Universidade de Aveiro
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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Marinha Aplicada, realizada sob a orientação científica da Professora Doutora Lorena Viloria Gómora, Professora e Investigadora do Programa de Investigación de Mamíferos Marinos da Universidad Autónoma de Baja California Sur e do Professor Doutor Mário Verde Pereira, Professor Auxiliar do Departamento de Biologia da Universidade de Aveiro.

Um agradecimento especial ao Programa de Investigación de Mamíferos Marinos (PRIMMA) da Universidad Autónoma de Baja California Sur.

o júri

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agradecimentos

Por detrás de uma dissertação esconde-se uma história que poucos conhecem, recheada tanto de momentos bonitos, como de muitos momentos de tristeza, incerteza e impotência. Uma dissertação é também resultado do contributo de várias pessoas, umas fomentando o nosso crescimento intelectual e outras sendo a nossa rede de suporte emocional, dando-nos o apoio e força necessários nos momentos mais difíceis. Esta dissertação não foi exceção.

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À minha família, em especial à minha irmã Lara, à minha mãe e ao meu pai, obrigada por me permitirem correr atrás dos meus sonhos, incentivando-me a sair da minha zona de conforto. Palavras nunca vão chegar para vos agradecer por tudo. Prometo compensar-vos pelas noites mal dormidas e pela minha ausência. Esta vitória também é vossa, porque se há coisa que são, é o meu maior exemplo de perseverança.

palavras-chave

bem-estar das baleias, *Eschrichtius robustus*, normatividade, ecoturismo, respostas comportamentais, conservação, México.

resumo

A observação de baleias tem vindo a aumentar nas últimas décadas no México. Para minimizar os potenciais impactos negativos das atividades de observação de baleias, foi implementado no México a normativa NOM-131-SEMARNAT-2010. Em áreas marinhas não protegidas, onde a vigilância é menor comparativamente a áreas protegidas, a adesão a esta normativa é uma incerteza.

Para dar resposta a esta questão, o presente estudo visa (1) analisar se a normativa mexicana é cumprida pelos operadores de observação de baleias, e (2) determinar a ocorrência de respostas comportamentais a curto prazo das baleias cinzentas (*Eschrichtius robustus*) à presença de embarcações. Este estudo foi realizado recorrendo ao método de amostragem instantânea durante a época de observação de baleias em 2022 no Complexo Lagunar da Bahía Magdalena, especificamente em Puerto Adolfo López Mateos, Bahía Magdalena e Bahía Almejas.

Com base nos dados recolhidos verificou-se que a normativa não é seguida pelos operadores de observação de cetáceos. É mais provável que as baleias não apresentem comportamentos de evasão à presença dos navios. No entanto, se a perturbação dos comportamentos de natação das baleias, que resulta no aumento da velocidade de natação (Puerto Adolfo López Mateos e Bahía Magdalena), e a perturbação dos comportamentos de socialização que originam reações agonísticas (Bahía Magdalena), continuarem a ocorrer, poderá, a longo prazo, afetar as reservas energéticas e o sucesso reprodutivo das baleias cinzentas. Em Bahía Magdalena, observou-se uma maior probabilidade de ocorrência de respostas evasivas quando as embarcações não cumpriam a normativa e quando havia um elevado número de barcos presentes.

Reforçar a vigilância da área, adaptar a legislação e educar turistas e operadores de embarcações sobre a normativa são algumas das medidas que devem ser adotadas. Desta forma, não só se poderia evitar o agravamento das infrações à normativa, como se poderia assegurar uma observação sustentável das baleias: uma em que as empresas de observação de baleias geram rendimentos, o stress causado ao animal é mínimo e se promove uma ética de conservação nos turistas.

keywords

whales welfare, *Eschrichtius robustus*, normativity, ecotourism, behavioural responses, conservation, Mexico.

abstract

Whale watching has been increasing in recent decades in Mexico. To minimize the potential negative impacts of whale watching activities the normative NOM-131-SEMARNAT-2010 was implemented in Mexico. In non-protected marine areas, where surveillance is lower compared to marine protected areas, the adherence to this normative is an uncertainty.

To address this statement, the present study aims to (1) analyse whether the Mexican normativity is being carried out by whale watching operators, and (2) to determine the occurrence of short-term behavioural responses of gray whales (*Eschrichtius robustus*) to the presence of vessels. This study was conducted using instantaneous sampling during the whale watching season in 2022 in Bahía Magdalena Lagoon Complex, specifically in Puerto Adolfo López Mateos, Bahía Magdalena and Bahía Almejas.

Based on data collected it was found that the normative is not followed by whale watching operators. Whales are more likely not to present avoidance behaviours to vessel presence. However, if the disruption of whale swimming behaviour that results in increased swimming speed (Puerto Adolfo López Mateos and Bahía Magdalena), and the disruption of socialisation behaviour which gives rise to agonistic reactions (Bahía Magdalena), continues to occur, it could, in the long-term, affect the energy reserves and reproductive success of gray whales. In Bahía Magdalena avoidance responses were more likely to occur when vessels did not comply with the normative and when high numbers of vessels were present.

Reinforce monitoring, adapting legislation and educate tourists and boat operators about the normative are some of the measures that should be adopted. This way not only the aggravation of infractions to the normative could be prevented but a sustainable whale watching would be ensured: one in which whale watching companies generate income, the stress caused to the animal is minimal and a conservation ethic is promoted in tourists.

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1. Introduction

1.1 Whales: Ecological importance and threats

Cetaceans are marine mammals belonging to the order Cetacea, which currently includes the suborders Mysticeti (baleen whales) and Odontoceti (toothed whales) (Jefferson et al., 2015). Cetaceans are responsible for significantly contributing to the functioning of the marine ecosystem, through long-distance migrations by whales, whose iron-rich faeces fertilize the ocean by increasing marine primary production, and through the circulation of micronutrients that influence the biogeochemistry of the marine ecosystem (Roman et al., 2017). Additionally, due to their high biomass, these living creatures can sequester carbon dioxide to a greater extent than trees, and their carcasses not only allow for carbon sequestration on the ocean floor but are also important sources of food (Roman et al., 2014).

Like many marine organisms, whales have been victims of anthropogenic actions, whether as collateral damage (for example, through climate change, bycatch, or ocean pollution, both noise and chemical), or directly (Avila et al., 2018). In fact, for centuries whales were heavily persecuted and captured for their meat, blubber, and bones, which led to a reduction in their numbers, even culminating in the extinction of several species (Jefferson et al., 2015). With the ban on commercial whaling under the International Whaling Commission's Moratorium in 1986, most of the nations involved in this industry were forced to readjust their practices and changed their perspective from seeing whales as consumable resources to exclusively promoting its conservation and profiting from it, therefore contributing to give rise to the whale watching industry (García-Cegarra & Pacheco, 2017; Hoyt & Parsons, 2014).

1.2 Whale watching industry: a brief history

Whale watching is a human activity included in ecotourism and defined as "encountering cetaceans (dolphins, porpoises and whales) in their natural habitat" for "scientific, educational, and/or recreational purposes" from boats, aircraft, specific points on land, or even with the watcher swimming or diving near the animal (Hoyt, 2009, p. 1223). The first records of this activity date back to the 1940s, when Carl Hubbs, a whale researcher, began a land-based gray whales watching along with his students from the University of California as part of an academic and governmental project (Hoyt & Parsons, 2014). Only in 1955 the commercial side of whale watching started when a fisherman from San Diego, California charged 1$ trip boats from winter to spring seasons to observe gray whales during their migration routes between the lagoons of Baja California, Mexico, and Alaska (Hoyt, 2009). In 1981, the first review of the worldwide whale watching industry estimated this activity was established in 3 countries with approximately 400 whale watchers, generating $14 million in expenditure (Hoyt, 2001). As previously mentioned, in 1986, commercial whale hunting, also known as whaling, was banned which significantly contributed to the exponential growth of whale watching. In fact, from 1991 to 1998 the whale watching industry grew on an average of 12.1% per year, being considered the biggest growth period in history: whale watching went from being in 31 countries with 4 million people experiencing it and spending $317.9 million to being in 87 countries, with 9 million whale watchers accounting for $1 billion expenditure (Hoyt, 2001). The most recent review available from 2008, estimates this industry attracts nearly 13 million participants in a total of 119 countries representing $2.1 billion in expenditure (O'Connor et al., 2009). During the ten-year period 1998-2008 this industry grew globally at an average rate of 3.7% per year, as much as the growth of global tourism, estimated around 4.2% annually (Hoyt & Parsons, 2014). Whale watching is even considered nowadays the most renowned ecotourism activity worldwide (Cunningham et al., 2012). Nevertheless, in a regional perspective whale watching is more prominent in certain regions, Mexico being one of the examples (Cisneros-Montemayor et al., 2010).

1.3 Whale watching impacts

Whale watching plays a crucial role in the local economies where it takes place (Vega et al., 2018). In addition, it can be educationally beneficial (Parsons, 2012): firstly, because it allows scientists to obtain information about socio-ecological aspects of cetaceans, which is useful in decision-making for coastal management and reducing impacts caused on them and their habitat (Hoyt, 2005); secondly, by allowing closer contact with cetaceans and providing information related with their biology, tourists are sensitized to the need of protecting wildlife, thus a conservation ethic is promoted in the individuals (Parsons, 2012).

Despite all the benefits associated with the practice of this activity, several studies have been conducted on the negative effects it may have if not sustainably managed, both in the short- and long-term (Argüelles et al., 2016; Santos-Carvallo et al., 2021). Some sources of perturbation generated by this activity in cetaceans include noise pollution created by vessel traffic, over occupation of an observation area with boats, excessive proximity of the boat to the animal, too much time spent interacting with cetaceans, high-speed approaching the animals, lack of whale watching regulation normative or lack of monitoring compliance with the implemented legislation (Hoyt & Parsons, 2014).

Whale watching can directly affect cetaceans as the collision with vessels can lead to injuries or even be lethal (Parsons, 2012). Additionally, these sources of perturbation have been proven to elicit short-term behavioural responses in cetaceans: movement patterns becoming more erratic and sinuous, swimming speed significantly increasing (Santos-Carvallo et al., 2021), increasing diving time (Stamation et al., 2010) and rate of respiration (Christiansen et al., 2014; Schuler et al., 2019), disruption of feeding (Christiansen et al., 2013; Lesage et al., 2017) and resting (Avila et al., 2015; Sprogis et al., 2020a, 2020b), increasing the volume of the vocalizations (Foote et al., 2004) and increasing breaching frequency (Avila et al., 2015) are some of the reported. These changes can be responsible for increasing energy expenditures which in a long-term may affect body condition, reproduction success, and survival rates of the animals, therefore negatively impacting the population dynamics and eventually becoming a threat to the conservation of the species (Christiansen et al., 2013; Lusseau & Bejder, 2007; Parsons, 2012; Santos-Carvallo et al., 2021). The responses of cetaceans to whale watching activities, commonly called evasion techniques, may vary depending on multiple factors, for example, the number of boats or the approach distance (Schaffar et al., 2013; Williams et al., 2009).

Despite all the described behavioural responses of cetaceans to stress, it should be noted that the absence of an observable reaction does not necessarily mean that the animal is not being affected (Gill et al., 2001; Wright et al., 2007). Some factors that might cause the tolerance of the animal to stress can be the lack of energy, being in an area of essential source of prey, or with a low rate of predation compared to other areas (Beale & Monaghan, 2004; Gill et al., 2001; Parsons, 2012).

However, to minimize the potential negative impacts caused by whale watching and therefore protect and conserve whales and their habitat some countries have established regulations (Cole, 2007).

1.4 Whale watching in Mexico

Mexico is among the top 10 destinations globally and was the first country to implement whale watching activities after the United States (Hoyt & Iñíguez, 2008). At the beginning of the 1970s took place the first free boat whale watching tours departing from San Diego, California and having San Ignacio's and Ojo de Liebre lagoons as destinations (Fleischer, 2002). At this time most of the trips were offered by U.S. companies with all the services included (e.g. travel, lodging, and food) (Vega et al., 2018). However, at the end of the 1980s, the Mexican government legislated a mandatory for tourist companies to use local vessels and guides for the observation of cetaceans. Whale watching in Mexico became an activity with economic profit for the local communities. It provides an economic alternative income for fishermen during the whale season (from mid-December until mid-April) but also contributes to the economic development of whale watching companies and third-party services related to it (Hoyt, 2004; Young, 1999).

The progressive growth of whale watching in Mexico over the years is reported in the review of Latin America whale watching Outlook by Hoyt and Iñíguez (2008): whereas in 1991 this activity was just in its beginning with approximately 2000 whale watchers contributing with around $3.2 million expenditure, from 1994 to 1998 whale watching grew significantly increasing from 12 000 participants to approximately 108 000, allowing an increase in revenues from $15 million to near $42 million. In 2006, whale watching was estimated to attract about 170 000 participants in Mexico, accounting for almost $86 million in expenditures (Hoyt & Iñíguez, 2008). At the time, this industry was growing by 5.8% per year, even surpassing the growth of general tourism (Urbán & Viloria-Gómora, 2021).

The practice of whale watching has been expanding along the Mexican coast, currently focusing mainly on the fin whale (*Balaenoptera physalus*) resident population within the Gulf of California and on three migratory species, gray whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*), and blue whale (*Balaenoptera musculus*) (Urbán & Viloria-Gómora, 2021). Whale watching official sites are defined every year by The Environment and Natural Resources Ministry from Mexico (Diario Oficial de la Federación [DOF], 2011). The main sites to observe gray whales are the coast of Ensenada as well as the western coast of the Baja California Peninsula, namely Ojo de Liebre Lagoon, San Ignacio Lagoon, and Bahía Magdalena Lagoon Complex (Ruiz et al., 2006). For humpback whale watching, the states of Sinaloa, Jalisco, Nayarit, Guerrero, Oaxaca, and the south of Baja California Sur, such as in Cabo San Lucas, are the selected (Urbán & Viloria-Gómora, 2021). Finally, the best locations to observe blue whales are Loreto Bay and the coast of Sonora (Urbán & Viloria-Gómora, 2021) (Figure 1).

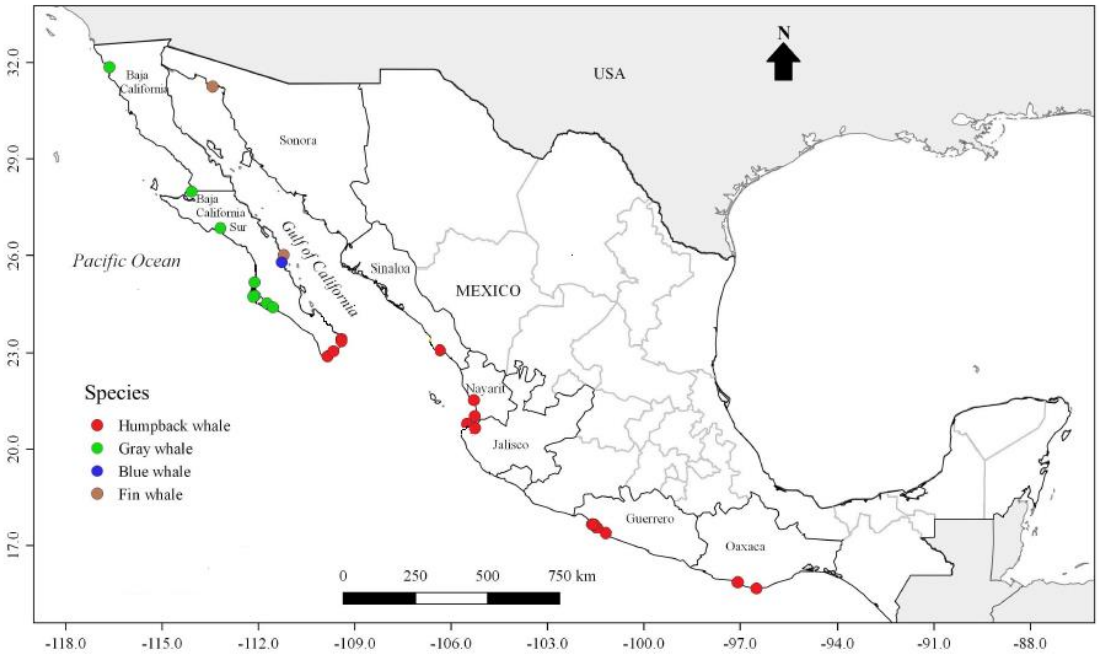

Figure 1. Whale watching sites in Mexico for the 4 four main observed species of whales: Humpback whale, Gray whale, Blue whale, and Fin whale (adapted from Urbán & Viloria-Gómora, 2021).

1.5 Mexican regulation of whale watching

In Mexico, the 131 Official Mexican Standard regulating whale watching activities was implemented in 1998. In 2011 it suffered some modifications as a result of the collaboration between companies, institutions, and non-governmental organizations of which stand out the Ministry of Environment and Natural Resources (SEMARNAT), General Directorate of the Primary Sector and Renewable Natural Resources and the Federal Attorney for Environmental Protection (PROFEPA), leading to the current NOM-131-SEMARNAT-2010 (DOF, 2011). This normative contemplates guidelines and specifications for the whale watching on species occurring in waters under the federal jurisdiction of the United Mexican States, based on scientific reports from other countries and on the precautionary principle, aiming to assure a minimal impact (DOF, 2011).

In the NOM-131- SEMARNAT-2010, 2 crucial zones are defined: the waiting area, where the vessel is within 240 meters from the whale, and the observation area, where the distance the vessel is from the whale depends on the size of the vessel (small vessels (< 10 meters long), medium vessels (≥ 10 <27 meters long), large vessels (≥27 meters long)) and the species under observation (Table 1) (DOF, 2011).

Table 1. Observation distances according to the species and size of the vessel (adapted from DOF, 2011).

Whale species	Observation distance	
	Small vessels	**Medium/large vessels**
North Pacific Right whale *(Eubalaena japonica)* Minke whale *(Balaenoptera acutorostrata)* Sei whale *(Balaenoptera borealis)* Bryde's whale *(Balaenoptera edenii)* Bryde's whale *(Balaenoptera brydei)* Humpback whale *(Megaptera novaeangliae)* Gray whale *(Eschrichtius robustus)* Sperm whale *(Physeter macrocephalus)*	60 meters	80 meters
Blue whale *(Balaenoptera musculus)* Fin whale *(Balaenoptera physalus)*	100 meters	120 meters

Considering the example of gray whales (and as with the other species inserted in the same group, as shown in Table 1), the observation distance for small vessels would be 60 meters whereas for medium/large vessels would be 80 meters as demonstrated in Figure 2.

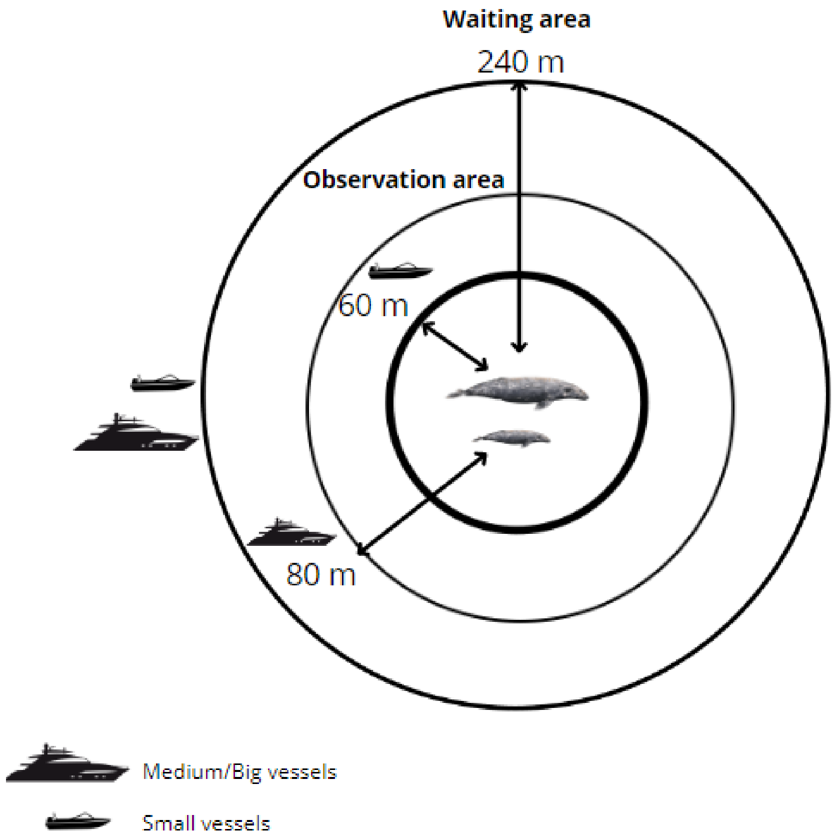

Figure 2. Waiting area and observation area for gray whale *(Eschrichtius robustus).*

In the NOM-131- SEMARNAT-2010 some of the most important guidelines that must be adopted during the approach and observation of whales are (DOF, 2011):

-whales must be approached in a diagonal line from behind and when following an individual/group of animals the vessel should move parallel to them (Figure 3);

-vessels must not encircle whales;

-in case of whales approaching the vessel, the vessel must wait for the animal to retreat in order to depart at low speed;

-the vessels must immediately move away at low speed if the animals show evasive swimming with sudden changes in direction and speed, make increasingly prolonged dives, interrupt their feeding, mating, or rearing activities;

-the duration of the observation period cannot exceed 30 minutes;

-a maximum of four boats with an individual/group of whales is allowed.

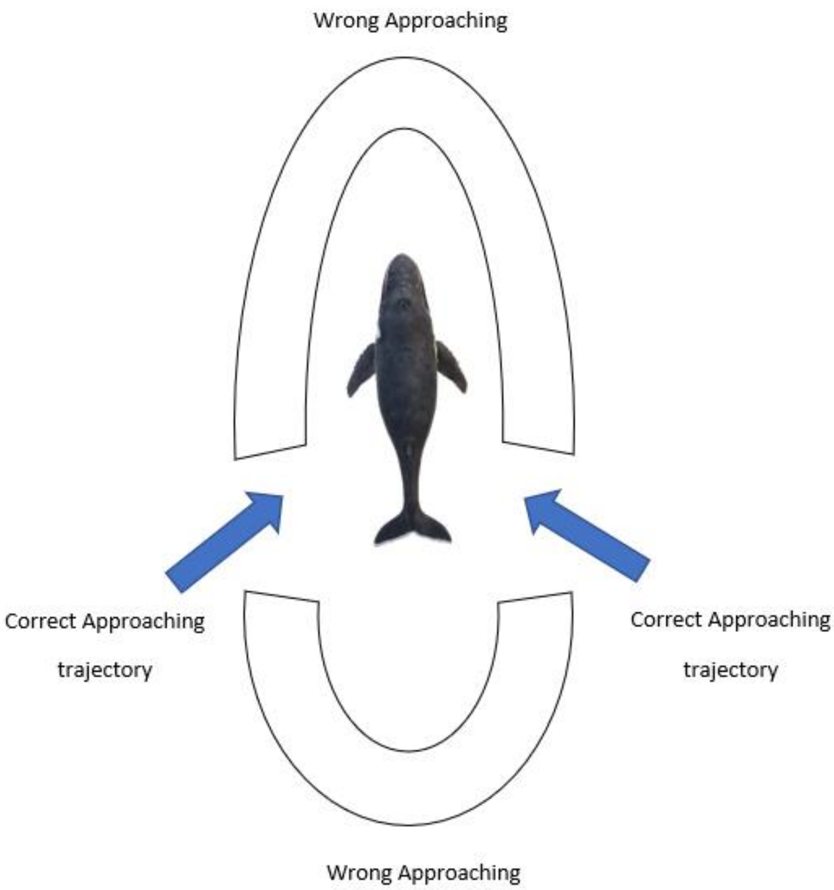

Figure 3. Vessel way of approaching whales.

SEMARNAT is responsible to issue whale watching permits, which are limited in number, specific to a certain location, and cannot be transferable, only shared among cooperatives or within families (Schwoerer et al., 2016). These permits only allow the activity during the season defined annually by SEMARNAT for each sighting area (DOF, 2011).

Compliance with the normative guidelines can be verified or requested by interested individuals through a "conformity assessment" carried out by PROFEPA or by Verification Units (UV) and non-compliance is sanctioned (DOF, 2011).

Despite this normativity, the main problem seems to be whether it is being applied in the field (Urbán & Viloria-Gómora, 2021). In marine protected areas, such as the El

Vizcaino Biosphere Reserve, classified as UNESCO World Heritage site and in which Laguna San Ignacio and Laguna Ojo de Liebre are included, there is a higher control and monitoring of these activities, being easier to ensure compliance (Hoyt, 2004; Urbán & Viloria-Gómora, 2021). However, in non-protected areas in Mexico, like Bahía Magdalena Lagoon Complex, a congregation site for the Eastern North Pacific gray whale and where whale watching tourism is well established, there is no certainty of the adherence to the regulations (International Whaling Commission [IWC], 2018).

1.6 Gray whale

1.6.1 External Anatomy

Gray whales (*Eschrichtius robustus* [Lilljeborg, 1861]) are Mysticeti that belong to the superfamily Balaenopteroidea and are the only members of the Eschrichtiidae family (Swartz, 2018). These marine mammals have long slim bodies with a tapered head, small eyes close to the corners of the mouth (Figure 4) and can weight up to approximately 4000 kilos (90000 pounds) and grow up to 15.3 meters (50 feet) long with females measuring slightly more than males (Jones & Swartz, 2009). Its skin is mottled from dark to light grey with white patches usually presenting barnacles and whale lice, a parasite also called cyamids, which are higher concentrated on the head and the tail (Swartz, 2018). Instead of a dorsal fin, a dorsal hump followed by 6 to 12 small humps or knobs, called "knuckles", can be found at two-thirds of the way back on its bodies (Jefferson et al., 2015). The pectoral flips are relatively short and the tail flukes have rounded edges and a prominent 10 to 25 cm wide deep notch in the middle of the ventral side (Jefferson et al., 2015).

Figure 4. Gray whale illustration (PRIMMA).

For feeding purposes, this animal has two short throat pleats that allow the throat to expand and create suction (Jefferson et al., 2015). Gray whales present yellowish baleens with approximately 130 to 180 coarse plates per side, each plate measuring 5 to 40 cm, being the Mysticeti with the shortest baleen and with the fewest plates (Jones & Swartz, 2009).

1.6.2 Distribution and migration

Currently are recognized two extant North Pacific populations of gray whales (Figure 5): the Western North Pacific (WNP) population and the Eastern North Pacific (ENP) population (Swartz, 2018).

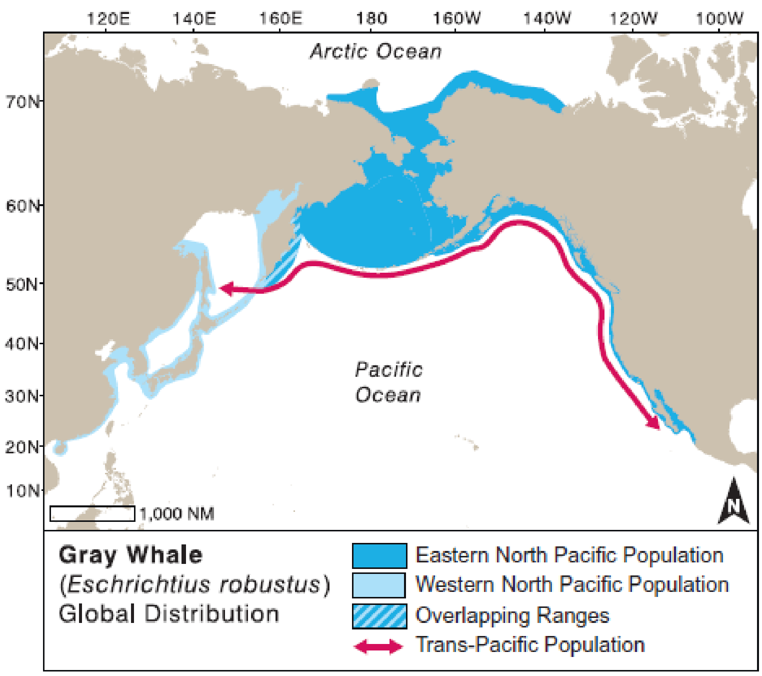

Figure 5. Gray whale Eastern North Pacific population and Western North Pacific population distribution (Swartz, 2018).

The WNP population was not able to recover from the massive hunt in the early 18th century and currently having between 271 and 311 individuals is considered under the IUCN as critically endangered (Cooke et al., 2018). The ENP population, however, was capable of recovering to the estimated pre-exploitation levels, between 15 000 and 24 000 individuals (Amerson & Parsons, 2018).

Gray whales from the ENP population feed from the end of May to the beginning of October in the shallow coastal and shelf waters between Alaska and Russia and along their northern coastlines, namely in The Gulf of Alaska, the southeastern Bering Sea, the southern Chukchi Sea, and the western Beaufort Sea (Swartz, 2018). In fall, for approximately 2 months, the ENP population undertakes its annual southward migration exiting the Bering Sea via Unimak Pass, Alaska, and following the coast to Mexico (Rice & Wolman, 1971; Rugh et al., 2001). The annual migration of this population is considered to be the longest of any Mysticeti, around 15.000–25.000 km (Swartz, 2018). Between December and April, mating and birthing of the ENP gray whales occurs in the western coast lagoons of Baja California, in Mexico (in these being included the Laguna Ojo de Liebre, Laguna Guerrero Negro, Laguna San Ignacio, and the Bahía Magdalena Lagoon Complex) (Jones & Swartz, 2009). At the end of March, ENP gray whales begin their departure from the wintering lagoons, migrating northward to their feeding areas (Urbán et al., 2021).

ENP gray whale distribution may be influenced by the Pacific weather events El Niño and La Niña (Swartz, 2018). During El Niño events the surface temperature of the Pacific waters increases and the migration of gray whales, particularly females with calves, is known to be shorter (Swartz, 2018). On the contrary during La Niña, when the sea surface temperature decreases, ENP gray whales migrate for longer distances, occasionally reaching the Gulf of California looking for warmer water (Swartz, 2018).

1.7 Research Aims

This study aims to monitor whale watching activity on gray whales, made from tourism vessels, in Bahía Magdalena Lagoon Complex, a non-protected marine area, and determine if the activity is causing any disturbance or negative impact on the behaviour of this species. The approach consists in:

-registering if the tour operators carry out the normative NOM-131-SEMARNAT-2010;

-recording the types and intensities of infractions to the normative;

-recording features related to whales namely the group composition;

-recording the whale behavioural state and the behavioural responses to the arrival and presence of vessels.

2. Methods

2.1. Study Site

Data were collected in Bahía Magdalena Lagoon Complex (between 24° 16´ and 25° 45´ N and -111° 20´ and -112° 18´ W), located on the Pacific coast of Baja California Sur (BCS), Mexico (Álvarez-Borrego et al., 1975). The Bahía Magdalena is a 1390 km^2 coastal lagoon complex parallel to the coast, originated by tectonic events, which is protected by three islands (Magdalena, Margarita and Creciente) with wide mouths allowing the lagoon complex-Pacific Ocean connection. The northern part of the complex, the Canal de Santo Domingo (137 km^2), is formed by narrow and relatively shallow mangrove channels (Funes-Rodríguez et al., 2007). The Canal de Santo Domingo has two mouths, Boca Santo Domingo and Boca la Soledad, the last one being closer to Puerto Adolfo López Mateos, a region of whale watching tourism. The middle part of the complex is composed of a series of channels and by Bahía Magdalena, an 883 km^2 lagoon with a 5.6 km wide mouth, Boca Entrada (Funes-Rodríguez et al., 2007). This area is used by the community of Puerto San Carlos for fishing and for nature-based tourism associated with gray whales. The southern region is formed by several lagoons, the largest one being Bahía Almejas (370 km^2), connected to the ocean by the Canal de Rehusa (Funes-Rodríguez et al., 2007). Bahía Almejas is used by the community of Puerto Chale for whale watching purposes.

The geographic and physical characteristics of the Bahía Magdalena Lagoon Complex, such as the subtropical location, the current regime (California Current and California Countercurrent), shallow mangrove channels, seagrass beds, networks of canals, sand bars, and islands create a diversity of habitats and nursery conditions that attract a great variety of both migratory marine and terrestrial species (Wilkinson et al., 2009). In the specific case of gray whales, it is suggested that the temperature and the protection the islands confer to coastal lagoons (including from the predation of calves by killer whales (*Orcinus orca*)) are the principal reasons for this species choosing this area as a breeding ground (Corkeron & Connor, 1999).

2.2. Data Collection

The 2022 data collection season was carried out in three different periods: the first period from 18th to 30th January, the second period from 7th to 18th February, and the last one from 27th February to 10th March. Surveys were conducted from a 7 meters vessel with a 70-hp outboard motor departing from Puerto San Carlos and which belongs to the whale watching company Blue Bay. Said company maintains a partnership with the marine mammals' research program (PRIMMA) from the Universidad Autonoma de Baja California Sur in La Paz, Mexico which allows the vessel to be used exclusively for research during the three-month season. Observations were performed when weather conditions provided good visibility to ensure reliable data collection (Beaufort Sea state of 2 or less, with no coastal fog or rain). The viewing area covered approximately 180° and was scanned with either the naked eye or binoculars. The research vessel was positioned within a 300 meters radius from the tourism vessels to provide an optimal viewing area. To minimize the impact of the research vessel on the whales, speed and distance to the animals were maintained constant as much as possible.

The predominant behaviour displayed by an individual or by most individuals (>50%) on a group (or "pod") before the approach of the tourism vessel (control conditions) as well as their reaction to whale watching vessels presence (impact conditions) were recorded by instantaneous sampling. When a tourism vessel was present, the individual or group closer to the boat was followed and the beginning time of the encounter and the GPS coordinates were recorded using a GARMIN 73 handheld GPS device and written down on the datasheet (Figure S1). Boats were considered to be "present" when the distance to the closest whale was <200 meters. The behaviour states prior to the presence of vessels and responses to the boat presence observed during the study are presented in Table 2 and were based on definitions used in other whale watching impact assessment studies (Martín-Montalvo et al., 2021; Stelle et al., 2008; Toro et al., 2021; Torres et al., 2018).

Table 2. Definitions of behavioural state and the response to boat disturbance for gray whales (*Eschrichtius robustus*) adapted from (Martín-Montalvo et al., 2021; Stelle et al., 2008; Toro et al., 2021; Torres et al., 2018).

States	Definition
Behaviour state	
Resting	The whale stays close to the surface remaining stationary or moving slowly.
Travelling	The whale propels itself in a consistent direction and speed.
Surface active	The whale displays energetic behaviour that can be observed from the surface (e.g., spyhopping, spinning).
Socialising	Two or more whales demonstrate physical interaction, including chasing, body contact and copulation.
Response to the boat	
Avoidance	Which covers (a) speeding, when the whale increased its travelling velocity; (b) dodging, when the animal abruptly changed its course; (c) agonistic reaction, when aggressive reaction against the boat was displayed (e.g., tail slap, pectoral fin slapping, jumping near the vessel).
Indifference	When no behavioural response was observed to the arrival and presence of a vessel.
Approaching	When the animal approached or interacted with the vessel.
Undetermined	When it was not possible to determine the animal's reaction.

For all sightings, the number of whales and composition of the group (adults solo or adult with calves, a calf being considered an individual considerably smaller, usually half of the size of the adult which it swims next to (Shane et al., 1986)) were registered. As these parameters are estimated visually, in encounters with high numbers of whales present may have occurred an over or under-estimation of the group size.

Finally, the vessel compliance with the Mexican whale watching regulation was evaluated by the naked eye. A vessel was considered non-compliant when at least one guideline of the regulation was not respected. For the purpose of this study, the guidelines evaluated were: the number of vessels with an individual/group of whales, observation time, the distance of approaching, vessel approaching trajectory, vessel position (encircling the whales), and vessel speed. The parameter vessel speed was estimated considering the velocity of the research vessel and the parameter distance of approaching was estimated by the visualization of known distances between two points in the sea.

When the tourism vessels left the whale or when the animal disappeared from the observation area, the encounter ended and time was recorded.

In addition to collecting data for the present study, biological monitoring, namely census was also carried out during the season at the Bahía Magdalena Lagoon Complex. Census are conducted once in each period of data collection and in each lagoon area, following predetermined survey track lines using GPS devices, to estimate the minimum number of gray whales in the area and compare with counts from previous years. The data collected from the census were crucial to draw comparisons between the minimum number of whales present in each area and the vessel number of infractions registered and take conclusions.

2.3. Data Analysis

To analyse the total sighting effort of the present study, the number of sightings, the number of days and hours tracking over the entire field season, and for each one of the three periods was calculated.

All geospatial analysis were performed using the software Quantum Geographic Information System 3.22.7 (QGIS). A base map of Baja California Sur provided by PRIMMA was used.

The package "ggplot2" of the RStudio version 2022.02.1+461 was used to plot bar charts for better graphical observation of the data and therefore visualize peaks.

Pearson's Chi-square Test for Independence was performed in RStudio, with the function chisq.test, to determine the relationship between categorical variables, namely between the variables vessel compliance with the normative and group composition and between vessel compliance with the normative and the whale behavioural response to the presence of vessels. Pearson's Chi-square Test for Independence compares the observed frequencies with the frequencies that would be expected if non-association between the variables was true (Sharpe, 2015):

$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

Where χ^2 is the Chi-Square value, O_i is the observed frequency and E_i is the expected frequency.

After statistical significance at 5% has been proved, the degree of association between the variables was measured using the coefficient of Phi (ϕ), since it is the one suggested for 2x2 contingency tables (Sharpe, 2015):

$$\phi = \sqrt{\frac{\chi 2}{n}}$$

where χ^2 is the Chi-Square test statistic and n is the total number of observations.

ϕ values range from -1 to 1, with absolute values of $\phi<0.1$ suggesting weak association, $\phi>0.5$ suggesting strong association, and in-between values meaning moderate association (Olivier & Bell, 2013). Negative values indicate the variables are inversely related.

If the Chi-square Test for Independence's assumption of more than 20% of cells having expected frequencies < 5 was violated (Kim, 2017), a Fisher's exact test using RStudio's function fisher.test was performed instead to determine significance association at *p-value* <0.05.

The Point-biserial correlation test was calculated with the function cor.test to ascertain the relationship between the categorical variable whale responses to vessel presence and the numerical variable number of vessels. When the *p-value* < 0.05 the correlation between the variables was considered statistically significant. The Point-biserial correlation coefficient ranges from -1 to 1, negative values meaning there is a negative correlation between two variables (das Gupta, 1960). The absolute values of correlation coefficients <0.2 suggest a weak correlation, from 0.2 to 0.3 a moderate correlation, and >0.3 a strong correlation (McGahee & Ball, 2009).

In statistical tests where whale behavioural response to the presence of vessels was one of the variables analysed, undetermined behaviours were excluded and responses were treated as binomial, avoidance and non-avoidance. Approaching and indifference behaviours were considered non-avoidance responses.

3. Results

3.1 Effort

During the whole season, a total of 44.14 hours throughout 23 days were spent collecting data on 477 sightings (Table 3). Bahía Magdalena was where most data were collected and more days were spent at, with 11 days of tracking resulting in 254 sightings. However, it was in Bahía Almejas where more hours were spent on effort - 19.65 hours. On the other hand, it was on Puerto Adolfo López Mateos where fewer sightings occurred and less effort was spent, with 76 sightings resulting from 5 days of tracking, a total of 7.16 hours spent on effort.

Table 3. Total number of whale watching sightings, days, and hours spent on tracking for each location during the field season.

Sighting location	Total number of sightings	Total number of days spent	Total number of hours spent
Puerto Adolfo López Mateos	76	5	7.16
Bahía Magdalena	254	11	17.33
Bahía Almejas	147	7	19.65
Total	477	23	44.14

If the data collected in each location are broken down by each period (Table 4), from 18th to 30th January 2022 (first period) most sightings and hours spent on effort were recorded in Bahía Almejas, despite being the place where fewer days were spent at.

Table 4. Number of whale watching sightings, days and hours of tracking during each field period for each location.

Sighting location	Period	Number of sightings	Days of survey	Hours of survey
Puerto Adolfo López Mateos	18-30 Jan	5	2	1.98
	7-18 Feb	71	2	4.13
	27 Feb-10 Mar	0	1	1.05
Bahía Magdalena	18-30 Jan	9	3	3.80
	7-18 Feb	201	6	10.90
	27 Feb-10 Mar	44	2	2.63
Bahía Almejas	18-30 Jan	41	1	3.90
	7-18 Feb	56	3	7.05
	27 Feb-10 Mar	50	3	8.70

During the second period (7th to 18th February 2022), 10.9 hours spent on effort throughout 6 days resulted in 201 sightings in Bahía Magdalena, the location where more effort was spent. In the last period of data collection (27th February to 10th March 2022), Bahía Almejas was the location where more sightings and more time was spent on effort, with 50 sightings as a result of 8.7 hours over 3 days. Despite the effort, no data were collected on that same period in Puerto Adolfo López Mateos.

3.2 Distribution

Most of the 477 sightings in the Bahía Magdalena Lagoon Complex occurred closer to the mouths of the lagoons that connect them to the open ocean, opposite to the Baja California Peninsula (Figure S2).

The distribution of whale watching sightings in the first period of data collection was mainly in the north region of Puerto Adolfo López Mateos on the eastern side of the lagoon mouth (Figure 6). In the second period, sightings occurred closer to Puerto Adolfo López Mateos but also along Boca la Soledad. Lastly, in the third period, no whales were sighted in this area.

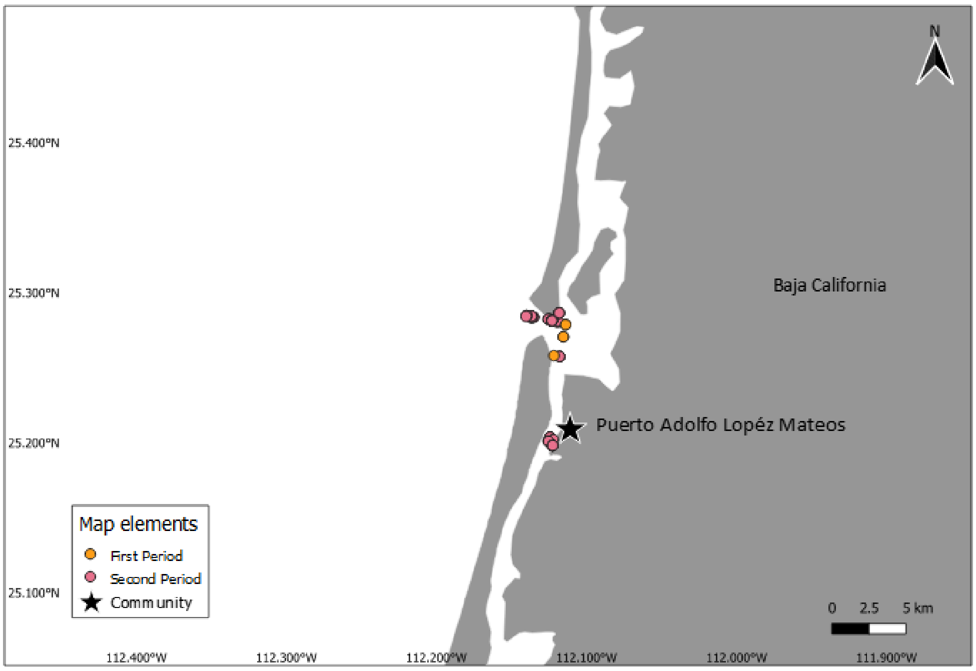

Figure 6. Whale watching sightings in Puerto Adolfo López Mateos over the three different field periods.

Figure 7 shows that in the three periods of data collection, the sightings were concentrated in the southwestern region of the Bahía Magdalena lagoon near the Boca

Entrada. In the third period, the sightings occurred slightly further into the lagoon compared to the other periods.

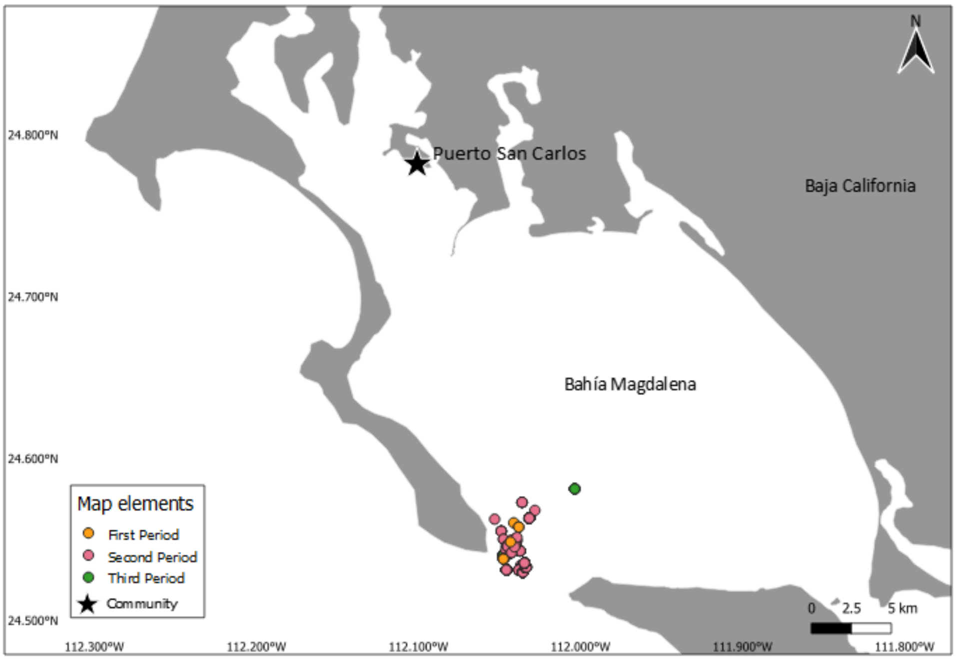

Figure 7. Whale watching sightings in Bahía Magdalena over the three different field periods.

In the first and third field periods data were collected inside the Bahía Almejas lagoon close to the Canal de Rehusa and in the second period along the mouth (Figure 8).

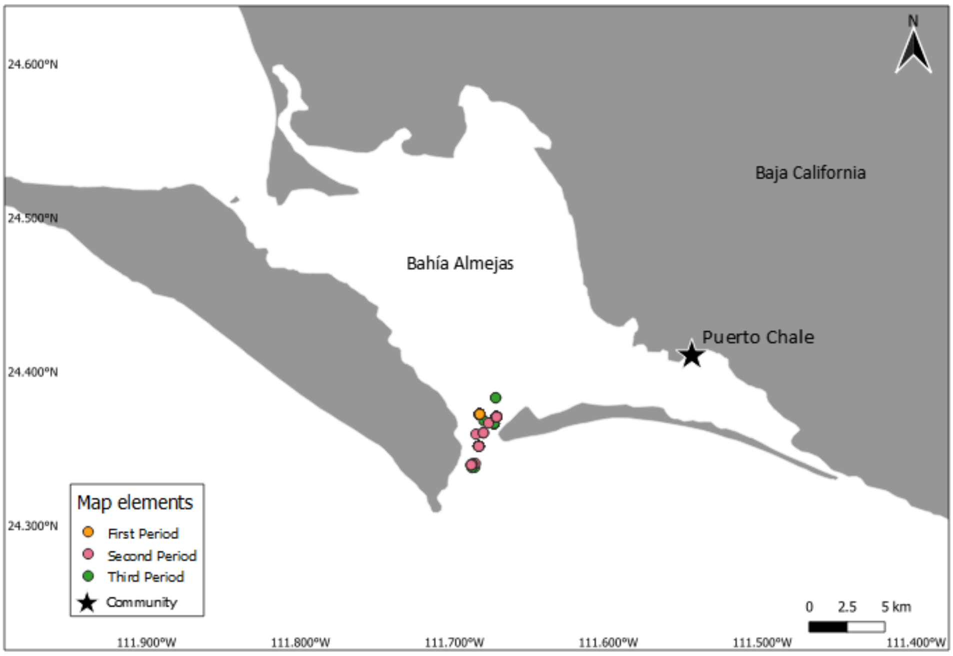

Figure 8. Whale watching sightings in Bahía Almejas over the three different field periods.

3.3 Puerto Adolfo López Mateos

3.3.1 Vessel compliance with the regulation

Of the total 76 sightings recorded in Puerto Adolfo López Mateos, in 72.4% of them the Mexican whale watching regulation was not complied with and in 27.6% the regulation was respected (Figure 9).

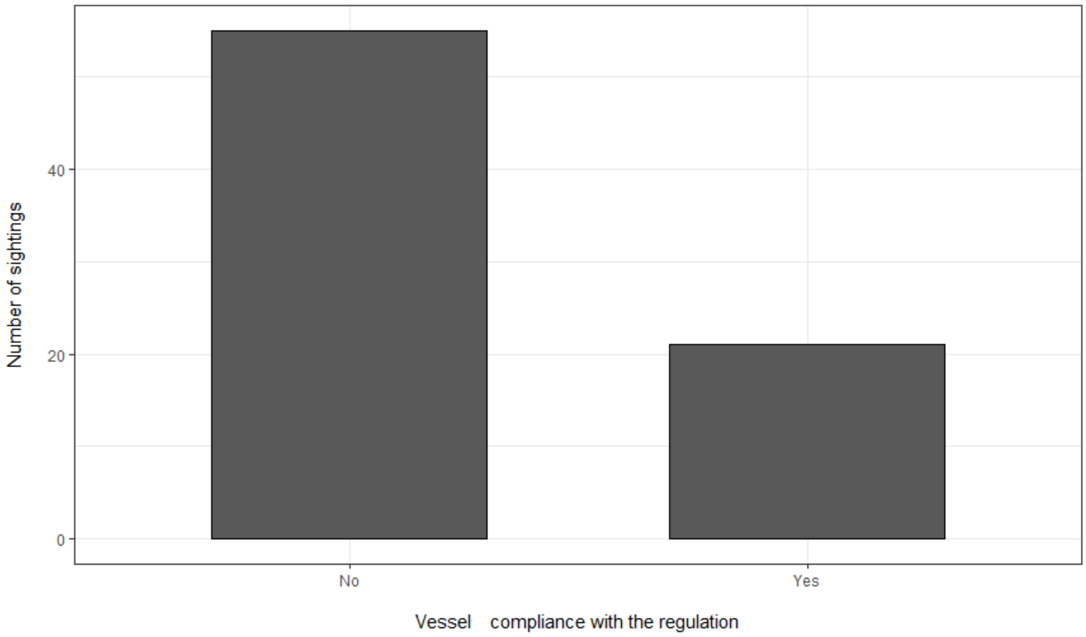

Figure 9. Number of sightings of compliance (n=21) and non-compliance (n=55) with the regulation in Puerto Adolfo López Mateos.

Analysis of the type of legislation guidelines that were not respected showed that in the majority (49.1%) vessels did not respect the distance from the animal, and the second principal infringement (29.1%) was the encirclement of the animals by vessels (Figure 10). The maximum observation time was never exceeded by vessels.

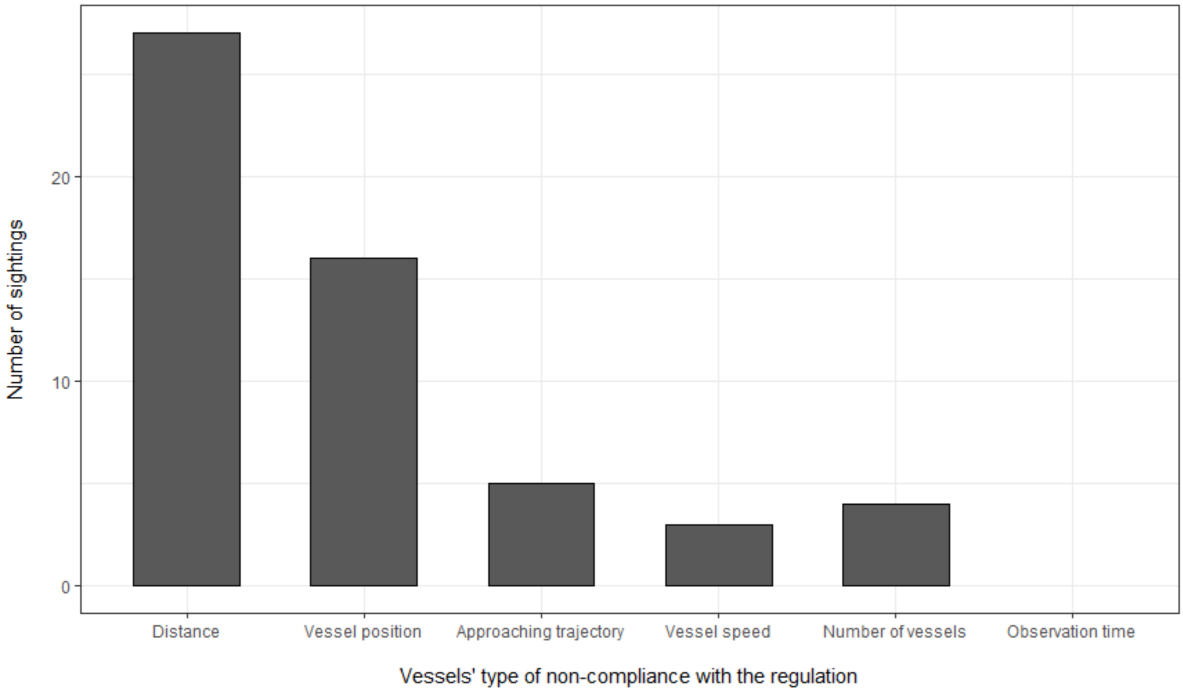

Figure 10. Type of vessel infractions to the regulation (distance n=27, vessel position n=16, approaching trajectory n=5, vessel speed n=3, number of vessels n=4, observation time n=0) in Puerto Adolfo López Mateos.

3.3.2 Vessel compliance with the regulation and group composition of whales

The number of sightings of adult solos was slightly lower than the number of sightings of adults with calves. Concerning adults solo, there were a higher number of sightings (54.3%) where the regulation was complied with. The opposite situation occurred concerning mothers with calves, with 95.1% of sightings recording some type of infraction of the implemented legislation. (Table 5).

Table 5. Whale group composition in compliance and non-compliance sightings in Puerto Adolfo López Mateos.

	Whale group composition	
Legislation compliance	Adult solo	Adult with calf
Yes	19	2
No	16	39

The Pearson's Chi-Square test of independence determined that the relationship between the compliance of the whale watching legislation and the whale group composition was significant ($X^2_{(1)}$ = 23.05, p= 1.58e-06; ϕ= 0.55), non-compliance being more likely to occur on encounters of adults with calves and compliance being more likely to occur on encounters with adult solos.

3.3.3 Vessel compliance with the regulation and number of whales per period

Table 6 illustrates the number of whales registered during the census surveys and the number of infractions noted at each one of the three field periods. In the first period, 23 whales were sighted and no infractions occurred. In the second period, the number of whales and infractions rose to 38 and 55, respectively. In the third period, no whales or infractions were noticed.

Table 6. Number of infractions to the normative and number of whales sighted in the census at the three field periods in Puerto Adolfo López Mateos.

Field Period	Number of whales	Number of non-compliance occurrences
First	23	0
Second	38	55
Third	0	0

3.3.4 Vessel compliance with the regulation and whale behavioural responses

In most sightings (56.6%) it was not possible to determine the whale behaviour in impact conditions. Nevertheless, in sightings where it was possible to be determined, the whales responded with indifference and in rare cases (5.3%) with avoidance (Figure 11).

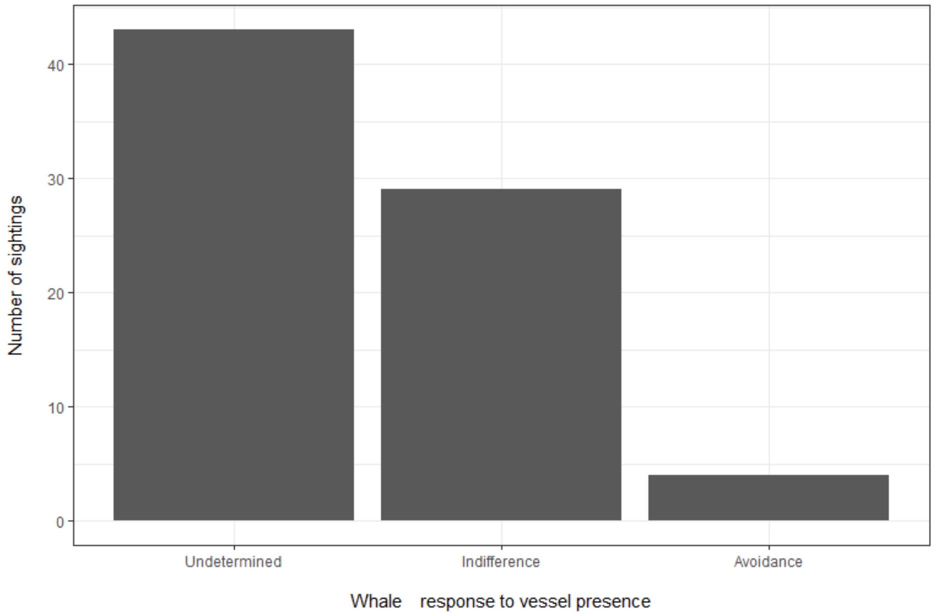

Figure 11 . Whale behavioural response to vessels presence (undetermined, n=43; indifference, n=29; avoidance, n=4) in Puerto Adolfo López Mateos.

No socialising behaviours were observed in Puerto Adolfo López Mateos (Figure 12). Resting and surface active behaviours were not affected by the presence of vessels. Avoidance responses only occurred in whales travelling, specifically in 15.4% of the sightings.

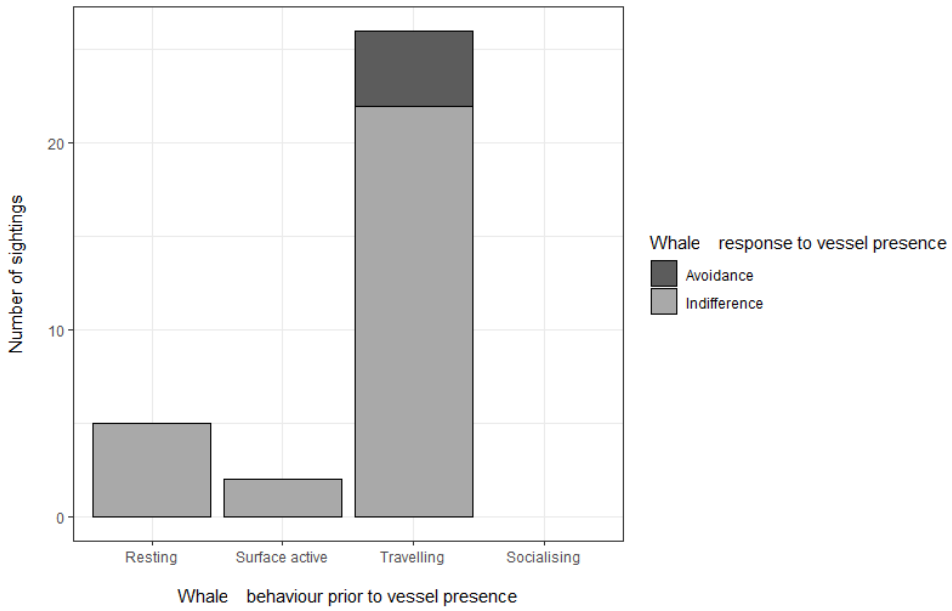

Figure 12. Whale behavioural states and response to vessel presence in Puerto Adolfo López Mateos (resting, n=5; surface active, n=2; travelling, n=26; socialising, n=0).

Increasing the travelling velocity was the only avoidance response by whales to the arrival of vessels (Table 7).

Table 7. Whale behaviour in control conditions and avoidance response in impact conditions in Puerto Adolfo López Mateos.

Behaviour prior to vessel presence	Avoidance response to vessel presence	Number of sightings
Travelling	Speeding	4

Avoidance responses only occurred when infractions were observed (Figure 13). In 37.9% of the sightings where whales showed indifference to the arrival of vessels the normative was not respected and in 62.1% it was respected. However, vessel compliance or non-compliance with legislation did not significantly affect the likelihood of occurring avoidance (p=0.28).

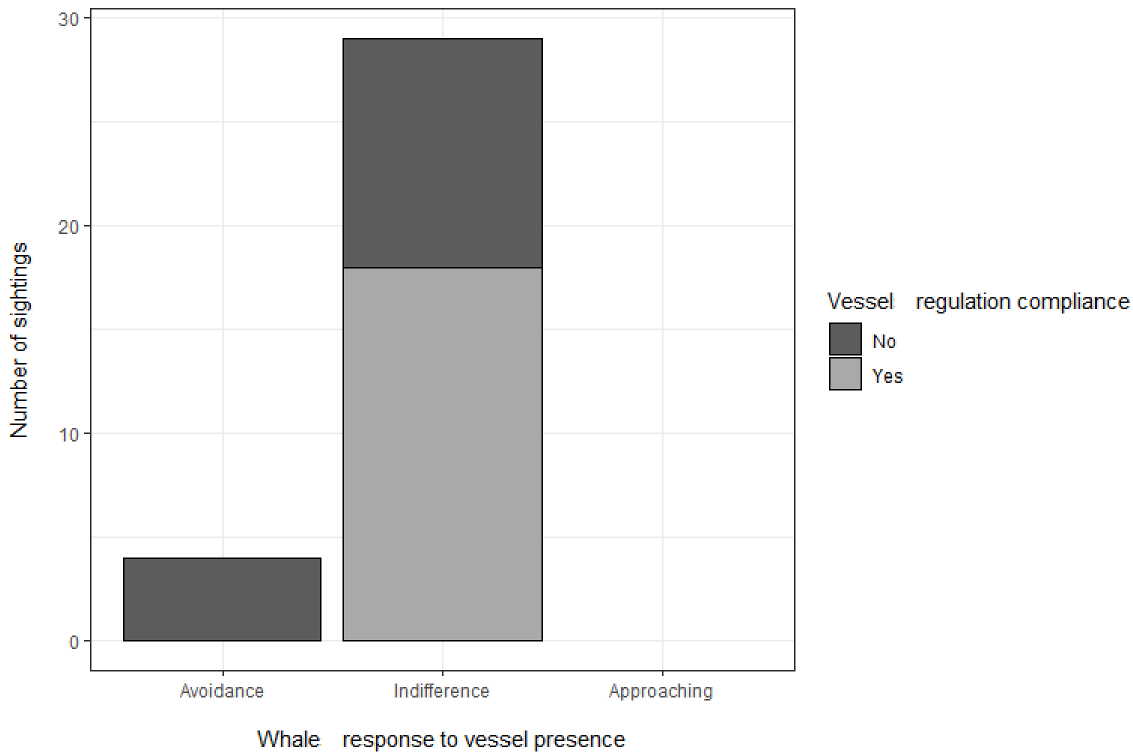

Figure 13. Whale response to vessels presence under conditions of regulation compliance (avoidance n=0, indifference n=18, approaching n=0) and non-compliance (avoidance n=4, indifference n=11, approaching n= 0) in Puerto Adolfo López Mateos.

In Puerto Adolfo López Mateos, we observed an average of 3 boats (maximum: 6, minimum: 1) and 1 whale (maximum: 3, minimum: 1) per sighting. The results obtained from the Point-biserial correlation test showed that the occurrence of avoidance responses does not seem to be statistically correlated with the number of boats (p=0.35).

3.4 Bahía Magdalena

3.4.1 Vessel compliance with the regulation

A total of 254 sightings were registered in Bahía Magdalena, non-compliance being preponderant in 73.2% of them (Figure 14).

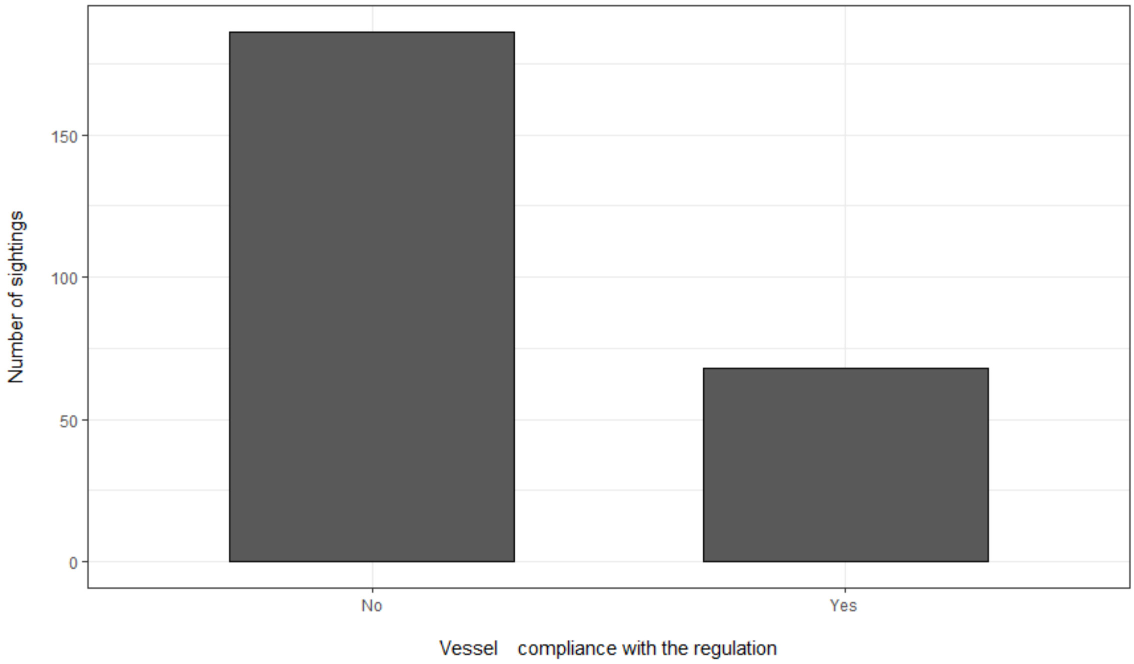

Figure 14. Number of sightings of compliance (n=68) and non-compliance (n=186) with the regulation in Bahía Magdalena.

The type of regulation that was not complied with is shown below in Figure 15. The distance to the animal (41.4%) and the vessel position (28%) were the two principal guidelines that were not respected. The vessel speed was the infringement that was less observed (2.2%).

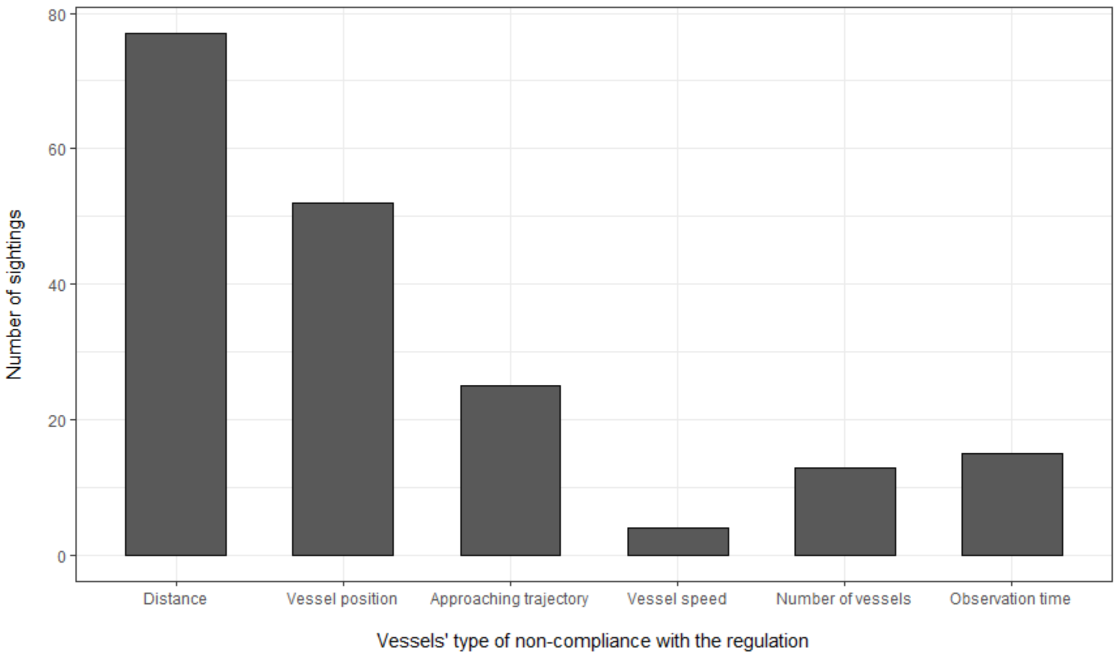

Figure 15. Type of vessels infractions to the regulation (distance n=77, vessel position n=52, approaching trajectory n=25, vessel speed n=4, number of vessels n=13, observation time n=15) in Bahía Magdalena.

3.4.2 Vessel compliance with the regulation and group composition of whales

Most of the individuals encountered in Bahía Magdalena were adults solo (Table 8). In both group composition categories, there was a higher percentage of records where the regulation was not fully respected (73.5% for adults solo and 60% for adults with calves). However, when performing a Fisher's exact test, the *p-value* obtained proved to be not significant (p=0.61, Odds ratio = 0.54, 95% CI = 0.06-6.63) determining there is not an association between the variables compliance with the regulation and the whale group composition in Bahía Magdalena.

Table 8. Whale group composition in compliance and non-compliance sightings in Bahía Magdalena.

	Whale group composition	
Legislation compliance	Adult solo	Adult with calf
Yes	66	2
No	183	3

3.4.3 Vessel compliance with the regulation and number of whales per period

In Bahía Magdalena in the first period, the number of whales sighted at census was higher than the number of infractions. In the remaining periods, the opposite situation was verified, with more infractions than the number of individuals counted (Table 9).

Table 9. Number of infractions to the normative and number of whales sighted in the census at the three field periods in Bahía Magdalena.

Field Period	Number of whales	Number of non-compliance occurrences
First	42	1
Second	39	157
Third	9	28

3.4.4 Vessel compliance with the regulation and whale behavioural responses

Gray whales in Bahía Magdalena were more frequently (71.7%) observed not having a behavioural response in impact conditions than were observed avoiding or approaching vessels. There was a small fraction of data (1.7%) where it was not possible to determine the whale response (Figure 16).

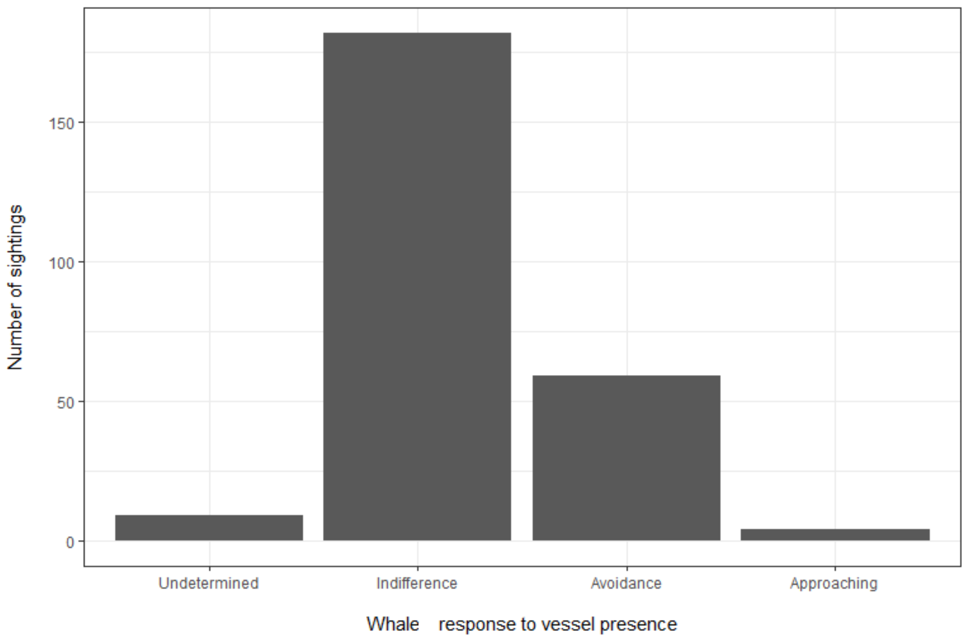

Figure 16. Whale behavioural response to vessels presence (undetermined, n=9; indifference, n=182; avoidance, n=59; approaching, n=4) in Bahía Magdalena.

Gray whales observed having surface active behaviours were not affected by the presence of vessels (Figure 17). Whales resting did not react to the arrival of vessels in 83.3% of the sightings (n=10). Whales travelling presented indifference to vessel presence in 80.7% of the sightings (n=159), had avoidance responses in 28.8% of the sightings (n=37), and were seen approaching the boats in rare situations (n=1). When on impact conditions, whales presenting social behaviours were seen responding with avoidance in 69% of the sightings (n=20), indifference in 20.7% of the sightings (n=6) and approaching the vessels on few occasions (n=3).

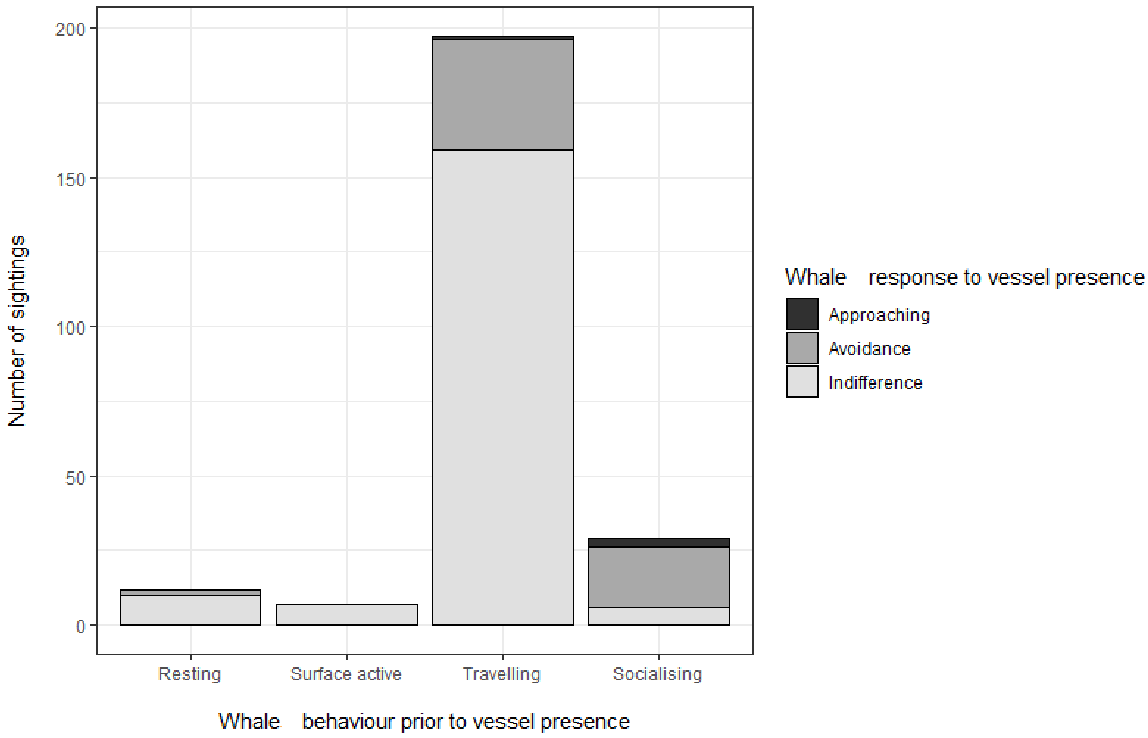

Figure 17. Whale behavioural state and response to the arrival of vessels in Bahía Magdalena (resting n=12, surface active n=7, travelling n=197, socialising n=29).

Analysis of the specific avoidance responses of gray whales in impact conditions reports that in 54.1% of travelling behaviour sightings the whale increased the speed, in 35.1% was observed any type of agonistic reaction and dodging was the less frequent response (Table 10). Whales socialising mainly (85%) presented agonistic behaviours whereas animals resting avoided the vessels by swimming fast.

Table 10. Whale behaviour in control conditions and avoidance response in impact conditions in Bahía Magdalena.

Behaviour prior to vessel presence	Avoidance response to vessel presence	Number of Sightings
Travelling	Agonistic reaction	13
	Dodging	4
	Speeding	20
Socialising	Agonistic reaction	17
	Speeding	3
Resting	Speeding	2

Indifference to the presence of boats and avoidance reactions occurred mostly on sightings where the normative was not respected (89.8% and 68.1% of the sightings, respectively). Concerning approaching behaviours, were observed in equal numbers in compliance and non-compliance conditions (Figure 18).

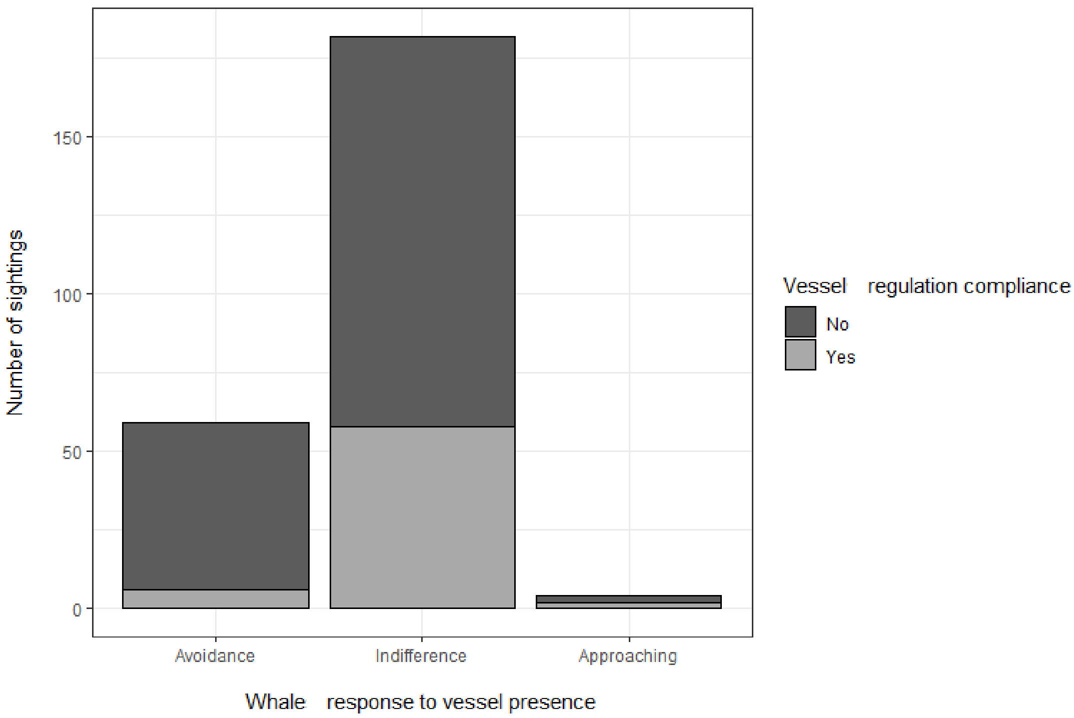

Figure 18. Whale response to vessels presence under conditions of regulation compliance (avoidance n=6, indifference n=58, approaching n=2) and non-compliance (avoidance n=53, indifference n=124, approaching n=2) in Bahía Magdalena.

Gray whale behavioural response to vessel presence was significantly affected by vessel compliance with the legislation ($X^2_{(1)}$ = 11.10, p= 8.62e-04; ϕ= -0.21), the likelihood of avoidance events being higher when infractions occurred (Table 11).

Table 11. Whale avoidance/non-avoidance responses to vessels and vessel compliance/non-compliance of the normative in Bahía Magdalena.

	Avoidance	**Non-avoidance**
Compliance	6	60
Non-compliance	53	126

In Bahía Magdalena an average of 4 boats (maximum: 8, minimum: 1) and 2 whales (maximum: 11, minimum: 1) were observed per sighting. The variable number of boats is statistically correlated (weak correlation) with the occurrence of avoidance responses by whales, these responses being more likely to be observed with higher numbers of boats present per sighting (r_{pb}=0.15, p=0.02).

3.5 Bahía Almejas

3.5.1 Vessel compliance with the regulation

A total of 147 sightings were recorded in Bahía Almejas, in 65.3% of them the whale watching normativity not being complied with by vessels (Figure 19).

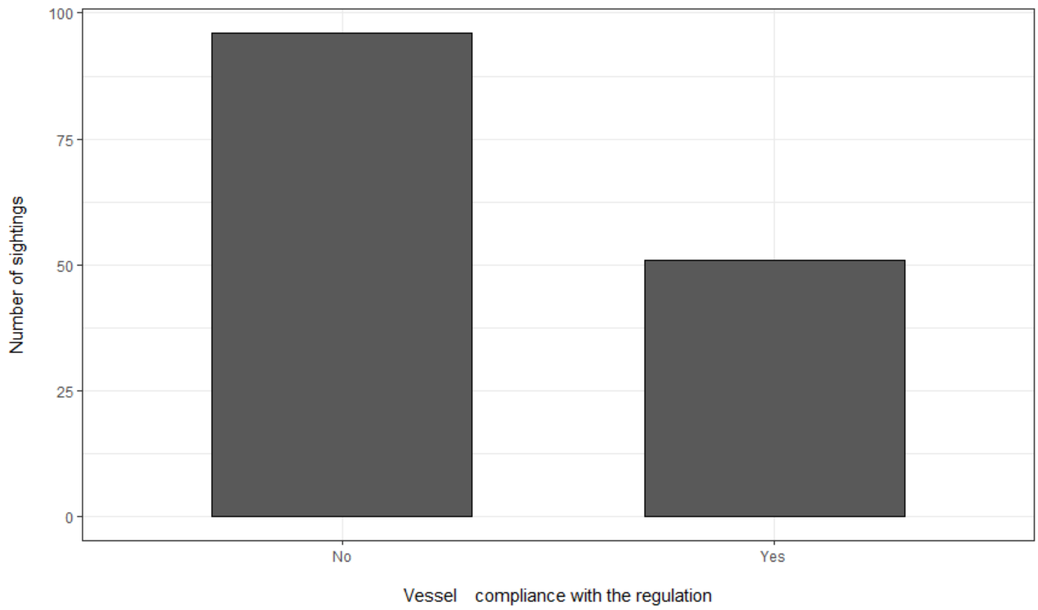

Figure 19. Number of sightings of compliance (n=51) and non-compliance (n=96) with the regulation in Bahía Almejas.

In terms of the legislation guidelines not complied with, the vessel-whale distance was the one less respected (49%), followed by the vessel encirclement of the animal (25%). The observation time was never infracted (Figure 20).

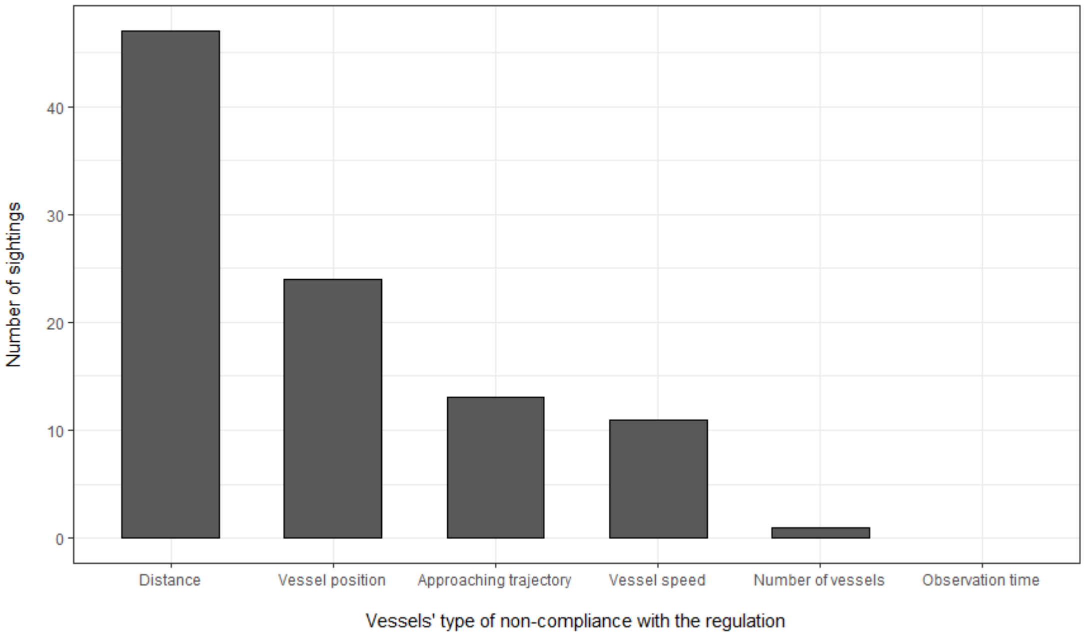

Figure 20. Type of vessels infractions to the regulation (distance n=47, vessel position n=24, approaching trajectory n=13, vessel speed n=11, number of vessels n=1, observation time n=0) in Bahía Almejas.

3.5.2 Vessel compliance with the regulation and group composition of whales

There was a higher number of data collected from adult solos than from adults with calves. In both group composition categories evaluated there were more violations of the regulation than compliance (64.5% for adult solo and 77.8% for adult with calf) (Table 12).

Table 12. Whale group composition in compliance and non-compliance sightings in Bahía Almejas.

	Whale group composition	
Legislation compliance	Adult solo	Adult with calf
Yes	49	2
No	89	7

As the *p-value* obtained from Fisher's exact test is not significant [*p*=0.50, Odds ratio = 1.92, 95% CI = 0.35-19.63], it can be concluded that there is no association between the variables compliance with the regulation and the whale group composition in Bahía Almejas.

3.5.3 Vessel compliance with the regulation and number of whales per period

In Bahía Almejas, during the whole field season a high number of whales were sighted contrasting with a low number of normative infractions (Table 13).

Table 13. Number of infractions to the normative and number of whales sighted in the census at the three field periods in Bahía Almejas.

Field Period	Number of whales	Number of non-compliance occurrences
First	146	35
Second	173	42
Third	24	19

3.5.4 Vessel compliance with the regulation and whale behavioural responses

In most sightings (77.6%) animals showed indifference to the presence of whale watching vessels and the second main response observed was even the approach of the animal to the boat (11.6%) (Figure 21). In 10.9% of the sightings, it was not possible to determine the whale response.

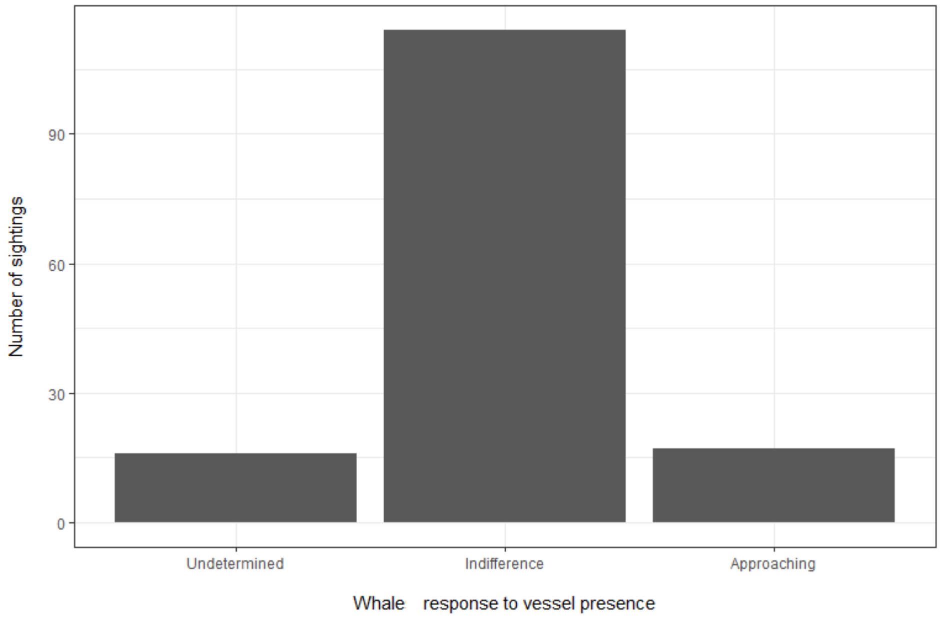

Figure 21. Whale behavioural response to vessels presence (undetermined n=16, indifference n=114, approaching n=17) in Bahía Almejas.

No avoidance responses were observed at impact conditions. When presenting social behaviour, whales responded to the arrival of vessels by approaching them. Whales displaying surface active behaviours did not show any reaction to the presence of vessels in 98.5% of the sightings (n=67) and only on one occasion were seen approaching the vessels (Figure 22).

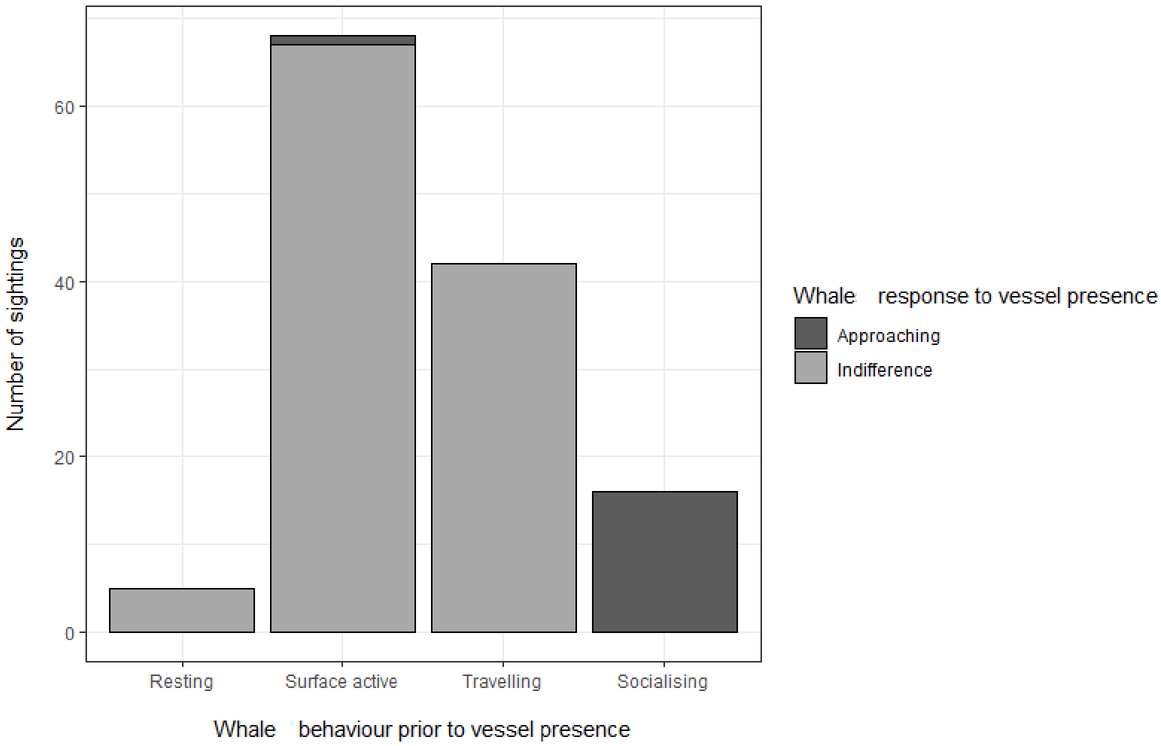

Figure 22. Whale behavioural states and response to vessel presence in Bahía Almejas (resting n=5, surface active n=68, travelling n= 42, socialising n=16).

Avoidance behaviours were not observed. Moreover, indifference and approaching responses occurred mostly on sightings where the normative was not respected (57% and 94.1% of the sightings, respectively) (Figure 23).

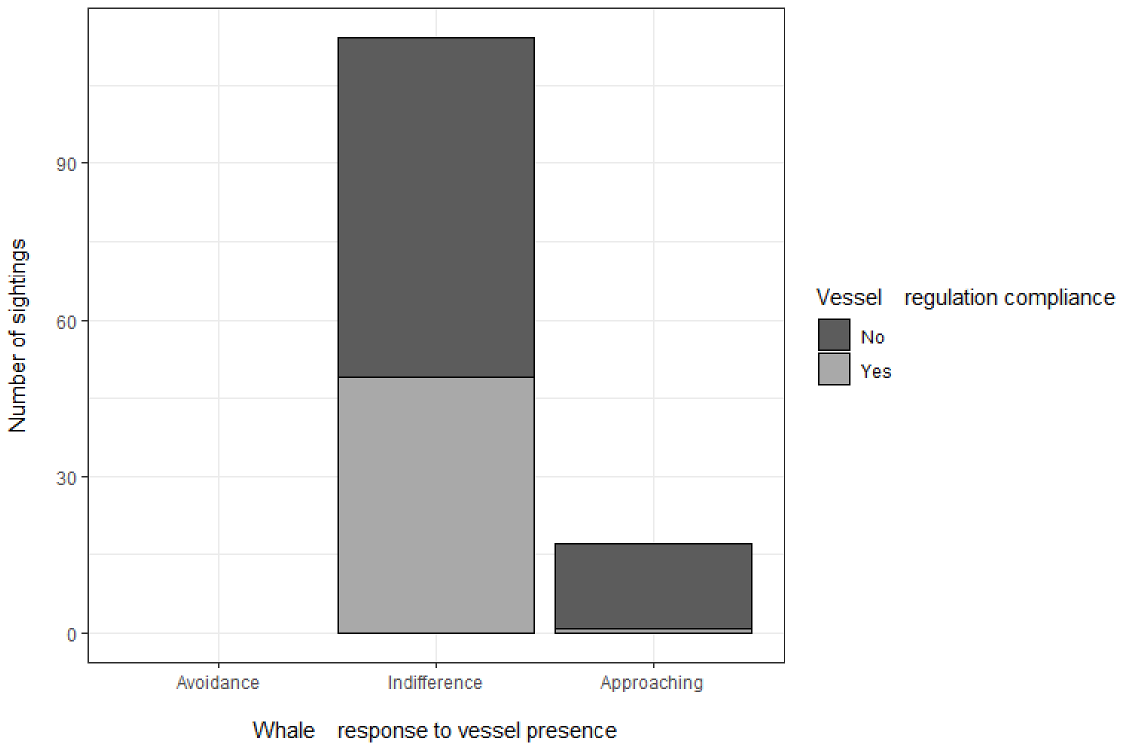

Figure 23. Whale response to vessels presence under conditions of regulation compliance (avoidance n=0, indifference n=49, approaching n=1) and non-compliance (avoidance n=0, indifference n=65, approaching n=16) in Bahía Almejas.

4. Discussion

Although concerns about the impacts whale watching might have on the behaviour of gray whales have existed since the beginning of the activity, few studies about this topic exist (Heckel et al., 2001). Considering whale watching has been increasing significantly in recent decades in Mexico (Hoyt & Iñíguez, 2008; Urbán & Viloria-Gómora, 2021), now, more than ever, it is important to study if how it is carried out whether may be having short, medium, and long-term impacts on the species that are the target of whale watching activity. This type of study is particularly important in non-protected marine areas since there is less control over the way whale watching is practiced (IWC, 2018). To contribute to filling some of these existing knowledge gaps, this study focused on the short-term impacts of whale watching on gray whales in the marine non-protected area Bahía Magdalena Lagoon Complex, more specifically in the areas of Puerto Adolfo López Mateos, Bahía Magdalena, and Bahía Almejas. A detailed analysis of how the whale watching tour operators providing these services carry out the activity was performed, reporting if the NOM-131-SEMARNAT-2010 is being complied with, registering the vessels main infractions to the normative in each of the lagoons, if any, and consequently the whale behavioural responses to the presence of those boats. Study the most observed infractions can be useful to various civil associations, including PRIMMA, which have been providing voluntary training on good whale watching practices to service providers (Urbán & Viloria-Gómora, 2021), and can use this information to make the training more efficient, namely adapting it to focus on the infractions that occur most frequently in a specific location.

Furthermore, the performance of this study is particularly relevant as since 2019 have been reported high numbers of dead gray whales found on beaches and floating offshore throughout their habitat, from Mexico to Alaska, which led the National Marine Fisheries Service (NMFS) to declare an “Unusual Mortality Event” for gray whales (Raverty et al., 2020)**.** Until the moment there is no certainty of the main cause of this event, but it is estimated that multiple factors may be at play, such as predation by orcas, poor body condition due to lack of food in the Arctic feeding grounds caused by climate change, entanglements in fishing nets, and vessel strikes (Christiansen et al., 2021). Given the high number of deaths of gray whales found in the last years and the fact that some individuals from the already critically endangered WNP population are known to frequent this area (Urbán et al., 2021; Weller et al., 2012), it is imperative to identify and reduce the practice of any potential stressful actions in order not to compromise the existence of this species.

4.1 Whale watching regulation compliance and behavioural responses

This study shows that despite the existence of the Mexican whale watching regulation NOM-131-SEMARNAT-2010, it is not being followed by whale watching industry operators in the lagoons of Bahía Magdalena Complex. In all the lagoons of the study site, the disrespect of the distance that should be kept between the animal and the vessel and the bad positioning of the vessel during the performance of the activity were the most observed. A study by Paredes-Lozano (2016) had already reported that back in 2016 those guidelines were not being respected by whale watching service providers in Puerto Adolfo López Mateos.

Attempting to find explanations for non-compliance with the legislation in force, several hypotheses were formulated. Firstly, it was analyzed if the number of infractions was related to the whale group composition, more specifically if infractions were potentiated in encounters of adults with calves. Bahía Magdalena Lagoon Complex is a gray whale breeding area and therefore tourists expect to see mothers with calves, which they prefer to follow over adult solos since as with other cetaceans, the calves are more charismatic and interactive with the boats (Amrein et al., 2020). Whereas for Puerto Adolfo López Mateos the occurrence of non-compliance events being more likely to occur on encounters of adults with calves was statistically significant, for Bahía Magdalena and Bahía Almejas does not seem to exist a significant relationship between the two variables.

Another possible explanation would be that the number of infractions to the normative would be inversely related to the number of whales present in the area, which proved to be true. During the first data collection period from 18th to 30th January, few whale watching sightings and infractions were noted in Puerto Adolfo López Mateos and Bahía Magdalena, probably due to the low demand for tourism caused by the low number of whales. In the second period usually the presence of tourists increases due to the higher abundance of whales (Paredes-Lozano, 2016). Although the number of whales remained roughly unchanged, the tourism demand increased, the number of sightings increased and a high number of infractions occurred. In Bahía Almejas, in the first and second field periods, a high number of whales was registered leading to a low number of infractions. In the last data collection period in all lagoons of the complex, whale abundance dropped significantly, and the sightings of whale watching vessels also became fewer because of the difficulty of finding whales, with many trips returning with no encounters, namely in Puerto Adolfo López Mateos where no whales were sighed and therefore no data were collected. The report resulting from the biological monitoring during the field season allowed us to conclude that in addition to the low number of whales in Bahía Magdalena Lagoon Complex throughout the season, caused by the continuation of the unusual mortality event, there was also an unexpected anticipation of the whale migration by 2 weeks in relation to other years, which may explain the scarcity of whales and consequently of whale watching sightings in the third period (Urbán et al., 2022).

Other possible reason for the observed non-compliance of the normative could be the number of permits assigned for whale watching compared to the number of whales in each lagoon. In the 2021-2022 season, 19 permits were allocated for Puerto San Carlos, 61 for Puerto Adolfo López Mateos, and 13 for Puerto Chale, each permit corresponding to a vessel (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT], 2022). The number of permits granted to Puerto San Carlos and Puerto Chale, which allow whale watching activities in Bahía Magdalena and Bahía Almejas respectively, seem to be adequate for the number of whales present whereas for Puerto Adolfo López Mateos the number of permits granted seems excessive for the number of animals. SEMARNAT's negligence in establishing the specific carrying capacity for this site and consequently the number of permits granted had already been criticized in previous studies (Paredes-Lozano, 2016). Regardless of the maximum number of permits allocated for each lagoon, the fact these permits allow whale watching activities to be carried out throughout the season, which has fixed dates and does not consider the number of whales present in the areas to end the season, leads to situations such as the third period of data collection, where there were too many permits for a small number of whales. Inclusively, even though the season in the Bahía Magdalena Lagoon Complex only ended on the 30th April 2022 (SEMARNAT, 2022), in Puerto Adolfo López Mateos by the beginning of March there were already no whales sighted during the census. One of the solutions to this situation could be the definition of more adaptable measures prohibiting whale watching activities when the number of animals is below a pre-established value. This measure is something that is already being implemented in Mexico with other marine animals watching activities, such as the whale sharks (*Rhincodon typus*) in Bahía de La Paz, where activities are prohibited when less than 5 individuals are present in the area (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT], 2021).

The lack of knowledge of the legislation in force for the practice of whale watching by service providers could also explain the occurrence of infringements. The origin of this lack of knowledge may be associated with the poor dissemination of the regulations, which is the responsibility of the Mexican government, specifically SEMARNAT. Alternatively, whale watching service providers may be knowledgeable of the normativity but choose to ignore it as it interferes with the business' financial profit or it might be inconvenient (Wiley et al., 2008). As an example, vessel speed allows to encounter whales quicker and being faster to return to the port and pick up more tourists, increasing the number of trips they offer daily (Lammers et al., 2013). Moreover, bending the normativity to allow a closer encounter with the whales may improve clients' satisfaction, which might translate into a higher tip for the service's staff and positive feedback, potentially leading to their service being more recommended in relation to other whale watching service servers at the area (Amerson & Parsons, 2018).

However, it is important to demystify this misconception some operators might have. Interview surveys on tourists to perceive their impression of whale watching activities in Banderas Bay have shown that they would be more likely to repeat the experience if no more than 2 boats were with 1 whale and in Loreto Bay, if mothers with calves were not crowded by boats (Avila-Foucat et al., 2013; Avila-Foucat et al., 2017). This type of survey provides information about the public's impression of how whale watching is being conducted and should be considered when defining normative guidelines as it would keep tourists visiting the area (IWC, 2018). Additionally, it is extremely recommended that tourists are educated about the already existent normativity and the importance of obeying it (Cárdenas et al., 2021). Studies have proven that whale watching alone can create an emotional bond between humans and whales, but changes in tourists' mindsets towards the conservation and protection of marine life are only possible when tours have a well-structured educational component, for example, with guides providing knowledge regarding the biology of whales, their ecological importance, and good whale watching practices (Johnson & McInnis, 2014). Another option would be to distribute brochures with this information to tourists during the tours informing them about the whale watching guidelines and why they are important (Sullivan & Torres, 2018). To educate tourists about whale watching good practices is providing tools that allow them to be an agent of control of the activity (Sullivan & Torres, 2018). Since the whale watching industry lives from the tourists who hire their services, being the quality of the service and tourist satisfaction important factors for it (Vega, 2019), the whale watching service providers may become more careful about the way they perform the activity if they perceive tourists are aware of the normative measures.

Regardless of whether these service providers are aware of the policies currently in place, there is a lack of monitoring and structural enforcement to ensure regulatory compliance by the Mexican responsible entities. The latest data available, dating back to the 2018-2019 season, report the occurrence of 0 inspections and 59 surveillance tours along all the areas where whale watching is authorized (Procuraduria Federal de Proteccion al Ambiente, 2020). In the 2015-2016 season in Puerto Adolfo López Mateos, insufficient surveillance and inspections had also been mentioned (Paredes-Lozano, 2016). The almost non-existent presence of PROFEPA not only allows authorized service providers to violate the regulations but also allows boats that are not licensed to carry out whale watching activities (Urbán & Viloria-Gómora, 2021). In fact, the guidelines to regulate the activity and minimize its impacts may be the best, but they will be ineffective if they are not accompanied by efficient monitoring and enforcement plans (Wiley et al., 2008). Reinforced monitoring and better enforcement protocols are therefore necessary. As the logistics and costs of having a patrol vessel daily may be impossible, some alternatives can be to have a vessel unpredictably patrolling the area, once a week or a month, leading service providers to be more cautious in how they carry out their activity (IWC, 2018). This strategy can also be complemented with the implementation of Automatic Identification

Systems (AIS) on vessels, based on automatic radio messages that allow tracking of their activity as it contains information on the name, position, speed, and course of the vessel at regular intervals (from 3 s to 3 min) which are then transmitted to AIS stations (Lapinski & Isenor, 2011). This type of system was firstly implemented for avoiding vessels collision. Nowadays, has proven to be valuable for multiple purposes, one of them being monitoring marine areas where whale watching takes place (Almunia et al., 2021). This type of monitoring by satellite tracking is also being carried out for the control of whale shark watching activities in La Paz, Mexico, where data is transmitted in real-time to the surveillance inspector in the area, which can immediately intervene if necessary (SEMARNAT, 2021).

Another strategy would be to convert the Bahía Magdalena Lagoon Complex into a marine protected area (MPA), since these areas have higher levels of surveillance of whale watching practices if it is not merely a "paper MPA" (Hoyt, 2004). Marine protected areas even can apply different regulatory measures than those that are applied nationally, adapted to the specific characteristics of the area (IWC, 2018). A proposal for the creation of a MPA from Laguna San Ignacio to Bahía Magdalena for the protection of gray whales is already being drafted and will soon be proposed to the Mexican government, to consider its approval (Urbán & Viloria-Gómora, 2021).

The results of this study revealed that gray whales were more likely not to display avoidance responses to vessel disturbance in any of the lagoons. Nevertheless, the observed avoidance responses by whales to vessel presence for each behavioural states (travelling, socialising, resting and surface active) were analysed. In Puerto Adolfo López Mateos, results revealed that whales travelling were affected by the arrival of vessels, increasing their displacement speed, although this type of response was less likely to be observed than whales being indifferent. Previous studies with gray whales had also reported increases in swimming speed as an avoidance response towards the presence of vessels (Swartz & Jones, 1978; Moore & Clarke, 2002; Heckel, 2001). Resting and surface-active whales did not seem to be affected by the arrival of vessels. During the surveys of this study, there were no encounters in which socialising behaviours were observed, and therefore this behavioural state could not be evaluated in control/impact conditions. In

Bahía Magdalena, whales presenting travelling and resting behaviours were more likely not to be disturbed by vessel arrival. In sightings of whales displaying travelling and resting behaviours and where avoidance did occur, speeding was the most common response observed. A study by Aurioles (1982) in Bahía Magdalena also observed changes in the displacement speed of gray whales as a response to vessel disturbance. Interruption of resting behaviours had already been reported in studies with other cetaceans, suggesting that if occurring successively in the long-term may affect the energy reserves and reproductive success of the species (Parsons, 2012; Visser et al., 2011). In sightings in which whales displayed socialising behaviours, the most observed response to boat arrival was avoidance, especially agonistic reactions. The disruption of socialising behaviours may be concerning in the long-term as it contributes to the reduction of mating events, and therefore influences population survival (Schuler et al., 2019). Whales sighted displaying surface active behaviours did not seem to be affected by vessel presence. In Bahía Almejas no avoidance responses were observed in impact conditions. In all of the sightings where whales presented socialising behaviours, the response to vessel arrival was even the approach to the boat. When surface active the whales also approached the boats, although the probability was lower compared to indifference.

The correlation between the occurrence of avoidance responses and the non-compliance with the regulations in force was also evaluated. In Puerto Adolfo López Mateos, this correlation was not statistically significant. In Bahía Magdalena, whales were more likely to display avoidance responses when vessels were not compliant with the regulations in force, particularly with a higher number of vessels present. In Bahía Almejas, no avoidance responses were observed regarding whether the normative was respected. It should also be noted that the majority of approaching sightings occurred in situations of non-compliance with the legislation.

It is important to reinforce that even if in some cases it was not observed a behavioural modification on whales when boats are present, it does not mean that the animals are not under stress as whales may exhibit physiological responses (Amrein et al., 2020; Schuler et al., 2019). Examining the fluctuation of the stress level associated with an animal's exposure to boats throughout the season could be a more reliable test (Noren &

Mocklin, 2012). Measurements of concentrations of the steroid hormone cortisol could be obtained by collecting blubber samples or blowhole spray by drone (Amrein et al., 2020; Teerlink et al., 2018).

Moreover, taking no action to solve the lack of monitoring and enforcement of the legislation may aggravate the bad whale watching practices from vessel operators in the future (Amrein et al., 2020). It could pose a danger to humans and whales and even be lethal for both, as encounters with high numbers of vessels, high-speed boats, and vessel coming too close to the animals or approaching at unexpected angles may trigger evasive techniques of whales and therefore result in whales-vessels collisions (Amrein et al., 2020; Guzman et al., 2013; Schoeman et al., 2020; Vanderlaan & Taggart, 2007). Mexico is the Eastern Tropical Pacific country with the highest number of vessel-whale collisions, with a total of 15 collisions, 6 of them involving tourism boats (Ransome et al., 2021). It is worth mentioning that one of those strikes resulted from a whale watching boat colliding with a calf humpback whale, in Nayarit, resulting in its death (Ransome et al., 2021). Furthermore, in the future, we could risk the abandonment of the area by gray whales, a similar situation to what happened in Ensenada, where the migration corridor of gray whales was facing displacement due to the ineffectiveness of the regulation and enforcement (Heckel et al., 2003).

4.2 Recommendations

Future behavioural studies should be complemented with other data collection methods, considering the number of sightings in which it was not possible to determine the animal's behaviour with the type of methodology adopted in this study. An alternative would be the use of unmanned aerial systems (UAS), also known as drones, that make tracking the animal less invasive, with less disturbance, and more effective, eliminating the difficulty of collecting data when several boats are present around whales (Torres et al., 2018). Additionally, with UAS it is possible to get a different angle of the animal's behaviour, as from boats it is only possible to collect data on whale activity at the surface, which is a small fraction for an animal that spends most of its time below the surface (Amrein et al., 2020). Drones also allow the collection of larger behavioural sample sizes and provide higher accuracy, as they rather shot the individual behaviour at every moment than determine how it varies over a longer period (Torres et al., 2018).

It would also have been pertinent to consider the evaluation of other factors to make the study more complete. Investigate the whale average dive duration, respiratory patterns and the deviation index (the mean of turning angles between consecutive positions while following the animal) are some of the examples, as they are likely to be altered when a whale is followed by whale watching boats (Fiori et al., 2019). This could inclusively be done by drones. Evaluating how the vessel-whale distance impacts the behaviour of the whale could also add some value to the study (Amrein et al., 2020). Despite being very time-consuming, demanding for staff, and having geographical limitations, land-based tools like theodolites are a good option for accurately producing distance measurements between vessels and whales (Almunia et al., 2021). Furthermore, collecting acoustic data would be advantageous as it could provide information about whale watching intensity, the concurrent number of vessels, and the total amount of time vessels spent in the proximity of whales (Pirotta et al., 2015; Schuller et al., 2019) as well as determining if there were any modifications to the structure and timing of whale calls to optimise their transmission when exposed to engine noise from boats, as studies have proven it may occur (Amrein et al., 2020; Dahlheim, 1988). Considering the observation of whales in poor body condition has been increasing in this lagoon complex (Christiansen et al., 2015), it would also be important to investigate the susceptibility of whale watching vessel impact according to different body conditions.

The last suggestion would be to investigate animals behaviour, not only before and during the whale watching performance, but also after the end of the activity since studies showed behaviour is sometimes likely to change only after boats leave the observation site (Santos-Carvallo et al., 2021).

5. Conclusion

The present study highlights that the whale watching activity in Bahía Magdalena Lagoon Complex is not following the NOM-131-SEMARNAT-2010. Non-compliance with the normative does not seem to have a single cause but it is rather the result of cumulative factors, some being local specific (e.g., In Puerto Adolfo López Mateos, the infringement of the normative tends to occur in encounters of adults with calves), and others being transversal to all the lagoons analysed in this study. Some of the explanatory variables to the non-compliance are the possible inadequacy of the legislation in what concerns the establishment of the duration of the season, the lack of knowledge of the legislation in force by vessel operators and not being environmentally aware of the impacts of their bad whale watching practices as well as the lack of monitoring and structural enforcement to ensure regulatory compliance by the Mexican responsible entities.

Gray whales in Bahía Magdalena Lagoon Complex were more likely to show indifference to vessel presence. Nevertheless, analysis of how whales respond to the arrival of whale watching vessels in different behavioural states revealed the occurrence of some responses that in the long-term may have consequences for the welfare and conservation of this species. An example of this is the whale behavioural switch from travelling to speeding in Puerto Adolfo López Mateos or from socialising to agonistic reactions in Bahía Magdalena.

The occurrence of avoidance reactions seems to be related to the non-compliance of whale watching vessels in Bahía Magdalena, especially when a higher number of vessels are present. A correlation between the occurrence of avoidance and non-compliance of the normative does not seem to be observed in Puerto Adolfo López Mateos. In Bahía Almejas, no avoidance responses were observed, the main response of whales to non-compliance even being their approach to whale watching vessels.

Whales may not exhibit avoidance behaviours, nevertheless being disturbed by vessel presence. For this reason, it would be important to carry out bioacoustics studies, to verify whether there have been changes in the structure and timing of whale calls, or physiological studies to evaluate fluctuations of the stress hormone cortisol throughout the season and therefore being able to obtain a more reliable conclusion.

Finally, it is important to solve the lack of monitoring and enforcement of the NOM-131-SEMARNAT-2010, to prevent the aggravation of the infractions, which could result in severe damage to people and gray whales. These measures should not only focus in reinforce monitoring or adapting legislation but also ensure that both boat operators and tourists are educated about regulations, the impact their actions can have, and how everyone wins when whale watching is done in a sustainable way. A sustainable practice of whale watching is one in which there is a balance between economic, ecological, and social dimensions, by ensuring that whale watching companies benefit economically from the services they provide, while the stress caused to the animal is minimal and tourists are aware of the importance of environmental conservation. Good whale watching practices, are in harmony with blue economy, using the ocean's resources for the economic growth of local communities, providing employment while preserving the ocean's health. Doing so, this study contributes to achieve the goals set for the 2021-2030 Ocean Decade that aims a productive and sustainable ocean economy valued by all.

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7. Supplementary material

PROGRAMA DE INVESTIGACIÓN DE MAMÍFEROS MARINOS

WHALE WATCHING RECORDS

DATE ______________________________

LOCATION ______________________________

Time	Latitude N	Longitude W	Group size	Group composition	Behaviour pior to vessel presence	Behavioural response	# vessels	Type Infraction NOM 131

Figure S1. Datasheet used during the study period.

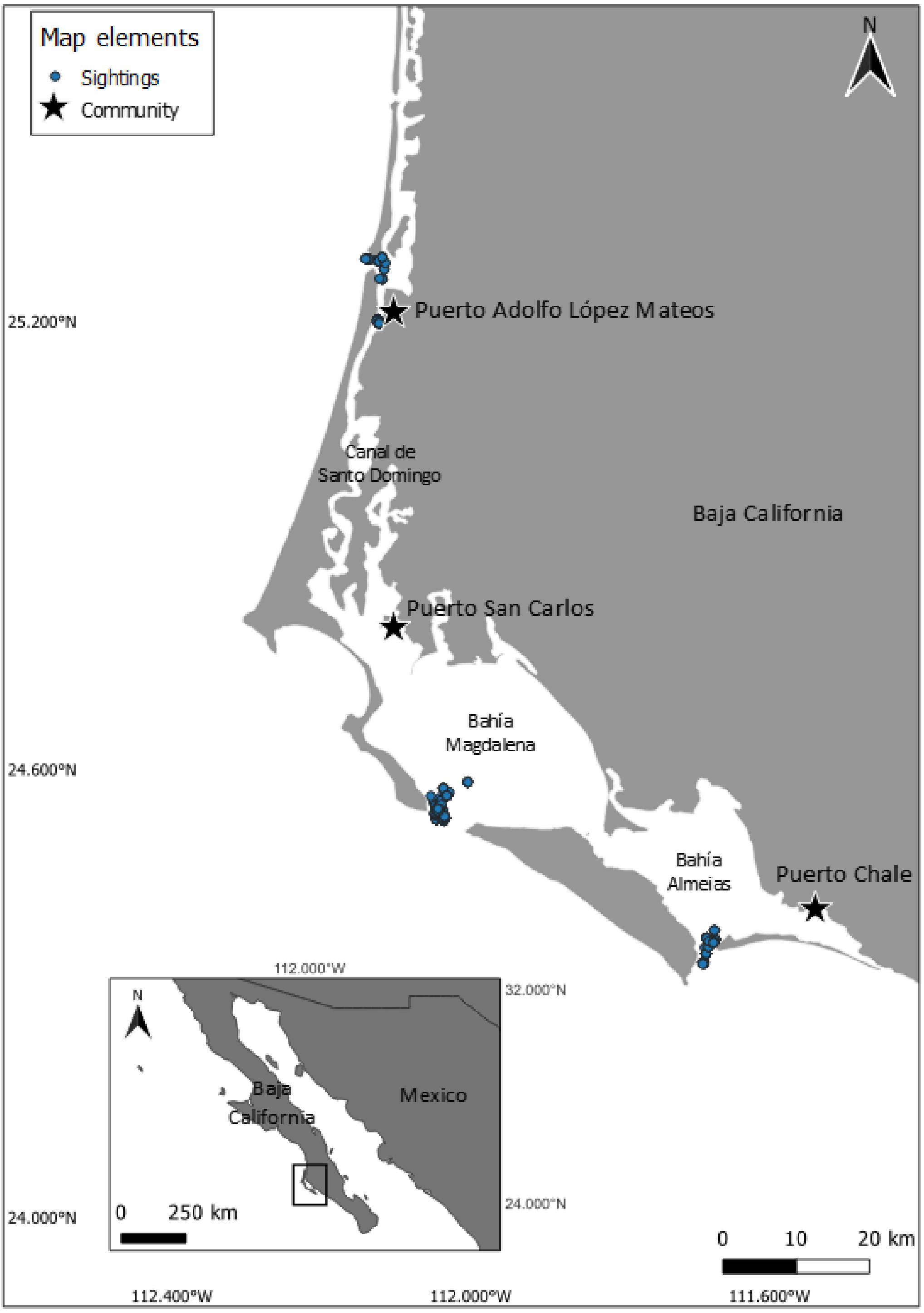

Figure S2. Whale watching sightings in Bahía Magdalena Lagoon Complex over the season.