Seasonal Variation of Bottlenose Dolphins (*Tursiops truncatus*) and the Effects of Boating in Cardigan Bay, Wales.

A dissertation submitted in partial fulfilment of the requirements

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ABSTRACT

Bottlenose dolphins (*Tursiops truncatus*) have been studied in Cardigan Bay, Wales, since the mid-1990s with routine monitoring since 2001. Among the numerous threats that threaten bottlenose dolphins, the effects of wildlife tourism is one which has been the focus of numerous studies. The Sea Watch Foundation conducts boat-based surveys from dolphin-watching vessels, privately charted boats, and land-based surveys from the New Quay pier. Since 2000 a series of boating codes of conduct have been instituted to protect bottlenose dolphins. This study aims to assess the abundance of bottlenose dolphins in Cardigan Bay using sightings data, assessing boat compliance to the local code when encountering bottlenose dolphins, and dolphin reaction to vessel encounters. A linear regression model was used to analyze survey data, along with T tests to test for statistically significant differences between selected years. Changes in dolphin abundance, dolphin encounters, calf abundance, total pod size, compliance and non-compliance with the code, and dolphin reactions to vessels all changed significantly between 2000 and 2010. These results indicated a healthy yet stable population. The number of calf sightings each year suggests the bottlenose dolphin population of Cardigan Bay has equal birth and death rates. Boat compliance with the code has not significantly changed over time, and there have been no significant changes in sightings and encounters since the code was instituted. This suggests that the code is not an effective tool for minimizing the adverse effects of boats on bottlenose dolphins. Despite the ineffectiveness of the code bottlenose dolphins have potentially been able to habituate to the increase in boat traffic.

KEYWORDS

abundance, bottlenose dolphin, dolphin vessel interaction, Cardigan Bay, Wales, habituation, survey

1 | INTRODUCTION

1.1 | The Bottlenose Dolphin

The bottlenose dolphin (*Tursiops truncatus*) is one of the world's most well-recognized cetaceans. With a worldwide distribution that only avoids high latitudes, these cetaceans are commonly separated between coastal and open ocean populations (Felix, 1994; Nykanen, 2019; Oudejans, 2015). As the name suggests, coastal populations have a home range close to shore, while oceanic populations have a home range 5 kilometers offshore (Thieleking, 2015). These populations can be further subdivided into resident and transient populations. Transient populations move from one location to another depending on the time of year, food, and mate availability, showing little to no site fidelity. (Gubbins, 2002; Conn, 2011; Nykanen, 2019). Resident populations exhibit long-term site fidelity with a home range that shows only slight variation between years (Gubbins, 2002). Individuals within a single bottlenose dolphin population can vary significantly in ranging patterns and can shift between local site fidelity and long journeys away from the site (Defran et al, 1999).

The common bottlenose dolphin inhabits harbors, bays, gulfs, nearshore coastal waters, and estuaries (Breed, 2016; Connor et al., 2000). These grey-colored dolphins get their name from a short thick rostrum which varies by subspecies. They can grow up to 4 meters long and weigh close to a ton (Galef, 2010). Female bottlenose dolphins breed between 5 and 15 years old, with the exact age varying between populations (Galef, 2010). Their gestation period is approximately 12 months, and they give birth every 3 to 6 years in the late spring. The calves can stay with their mothers for up to 5 years (Galef, 2010).

Bottlenose dolphins possess a high brain-to-body weight ratio, comparable to humans, and more neural pathways than a human brain (Connor et al., 2000; Connor, 2007). The interaction between ecology, alliance relationships, and social competition contributes to the complexity of bottlenose dolphins' brain size (Connor et al., 2000; Connor, 2007). Bottlenose dolphins exceed humans in the fissurization and convoludness of the cerebral cortex, which play a role in conflict monitoring and response selection (Huster et al., 2009). The corpus callosum, which is responsible for transmitting learned behavior between hemispheres of the brain in a bottlenose dolphin, is slightly smaller than that of a human and larger than that of most other mammalian species (Reis, 1997). These adaptations allow bottlenose dolphins to create complex responses to anthropomorphic disturbances.

Bottlenose dolphins typically live in a fission-fusion society where individuals associate in small groups that change frequently within a larger group (Connor, 2007). A study of the bottlenose dolphin population in Shark Bay, Australia, described three levels of alliance within social networks (Connor, 2007). The first level of alliance describes forming and maintaining courtship relationships with females of the same species. These relationships may last a few minutes or weeks and involve three to four males. The second level of alliance is the cooperation between first-order alliances, where males interfere with other first-order relationships or try to defend themselves. Third-level alliances are the interactions between second-level alliance groups working together. The exact layout of these groups is unknown (Connor, 2007). Studies have indicated that bottlenose dolphins have a well-adapted visual system for motion detection which they use for prey detection, tracking, pursuing, and avoiding predators (Connor, 2007). Bottlenose dolphins possess the cognitive intelligence to recognize themselves in a mirror and learn novel synchronous behaviors, as well as mimic behaviors (Okuda, 2022), (Bruck et al., 2013), (Killian, 2003).

1.2 | Habituation

Habituation is a learning process in which a behavioral response to a stimulus is reduced after repeated presentations of that stimulus (Rankin et al., 2009). In a lab setting, the response magnitude should steadily decrease as a stimulus is repeatedly applied (Higham, 2011). Three diagnostic criteria exist to distinguish between response declines produced by non-learning factors and those created by habituation (Christoffersen, 1997). These criteria include dishabituation, sensitivity of spontaneous recovery to the stimulation rate, and stimulus specificity (Kucharsky et al., 2022). Without cognitive testing, it is difficult to pinpoint the specific mechanisms many animals use to habituate. A study of harbor seal (*Phoca vitulina*) response and habituation to transient and non-transit orca whale vocalizations off the coast of California found that seals of a particular resident population responded to specific calls from specific populations of orcas (Deecke et al., 2002). The resident seal population recognized the calls of the seal-eating transient population of killer whales and would move away when this population of killer whales was close by. This same population of seals would not respond to the calls of the fish-eating local population of killer whales (Deecke et al., 2002). Studies have also been conducted on zebrafish (*Danio rerio*) and fiddler crabs (*Uca vomeris*), discovering that both of these species can habituate to specific environmental conditions (Raderschall et al., 2011), (Wong et al., 2010). It is important to note that once the constant stimuli were removed from the environment of the fiddler crabs and zebrafish, they reverted to an innate response to these stimuli.

Young mammals possess an innate exploratory behavior. Exploratory behaviors are measured using animal approach time to novel objects and the distance they move from familiar objects toward novel ones (Bejder et al., 2009). Juvenile bottlenose dolphins and elephant seals are more likely to approach novel objects than their human counterparts (Lopes et al., 2016). This exploratory behavior diminishes as the animal matures. The perception of habituation could be the product of three factors: displacement, ecology, and physiology (Higham et al., 2008). More tolerant animals can stay in an area, while those less tolerant are displaced. Physiological impairment could cause reduced responsiveness to human stimuli. More suitable habitats with less human interference could be unavailable to a particular population. Penguins showed increased heart rates when approached by humans while incubating artificial eggs, even though no outward reaction was measured (Ellenberg et al., 2009). An essential aspect of habituation is stimulus control, which are naturally occurring behaviors that resist change via human-caused stimuli (Bejder et al., 2006). When charismatic cetaceans such as bottlenose dolphins perform behaviors that include bow riding and leaping out of the water, these animals are assumed to be doing this by choice. These behaviors are hypothesized to result from stimulus control rather than choice (Lusseau et al., 2003; Lusseau., 2006).

Tolerance is sometimes used interchangeably with habituation. While these terms overlap in definition a distinction must be made. Tolerance is "the ability or willingness to tolerate the existence or behavior that one dislikes or disagrees with, and the capacity to endure continued subjection to something without adverse reactions" (Oxford Languages, 2023). Tolerance is not inherently a taught reaction to stimuli whereas habituation is. For example bottlenose dolphins have a higher depth tolerance than porpoises, which is not a taught response but an inherent trait of the bottlenose dolphin (Fahlman et al., 2023).

1.3 | Bottlenose Dolphin Vessel Interactions

Boating traffic is one of the most serious threats to the bottlenose dolphin population in Cardigan Bay. Dolphins can hear 167 decibels up to 487 meters away (Straham et al., 2020). Small to medium sized boats like the ones in New Quay produce sounds with source levels of anywhere from 70 decibels while idling to 169 decibels while moving (Erbe, 2006). This means in most cases the dolphins can hear the boats long before the boats can see the dolphins.

As a result of a rise in the popularity of wildlife tourism, vessel interactions with bottlenose dolphins have increased over the past two decades (Parsons, 2012). In 2009, an estimated 13 million tourists went on trips to see marine mammals in their natural habitat (Parsons, 2012). Populations of bottlenose dolphins in the Mediterranean and Australia have shown that noise pollution and visual stimuli are the primary drivers of alterations in their behavior (Papale, 2011, Bejder, 2006). Vessel size, abundance, noise produced, and time spent near target populations all contribute to decreasing populations of bottlenose dolphins in some areas (Bejder, 2006). Given dolphin reliance on acoustics for predator/prey detection, communication, and orientation, boat engine size plays an essential role in dolphin reactions to certain vessels (Bejder, 2006). Vessel interactions have been known to alter the behavioral budget of bottlenose dolphins. These interactions can decrease bottlenose dolphin foraging, resting, and socializing times (Lusseau et al., 2006; Puszka, 2021). Interacting with vessels can also alter group cohesion, vocalization, abundance, and dive duration (Figure 1). Reductions in vocalization range and vocalization patterns have been studied in two unrelated populations of bottlenose dolphins (Marian et al., 2021; Evans et al., 1992). Changes in group cohesion, including decreases in the distance between individual dolphins as well as more erratic swim speeds and travel directions have all been recorded (Bejder et al., 2006; Bechdel et al., 2009)

1.4 | Marine Protected Areas

The conservation status of bottlenose dolphin populations varies from stable populations in Wales and Scotland to critically endangered in Doubtful Sound, New Zealand (Currey et al, 2008, New et al, 2015). In the past two decades, considerable research has been conducted into the biologically significant effects of anthropogenic activities on cetacean populations (Philips et al., 2014; Lusseau et al., 2005; Vollmer, 2013). According to The National Oceanographic and Atmospheric Administration (NOAA), the most pressing threats to bottlenose dolphin populations are interactions with fishing gear, habitat destruction and degradation, biotoxins, harassment, and interference with feeding activities (NOAA, 2023). Interactions with boats significantly interfere with bottlenose dolphin feeding and other social activities (New et al, 2013).

The EU, USA, and other countries worldwide have set up a series of Marine Protected Areas (MPA's) to mitigate these and many other anthropomorphic effects. MPA's are areas of the ocean established to protect habitats, species, and processes essential for healthy functioning marine ecosystems (Defra, 2023). According to the Welsh government, the 139 MPA's ecosystem

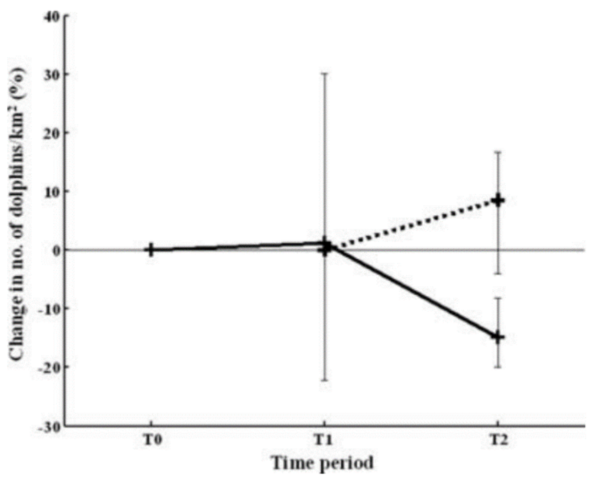


Figure 1: Change in dolphin abundance with boats (solid line) and without boats (dotted line) in Monkey Mia Australia (Smith et al., 2008).

services include supporting the healthy functioning of the marine environment, generating tourism, providing recreational benefits, and contributing to human wellbeing. These MPAs cover 69% of coastal waters and 50% of all Welsh waters (Figure 2). Welsh coastal MPA's are organized between SPAs, SACs, and SSSIs. SAC's (Special Areas of Conservation), including the bottlenose dolphin, protect specific habitats and species under the European Habitat Directive. Under the European Bird's Directive, SPA's (Special Protection Areas) protect wild bird populations. SSSIs, (Sites of Special Scientific Interest) protect certain wildlife and geology under the Wildlife and Countryside Act. To protect bottlenose dolphins the Welsh government created two SACs in Pen Llyn a'r Sarnau and Cardigan Bay.

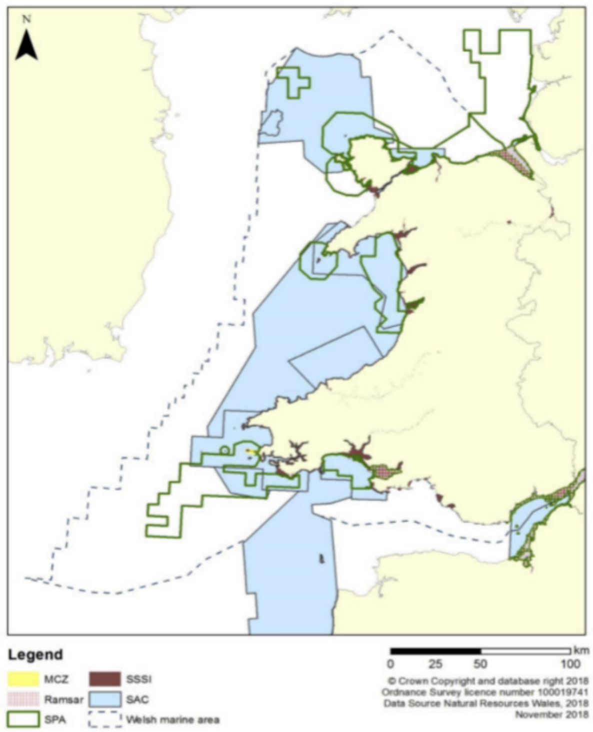


Figure 2: Areas of protection along coastal Wales.

In Wales, UK, cetaceans are protected under the Conservation of Habitats and Species Regulations of 2017. Under this law, it is unlawful to injure or kill a wild animal, deliberately disturb wild animals, or damage and destroy a breeding site or resting place of these animals. Disturbance under this law includes impairing an animal's ability to survive, breed, or raise its young (NRW 2017). It is also illegal to significantly affect marine mammal species' local distribution or abundance. According to the Sea Wise Code in Wales, marine animals should be allowed to approach vessels rather than be pursued by them. The vessels should not alter their course or exceed 6 knots while close to marine mammals. Approaching within 100 meters of seals, cetaceans, basking sharks, and nesting birds is illegal; boats cannot stay near these animals for more than 15 minutes (SWC). Boaters must avoid fast directional changes when approaching a marine mammal; no more than three boats are allowed around the 100-meter mark of any of the animals listed above (Figure 3). Vessel engines and propellers must be well maintained and fitted with guards to reduce the risk of injury from boat strikes.

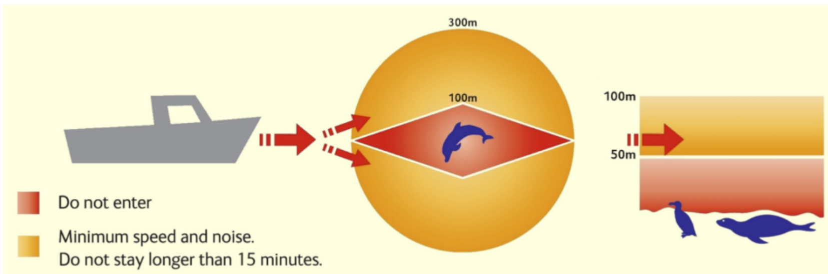


Figure 3: Boating code of conduct when interacting with marine cetaceans, mammals, and birds.

1.5 | Cardigan Bay, Wales

Cardigan Bay covers approximately 5500 km^2 on the southwest coastline of the UK, making it the largest bay in the UK. It stretches over 100 km from the Llyn Peninsula in the north to St. David's Head in the south. Like much of the UK coastal region, it is a shallow bay, only reaching maximum depths of 60 meters. The substrate of Cardigan Bay is heterogeneous, varying from gravel and shell, shingle, and mud, to broken shell and sand. The areas with stronger currents have an increased amount of gravel. In those areas with weaker currents, mud is more present. Cardigan Bay is frequently exposed to strong southwest and westerly winds with gales from October to March. During these months, dolphins take refuge in northward-facing bays, including New Quay and Ynys Lochtyn (Pesante et al., 2008). Sea surface temperatures are influenced by seasonal variation and freshwater input. The sea surface temperature ranges from 16°C in August and September in coastal water and 20°C in offshore waters in the same months to 5-8.5°C in February and March. Cardigan Bay has a wide range of marine habitats, including estuaries, reefs, littoral and sublittoral habitats, and many offshore habitats. These habitats support a wide range of marine flora and fauna species.

1.6 | New Quay, Cardigan Bay, Wales

Areas with high biodiversity and other economic and social factors have tourism-dominated economies (Newsome, 2012). New Quay, Wales, located in the center of Cardigan Bay, is one of these areas whose economy relies on the marine tourism industry. During peak tourist season in New Quay (July-September), 1.5-hour whale-watching trips go out three times daily, and tours lasting over 2 hours leave twice daily. During the off-season, 1.5-hour tours run twice daily, and two-plus-hour tours run once daily (Vergara-Pena, 2020). In 2013, 651 trips brought 1.7 million pounds to the local economy. Five boats bring approximately 10,000 people on whale-watching tours each year (Vergara-Pena, 2020). New Quay sits in a shallow, enclosed basin, surrounded by high cliffs, long sand beaches, and small coves with depths ranging from 1 to 12 meters. As a result of nutrient upwelling from the North Atlantic warm waters and cool water surrounding Ireland, the area provides fertile feeding grounds for a host of cetaceans, sea birds and fish (Feingold et al., 2012). Cardigan Bay's semi-resident dolphin population is estimated to be between 200 and 300 individuals (Feingold et al., 2012). This population is considered to be an open one, with individuals moving in and out regularly. Offshore New Quay, the resident population feeds on a range of fish including flatfish, dragonet, pollock, wrasse, sand eel, salmon, sea trout, and blennies (Dunn et al., 2002).

The resident population of bottlenose dolphins in Cardigan Bay has been studied since 1990s, with routine monitoring surveys since 2001, and data available from 2000. Monitoring the health of this population is crucial in fisheries and tourism management in Cardigan Bay. Several studies into the effects of dolphin watching and other boating activities have been conducted in Cardigan Bay, Wales (Lamb, 2004; Richardson 2012; Hudson, 2014; Koroza, 2018; Vergara-Peña, 2020). These studies are mainly unpublished master’s theses.

A rapidly shifting population of bottlenose dolphins combined with an increase in visitors to New Quay and Cardigan Bay requires up-to-date information on dolphin abundance and vessel interactions. This study will review bottlenose dolphin sightings, bottlenose dolphin vessel interactions, and vessel compliance to the local code of conduct from 2000-2023. The aim is to investigate trends in the population of bottlenose dolphin population in Cardigan Bay and the possible effects of boat abundance on the bottlenose dolphin population.

2 | METHODS

2.1 | Land Based Surveys

2.1.2 | New Quay Pier

Opportunistic land-based surveys were conducted by Sea Watch Foundation Interns on New Quay Pier. The pier was chosen due to its proximity to the New Quay harbor, which allowed for the close monitoring of dolphin vessel interactions and for ease of photo identification. The pier also gave the viewer a 180+ degree field of view. Located at 52.125774 N -4.212210 W, the observer could watch east towards the reef, southeast towards New Quay beach, north and northeast towards the deeper parts of Cardigan Bay and Aberaeron, and northwest towards New Quay headland, which partially blocked the observable area. Observations would run Monday through Friday, in sea states below four and visibility greater than 1 km. One to two Sea Watch interns would begin observations between 07:00 and 09:00 in the morning, switching watches every 2 hours until 17:00 on weekdays and from 11:00 to 17:00 on weekends. Three groups of Sea Watch interns would live in New Quay for 2-months, from April to October. Fixed objects in the observable area, such as a buoy and radio tower, were given to estimate the distance from the pier to the observed animals. These fixed structures were also used in recording visibility. Interns would receive a bright-colored vest embroidered with the Sea Watch logo to differentiate them from the public. The observers would spend 80% of the observation time using their eyes and 20% of the time using binoculars. This method was preferential given the size of the observation area, as binoculars would greatly limit the observers' field of view.

2.1.3 | New Quay Headland

The second land-based survey location was New Quay headland (52.12982 N, 4.22354 W) northwest of the New Quay pier (Figure 4). Observations were taken between 08:00 and 15:00. Previous studies recommended observation between 09:00-15:00 for the most effective use of time (Hudson, 2014). 42 observation hours were logged between June 6th and June 15th, 2023 at New Quay headland. The headland has approximately 170 degrees of vision but its height allows for increased vision out to sea. This location investigates an area that cannot be viewed from the pier or town proper. All the dolphin-watching cruises, as well as many fishing and private vessels pass through this area. When monitoring vessel-dolphin interactions, many boats breach boating codes when not in sight of the pier. Data collection on the headland mirrored that of the pier-based land watch. Additionally, a theodolite was used during the headland observations to track bottlenose dolphins in a non-intrusive manner.

Figure 4: Satellite image of New Quay, Wales with land watch observation's locations.

2.2 | Data

At both land-based sites, effort and environmental data were collected every 15 minutes. Environmental data included sea state (according to the Beaufort scale), wind direction, number of boats, type of boats (according to the scale provided by the Sea Watch Foundation), and visibility (on a scale of 1-4). Effort data recorded included time, latitude, longitude, transect #, leg #, speed, course degree, glare, effort type, precipitation, sea state and visibility, every 15 minutes. Dolphin sightings and vessel interactions were recorded on a separate page. When a dolphin was spotted, the time of day, number of dolphins, group composition, distance from the observer, and behavior, were recorded. Changes in behavior were monitored and recorded every 15 minutes. Dolphin vessel interactions would begin when the dolphins were 300 meters or less away from a boat. During these interactions, all the data above would be collected, as well as the type of boat, length of interactions, changes in dolphin behavior, and boat adherence to the code.

2.3 | Theodolite Studies

A theodolite is a surveying instrument used to measure horizontal and vertical angles (Vergara-Pena, 2020). Prior to using the instrument, it must be leveled and calibrated. Mounted on a tripod, theodolites are used in the field to obtain accurate angular measurements for triangulation. The theodolite was placed at an elevation of 244 ft. Sea Watch land watch sighting forms were used in conjunction with additional columns for boat and dolphin locations. During interactions, the theodolite was used to mark the location of both boats and dolphins. Dolphin vessel interactions recorded on the New Quay pier would not include the distance between the vessel and dolphins. Only the observations taken on the headland would include this data.

2.4 | Boat Based Surveys

Four boat-based surveys were undertaken during the fieldwork period of June 6th to June 15th. However, many more boat-based surveys are used in the results. The Sea Watch Foundation runs many dedicated boat-based line-transect surveys in Cardigan Bay throughout the 6-month observation period. Surveys would either be full-day 06:30-18:00 or half-day 06:30-12:30 and follow as many transects as could be completed within the allotted time (Figure 5). Similar to land watch surveys, tasks would switch every two hours for the observation period. Observation-based tasks include the primary observer, who would sit on the bow using a combination of the naked eye and binoculars, and the secondary observer sitting in an observation chair above the helm using their naked eyes and binoculars. Other tasks included effort data collection and photo identification aids. Primary and secondary observers record the time and date and sighting, GPS location, distance that the animal is first observed, behavior every three minutes, change in animal behavior, name of the observer who spotted the animal, species, number of animals, and group composition. Effort and environmental data would be recorded every 15 minutes and when an animal sighting was made. This included time, latitude, longitude, transect, leg number, transect point, speed, course, glare, effort type, precipitation, visibility, sea state, and sighting reference. If not on the transect, casual sightings and only the effort and environmental data would be collected.

Data collected during the boat-based surveys cannot be used to investigate bottlenose dolphin habitation to boats due to the survey boat's own interference. These data are used primarily for estimating bottlenose dolphin abundance and distribution data around Cardigan Bay.

The Sea Watch Foundation classifies a sighting as any time a dolphin is spotted by any observer. Dolphin vessel encounters begin when a dolphin comes within 300 meters of a vessel and end when one or both parties move away. Every encounter includes sightings but not every sighting includes an encounter.

2.5 | Data Analysis

Sightings and encounter data were the primary data sets for analysis. Sightings data consisted of the number of dolphins sighted over a given time period, month and year of sighting, total dolphin group size, number of juveniles and calves, some behaviors exhibited by the dolphins during the sightings, and location of sighting. Encounter data consisted of distance between vessels and dolphins, boat reaction, dolphin behavior and reaction, number of boats, and month and year of encounter. A linear regression model was used on both data sets. The data was not treated or changed before being graphed. Time was used as a continuous variable in combination with sightings and encounter counts. Effort hours were not used in this study due to the lack of availability of this data. T tests were used to track differences between certain years. Counts are sometimes expressed as percentages depending on the other variables being graphed. Available sightings data extends from 2000-2023 and available encounter data extends from 2010-2023. Previous studies on the population of bottlenose dolphins in Cardigan Bay have used survey effort, the number of hours in each period dedicated to surveying (Hudson, 2014, Vergara-Pena, 2019, Lohrengel et al., 2020). Effort hours were not available for this study, and therefore do not influence the conclusions below.

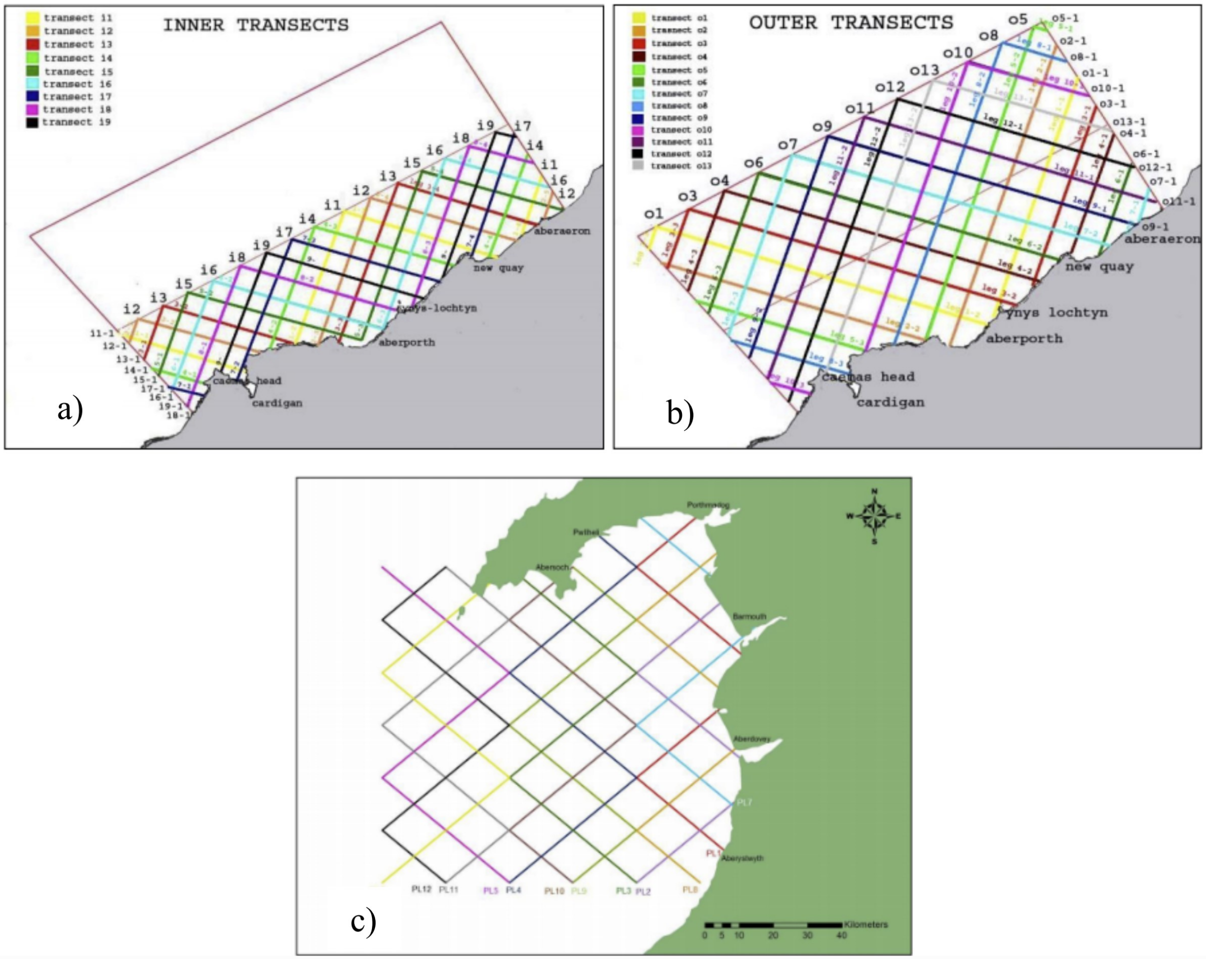


Figure 5: Cardigan Bay transect map for boat surveys.

3 | RESULTS

3.1 | Sightings and Encounters

From 2000-2023 approximately 17,127 individual sightings of bottlenose dolphins were made by the Sea Watch Foundation in Cardigan Bay. A Welch two-sample T-test was used on the first sighting year, 2000, and the most recent complete sighting year, 2022. This test assumed a linear relationship between the time and number of sightings in each year. This test yielded non-significant results (P-value: 0.2414). The second Welch two-sample T-test was used in the first encounter year, 2010, and the most recent completed encounter year, 2022. This test also yielded

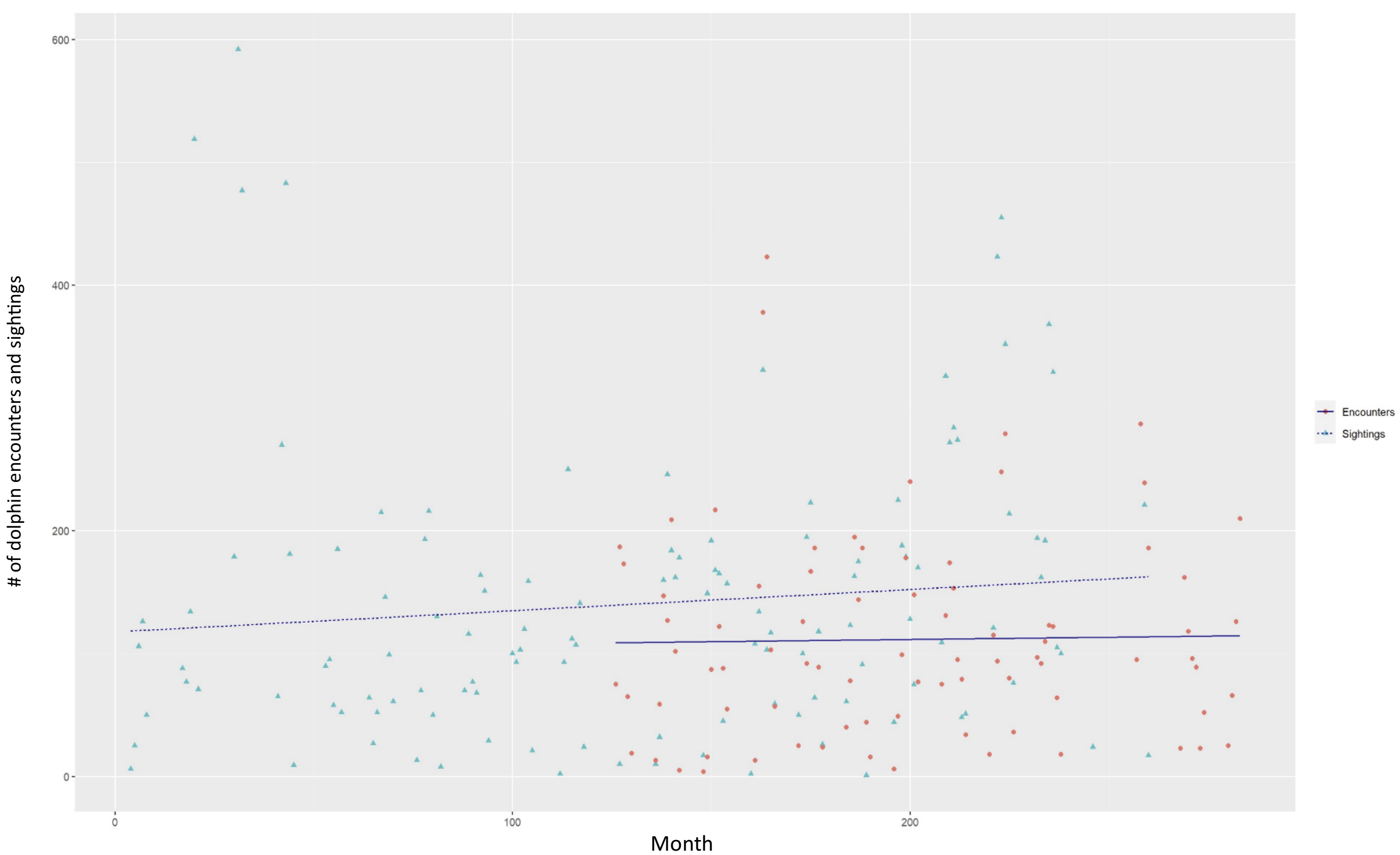


Figure 5: Number of sightings per month from 2000-2023 and the number of encounters per month from 2010-2023. January 2000 was labeled month 1 and every subsequent month was given the next number until June of 2023. The Y-axis represents the number of sightings and encounters per month.

non-significant results (p-value: 0.5578). A linear regression model was used to test for significant changes in the number of encounters from 2010 to 2023. This model yielded non-significant results (p-value: 0.7628). The results above concur with (Figure 5) where the trend line for the number of sightings and encounters is close to horizontal.

A linear regression model was used to test the significance of calf abundance from sightings data from 2000-2023. This test was non-significant (p-value: 0.1827). A linear regression model was used to test the significance for a trend in juvenile abundance using sightings data from 2000-2023. This test was insignificant (p-value: 0.4875). A linear regression model was used to test significance of total group size significance using sightseeing data from 2000-2023. This test was insignificant (p-value: 0.9301). These results concur with (Figure 6) where trend lines for calf and juvenile abundance and total group size are close to horizontal.

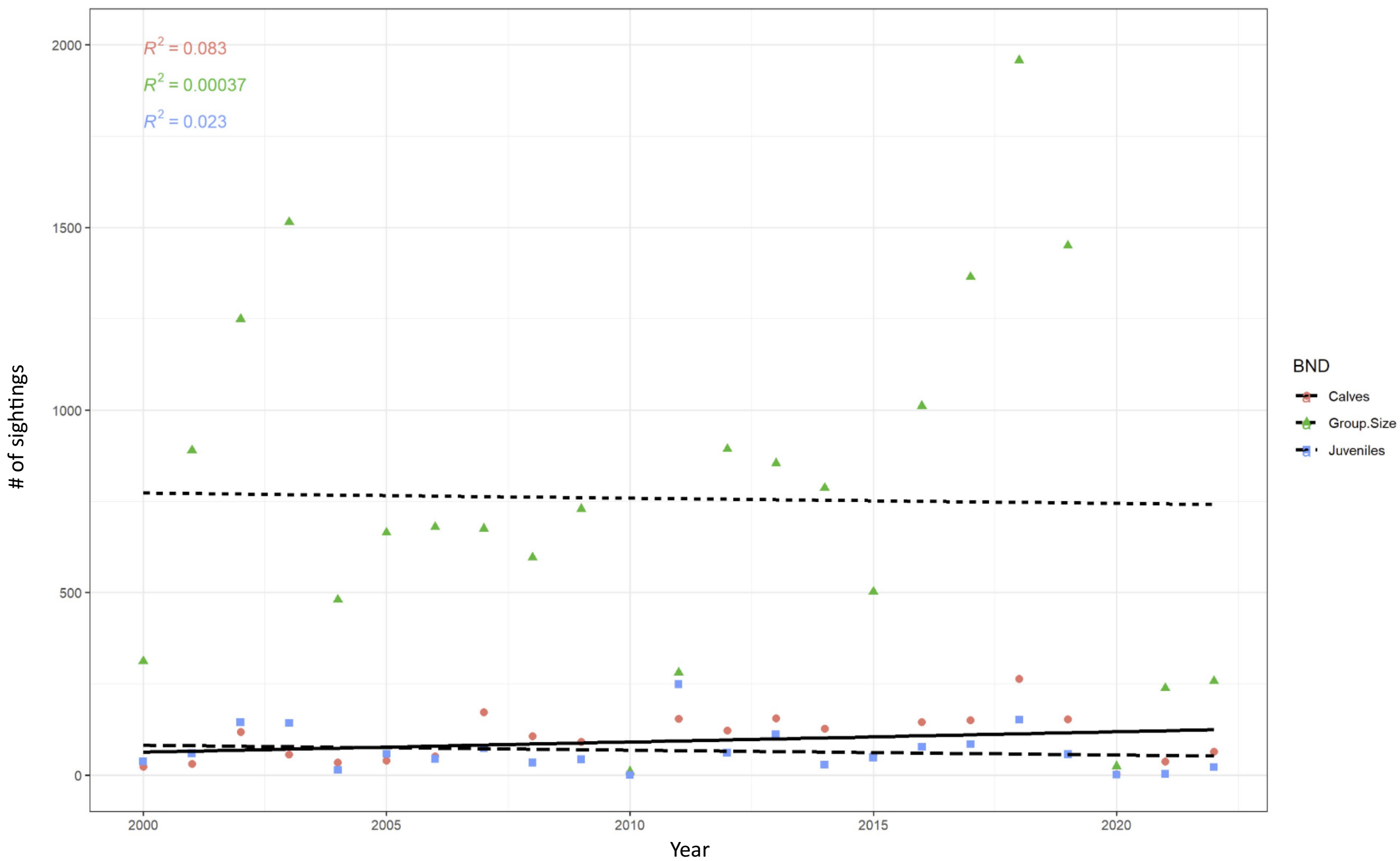


Figure 6: Calf, juvenile and total group size sightings data from 2000-2023 with R^2 values. Value= number of sightings per year.

3.2 | Dolphin and Boat Reactions and Behavior

Bottlenose reactions to the approach of a boat was recorded as A, T, N (Table 1). A linear model was used to test for significant changes in the frequency of dolphins swimming away from boats during interactions. This test yielded non-significant results (p-value: 0.5448). A linear model was used to test for significant changes in the frequency of dolphins swimming toward boats during interactions. This test yielded insignificant results (p-value: 0.1979). A linear model was used to test for significant changes in the frequency of no recorded change or neutral reaction in dolphin behavior during vessel interactions. This test yielded non-significant results (p-value: 0.5628).

Table 1: Abbreviated forms and there meaning for categorizing dolphin reaction to boats during encounters.

A= Swimming away from boat
T= Swimming towards boat
N= No reaction

During interactions, boat reactions to bottlenose dolphins were recorded as N1, N2, N3, N4, Y1, Y2 (Table 2). A linear model was used to test significant changes in N1 boat reactions from 2012-2023. The test yielded non-significant results (p-value: 0.1391). A linear model was used to test significant changes in N2 boat reactions from 2012-2023. The test yielded insignificant results (p-value: 0.8496). A linear model was used to test significant changes in N3 boat reactions from 2012-2023. The test yielded non-significant results (p-value: 0.7531). A linear model was used to test significant changes in N4 boat reactions from 2012-2023. The test yielded non-significant results (p-value: 0.2062). A linear model was used to test significant changes in Y1 boat reactions from 2012-2023. The test yielded significant results (p-value: 0.004269). A linear model was used to test significant changes in Y2 boat reactions from 2012-2023. The test yielded insignificant results (p-value: 0.4126). Linear models concur with (Figure 10) where many of the trend lines are horizontal for those tests that yield non-significant results, and not horizontal for those tests which yield significant results. From 2010-2015 boats breaking the code were recorded in 10.3% of encounters. 2016-2023 saw a slight decrease in boats breaching the code.

Table 2: Vessel reaction designations and definitions.

Y1= No wake speed and no erratic changes in course when passing cetaceans.	Y2= Slowed down and gradually stopped
N1= Too fast, bow/wake speed, white water visible	N2= Erratic course to approach to avoid/follow cetaceans
N3= Attempted to touch/feed/swim with cetaceans	N4= Exceeded 8 knots inside yellow buoys

Table 3: Dolphin behavior abbreviations used by The Sea Watch Foundation.

SS= Slow Swim	S= Socializing
NS= Normal Swim	O= Other
FS= Fast Swim	U= Unknown
SF= Suspected Feeding	N= Not Recorded
FF= Feeding (Fish seen)	AB= Aerial behavior
L= Leaping	PB= dolphin hits water with any part of body
B= Bow Riding	GS= Group splits

with 9.7% of total dolphin encounters. In 2010 alone, 10.3% percent of boat encounters had boats breaching the code. 13 years later, 11% of encounters involved breaches of the code.

Bottlenose dolphin reaction to vessels was graphed in combination with behaviors (Table 3) dolphins exhibited before and during vessel interactions (Figure 7) as a percentage. In 2010-2023, 80.2% of bottlenose dolphin reactions were neutral, 11.7% of recorded responses were away, and 8.1% were towards. Bottlenose dolphin behavior NC was recorded in 34.1% of encounters, behavior NS was recorded in 23.6% of encounters, and behavior SF was recorded in 22.9% of encounters. In 12.5% of encounters, dolphins moved away from vessels. 4.3% of this dolphin reaction was while the dolphin exhibited behavior NS, which was the highest of any behavior exhibited by dolphins when they moved away from a vessel. Behavior NS also showed the highest percentage of dolphins moving towards vessels at 2.7%.

Land surveys collect data on every boat that is seen in New Quay Bay during the study period, including those not interacting with dolphins. Each boat is categorized by its type of activity at sea, size and or vessel type (Table 4). VPBs had the most interactions with dolphins as they were the ones whose main purpose was to locate dolphins. During each dolphin vessel encounter, the distance between the dolphin and vessel was recorded by category (Table 6). Each dolphin's

Table 4: Boat type abbreviations used by the Sea Watch Foundation.

sMB= Recreational motorboat, <15m	
mMB= Recreational motorboat, 15-30m	RB= Rowboat, kayak, or other paddled craft
SB= Racing type speedboat or RIB	JS= Jet ski
YA= Yacht or any boat under sail (including wind surfer)	R= Cetacean research boat
FI= Fishing boat	FE= Ferry
VPB= Visitor passenger boat	LS= Large Ship, >30m

reaction (away, neutral, and towards) was plotted against the distance each boat was from the dolphins when they exhibited those reactions (Figure 7). During encounters where dolphins swam away from vessels, 60.7% of vessels were less than 50 meters from dolphins. 25.2% of vessels were between 50 and 100 meters from dolphins. In 70.6% of encounters where dolphins swam towards vessels, those vessels were less than 50 meters from the dolphins.

Table 5: Distance estimates and abbreviations used by The Sea Watch Foundation.

A= Distance is less than 50 meters	B= Distance is between 50 and 100 meters
C= Distance is between 100 and 200 meters	D= Distance is between 200 and 300 meters

Ten boats were commonly seen interacting with bottlenose dolphins in and around New Quay (Table 5). Each boat has a different skipper, engine size, and maneuvering capabilities, eliciting a different reaction from bottlenose dolphins (Figure 8). Cerismar caused dolphins to swim away from it in 2.7% of its interactions and caused them to swim towards it in 34.7% (Figure 9). 17% of AB2-AB2's dolphin encounters resulted in dolphins swimming away from the vessel, the most of any boat. These 10 boats caused dolphins to swim away in 9.7% of encounters and swim towards in 9.1% of encounters.

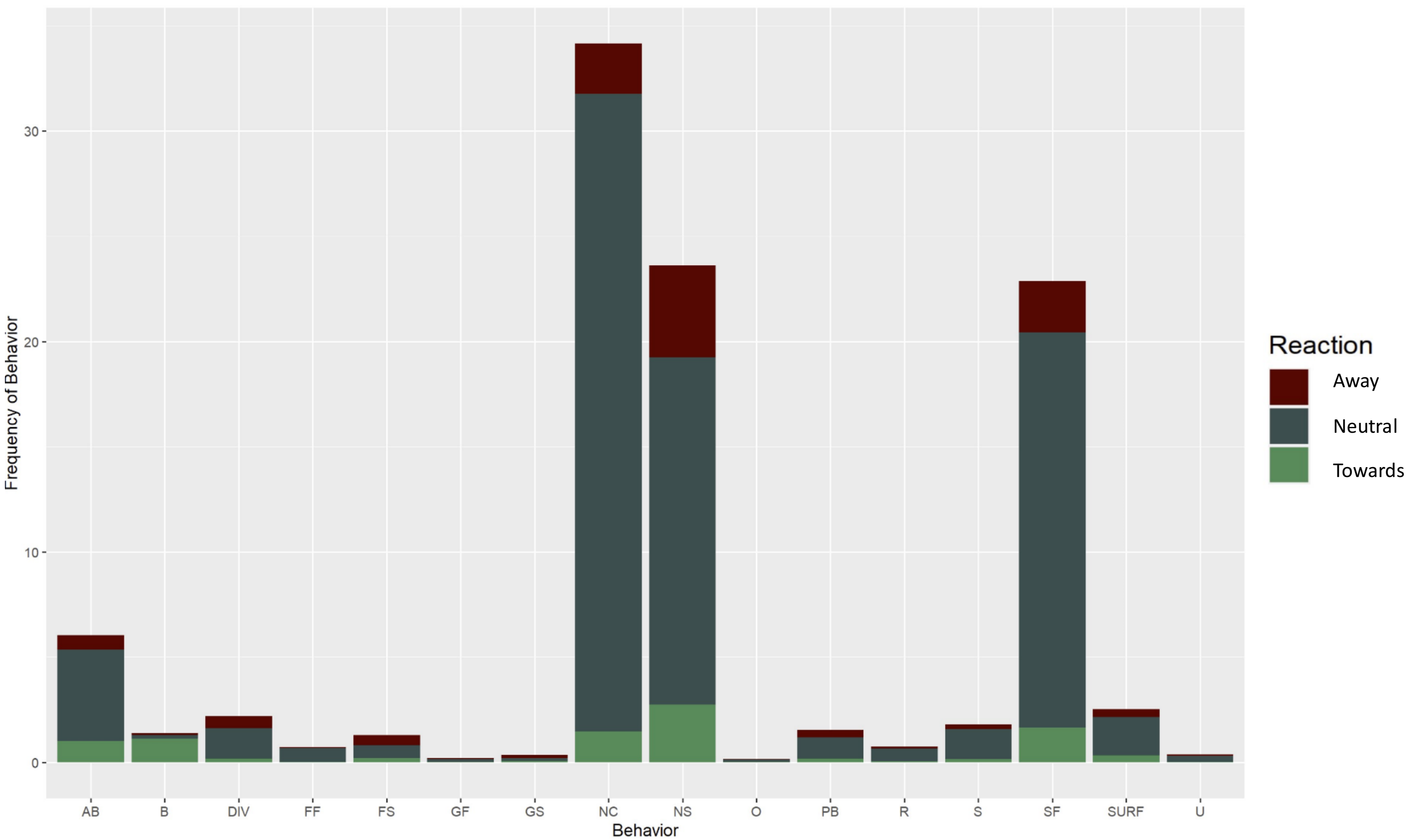


Figure 7: Bottlenose dolphin behavior before and during vessel encounters expressed as a percentage. The 16 columns together add up to 100% of the behaviors. Each column itself indicates the whether the reaction occurred when the dolphins moved towards, away, or didn't move in relation to the boat.

Table 6: Boats commonly viewed by The Sea Watch Foundation and their abbreviations.

AB=AB2-AB2 (FI)	E6= Ermol VI (VPB)
AL= Anna Lloyd (VPB)	ISL= Islander (FI)
CM= Cerismar (VPB)	SUL= Sulaire (VPB)
DC= Dream Catcher (VPB)	VI= Viking (VPB)
DUN= Dunbar Castle (VPB)	
E5= Ermol V (VPB)	

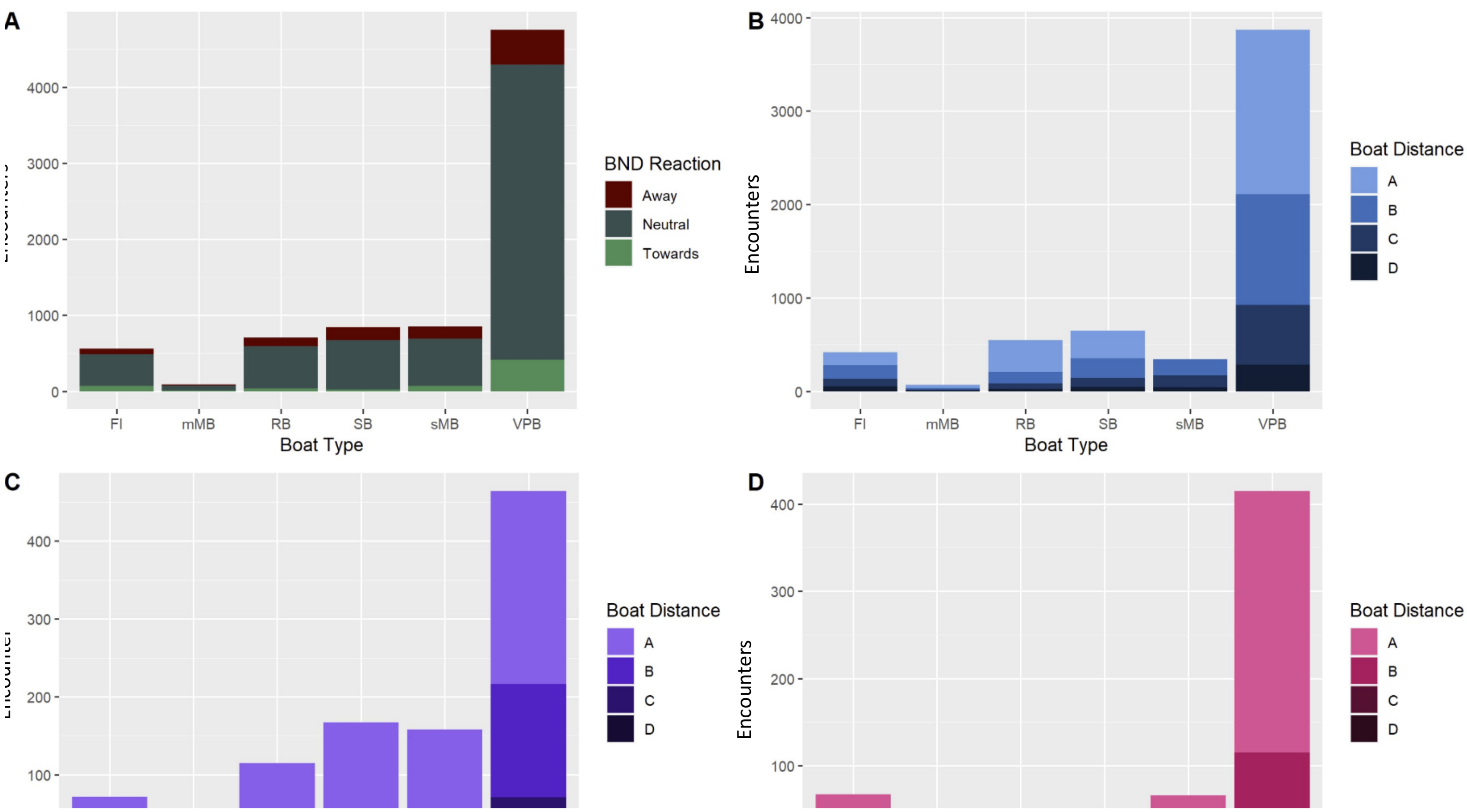


Figure 8: A: Bottlenose dolphin (BND) reaction to most frequently viewed boat types. B: Dolphin neutral reaction behavior based on the distance of each boat type. C: Dolphin moving towards certain boat types based on the vessel distance. D: Dolphins moving away from vessels based on vessel distance.

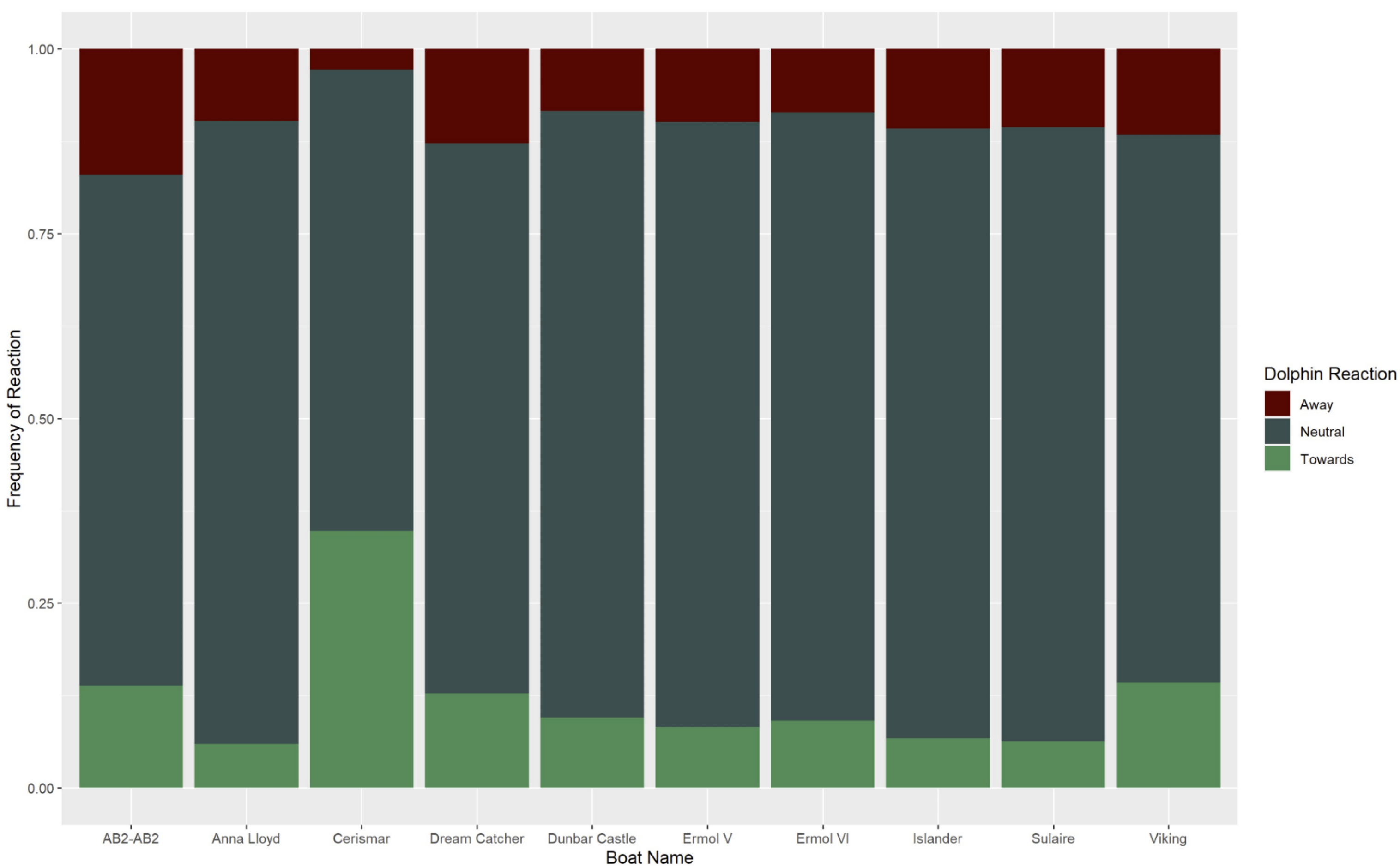


Figure 9: Dolphin reaction to 10 of the most viewed boats in New Quay expressed as a percentage, during vessel encounters.

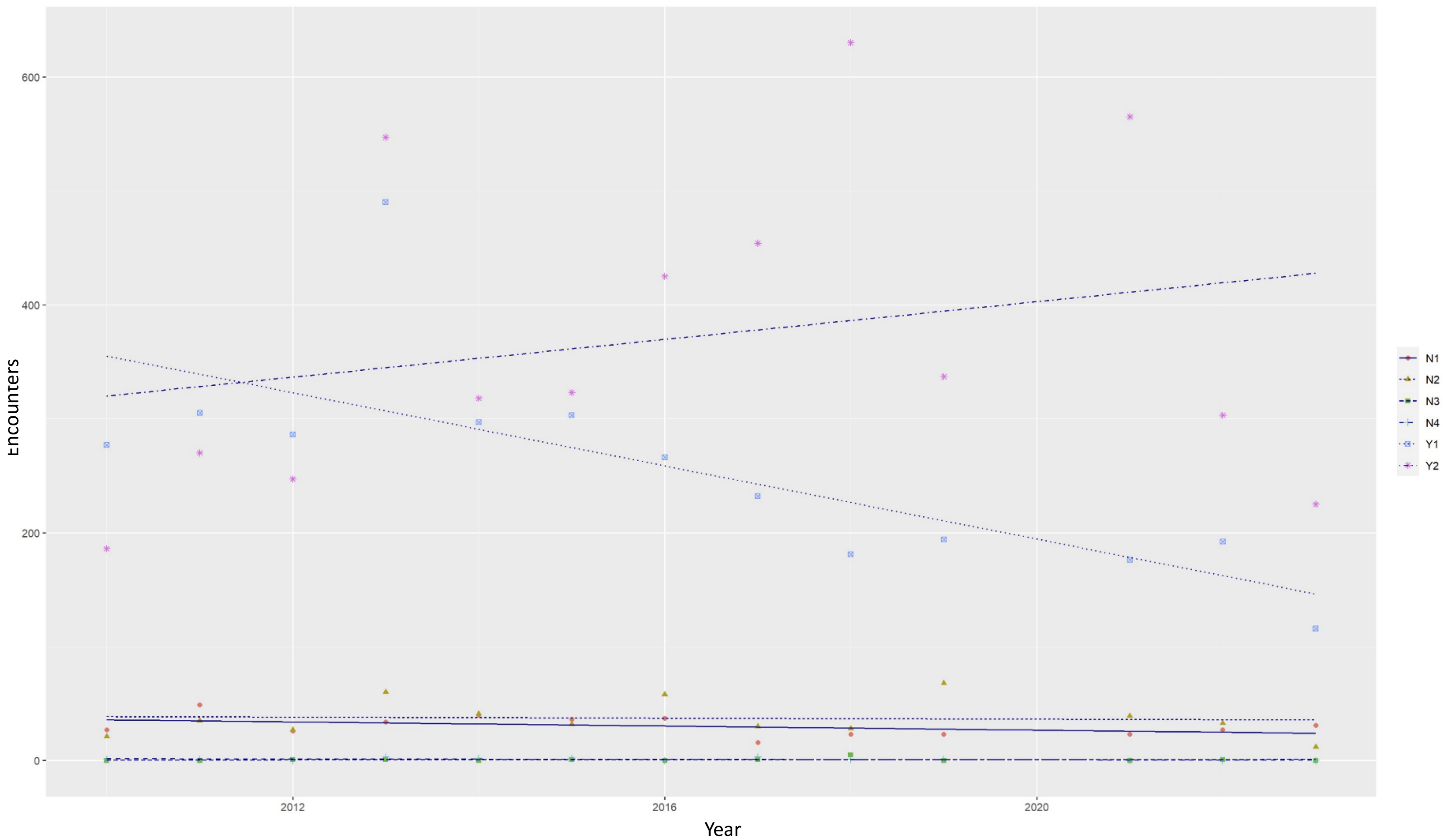


Figure 10: Change in the frequency of boat reactions from 2010-2023 expressed as a value.

The Sea Watch Foundation has recorded 8,886 bottlenose dolphin vessel encounters since 2010. In 2010, 6.5% of encounters had dolphins swimming away from vessels, while 3% of encounter had dolphins swimming towards the vessel (Figure 11). In 2012 12.8% of encounters reported dolphins swimming away from the vessel, and 5.6% of encounters reported dolphins swimming toward the vessel (Figure 12). In 2014 19.5% of encounters reported dolphins swimming away from vessels, and 11.7% of encounters reported dolphins swimming toward vessels (Figure 13). In 2016 10.3% of encounters reported dolphins swimming away from the vessel, and 6.2% of encounters reported dolphins swimming toward vessels (Figure 14). In 2018 9.5% of encounters reported dolphins swimming away from vessels, and 8% of encounters reported dolphins swimming toward vessels (Figure 15). In 2021 9.1% of encounters reported dolphins swimming away from vessels, and 11.2% of encounters reported dolphins swimming towards vessels (Figure 15). In 2023 5.4% of encounters reported dolphins swimming away from vessels, and 8.3% of encounters reported dolphins swimming toward vessels (Figure 16).

Table 7: Vessels commonly spotted around New Quay, Cardigan Bay. The engine type (which directly impacts sound emitted by the vessel) and length of each vessel. Information on the other vessels in figure 9 are unavailable.

Vessel Name	**Length (m)**	**Engine Type**
Islander	7	60 hp petrol (2x)
Sularie	10.05	350 hp diesel
Dunbar Castle II	9.7	120 hp diesel
Ermol V	11.5	128 hp diesel (2x)
Ermol VI	10.9	350 hp diesel
Anna Lloyd	10.05	150 hp diesel (2x)

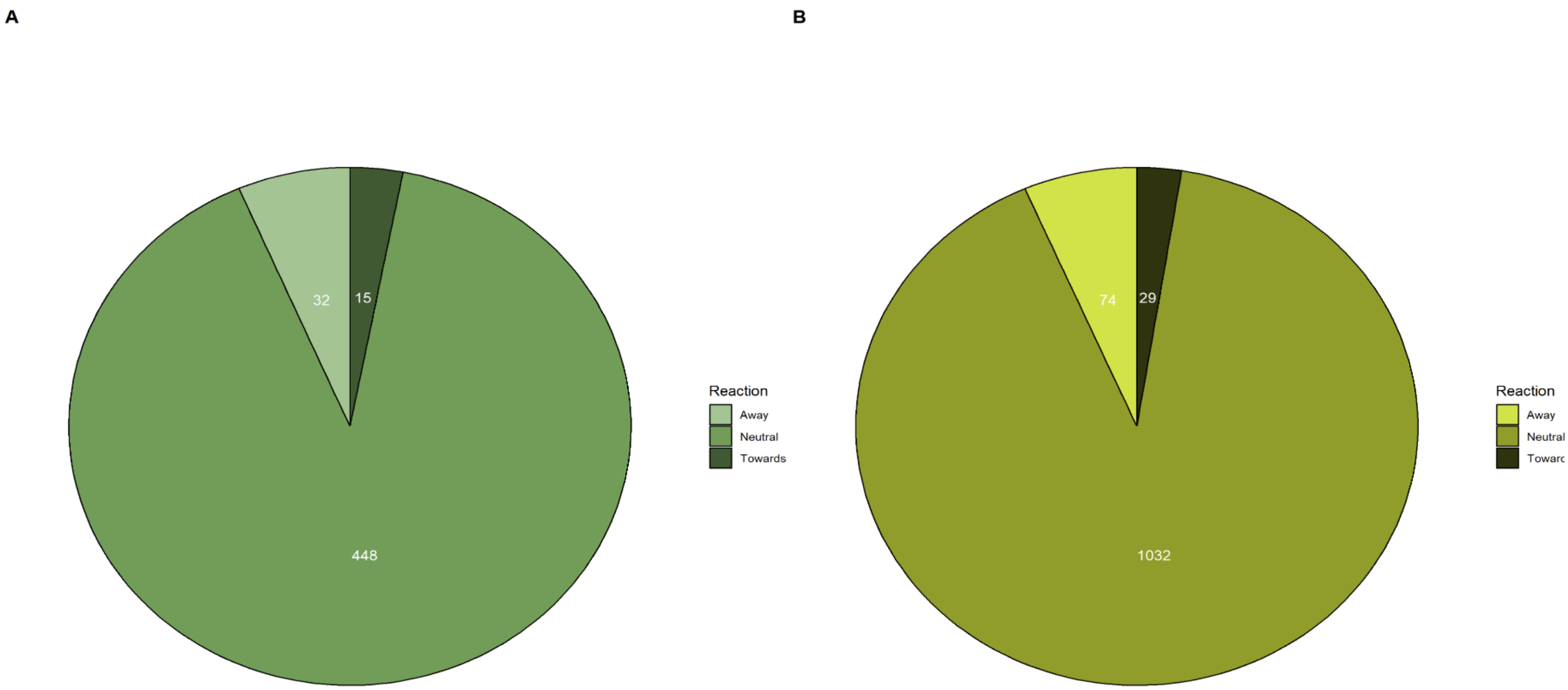


Figure 11: Dolphin reaction to vessels in A 2010 and B 2011

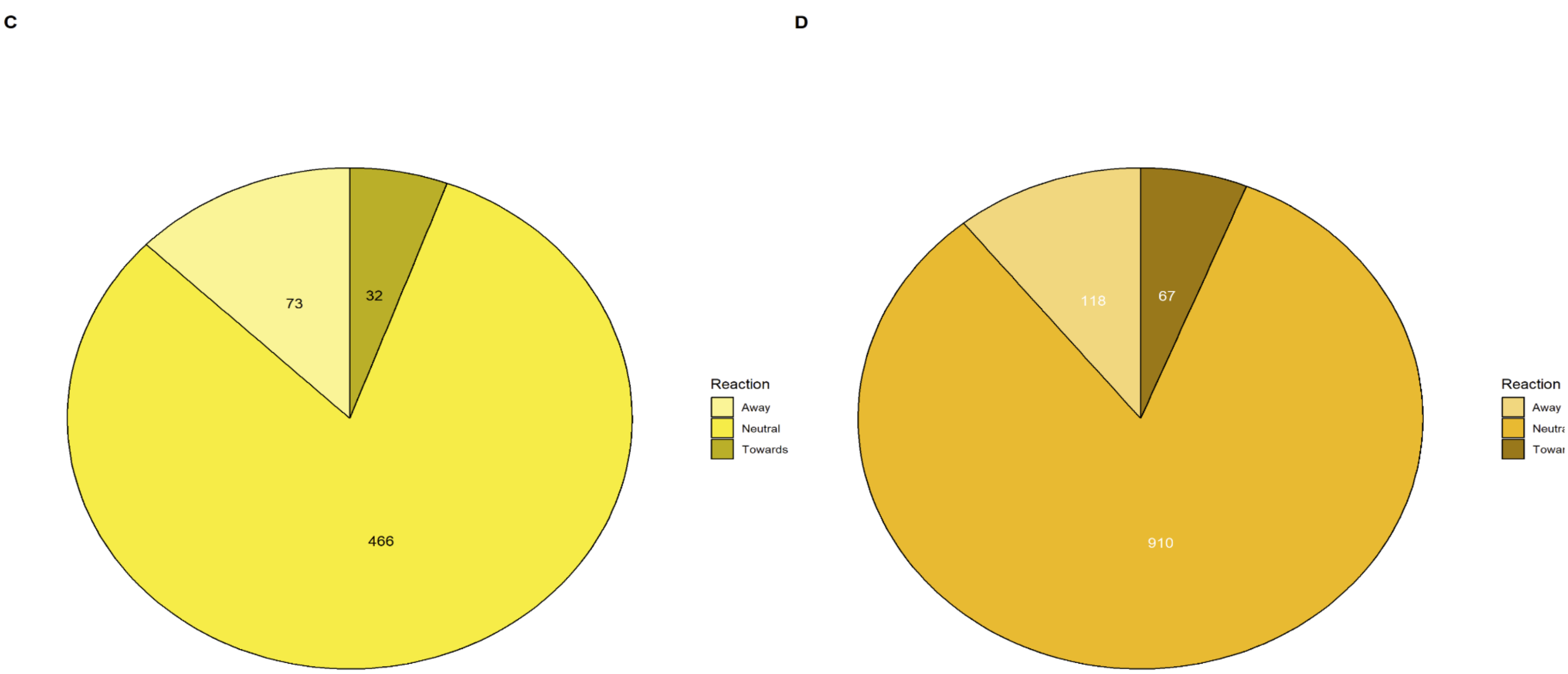


Figure 12: Dolphin reaction to vessel in C 2012 and D 2013

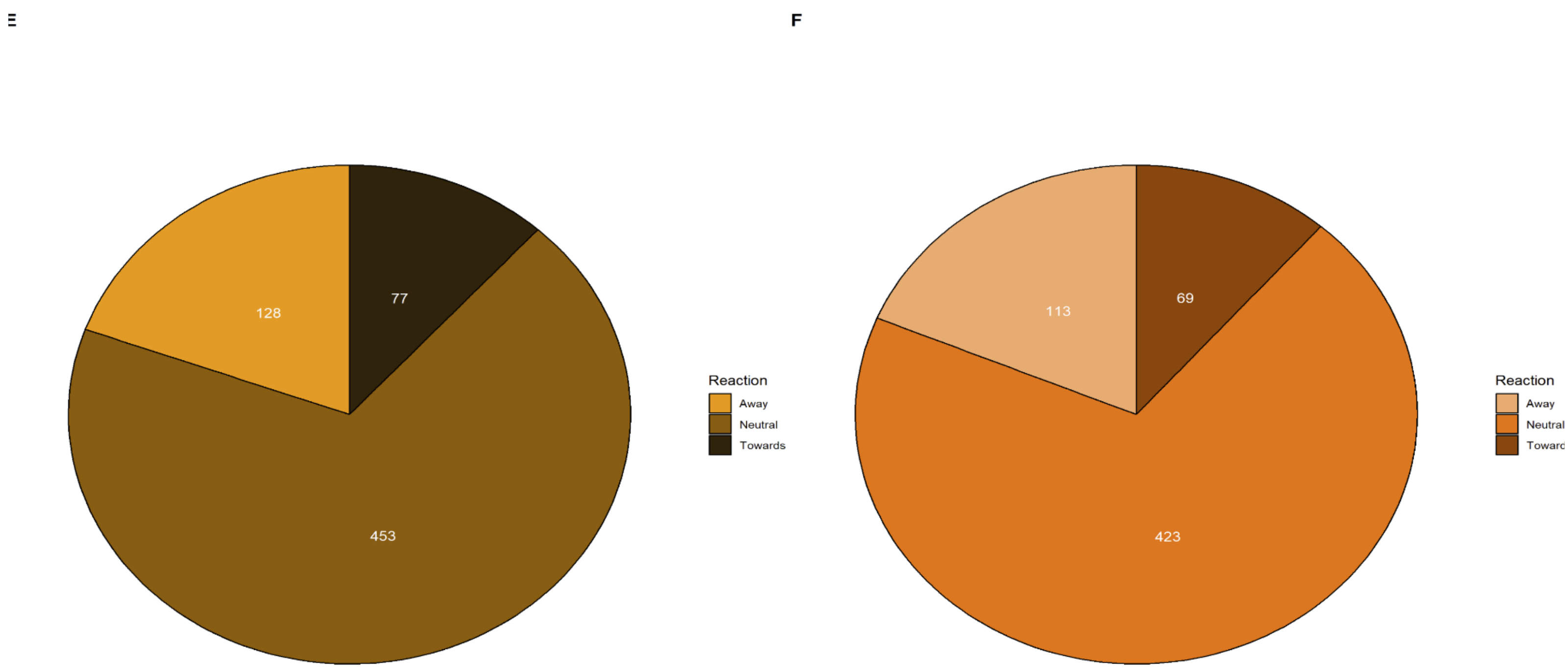


Figure 13: Dolphin reaction to vessels in E 2014 and F 2015

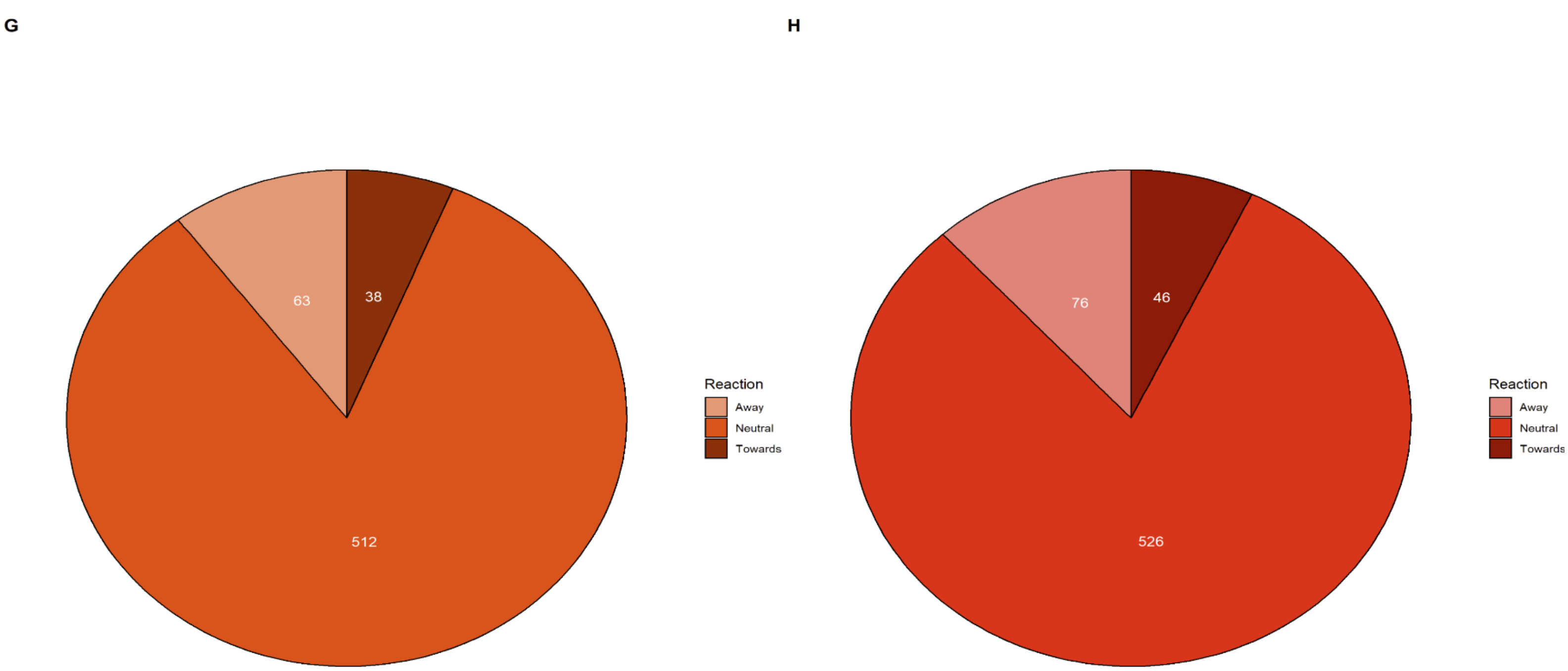


Figure 14: Dolphin reaction to vessels in G 2016 and H 2017

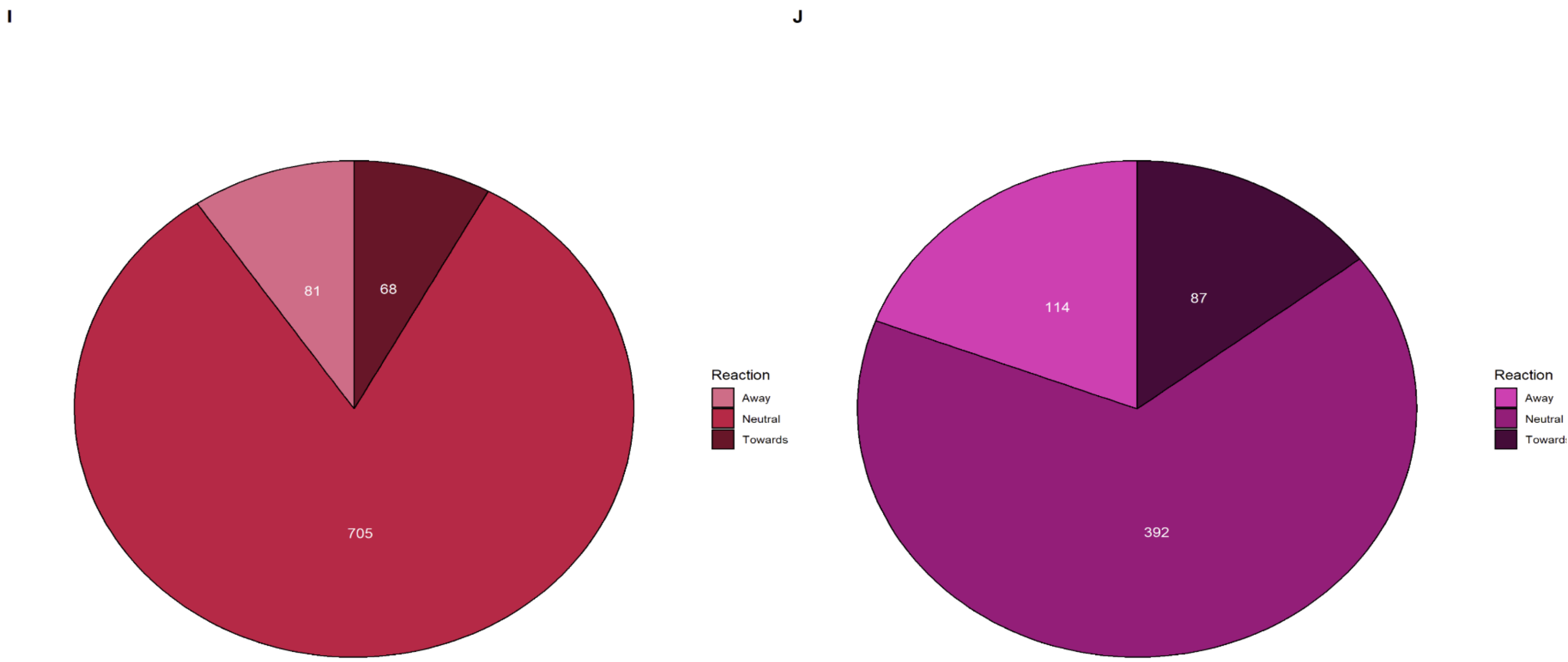


Figure 15: Dolphin reaction to vessels in I 2018 and J 2019

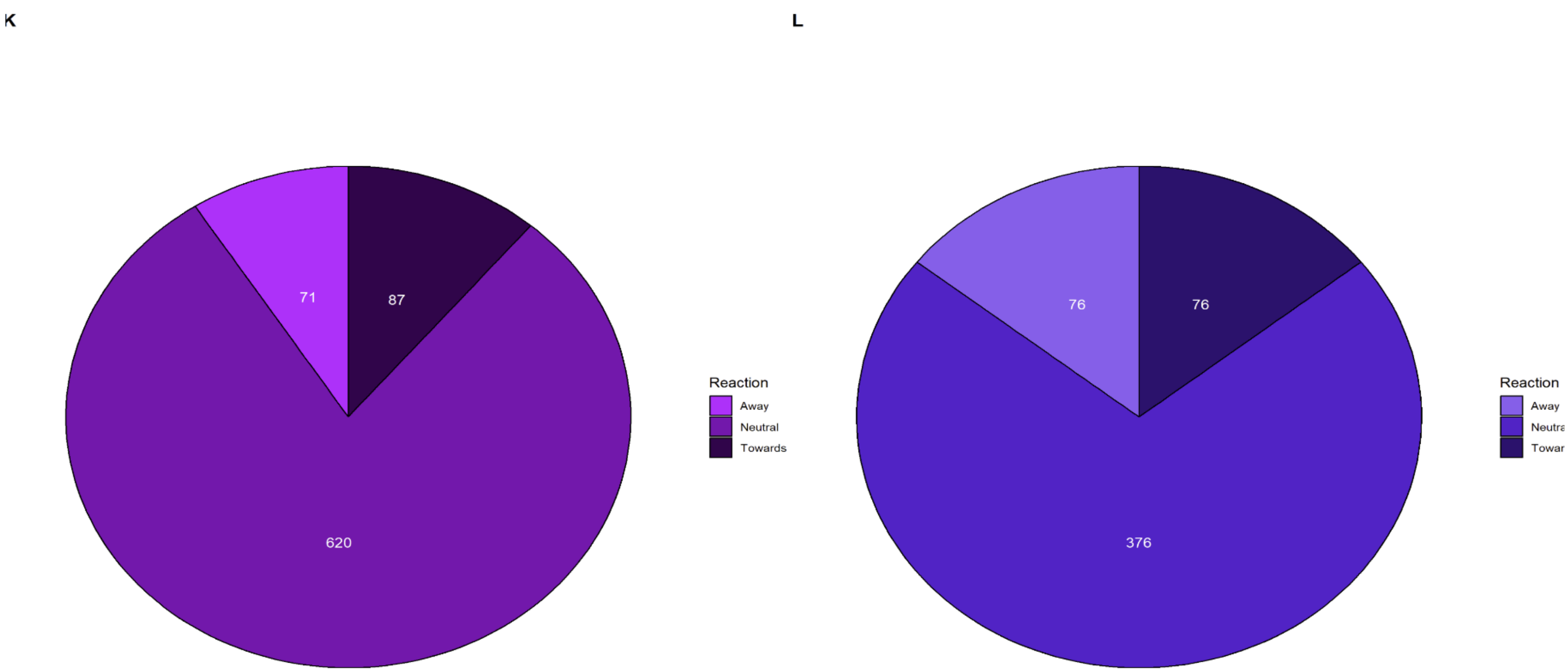


Figure 16: Dolphin reaction to vessels in K 2021 and L 2022

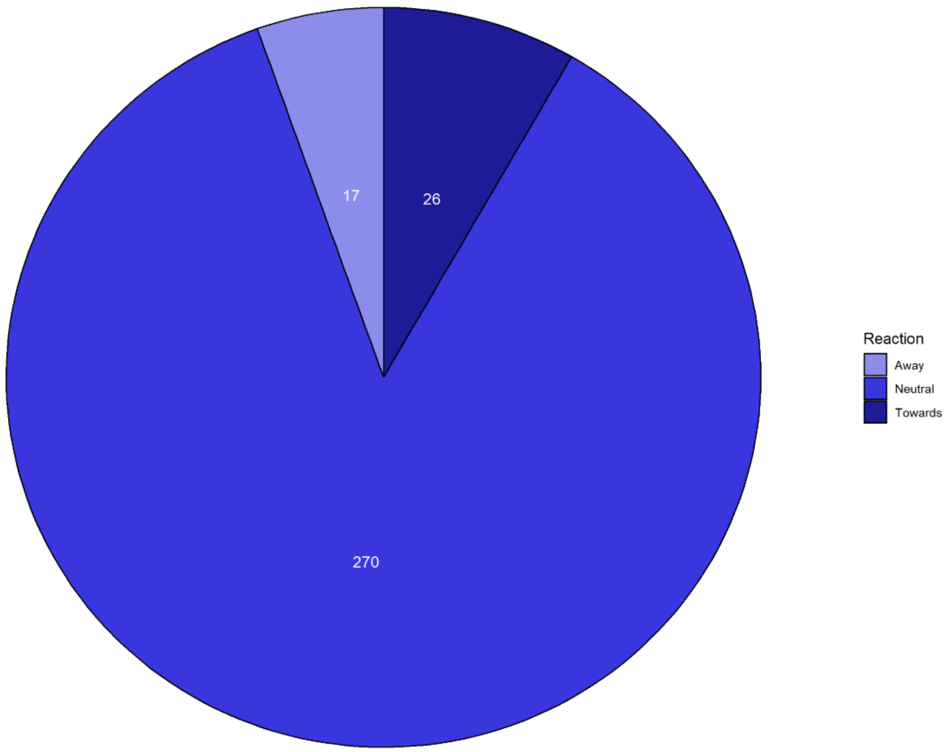
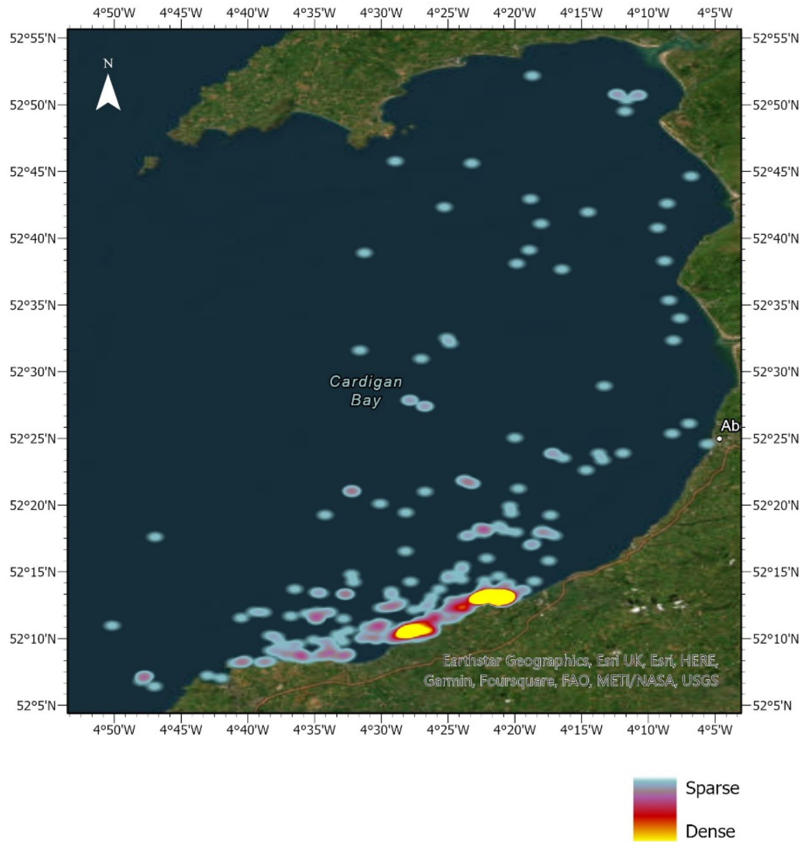


Figure 17: Dolphin reaction to vessels in 2023.

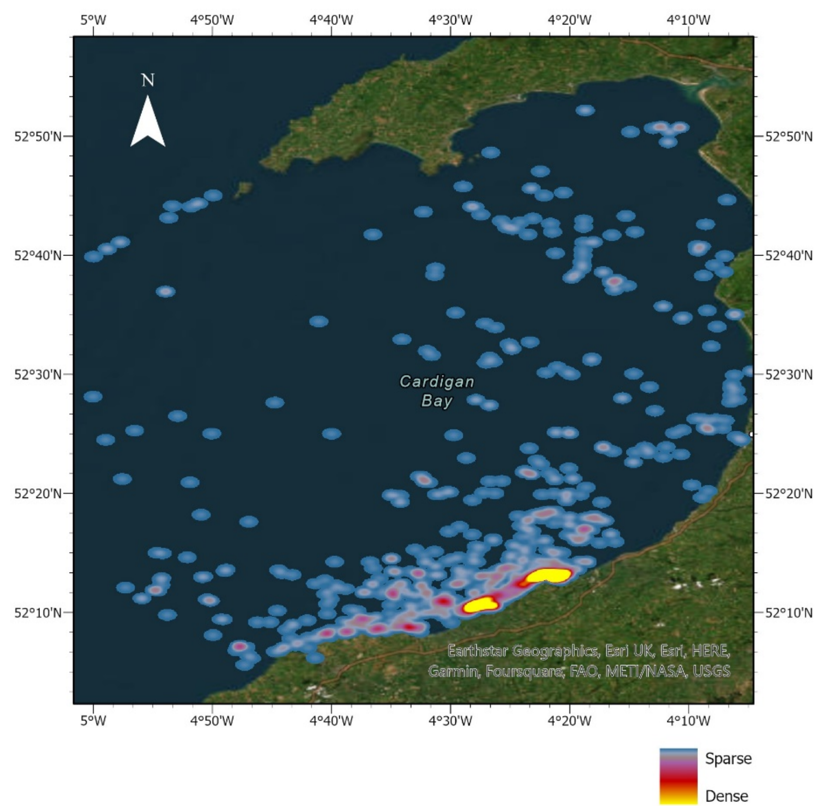
3.3 | Mapping Dolphin Abundance in Cardigan Bay

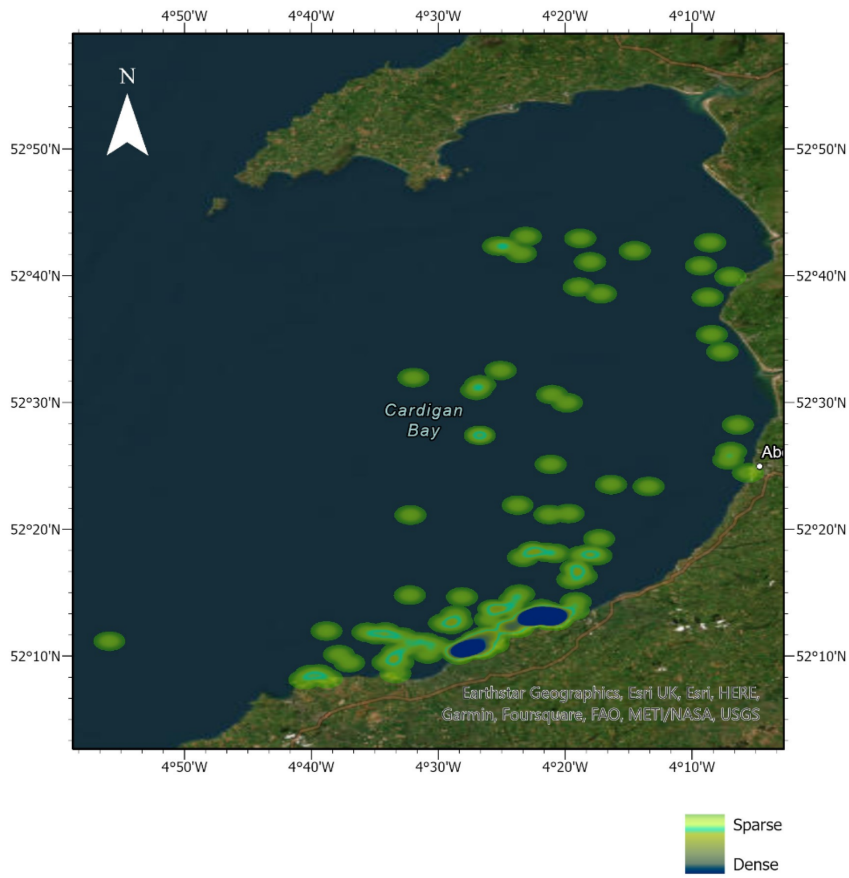
The Sea Watch Foundation does not record the exact location of bottlenose dolphins during boat based surveys. Instead the GPS locations that were used to make the maps below are of the location of the boat from which the sighting was made. However, ranges and angles are taken so the precise location can be determined. Ranges are typically less than 300 meters from the vessel so, for this study, the plots showing the veseel locations are taken as broadly equilivant to that of the animals. The distribution of calves is mapped on (Map 1), bottlenose dolphin abundance based on sightings data is mapped on (Map 2), and abundnace during peak tourist season is mapped on (Map 4). Maps 3 and 5 show the distribution of those encounters in which dolphins exhibited a behavioral change in response to vessel presence. (Map 3) shows those encounters where dophins swam towards the vessel and (Map 5) shows those encounters where dolphins swam away from vessels.



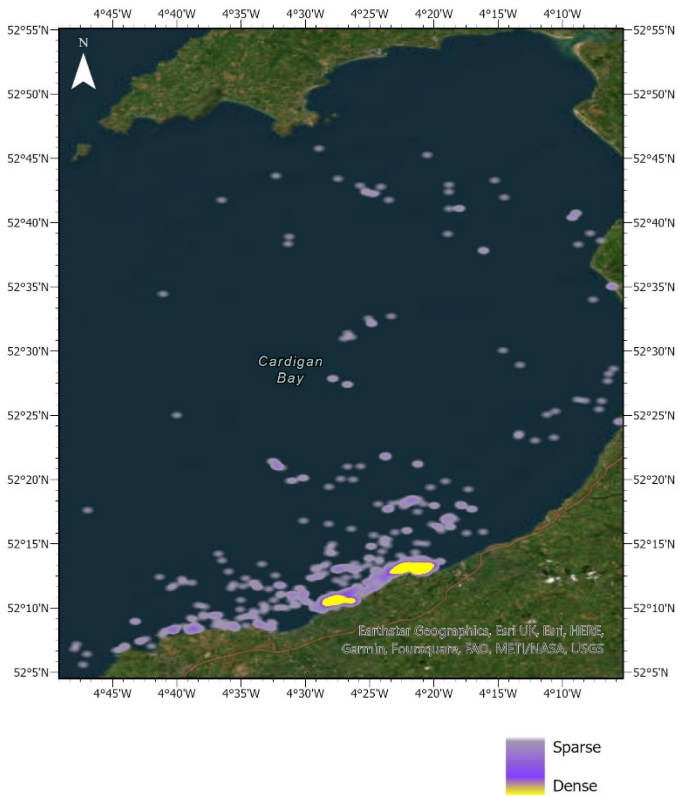
Map 1: Cardigan Bay heat map of calf sightings from boat-based observations. Densest area on the map is around New Quay where land watches take place.

Map 2: Cardigan Bay, Wales heat map of bottlenose dolphin sightings from boat-based observations. Densest area on the map is around New Quay where land watches take place.

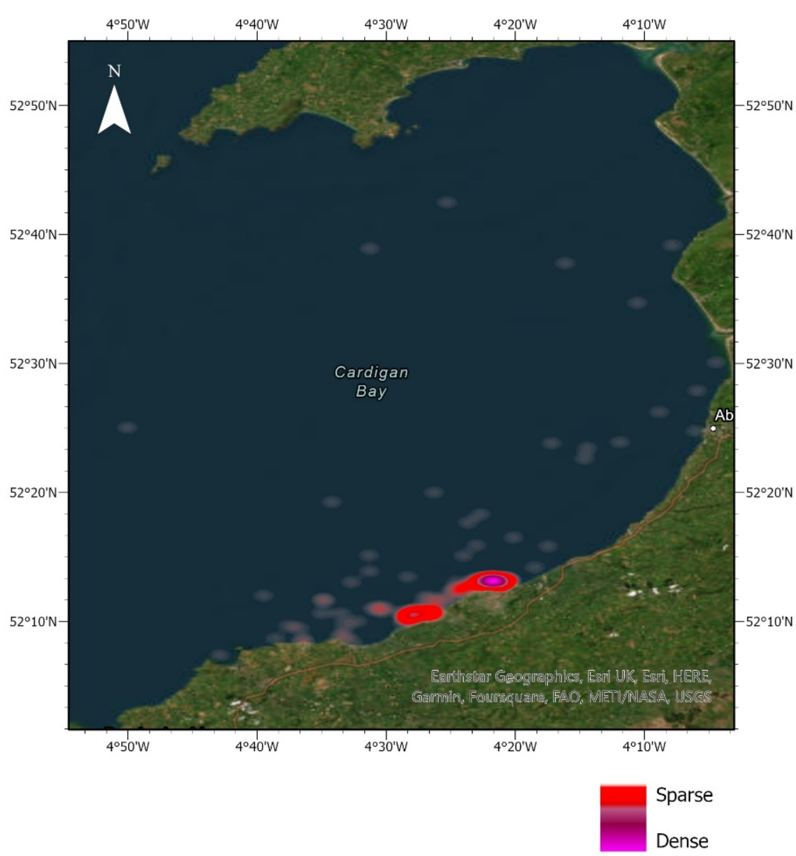




Map 3: Cardigan Bay heat map of bottlenose dolphin reactions to boats by swimming towards boats from dedicated boat-based surveys. Densest area on the map is around New Quay where land



Map 4: Cardigan Bay heat map of bottlenose dolphin sightings during the peak tourism season from boat-based surveys. Densest area on the map is around New Quay where land watches take place.



Map 5: Cardigan Bay, Wales heat map of bottlenose dolphin reaction to boats, by swimming away from boats, from boat-based sightings. Densest area on the map is around New Quay where land watches take place.

4 | DISCUSSION

4.1 | Bottlenose Dolphin Abundance in Cardigan Bay, Wales

The bottlenose dolphin population in Cardigan Bay has been studied since 2001. Since then, tourism and other marine activities have increased, with a corresponding increase in the number of boats (Vergara-Pena, 2020). Despite this, dolphin vessel encounters have not exponentially increased from 2000-2023. Approximately 7% of bottlenose dolphins commonly photographed in Cardigan Bay have only been sighted within the Cardigan Bay SAC (Hudson, 2014). These make up a part of the resident population of dolphins and would react differently to commonly viewed boats than a transient dolphin (Hudson, 2014). Bottlenose dolphin juvenile sightings (Figure 6) show a slight yet non-significant decrease in sightings from 2000-2023 and a slight increase in calf sightings. While this could result from human error in distinguishing between a calf and juvenile or adult and juvenile, it could indicate increased reluctance for mothers to bring calves in contact with vessels (Constantine, 2004). Total group size is based on the number of individual dolphins sighted per month per year from land and boat-based surveys; it has remained stable since 2000. This indicates a stable population that is neither growing nor shrinking. These results contradict findings from 2017 using mark recapture methods, these results indicated a non-significant decrease in the population (Lohrengel et al., 2017). However, a 2020 OSPAR report indicated that the bottlenose dolphin abundance based on mark recapture methods had stabilized after a 10-year decline (Evans, 2022). Despite the stable population in Cardigan Bay other populations around the UK have shrunk, such as those in Moray firth Scotland (Wells, 2004; Evans, 2020; Hastie, 2006).

When studying long-lived animals such as bottlenose dolphins, which can live between 30 to 50 years in the wild, having only 23 years of data it is difficult to draw concrete conclusions about long term population trends (Mann et al., 2000). One workaround is to study the number of calves present each year. Cardigan Bay is considered an important nursery ground for young calves with a birthing rate using an open population model of 9.4% (NRW, 2018). Calf sightings from 2000-2023, had a non-significant change. Even in five-year intervals, the average time it takes for a calf to mature into a juvenile, there is no significant change in sightings (Mann et al., 2000). This concurs with the other non-significant results from linear regression models of sightings data. By the metrics discussed above, despite a decrease in population from around 2010-2020, calf sightings remained stable (Lohrengel et al., 2017).

It should be noted that according to some population studies, using a Poisson distribution fits best with survey and count data (Joe, 2005). Using a Poisson distribution on sightings data yielded a (p-value 1.1611e-203), which indicates the data are a very poor fit for this type of distribution. Compared to the R^2 values using a linear model, which also does not fit the line, a linear distribution model was a better choice given the characteristics of the data.

Most bottlenose dolphin calf sightings were recorded near shore (Map 1). While this trend extends to the total amount of sightings due to survey bias, juvenile and adult bottlenose dolphins tend to travel further offshore than females with calves (Bejder et al., 2006). This observation confirms the findings of maps 1 and 2, where calves are more commonly spotted close to shore and older dolphins spotted in higher concentrations further offshore. Many sightings were recorded on designated boat-based line transects which concentrate on coastal areas. The Sea Watch Foundation also uses citizen scientists to report bottlenose dolphin sightings, many of which originate from local boaters. The number of sightings does not directly correlate to number of sightings, yet the number of boats in Carrigan Bay, most of which stay within the coastal strip has been rising for around a decade (Vergara-Pena, 2019). Vessels in close contact with bottlenose dolphin calves can have several adverse effects on those calves, as well as increase the chances for those claves to become habituated later in life (Raderschall, 2011; Smith, 2008; Feingold et al., 2013).

4.2 | Boating Adherence to Code

Special areas of conservation were formally designated in Wales in 1994, when the UK government adopted the guidelines set about by The Habitats Directive in 1992 (Leg.gov.uk 2023). This directive only prohibits the deliberate disturbance of marine mammals during breeding, rearing, hibernation, and migration. With this designation came the boating code for interacting with marine mammals. Before 2004, there were no legal ramifications for breaking the code of conduct. (Potts, 2014). Changes in sightings data trends for juveniles, calves, and the total group were non-significant for the four years before and after 2004. These results could indicate two trends, the first is that boaters were respecting the bottlenose population before 2004 or that the code does nothing to mitigate the harmful effects of boats on bottlenose dolphins and the presence of boats and not boat behavior has the greatest effect on the bottlenose dolphin population.

From 2010-2023, 10% of vessels around New Quay harbor violated the code. According to Natural Resource Wales, vessels that comply with the code are four times less likely to physically injure marine mammals in their vicinity (NRW, 2019). The fear of physical harm is one of the two main drivers in dolphin, vessel avoidance behaviors (Richardson, 2012). Linear models reveal that there have been no significant changes in the frequency of non-compliance in boats since 2010. Although no boat strikes have been recorded in Cardigan Bay since 2000. Some dolphins photographed by the Sea Watch Foundation have injuries consistent with boat strikes. While boats not complying with the code have not significantly changed since 2010, boats exhibiting behavior Y1 (no wake speed and no erratic changes in course when passing cetaceans) have changed significantly since 2010. Over 60% of vessels in New Quay harbor are VPBs, (visitor passenger boats) vessels owned by wildlife watching companies. If these vessels consistently breach the code, the company may suffer monetary losses. The significant increase in boats exhibiting Y1 behavior is positive for the boating community of New Quay, as this may be the result of increased awareness of the effects of boats on dolphins. There have been no significant changes in boats exhibiting any other behaviors. Comparing just 2010 with 2023, there was a 1.3% rise in noncompliance, but linear models indicate this change is a non-significant rise. Noncompliance to code does not directly correlate with bottlenose dolphins swimming away from vessels, but it does increase the chance of this reaction. Most boats not complying with the code were around New Quay harbor and headland, in part due to sample bias. The headland cannot be viewed from the pier and is where many VPBs travel. This is also the result of survey bias, as some of the transects used during designated boast-based surveys follow the route commonly used by wildlife watching vessels.

As behavior Y1 increased significantly, behavior Y2 (slowed down and gradually stopped) has decreased since 2010. This indicates a shift from boaters who are already complying with the code. Y2 is not a breach of the regulation, it is rather more harmful than behavior Y1, but not risky enough to be illegal. According to the code, boats are not permitted to have their engines running within 100 meters of marine mammals unless they leave the vicinity after 15 minutes. Most boat encounters saw boats within 50 meters of bottlenose dolphins (distance A). A greater number of boats were within 100 meters of dolphins than the number of dolphins who swam towards these boats. The discrepancy could result from the underreporting of boats breaching the code. This trend stayed consistent throughout all boat sizes regardless of task and size. While most boats comply with the code. There is still work to be done further to reduce the amount of noise pollution in Cardigan Bay, as it is a significant contributing factor in dolphin and vessel avoidance behaviors (Sorensen et al., 2023). One possible solution includes further restricting engine size and implementing additional sound shielding measures.

There were no significant changes in vessel encounters, sighting rates, and negative reactions to vessels before and after 2004 when the current version of the code of conduct was adopted, which may indicate that the code is not an effective tool in regulating vessels. According to the Welsh government, the code "puts forward sensible guidelines to minimize the disturbance to wildlife." The current code achieves the absolute minimum of this goal. While the code lays out standard guidelines to protect marine mammals that countries such as the United States and Australia only later adopted, it does not do enough to ensure the populations of marine mammals are protected against sound pollution (Table 7). The north and west Wales marine code in Gwynedd prioritizes tourism over animal safety.

4.3 | Bottlenose Dolphin Reaction Behavior

When dolphins move away from a vessel during an interaction, it is viewed as a negative response to the encounter. If a dolphin moves towards a vessel during an interaction, it is considered a positive response to vessels (Papale et al., 2011). From 2010—2023, there was no significant change in behavioral responses to vessel reactions. A greater number of dolphins swam away from boats than towards boats during vessel interactions. This is consistent with other studies on bottlenose dolphin reactions to vessels (Stensland, 2007). Birthing season in Cardigan Bay coincides with the beginning of peak tourist season (Urian et al., 1996). This is also when dolphin-watching tour operators increase the number of daily trips. During their first year of life, calves will swim beneath their mothers as they lack the strength and knowledge to swim and hunt for themselves (Hill et al., 2007). The mother-calf pairs will stay closer to shore in shallower waters away from potential threats (Hill et al., 2007). This puts these pairs in contact with the influx of summer tourist boats. No data is available on the exact age makeup of the pods that encounter boats. It can be inferred that many of the pods that avoid boats include younger dolphins.

Any change in dolphin behavior resulting from a vessel encounter is essential to monitor. The data collected by Sea Watch shows no differentiation between behavior before and during vessel encounters. In most cases, the encounter begins when the dolphin is spotted, and the behavior is recorded. Changes in behavior are not recorded in every encounter. Bottlenose dolphins exhibited three primary behaviors during encounters: normal swimming, suspected feeding, and aerial behavior. These three behaviors are the most recorded behaviors in bottlenose dolphin populations (Bruck, 2013). Normal swimming encompasses a range of potential social and hunting behaviors unknown to the observer. Normal swimming was the behavior exhibited by most dolphins who had adverse reactions to vessels. Communication and echolocation are crucial for effective bottlenose dolphin hunting (Lopez, 2006). The high-decibel sounds emitted by boats can distract and disrupt hunting and other social and feeding behaviors (Constantine, 2002). Dolphins avoid loud boats while actively hunting (Toth et al., 2011).

Bottlenose dolphins are curious mammals who will approach novel objects, including boats. Only about 8% of vessel encounters included dolphins moving toward the vessel. In countries with more lenient regulations on dolphin vessel interactions, the rate at which dolphins approach boats increases (Connor et al., 2015). Areas such as Sarasota Bay, USA and Shark Bay, Australia allow swimming and handfeeding of wild dolphin populations (Connor et al., 2015), (Buckstaff, 2006). Once an animal is hand-fed by humans, it associates humans and objects such as a boat with food. These associations will lead them to move towards boats whenever they are in the vicinity (Orams, 2002). Bottlenose dolphins in Cardigan Bay have had less direct human interaction than other wild populations and are not attracted to vessels at the same rate as other populations. In most cases, bottlenose dolphins will not approach anything that they consider a threat, especially when calves are present (Rodel et al., 2014). Dolphins can perceive different boats differently depending on the boat's behavior (Highfill, 2007, Hudson, 2014). If a vessel has exhibited erratic behavior which breaks the code, dolphins will be more likely to avoid those boats (Highfill, 2007). Boats who exhibit compliant behavior around dolphins will be more likely to have those dolphins approach them, as they are not perceived as a threat. Low attraction rates and stable population numbers may indicate that this population is tolerant to boat traffic, and the code keeps the status quo between vessels and bottlenose dolphins.

4.4 | Habituation

Population trends of bottlenose dolphins in Cardigan Bay in 2023 was more or less the same as in 2000, indicating that the bay has not become a particularly unsafe place to live due to increasing vessel presence. With an increase in vessel traffic and a fairly steady, yet small decline in bottlenose dolphin population since 2012 may indicate some amount of tolerance or habituation. Approximately 80% of all dolphin reaction to boats were neutral. This shows there was no change in dolphin behavior due to vessel proximity. Dolphins give birth typically every 3-7 years. If vessels had become a severe concern for the population, there would be a sudden decrease in sightings, particularly calves, followed by a steady increase as those calves become more independent. This has not been the case, as calf sightings have not changed significantly since 2000. Dive interval is a method to test dolphin reaction to vessels. The longer the dive time, the less dolphins want to be in contact with a vessel (Vergara-Pena, 2020). The Sea Watch Foundation does not routinely track dive time so only small-scale investigations can be conducted. Some of these investigations have concluded that there is a change in dive time when certain boats are present (Vergara-Pena, 2020), (Hudson, 2016). Given the non-significant difference in both sightings and encounters, it can be assumed that this change in dive time is also insignificant.

Like many marine mammal family groups, knowledge is passed down through the matriarch (Lusseau, 2007). With at least four generations of dolphins living together in Cardigan Bay, boats exhibiting aggressive behavior are known to most pods that inhabit Cardigan Bay. Teaching boat recognition to offspring is a sign that this recognition is a learned behavior, a benchmark of habituation (Lusseau, 2007). Habituation could drive the stagnant encounter rates if this population has learned how to live alongside the boats. The population does not exhibit many abnormal or erratic behaviors on a scale indicating significant scale disturbances. As the number of boats has increased, the number of encounters has not significantly increased with it. This could suggest that these dolphins have formed habits regarding boats and the number of boats has not increased enough to elicit a change in these habits. Conditions must remain stable for animal habits to remain the same (Costello, 2009). In changing environments such as New Quay with increased boat traffic and fishing, every generation of dolphins would be different from the one that came before. The ecosystem has changed, but the population has remained the same in attitude towards boats and overall numbers, indicating that these habits and behaviors are taught. Studies show that habituation can be unlearned if the habituated animal is not in regular contact with the stimuli to which they are habituated to respond (Raderschall et al., 2011). This is not a concern for the bottlenose dolphin population in New Quay, as boat tours run every day in the summer and almost every day in the offseason. Fishing and pleasure vessels are seen almost every day during the survey season so the dolphin population is constantly in contact with vessels.

Bottlenose dolphins have personalities that lend themselves to unique reactions to stimuli (Highfill, 2007). Dolphins have individual tolerances to vessel interactions and other anthropomorphic stimuli. Sometimes, this reaction is dictated by an elder or other influences on pod dynamics (Highfill, 2007). Decision-making is a complex process based on a myriad of factors (Milkman et al., 2009). One of these factors is tolerance to previous outcomes of similar experiences. Tolerance in decision-making is different than stable biological tolerance and can be learned over time but not taught in the same way habituated behaviors are. Due to the differences between habituation and tolerance, the bottlenose dolphin population of New Quay shows signs of habituation and tolerance to vessel traffic. Habitation informs each dolphin's tolerance to vessel interactions.

One way habituation can affect a dolphin's tolerance to vessel interactions is the difference between reaction type and vessel name. Many of the named boats recorded by the Sea Watch Foundation are dolphin-watching boats, including the Cerismar. This boat has been running in New Quay for nearly a decade and has the highest rate of positive dolphin reactions during encounters and the lowest rate of adverse reactions. As previously discussed, commercial dolphin-watching vessels are more incentivized to abide by the code. AB2-AB2, on the other hand is a fishing vessel and, has the highest rate of negative reactions during encounters. This boat does not breach the code significantly more than any other boat in New Quay, yet dolphins perceive it as a more significant threat than other vessels. AB2-AB2 has the largest and loudest engine of the boats in Graph 5. AB2-AB2 has been running in New Quay since at least 2010. From then until 2023, around half a generation of dolphins has been born in Cardigan Bay. The fact that the rate of negative reactions to this boat has also been unchanging since 2010 indicates that calves may have learned to avoid this vessel over other vessels. Different tolerances amongst dolphins could be why this vessel has a range of reactions.

The bottlenose dolphin population of Cardigan Bay, Wales, has fluctuated over the past 23 years. The number of encounters has remained stable with no statistically significant changes since 2010, and the number of sightings has not significantly changed since 2000. A reinterpretation of the code which led to stricter penalties and enforcement in 2004, has had little effect on the bottlenose dolphin population. One potential reason for this is dolphin habituation to vessels in Cardigan Bay, which could also explain the lack of significant change in dolphin reactions to vessels. A statistically significant change in boats switching from behavior Y2 to behavior Y1 shows that public awareness and concern around bottlenose dolphins has increased since 2004. This may be the only positive outcome of the code, as there was no statistically significant change in negative reactions to vessels before and after 2004. Positive and neutral responses to vessels have also not significantly changed since 2004. These results show population adapted to recent increases in boating traffic. Even though most boaters comply with the code, the code does not fully protect the marine mammals in Cardigan Bay.

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