SHIPNEXT*. Accessed 27 May 2023, from https://shipnext.com/port/5821b8c40dd99d0cf03f07a0

Canada, T. (2021, 4 januari). Transport Canada. Acessed 28 augustus 2022, from https://tc.canada.ca/en

Canada, T. (2022, 21 April). Protecting North Atlantic right whales from collisions with vessels in the Gulf of St. Lawrence. *AMSI 15540108*. AMSI. Accessed 28 August 2022, from https://tc.canada.ca/en/marine-transportation/navigation-marine-conditions/protecting-north-atlantic-right-whales-collisions-vessels-gulf-st-lawrence

Chen, F., Shapiro, G. I., Bennett, K. A., Ingram, S. N., Thompson, D., Vincent, C., Russell, D. J. F., e.a. (2017). Shipping noise in a dynamic sea: A case study of grey seals in the Celtic Sea. *Marine Pollution Bulletin*, *114*(1), 372–383. doi:10.1016/j.marpolbul.2016.09.054

Comodoro Rivadavia Port. (2023).*SHIPNEXT*. Accessed 27 May 2023, from https://shipnext.com/port/comodoro-rivadavia-arcrd-arg

Conn, P. B., & Silber, G. K. (2013). Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. *Ecosphere*, *4*(4), art43. doi:10.1890/ES13-00004.1

Doom, M., Cornillie, P., Gielen, I., & Haelters, J. (2013). De invloed van geluidspollutie op zeezoogdieren. *VLAAMS DIERGENEESKUNDIG TIJDSCHRIFT*, *82*(5), 265–272.

Dunlop, R. A., Cato, D. H., & Noad, M. J. (2008). Non-song acoustic communication in migrating humpback whales (*Megaptera novaeangliae*). *Marine Mammal Science*, *24*(3), 613–629. doi:10.1111/j.1748-7692.2008.00208.x

Emmons, C. K., Hard, J. J., Dahlheim, M. E., & Waite, J. M. (2019). Quantifying variation in killer whale (*Orcinus orca)* morphology using elliptical Fourier analysis. *Marine Mammal Science*, *35*(1), 5–21. doi:10.1111/mms.12505

Erbe, C., MacGillivray, A., & Williams, R. (2012). Mapping cumulative noise from shipping to inform marine spatial planning. *The Journal of the Acoustical Society of America*, *132*(5), EL423–EL428. doi:10.1121/1.4758779

Español-Jiménez, S., & van der Schaar, M. (2018). First record of humpback whale songs in Southern Chile: Analysis of seasonal and diel variation: HUMPBACK WHALE SONGS. *Marine Mammal Science*, *34*(3), 718–733. doi:10.1111/mms.12477

Estes, J. A., DeMaster, D. P., Doak, D. F., Williams, T. M., & Brownell, R. L. (2006). *Whales, Whaling, and Ocean Ecosystems*. University of California Press.

Euronav. (2022, 18 februari). Euronav—Euronav makes whale protection measures mandatory for its fleet. Geraadpleegd 28 augustus 2022, van https://www.euronav.com/investors/company-news-reports/news/2022/euronav-makes-whale-protection-measures-mandatory-for-its-fleet/

Farcas, A., Powell, C. F., Brookes, K. L., & Merchant, N. D. (2020). Validated shipping noise maps of the Northeast Atlantic. *Science of The Total Environment*, *735*, 139509. doi:10.1016/j.scitotenv.2020.139509

Fin whale. (2022, 27 August).*Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Fin_whale&oldid=1107022200

Firestone, J., Lyons, S. B., Wang, C., & Corbett, J. J. (2008). Statistical modeling of North Atlantic right whale migration along the mid-Atlantic region of the eastern seaboard of the United States. *Biological Conservation*, *141*(1), 221–232. doi:10.1016/j.biocon.2007.09.024

Fordyce, R., & de Muizon, C. (2001). Evolutionary history of cetaceans: A review. *Secondary Adaptation of Tetrapods to Life in Water* (pp. 169–233).

Garaffo, G., Dans, S., Pedraza, S., Degrati, M., Schiavini, A., González, R., & Crespo, E. (2011). Modeling habitat use for dusky dolphin and Commerson's dolphin in Patagonia. *Marine Ecology Progress Series*, *421*, 217–227. doi:10.3354/meps08912

Gero, S., & Whitehead, H. (2016). Critical Decline of the Eastern Caribbean Sperm Whale Population. (S. Li, Red.)*PLOS ONE*, *11*(10), e0162019. doi:10.1371/journal.pone.0162019

Goodall, R., & Natalie, P. (2009). Peale's Dolphin. *Encyclopedia of Marine Mammals* (pp. 844–847). Elsevier. doi:10.1016/B978-0-12-373553-9.00196-6

Greece takes first measures to protect sperm whales from ship collision. (2021, 19 februari). Geraadpleegd 28 augustus 2022, van https://www.wwfmmi.org/?2204941/Greece-first-measures-to-protect-whales-ship-collision

Harrison, M. (1952). An Experimental Study of Single Bubble Cavitation Noise. *The Journal of the Acoustical Society of America*, *24*(6), 776–782. doi:10.1121/1.1906978

Hellenic Trench. (n.d.).*Marine Mammal Protected Areas Task Force*. Retrieved from https://www.marinemammalhabitat.org/portfolio-item/hellenic-trench/

Hoe walvissen het klimaat veranderen. (2014). Geraadpleegd van https://www.youtube.com/watch?v=M18HxXve3CM

Horwood, J. (2009). Sei Whale. *Encyclopedia of Marine Mammals* (pp. 1001–1003). Elsevier. doi:10.1016/B978-0-12-373553-9.00231-5

Humpback whale. (2022, 27 August).*Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Humpback_whale&oldid=1107023494

IBM. (z.d.). Sea change—Setting a new course for ocean research. Geraadpleegd 28 augustus 2022, van https://www.ibm.com/case-studies/mayflower/

Iñíguez, M. A. (2001). Seasonal distribution of killer whales (Orcinus Orca) in Northern Patagonia, Argentina.

Jefferson, T. A., Weir, C. R., Anderson, R. C., Ballance, L. T., Kenney, R. D., & Kiszka, J. J. (2014). Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation: Distribution of Risso's dolphin. *Mammal Review*, *44*(1), 56–68. doi:10.1111/mam.12008

Jones, G. (2005). Echolocation. *Current Biology*, *15*(13), R484–R488. doi:10.1016/j.cub.2005.06.051

Keller, C., Garrison, L., Baumstark, R., Ward-Geiger, L., & Hines, E. (2012). Application of a habitat model to define calving habitat of the North Atlantic right whale in the southeastern United States. *Endangered Species Research*, *18*(1), 73–87. doi:10.3354/esr00413

Koen, A. M., Alberto, C. E., Aníbal, G. N., Noemí, P. S., & Alberto, C. M. (1997). Diet of dusky dolphins, Lagenorhynchus obscurus, in waters off Patagonia, Argentina.

Kozaczka, E., & Grelowska, G. (2004). *Shipping Noise*. (Gdansk University of Technology, Naval University in Gdynia, Gdynia & Gdansk, Poland).

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., & Podesta, M. (2001). COLLISIONS BETWEEN SHIPS AND WHALES. *Marine Mammal Science*, *17*(1), 35–75. doi:10.1111/j.1748-7692.2001.tb00980.x

Mann, J., Connor, R., Tyack, P. L., & Whitehead, H. (2000). *Cetacean Societies: Field Studies of Dolphins and Whales*. University of Chicago Press.

MarineTraffic. (2023a). Port of COMODORO RIVADAVIA (AR CRD) details—Departures, Expected Arrivals and Port Calls. *MarineTraffic.com*. Accessed 27 May 2023, a from https://www.marinetraffic.com/en/ais/details/ports/17349?name=COMODORO RIVADAVIA&country=Argentina

MarineTraffic. (2023b). Port of CALETA OLIVIA (AR CVI) details—Departures, Expected Arrivals and Port Calls | AIS MarineTraffic. *MarineTraffic.com*. Accessed 27 May 2023, b from https://www.marinetraffic.com/en/ais/details/ports/24083?name=CALETA OLIVIA&country=Argentina

Mayflower: Robot-ship to seek out mysteries of the ocean. (2021). Geraadpleegd van https://www.youtube.com/watch?v=7JlU0mtXSNY

Miloslavich, P., Klein, E., Díaz, J. M., Hernández, C. E., Bigatti, G., Campos, L., Artigas, F., et al. (2011). Marine Biodiversity in the Atlantic and Pacific Coasts of South America: Knowledge and Gaps. (S. Thrush, Ed.)*PLoS ONE*, *6*(1), e14631. doi:10.1371/journal.pone.0014631

Morais, I. O., Danilewicz, D., Zerbini, A. N., Edmundson, W., Hart, I. B., & Bortolotto, G. A. (2017). From the southern right whale hunting decline to the humpback whaling expansion: A review of whale catch records in the tropical western South Atlantic Ocean. *Mammal Review*, *47*(1), 11–23. doi:10.1111/mam.12073

MSC Takes Action to Save Endangered Whales in the Mediterranean. (2022, 27 januari).*MSC*. Geraadpleegd 28 augustus 2022, van https://www.msc.com/en/newsroom/news/2022/january/msc-takes-action-to-save-endangered-whales-in-the-mediterranean

New, L. F., Hall, A. J., Harcourt, R., Kaufman, G., Parsons, E. C. M., Pearson, H. C., Cosentino, A. M., e.a. (2015). The modelling and assessment of whale-watching impacts. *Ocean & Coastal Management*, *115*, 10–16. doi:10.1016/j.ocecoaman.2015.04.006

Noad, M. J., Cato, D. H., Bryden, M. M., Jenner, M. N., & Jenner, K. C. S. (2000). Cultural revolution in whale songs. *Nature*, *408*(6812), 537–537. Nature Publishing Group. doi:10.1038/35046199

OceanCare. (2019, 23 oktober). The Hellenic Trench is important for marine mammals! *OceanCare*. Geraadpleegd van https://www.oceancare.org/en/the-hellenic-trench-is-important-for-marine-mammals/

Orcas Hunt For Herrings | World's Deadliest Whale | National Geographic Wild UK. (2020). Geraadpleegd van https://www.youtube.com/watch?v=8VWhvpMeu1s

Orka. (2022, 17 May).*Wikipedia*. Retrieved from https://nl.wikipedia.org/w/index.php?title=Orka&oldid=62052328

Parsons, E. C. M. (2012). The Negative Impacts of Whale-Watching. *Journal of Marine Biology*, *2012*, 1–9. doi:10.1155/2012/807294

Payne, R. S., & McVay, S. (1971). Songs of Humpback Whales: Humpbacks emit sounds in long, predictable patterns ranging over frequencies audible to humans. *Science*, *173*(3997), 585–597. doi:10.1126/science.173.3997.585

Pinedo, M. C., Barreto, A. S., Lammardo, M. P., Andrade, A. L. V., & Geracitano, L. (2002). Northernmost records of the spectacled porpoise, Layard's beaked whale, Commerson's dolphin, and Peale's dolphin in the southwestern Atlantic Ocean.

Prieto, R., Janiger, D., Silva, M. A., Waring, G. T., & Gonçalves, J. M. (2012). The forgotten whale: A bibliometric analysis and literature review of the North Atlantic sei whale Balaenoptera borealis: North Atlantic sei whale review. *Mammal Review*, *42*(3), 235–272. doi:10.1111/j.1365-2907.2011.00195.x

Reyes, L. M. (2006). Cetaceans of Central Patagonia, Argentina. *Aquatic Mammals*, *32*(1), 20–30. doi:10.1578/AM.32.1.2006.20

Ronen, D. (2011). The effect of oil price on containership speed and fleet size. *Journal of the Operational Research Society*, *62*(1), 211–216. doi:10.1057/jors.2009.169

Rowntree, V. J., Payne, R. S., & Schell, D. M. (2020). Changing patterns of habitat use by southern right whales (Eubalaena australis) on their nursery ground at Península Valdés, Argentina, and in their long-range movements. *J. Cetacean Res. Manage.*, 133–143. doi:10.47536/jcrm.vi.298

Ruiter, K. (2017, 20 August). Kadaver dode vinvis op Texel is 'al van verre te ruiken'. Accessed 28 August 2022, from https://nos.nl/artikel/2188918-kadaver-dode-vinvis-op-texel-is-al-van-verre-te-ruiken

Sèbe, M., Kontovas, C. A., & Pendleton, L. (2019). A decision-making framework to reduce the risk of collisions between ships and whales. *Marine Policy*, *109*, 103697. doi:10.1016/j.marpol.2019.103697

Ship noise. (2019). Geraadpleegd 28 augustus 2022, van https://www.imo.org/en/MediaCentre/HotTopics/Pages/Noise.aspx

Simon, M., Ugarte, F., Wahlberg, M., & Miller, L. A. (2006). ICELANDIC KILLER WHALES *ORCINUS ORCA* USE A PULSED CALL SUITABLE FOR MANIPULATING THE SCHOOLING BEHAVIOUR OF HERRING *CLUPEA HARENGUS*. *Bioacoustics*, *16*(1), 57–74. doi:10.1080/09524622.2006.9753564

Sperm whale. (2022, 23 August).*Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Sperm_whale&oldid=1106108457

Tamura, T., & Konishi, K. (2009). Feeding Habits and Prey Consumption of Antarctic Minke Whale (*Balaenoptera bonaerensis*) in the Southern Ocean. *Journal of Northwest Atlantic Fishery Science*, *42*, 13–25. doi:10.2960/J.v42.m652

Tyack, P. L., & Clark, C. W. (2000). Communication and Acoustic Behavior of Dolphins and Whales. In W. W. L. Au, R. R. Fay, & A. N. Popper (Red.), *Hearing by Whales and Dolphins*, Springer

Handbook of Auditory Research (pp. 156–224). New York, NY: Springer. doi:10.1007/978-1-4612-1150-1_4

Vanderlaan, A. S. M., & Taggart, C. T. (2007). VESSEL COLLISIONS WITH WHALES: THE PROBABILITY OF LETHAL INJURY BASED ON VESSEL SPEED. *Marine Mammal Science*, *23*(1), 144–156. doi:10.1111/j.1748-7692.2006.00098.x

Vinvis die in 2017 op Texel strandde is grootste dier op Nederlandse kust ooit. (2022, 21 januari). Geraadpleegd 28 augustus 2022, van https://nos.nl/artikel/2413988-vinvis-die-in-2017-op-texel-strandde-is-grootste-dier-op-nederlandse-kust-ooit

Wade, P. R., Kennedy, A., LeDuc, R., Barlow, J., Carretta, J., Shelden, K., Perryman, W., e.a. (2011). The world's smallest whale population? *Biology Letters*, *7*(1), 83–85. doi:10.1098/rsbl.2010.0477

Westbury, M. V., Thompson, K. F., Louis, M., Cabrera, A. A., Skovrind, M., Castruita, J. A. S., Constantine, R., et al. (2021). Ocean-wide genomic variation in Gray's beaked whales, *Mesoplodon grayi*. *Royal Society Open Science*, *8*(3), rsos.201788, 201788. doi:10.1098/rsos.201788

Whale Guardians, Great Whale Conservancy, International fund for Animal Welfare, OceanCare, The Pelagos Cetacean Research Institute, Hellenic Centre for Marine Research, & World Wide Fund for Nature. (2022). Recommended routing guidelines for Hellenic Trench, Greece.

Whitehead, H. (2018). Sperm Whale. *Encyclopedia of Marine Mammals* (pp. 919–925). Elsevier. doi:10.1016/B978-0-12-804327-1.00242-9

Wichers, J. (2013). *Guide to Single Point Moorings*. WMooring.

Wikimedia Commons contributors. (2020a). *File:DuskyDolphin.jpg*. Accessed 28 May 2023, a from https://commons.wikimedia.org/w/index.php?title=File:DuskyDolphin.jpg&oldid=476547167

Wikimedia Commons contributors. (2020b). *File:LF Pilot Whale Goban Spur.jpg*. Accessed 28 May 2023, b from https://commons.wikimedia.org/w/index.php?title=File:LF_Pilot_Whale_Goban_Spur.jpg&oldid=490746448

Wikimedia Commons contributors. (2020c). *File:Grampus griseus Reconstitution.jpg*. Accessed 28 May 2023, c from https://commons.wikimedia.org/w/index.php?title=File:Grampus_griseus_Reconstitution.jpg&oldid=509224958

Wikimedia Commons contributors. (2022a). *File:Lagenorhynchus australis.jpg*. Accessed 28 May 2023, a from https://commons.wikimedia.org/w/index.php?title=File:Lagenorhynchus_australis.jpg&oldid=656128705

Wikimedia Commons contributors. (2022b). *File:Stranded Gray's beaked whale.jpg*. Accessed 28 May 2023, b from https://commons.wikimedia.org/w/index.php?title=File:Stranded_Gray%27s_beaked_whale.jpg&oldid=659721019

Wikimedia Commons contributors. (2022c). *File:Southern Right Whale (Eubalaena australis) (16358018502).jpg*. Accessed 28 May 2023, c from https://commons.wikimedia.org/w/index.php?title=File:Southern_Right_Whale_(Eubalaena_australis)_(16358018502).jpg&oldid=669850590

Wikimedia Commons contributors. (2022d). *File:Sei whale mother and calf Christin Khan NOAA.jpg*. Accessed 28 May 2023, d from https://commons.wikimedia.org/w/index.php?title=File:Sei_whale_mother_and_calf_Christin_Khan_NOAA.jpg&oldid=638552950

Wikimedia Commons contributors. (2023a). *File:Commdolph01.jpg*. Accessed 28 May 2023, a from https://commons.wikimedia.org/w/index.php?title=File:Commdolph01.jpg&oldid=753599948

Wikimedia Commons contributors. (2023b). *File:Killerwhales jumping.jpg*. Accessed 29 May 2023, b from https://commons.wikimedia.org/w/index.php?title=File:Killerwhales_jumping.jpg&oldid=741456347

Wittekind, D., & Schuster, M. (2016). Propeller cavitation noise and background noise in the sea. *Ocean Engineering*, *120*, 116–121. doi:10.1016/j.oceaneng.2015.12.060

Yorio, P., & Caille, G. (2004). Fish waste as an alternative resource for gulls along the Patagonian coast: Availability, use, and potential consequences. *Marine Pollution Bulletin*, *48*(7–8), 778–783. doi:10.1016/j.marpolbul.2003.11.008

8 Annex

Annex 1

The interview with César Augusto Gribaudo is added to this thesis as annex 1. César Augusto Gribaudo is very familiar with the region of Caleta Olivia and Comodoro Rivadavia. He helped to get a better insight into the data and the created maps.

Tanker

What does the Puerto of Comodoro Rivadavia look like? Can tankers enter?

No, tankers cannot enter the port of Comodoro Rivadavia and the port of Caleta Olivia. Only small vessels like fishing, pilot, tugs etc. The area before the port of Comodoro is for the tankers to wait at an anchorage area to get the authorisation for loading or unloading the cargo. After the authorisation they will move to the buoy.

When do the tankers go from one SPM buoy to the other, because this rarely happens according to the data.

When one tanker is not fully loaden, this ship will go to the other buoy for more oil. This rarely happens. Most of the time one tanker goes to only one buoy and not to both buoys.

Is there a plan or equipment for when there is an accident with a tanker or an oil spill?

No, because it has been 30 years since there were oil spills. 30 years ago, the buoys got changed to buoys with a better technology. Since the new buoys, there are no oil spills anymore. With the old buoys, oil spills happened every loading and discharging.

Fishing

Is there a difference between the fishing activity during the winter and summer season?

Yes, the fishing activity is changing during the year, but the tanker vessel activity is almost similar every day. In Caleta Olivia, during the summer the fishing activity is higher than during the winter. In the south of Gulf of San Jorge is an area, in front of Monte Loaysa where no fishing is allowed, only sailing is allowed.

Law enforcement

You can see on the map that the law enforcement ships are staying close to the coastline. Do you know which ships they are checking?

The law enforcement ships are checking fishing vessels.

Cetaceans

Which type of whales are inhabiting the Gulf of San Jorge?

Whales are spotted in these waters most frequently, during the months February, March, April and May. The months January and December are high season for the whales as well.

During these months many fin whales, sei whale and humpback whales are spotted. From June until October right whales will come to these waters for feeding with their cubs.

There are more whales in Caleta Olivia than in Comodoro Rivadavia. Approximately 95 percent of the whales are living in the area close to Caleta Olivia.

Annex 2

Annex number two are the excel files with all the data of Spire Global. The files are put together in a zip file. These files include all the collected AIS data from Spire Global for the year 2022. With this data all the different maps in this thesis are created.