Habitat use and interaction of *Tursiops truncatus* with boat traffic in New Quay Bay, West Wales.

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science (MSc) in Marine Environmental Protection

Habitat use and interaction of *Tursiops truncatus* with boat traffic

in New Quay Bay, West Wales.

Bangor University

By Chelsea Drew Perrins

BSc Marine Biology (2019, University of Portsmouth)

School of Ocean Sciences

Bangor University

Gwynedd, LL57 2DG, UK

www.bangor.ac.uk

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Chelsea D Perrins[1]

[1]School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, UK.

Chp21bps@bangor.ac.uk

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Abstract

The assignment of Special Areas of Conservation (SAC) to Cardigan Bay was made with the intention of protecting and conserving the species and habitats that reside here. Megafauna like the bottlenose dolphin *Tursiops truncatus* have been located within the SAC area, and have been studied at New Quay by the Sea Watch Foundation (SWF) since 2001. This species is integral for understanding and managing the anthropogenic impacts from vessel traffic on the three marine mammal conservation species (*Tursiops truncatus, Phocoena phocoena,* and *Halichoerus grypus*). Working in collaboration with SWF, this study aimed to expand on vessel use and behaviour within New Quay Bay, as well as continuing with the temporal study of the semi-resident population of bottlenose dolphins. With a comparison of this study's data to the historical data extracted from the SWF database, it was confirmed that the semi-resident population of *Tursiops truncatus* is still responding to interactions with both positive (towards or neutral) and negative (away) responses. These responses vary with vessel conformity to the marine code of conduct (X^2=48.4, p=0.005). The bottlenose dolphin population is not deterred from a location by vessel traffic as there was no significant difference in dolphin sightings between sites (p=0.871). However, there was a significant difference for calf sightings (p=0.003), with highest frequency of sightings occurring at the harbour (0.16±0.431 calves observed).

Keywords: behaviour, boat disturbance, bottlenose dolphin, Cardigan Bay, habitat use, land-based observation, *Tursiops truncatus*, vessel traffic.

1 Introduction

The bottlenose dolphin (*Tursiops truncatus*) population within New Quay Bay has been observed using a variety of habitats, such as the reef to the east for feeding and foraging as well as the harbour area for shelter and rest. However, ecotourism and coastal resources have led to the exploitation of this zone by humans in the form of vessel traffic. This disturbance can interrupt and even inhibit *Tursiops truncatus'* behaviour and natural exploitation of the area (Simmonds at al. 2013).

Tursiops truncatus form fission-fusion societies; this fluid group cohesion and frequent exploitation of the coastal zone allows them to form a group composition linked to available resources and group/individual requirements (Reay 2009). This fluid dynamic also means some individuals will travel from coastal zone to open ocean with no fixed home location, and others will remain in one area their entire lives, migrating a short distance along the coastline following prey (Weir & Stockin, 2001). In the case of New Quay, this has led to a semi-resident population, where some individuals migrate here, some are visitors, and some are permanent residents. Their sociability and higher sighting rate (Parker, 2017) makes them preferable of the three marine mammal species present here for assessing the presence and habitat usage within the Cardigan Bay SAC (Special Area of Conservation est. 2001). Of the three marine mammal HD annex II species, bottlenose dolphin (*T. truncatus*) harbour porpoise (*Phocoena phocoena*) and Atlantic grey seal *Halichoerus grypus*), the observable presence from land through surface-based activities and behaviour, such as aerial displays and bow riding, makes *Tursiops truncatus* a suitable species for observing and analysing the anthropogenic tolerance of these marine mammals. The main anthropogenic impact which has been developing through ecotourism over the past few decades is the increase in boat traffic.

The semi-resident population of *Tursiops truncatus* in New Quay Bay has been present here since the 1920's (Vergara-Peña, 2014) with their frequency and habitat use being recorded by Sea Watch Foundation (SWF) and Cardigan Bay Marine Wildlife Centre (CBMWC). The bay is continuously being studied to ascertain whether the management plan is still effective for the conservation species and habitats, and if the marine code of conduct is being adhered to by vessel traffic. Historically this population has coexisted alongside small fishing fleets and ecotourism boat tours. However, the past few decades have noted an increase in ecotourism at New Quay Bay (Pierpoint et al., 2009). Now no longer restricted to just wildlife boat tours, the site exploitation has expanded to include recreational vessels. The recreational use of New Quay alongside commercial use has led to an increase in motor boats, sailing boats, speed boats and other recreational vessels, all with various types of power and size. There is also a variation in the compliance of these various vessels to the marine code of conduct towards marine mammals. So even though the management plan and marine code of conduct were implemented specifically to conserve and protect marine mammals including *Tursiops truncatus*, the pressure of vessel traffic could result in site fidelity changing. There are also health implications caused from disturbance as dolphins, and other marine mammals, can receive injuries from collisions with vessel and fishing gear. Stress and anxiety can also result from separation from social groups and interruption to behaviour routines such as resting and feeding (Lamb & Ugarte 2009; Richardson, 2012).

Past SWF publications have shown a limited view into vessel behaviours, especially outside of dolphin-vessel interactions. Preferring instead to focus on the bottlenose dolphin exploitation of New Quay Bay and the responses to direct anthropogenic interactions. This has provoked a further investigation into bottlenose dolphin presence-absence and their responses in the bay with active vessel types (vessels actively using the bay during the observation period), as well as the vessel's level of conformity to the marine code of conduct regardless of whether dolphins are sighted as present or not.

It was the main aim of this study to work in collaboration with SWF and to perform land-based observations, conducted in June and July 2022, to assess *T. truncatus* semi-resident populations habitat usage, behaviour and reaction to boat activity in New Quay Bay. And to compare those data with the SWF historical data of previous years of recordings (2010-2021) to assess on a temporal scale whether the dolphin's usage, behaviour and reaction to vessels is being tolerated or not.

H1. *Tursiops truncatus* presence at New Quay Bay is influenced by environmental factors.

H2. The environmental factors (sea state, tide and weather) have an effect on dolphin presence at locations within New Quay Bay.

H3. *Tursiops truncatus* behaviour towards boats is influenced by vessel characteristics.

H4. *Tursiops truncatus* behaviour will change with presence of boats.

H5. The environmental factors affect behaviour of *Tursiops truncatus* in the presence of boat activity.

H6. Vessel characteristics (type, distance, behaviour, name) will have an effect on dolphin response.

2 Materials and Methods

2.1 Study Area

New Quay in West Wales is a frequently visited tourist hot spot during the summer months, as well as a coastal and fishery resource for residents. Due to the high vessel concentration and the abundance of conservation priority species, the Ceredigion County Council (2022) implemented the 'Ceredigion Water Users Marine Code of Conduct'. The aim is to still allow vessel traffic in for sustainable exploitation of the area, but also having guidelines to reduce the impact and risk on the animals within the bay. However, in recent years there has been an increase in boats which is causing a greater disturbance on the species and habitats within the area. One such increase has been the recent introduction of another visitor passenger boat (VPB) for the purpose of sea wildlife tours. The Dreamcatcher is a 12-passenger twin hull vessel, implemented into service for Dolphin Spotting Boat Trips in 2021.

2.2 Effort

Observations were conducted from the harbour wall towards the seaward end to allow for an unobstructed view of the entire study site, from the headland in the north-west, the reef to the west, and the southern portion of the harbour docks. These observations were conducted over two hours within the time frame of 7 am to 9 pm, allowing for daylight hours, during the months of June and July. It was required to have at least two observers so observations over the New Quay area could continue from one while the other was recording the data into the specific data forms. When only one observer was present a dictaphone was used to take data-heavy recordings while still continuing the observations, with basic information recorded onto the map forms for later detailed data addition. There were two data sets recorded for each observation, the general Sea Watch Foundation (SWF) forms and the Vessel Traffic forms. Along with both data collection forms, a compass, binoculars and camera were used for each observation. The compass was used for ascertaining the direction of travel of both dolphins and vessels, as well as wind direction. Binoculars were required for each observer to assist with sightings of *T. truncatus* and the group composition (group numbers and presence of calves). The binoculars were also useful with identifying individual vessels by their name or other identifier (vessel colour or association to a specific organisation). The digital camera (Nikon D2500) was fitted with a telephoto lens (55-200 mm focal range) and used to record vessel types, *T. truncatus* site usage and behaviour, and any *T. truncatus* dorsal fins with side profiles to identify individuals from the SWF database. However, comparison of the photographs taken with the images from the database are reliant on good visibility conditions and unobstructed focused side profile views of the dolphins.

At the start of every observation, the following environmental factors were recorded: sea state, weather, wind direction, tidal state and visibility. Sea state was measured using the Beaufort Scale 0-6. Tidal state was found using the time and date of the recording and sorted into one of four categories, either high, low, rising or falling. Visibility was assessed on a scale according to SWF guidelines with visibility ranging from greater than 10 kilometres down to less than 1 kilometre (scale in Table 1) The weather data were placed into one of the following: sunny, clear, overcast, cloudy, foggy, light showers and raining. For health and safety reasons and visibility limitations, observations were stopped during adverse conditions such as sea state above 5, weather worse than just rain, strong wind force, or visibility less than 2 km. If observations continued, then these conditions would have severely affected the recording probability of observable presence of *T. truncatus*. Due to the risk of exposure at the harbour wall observation point, weather conditions of intense sun or rainfall were checked for in advance of observations. However, if conditions were assessed to be beyond safe levels, then observations were cancelled or discontinued until the weather conditions improved.

2.2.1 Sea Watch Foundation methodology of land-based recordings

Following established Sea Watch Foundation (SWF) land-based survey guidelines (Koroza, 2018), observations were conducted for two hours at a time, with multiple observations conducted in a day dependent on conditions. The recordings were divided into eight 15-minute intervals with environmental data, *T. truncatus* data, and boat-dolphin interactions being recorded into the set SWF forms and maps. For a single observation, there was one set of SWF forms in a table format (SWF forms in Table 5-7) and eight maps, one to be used for each interval of that observation. On the SWF forms, the *T. truncatus* and boat-dolphin interactions were recorded. The recording of *T. truncatus* presence and location was conducted every 15 minutes over a two-hour observation period. Individual and group composition as well as behaviour and direction of travel will also be recorded. Boat-dolphin interactions occurring within 300 metres of each other involved the recording of number of vessels, vessel compliance/behaviour, location, dolphin behaviour, composition, and dolphin response to vessels. In order to obtain an improved overview of the vessel impact on *T. truncatus*, all interactions between boats and dolphins were recorded instead of just the first interaction of that 15-minute interval. This was decided on during a pilot observation when different groups/individuals of dolphins were involved in interactions as well as multiple interactions from different boats or behaviours (adherence to the code of conduct, Table 2) occurred within a 15-minute interval. Also, to include vessel data from the Vessel Traffic forms, the maps were altered so that across each of the eight maps for a single observation period, the vessel type and behaviour could be recorded alongside *T. truncatus* numbers and interactions for the entire survey site (altered maps Figure 4).

2.2.2 Methodology for Vessel Traffic data forms

With the Vessel Traffic data forms, the vessel type, location, direction of travel and behaviour were recorded continuously over the two-hour observation period. Alongside the vessel type (Table 3), any other identifying features such as colour, boat name and association were recorded. In terms of behaviour, the vessel's adherence to the marine code of conduct towards marine mammals was used. The behaviour is divided into two categories, adhering to the code (Y) and not adhering to the code (N). This is the same system used by SWF with the inclusion of a third value in the adherence category (Y0 – vessel is stationary or drifting with currents, not under powered movement). Additional recordings included any changes to the environmental factors stated in the primary SWF methodology.

2.3 Statistical Analysis

The land-based data collected June-July 2022 and the historical land-based data from June and July 2010-2021 extracted from the Sea Watch Foundation database were analysed using data analysing software IBM SPSS Statistics 27. A significance level of $p<0.05$ was used. Both parametric (General Linear Models and ANOVA) and non-parametric (Chi-squared and Kruskal-Wallis) tests were applied to assess presence, behaviour, and vessel relationships within and between groups. Before any analyses could take place, both SWF and Vessel Traffic data sets required formatting. The visibility scale was recategorized into a scale of 1-5 in descending order of visibility (1-5: >10 km, 6-10 km, 2-6 km, 1-2 km, <1 km). With the Vessel Traffic data forms, some sightings had recorded multiple vessel behaviours (e.g. N1 and N2). In order to make analyses easier for these values, the vessel activity was formatted into a scale of 0 to 15. The dolphin behaviours were sorted into five categories: resting, feeding, diving, socialising and travel. These were then placed on a numerical scale 1-5 and with 0 as unknown. This scale was then continued to 30 allowing for different combinations of the five categorised behaviour groups e.g. behaviour from categories observed in groups 3 and 5 was given the code 22 and was described as travelling and diving. This formatting style was also applied to the historical data set to allow for comparison with the current (June-July 2022) data sets.

3 Results

General observations of the survey site during the pilot land-watch and the study's land-watch identified other forms of ecotourism at New Quay besides vessel traffic. Recreational anglers frequently used the harbour wall and headland rocks for casting from. The beach between the headland and the pier is also a dog beach used by both residents and tourists. The frequency of both people and dogs occasionally led to overcrowding of the tiny beach, as well as generating noise. Various people also enjoyed the recreational sports of swimming, diving, snorkelling and spear fishing along the shore line from the headland to the sea end of the harbour wall. Large bird gatherings were also occasionally noted to frequent the headland. This gathering of >50 seabirds, often seen floating around or aerial diving at the headland, were actually taking advantage of the whelk fishery output pipe for easy catch food. There was also the less frequent appearance of grey seals, one of which was sighted resting and diving along the harbour wall on 28th June during an evening observation (sighted 20:00 – 21:27, end of observation).

Due to bad weather conditions and severely reduced visibility (1-2 kilometres), the land watch on the 26th June had to be discontinued 15 minutes early. Also, there was concern over the excessive noise pollution being created on occasion by the blue and red VPB's. In other studies, it has been noted that this could be caused by bad maintenance of the engine or propellors.

Identification of *Tursiops truncatus* individuals from the photographs taken during June and July 2022 was unsuccessful. This was in part due to the camera's limited zoom function as the distance from the dolphins and the harbour wall observation point was too great for most photos. There was also difficulty with focusing on side profiles especially during sunny or raining conditions as side profile photos were either out of focus, cast in shadow or obscured by waves and surfacing splash. However, the photo identification was useful for identifying specific vessels by boat name as well as recording active adherence and non-adherence of vessels to the marine code of conduct.

3.1 Habitat use

General linear models and one-way ANOVAs were used to determine whether dolphins and their calves had a location of high frequency of sightings. Using the general linear models (Univariate), the number of calves observed, total dolphin numbers observed and frequency of sightings at locations within the study site were found to be statistically significant (frequency of sightings at locations $p=0.004$, total dolphin numbers sighted $p<0.001$, and location sightings with dolphin sightings $p<0.001$). Using one-way ANOVA to assess the significant difference between total dolphin sightings across the six designated locations of the study site, it was determined that there was no statistically significant difference between locations and total number of dolphins sighted ($F(5, 985)=0.368$, $p=0.871$). The Tukey post hoc test revealed that no location was statistically significant ($p>0.05$). Looking at the preliminary results (Figure 2), the total dolphin sightings were highest at the Reef ($n=309$, 2.12 ± 1.18). The maximum number of dolphins observed in one sighting was six *T. truncatus* at the Reef; however, at the Harbour and Harbour Wall, there was a maximum of nine *T. truncatus* sighted (H: $n=158$, 2.05 ± 1.63; HW: $n=91$, 1.98 ± 1.79).

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(4, 392)=4.071$, $p=0.003$) for calf sightings. A Tukey post hoc test revealed that the number of calves observed was statistically significantly lower for the Headland (0 ± 0.000 calves observed, $p=0.012$) and Reef (0.02 ± 0.0142 calves observed, $p=0.002$) locations compared to the Harbour (0.16 ± 0.431 calves observed). There was no statistically significant difference in the number of calves observed between the other locations ($p>0.05$). Looking at the total calf sightings for each location (Figure 3), the Harbour had the highest number of calves sighted ($n=12$, 0.16 ± 0.431 calves observed) whereas the Headland and Reef had the lowest. The harbour hosted a maximum of two calves during observations, the highest frequency of dolphin calves observed in June and July 2022. There were no adult or calf *T. truncatus* sightings at the Beach area, located between the Headland and the Harbour Wall.

Using general linear models, *T. truncatus* behaviour was analysed for statistical significance of location and direction of travel. The factors' location, direction of travel, and the two factors combined were found to be not statistically significant ($p=0.280$; $p=0.345$; $p=0.332$). A Chi square test for association was performed on location and dolphin direction of travel to determine if there was a similarity between these factors. *T. truncatus* have a statistically significant association between the location within the bay and their direction of travel ($X^2=1624$, $p<0.001$). Phi and Cramer's V both have a statistical significance ($p<0.001$; $p<0.001$), suggesting a strong association between location and direction of travel for *T. truncatus*. A one-way ANOVA was also performed on the behaviour recorded and the location at which dolphins were sighted. There was a statistically significant difference between groups ($F(5, 985)=2.613$, $p=0.023$); however, the Tukey post hoc test revealed that there was no statistical significance between *T. truncatus* behaviour and location.

With a Chi square test, the location of *T. truncatus* sightings was compared to the environmental factors: sea state, tidal state, visibility, weather condition, and wind direction. All Pearson Chi squared significance values for these five environmental factors were found to be statistically significant: X^2(sea state) = 202, p<0.001, X^2(tidal state) = 1323, p<0.001, X^2(visibility) = 1186, p<0.001, X^2(weather condition) = 1330, and p<0.001, X^2 (wind direction) = 202, p<0.001. The Phi and Cramer's V values showed a significantly strong association between the environmental factors and *T. truncatus* sighted locations within the study site.

Bottlenose dolphin sightings were analysed for any statistically significant relationship with the recorded environmental factors. Using a combination of general linear models and one-way ANOVAs, it was determined that sea state had no statistically significant difference between each level of the Beaufort scale (F(4, 986)=1.487, p=0.204). However, the weather was determined to be statistically significantly different (F(6, 984)=56.9, p<0.001) between groups using one-way ANOVA. The Tukey post hoc test indicated bottlenose dolphin sightings were statistically significantly lower for overcast (n=174, 1.87±1.14 dolphins, p<0.001), showers (n=70, 1.89±0.97, p<0.001), and raining (n=14, 1.89±0.94, p<0.001) weather conditions compared to clear weather (n=10, 3.50±1.51). Also, there was a statistically significantly lower sighting of bottlenose dolphins for cloudy conditions (n=87, 2.48±1.85, p<0.001) compared to overcast weather. With general linear models' sea state with weather (p=0.025), and sea state with tide (p=0.010) were found to be statistically significant for *Tursiops truncatus* behaviour observed at the site. The one-way ANOVA tests of the environmental variables against *T. truncatus* behaviour showed a statistical significance for weather (F(6, 984)=2.12, p=0.135), visibility (F(3, 987)=3.68) and tide (F(4, 986)=3.31, p=0.010). The Tukey post hoc tests, however, did not reveal any significant difference between groups.

3.2 Dolphin presence

A Kruskal-Wallis H test was used to analyse boat type with sightings of dolphins and calves. There was no statistically significant difference between *T. truncatus* sightings and boat type (H=7.879, p=0.343). There was a statistically significant difference between calf sightings and boat type (H=14.099, p=0.049). With a mean rank calf sighting of 103.50 for small motor boats and medium motor boats, 135.36 for speed boats, 122.57 for sail powered vessels, 154.90 for fishing boats, 127.13 for visitor passenger boats, 158.25 for paddle powered vessels, and 232.00 for cetacean research vessels. Using a pairwise comparison, it was identified that sail powered vessels (p=0.048) and visitor passenger boats (p=0.009) were statistically significantly different to paddle powered vessels.

3.3 Vessel traffic

With a Chi square test, it was determined that there was a statistically significant association between vessel type and location within the study site during the June and July observations of 2022. (X^2=245, p<0.001). The statistically significant values for Phi and Cramer's V (p<0.001; p<0.001) suggests the relationship between vessel type and location is a very strong association. The environmental factors were analysed against vessel location using Chi square to test for any association (Figure 4). Of the five environmental variables, weather condition (X^2=17.0, p=0.073) was the only one that was not statistically significant. The Phi and Cramer's V significance values also suggest a weak link between weather and vessel location (p=0.073; p=0.073). Chi square was also used to analyse the environmental variables against vessel type. All five environmental recording factors were statistically significantly associated strongly with vessel type: X^2(Wind direction)=195, p<0.001, Phi p<0.001, Cramer's V p<0.001; X^2(Sea state)=121, p<0.001, Phi p<0.001, Cramer's V p<0.001; X^2(Tidal state)=217, p<0.001, Phi p<0.001, Cramer's V p<0.001; X^2(Weather condition)=237, p<0.001, Phi p<0.001, Cramer's V p<0.001; and X^2(Visibility)=108, p<0.001, Phi p<0.001, Cramer's V p<0.001.

Chi square analysis determined that vessel name and vessel location are statistically significant and strongly associated, X^2=285, p<0.001 (Phi p<0.001, Cramer's V p<0.001). The Chi square test also confirmed that the vessel name and environmental variables are statistically significant (Environment X^2 p<0.001), and are strongly associated (Phi p<0.001, Cramer's V p<0.001).

Vessel type and their compliance to the marine code was analysed using one-way ANOVA. It was determined that vessel's compliance to the marine code is dependent on the type of vessel as the Anova results showed a high statistically significant difference of boat behaviour between types ($F(8, 1197)=7.019$, p<0.001). Referring to the Tukey post hoc test, mMB (n=85, 3.21±2.56, p=0.017) was statistically different in behaviour compared to YA (n=66, 1.89±0.50). Vessel behaviour was also statistically significantly lower for YA (p<0.001), FI (n=63, 2.54±1.69, p=0.005), and RB (n=233, 2.65±2.01, p<0.001) vessel types compared to SB (n=141, 3.87±3.59). Also, VPB (n=553, 3.23±2.21, p<0.001) and LS (n=7, 5.43±3.65, p=0.004) compliance to the code of conduct were both statistically significantly lower than YA. There was also a significant statistical difference in behaviour between FI (n=63, 2.54±1.69, p=0.048) and LS, VPB (p=0.038) and RB, and RB (p=0.049) and LS.

3.4 Boat-dolphin interactions

The response of bottlenose dolphins to various vessel characteristics such as vessel type, named vessel, and behaviour of vessel are all vital for understanding the impact of vessel traffic and the dolphin's tolerance towards vessel disturbance. Using the Chi square test of association, dolphin responses (positive and negative) were analysed with vessel type (Table 8). The responses (X^2(Response)=15.9, p=0.318, Phi p=0.318, Cramer's V p=0.318) were found to be in a very weak and not statistically significant associative relationship with vessel type. Statistically, there is not a specific response from *T. truncatus* during an interaction with a specific vessel type.

Tursiops truncatus response to specific vessels, which have been identified by unique features or the vessel's name, were analysed using Chi square. Responses were not statistically significantly associated with individual vessels (X^2= 16.7, p = 0.405). Looking at the graph (Figure 5) of responses to each of these identified vessels, the majority were recorded as unknown, and of the recorded responses, the majority were responding to Dreamcatcher and Dunbar Castle 2 negatively (attempting to avoid the vessel), and both positive and negative reactions were recorded for Ermol 6. All three of these vessels are visitor passenger boats responsible for encouraging ecotourism at New Quay by providing wildlife tours.

Vessel compliance and bottlenose dolphin responses (Figure 6) were statistically significantly associated for dolphin-boat interactions recorded in June and July 2022 (X^2 = 48.4, p = 0.005, Phi p = 0.005, Cramer's V p = 0.005). Even though a majority of the responses were recorded as unknown, those that were recorded as positive or negative responses occurred in response to vessels displaying behaviour Y1 and Y2. Chi squared analysis of interaction and the five environmental factors was performed to determine if there was any association. All five environmental factors had a Pearson Chi square significance value of p<0.001: X^2(Weather) =

99.7, p<0.001, X^2(Wind) = 32.9, p<0.001, X^2(Sea state) = 24.2, p<0.001, X^2(Tide) = 68.1, p<0.001, and X^2(Visibility) = 56.6, p<0.001.

3.5 Temporal study

Historical data were extracted from the Sea Watch Foundation database, specifically the land-based observations conducted from the harbour wall during the summer months of June and July. These data, dating back from present day to the 11th of June 2010, were formatted with the same codes used for the 2022 observation data sets. They were then analysed using SPSS.

To assess vessel type and their compliance with the marine code of conduct, the data were analysed using a one-way ANOVA test. The vessel types in terms of compliance to the marina code were found to be statistically significantly different (F(5, 3714)=19.92, p<0.001). The Tukey post hoc test showed that, just like the 2022 data collection, SB (n=864, 2.97±1.41) and YA (n=292, 2.50±1.17) are statistically significant (p<0.001), as well as SB and FI (n=263, 2.39±0.71, p<0.001), YA and VPB (n=1967, 2.39±0.71, p<0.001), and VPB and RB (n=332, 3.15±1.55, p=0.004). There were other statistically significant differences between vessel types from the historical data. And the compliance of RB (p<0.001) and JS (n=2, 5±0.00, p = 0.040) were statistically significantly lower than YA. Compliance in the vessel types VPB (p<0.001), RB (p<0.001) and JS (p = 0.027) was statistically significantly lower than for FI. The graph of the historical sightings of vessel type and compliance (Figure 7) shows a high recording of VPBs which is to be expected due to their purpose of providing marine wildlife tours. There is also a lot of different vessel types showing compliance (Y1 and Y2 behaviour) in the historical data. The variation in behaviour of vessels between vessel types for this historical data shows that for the past decade there has not been a complete strict adherence to the marine code of conduct. And the fact that there is still variation in the 2022 data shows there is still no strict adherence to the code. The statistical analysis supports this as with the 2022 data set, the one-way ANOVA concluded a statistical significance in the different vessel types (p<0.001).

Since the response of *Tursiops truncatus* was not included with the extracted historical data set, the vessel compliance was analysed with dolphin behaviour using the Chi square test for association (similarity). The dolphin behaviour was found to be statistically significantly associated to the bottlenose dolphin activity (X^2 = 387, p = 0.010). And the Phi and Cramer's values (p=0.010; p=0.010) suggest a very strong association between vessel compliance and dolphin behaviour. In Figure 8, the vessel behaviour Y2 and the combined behaviour Y2+N1+N2 frequently occurred with the dolphin behaviours, feeding, travelling, feeding/socialising, and feeding/travelling.

As well as compliance, the vessel type was also analysed with the dolphin behaviour to get a general overview of any significance between vessel types for *Tursiops truncatus*. With Chi square analysis it was determined that vessel type was statistically significant (X^2 = 220, p<0.001) for the historical data set. To further understand the historical impacts of vessel traffic on dolphins, the range of vessels from the dolphins during interactions was analysed using Chi. In terms of dolphin activity, the vessel range was found to be statistically significant (X^2 = 113, p = 0.011) with a strong association between the two variables (Phi and Cramer's V, p = 0.011). Looking at the Figures 9 and 10, it appears that feeding behaviour was one of the more likely behaviours to be sighted in the past decade. That includes during shorter range interactions between vessels and dolphins.

1 Discussion

Environmental factors had a significant impact on dolphin sighting location, frequency of dolphin sightings and dolphin behaviour. This applied in particular to weather condition, visibility and tide. As Fernandez-Betelu (2019) suggested, these factors can create patterns for natural behaviour. It would be interesting through future SWF studies to determine if environmental factors are an important driver and have any impact on the interactions with vessels.

Both the SWF historical data and 2022 data sets suggest that a) dolphin activity around vessels changes with vessel type, and that b) dolphin response to an interaction event varies with both vessel type and the vessel's compliance. With a comparison of this study's data to the historical data extracted from the SWF database, it was confirmed that the semi-resident population of *Tursiops truncatus* are still responding to interactions, showing both positive (towards or neutral) and negative (away) responses. These responses vary with vessel conformity to the marine code of conduct (X^2=48.4, p=0.005). When the statistical analysis is considered with the preliminary data presented in the figures, it could be questioned as to which vessels are responsible for the variation in compliance.

Before an interaction occurred, feeding behaviour was the most common category of behaviour exhibited, particularly for the closer interactions. This could be an important factor for the Ceredigion County Council to consider as the dolphins are often seen feeding at the reef location. If whilst feeding, the dolphins are less aware of their surroundings and are unable to realise that vessels are heading towards where they are surfacing, grievous injuries could occur. Louro (2007) suggested analysing the movement of prey species to be able to better assess the true areas of feeding for *Tursiops truncatus.* As was briefly seen on a few occasions during observations, mackerel and other prey fish were seen entering the bay from the headland and heading towards the reef via the harbour wall. It is recommended that SWF work with local fisherman to understand the movement of the prey species. From such studies, perhaps a feeding corridor could be created for the dolphins where during certain times of the day, no vessels can enter under power.

The bottlenose dolphin population is not restricted from any particular location by the vessel traffic as there was no significant difference in dolphin sightings between sites (p = 0.871). However, there was a significant difference for calf sightings (p = 0.003), with highest frequency of sightings occurring at the Harbour (0.16±0.431 calves observed).

Data Availability Statement

The datasets generated at the time of June-July 2022 for this study are available on request to the author [Chelsea D Perrins, chp21bps@bangor.ac.uk]. Data collected by Sea Watch Foundation (historical datasets used in analysis) are available upon request with permission from Sea Watch Foundation.

Ethics Statement

During this study, no experiments or direct interaction with the target species were conducted, so no ethical permissions were required.

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Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Tables

Table 1 Visibility scale implemented according to Sea Watch Foundation guidelines for land-based observations.

Visibility (km)
> 10
6 – 10
2 – 6
1 – 2
< 1

Table 2 Codes of vessel behaviour in terms of adherence level to the marine code of conduct towards marine mammals. Modified from the Sea Watch Foundation codes with the addition of a third form of adherence to the code when vessel is stationary/non-powered movement (Y0).

Vessel behaviour towards code of conduct:	Description:
Y0	Vessel is stationary or drifting along with current, not under any powered movement.
Y1	No wake speed, no erratic course changes, steady powered movement.

Y2	Slowed down and gradually stopped, no erratic course changes.
N1	Too fast, bow/wake from speeding, white water visible.
N2	Erratic course changes, attempts to approach/avoid/follow dolphins.
N3	Attempted to touch/feed/swim with the dolphins.
N4	Exceeded 8 knots inside of yellow buoys.

Table 3 Codes of vessel type to be used for interaction recordings in the Sea Watch Foundations forms and for recording vessel movement in the Vessel Traffic data forms and associated maps.

Vessel type	Description
sMB	Recreational motor boat <15 m
mMB	Recreational motor boat 15-30 m
SB	Racing boat or RIB
YA	Any vessel under sail
FI	Fishing boat
VPB	Visitor Passenger Boat
RB	Row, kayak, paddle craft
JS	Jet ski
R	Cetacean research vessel
FE	Ferry
LS	Ship >30 m

Table 4 Behaviour of Tursiops truncatus *and associated codes to be used for the Sea Watch Foundation forms.*

Behaviour	Code	Definition
Feeding	FF	Rapid energetic surfacing and dives in various direction. Prey often observed at surface.

Suspected feeding	SF	Rapid energetic surfacing and dives in various direction. Visible dolphin effort to catch prey. Prey not observed at surface.
Fast swimming	FS	Fast swimming in one direction, often leap out of water to increase speed.
Normal swimming	NS	Continuous swimming path with short frequent dives.
Aerial behaviour	AB	Acrobatic movements, jumping out of water.
Percussive behaviour	PB	Hitting water and landing on it with any part of body.
Resting	R	Slow movement, synchronous and steady. Quick dives may be observed.
Socialising	S	Interactive activities such as rubbing, chasing, genital inspections and play with other dolphins.
Travelling	T	Persistent and directional movement.
Group splits	GS	Group splits or separates in distance >100 m.
Group form close	GC	Individuals join together to form a close group.
Bow riding	B	Riding on waves generated by boats, vessels and ships.
Surfacing	SURF	Often surfacing and short dives.
Diving	Div	Diving for long periods of time with changes in direction. Diving might be correlated with foraging.
Unknown	U	Unrecognisable behaviour.

Table 5 Land-based form from Sea Watch Foundation for a single observation of two hours. Each map reference (A-H) indicates one of the eight 15-minute intervals for recording data. For each interval, the start and end time is recorded under Effort time. The environmental variables are also recorded using the SWF scale for sea state and visibility. T. truncatus *sightings include the number of dolphins and the behaviours they exhibit in that interval. Their location is recorded onto the associated map using the appropriate symbol. The boat encounter number refers to the encounter between dolphin and boat which is recorded in Table 1(C) along with the time at start of encounter. Notes are used for other observations such as other marine mammals sighted (grey seal and harbour porpoise) or changes in the weather conditions.*

Map	Effort time (GMT/BST)	Sea State	Wind Direction	Visibility	Sighting	Boat enc. No.	Notes

	Start	End						
A								
B								
C								
D								
E								
F								
G								
H								

Table 6 Land-based form from Sea Watch Foundation for a single observation. A tally of vessel type is recorded for the entire observation period.

Boat Type		Log	Total
sMB	Recreational motor boat <15 m		
mMB	Recreational motor boat 15-30 m		
SB	Racing boat or RIB		
YA	Any vessel under sail		
FI	Fishing boat		
VPB	Visitor Passenger Boat		
RB	Row, kayak, paddle craft		
JS	Jet ski		
R	Cetacean research vessel		
FE	Ferry		
LS	Ship >30 m		

Table 7 Land-based form from Sea Watch Foundation for a single observation. Boat-dolphin interactions are recorded with time of start of interaction included with number of the interaction. All boat types within a 300-metre radius of the dolphin are recorded along with any identifiers recorded under boat name. Distance to animals is sorted into four groups: A less than 50 m, B 50 to 100 m, C 100 to 200 m, and D 200 to 300 m from dolphin. Cetacean behaviour was recorded using the code from SWF. Response to boat was marked Away, Towards, Neutral or Unknown. Notes was used to record the dolphin group composition, and additional notes on boats from the interaction e.g. red VPB actively chased dolphin group beyond headland. The location of each interaction was recorded into the corresponding map.

Boat enc. No.	Boat Type	Boat Name	No. boats 300 m	Distance to animals	Boat behaviour	Cetacean behaviour	Response to boat	Notes
							A/T/N/U	
							A/T/N/U	
							A/T/N/U	
							A/T/N/U	
							A/T/N/U	

Table 8 Known recorded responses of Tursiops truncatus *to different vessel types during interactions within 300 metres of the dolphin individual or group.*

Response	Total vessels	sMB	mMB	SB	YA	FI	VPB	RB	R
Negative	35	0	1	5	3	1	21	3	1
Positive	24	0	0	4	2	0	18	0	0

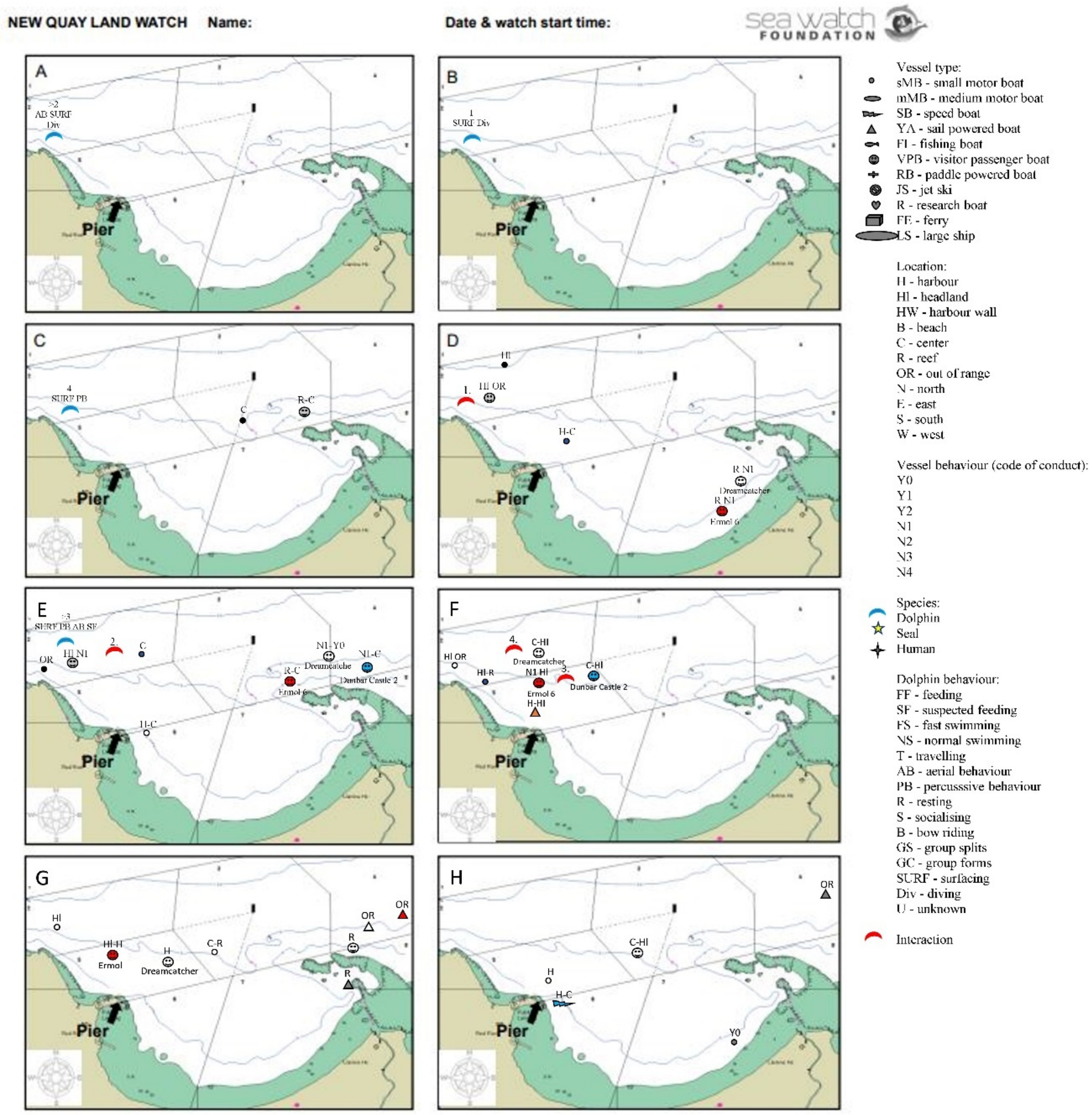

Figure 1 Sample maps from Sea Watch Foundation for a single two-hour observation, each map for a 15-minute interval. The modified key on the right allows for recording of T. truncatus *sightings along with interactions and vessel traffic. The letters above the vessel symbols on the maps indicate their location and direction of travel for that interval. When possible, vessel symbols are reflective of the boat colour, and boat name printed below the vessel symbol. Each interaction (red crescent) has a number indicating the order of the interactions. Above each dolphin symbol (blue crescent) is the composition of that group and the behaviours they exhibited.*

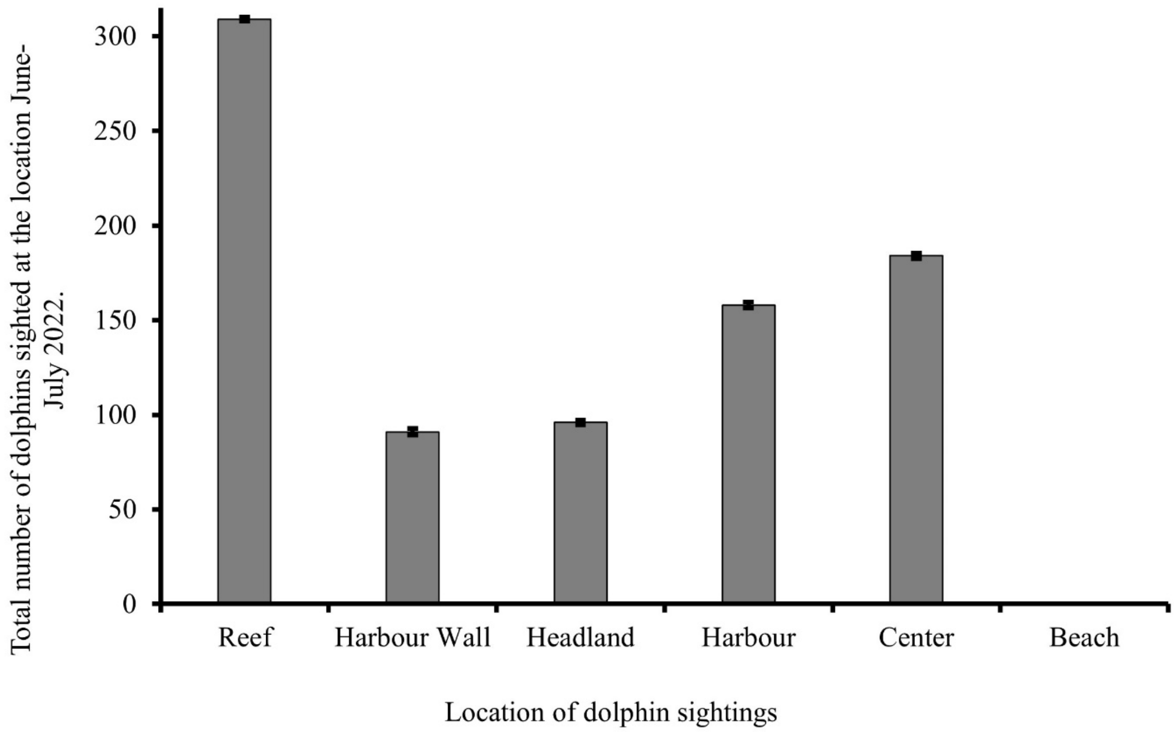

Figure 2 Total Tursiops truncatus *sightings at six locations across the study site during June and July 2022 observations. Standard deviation error bars.*

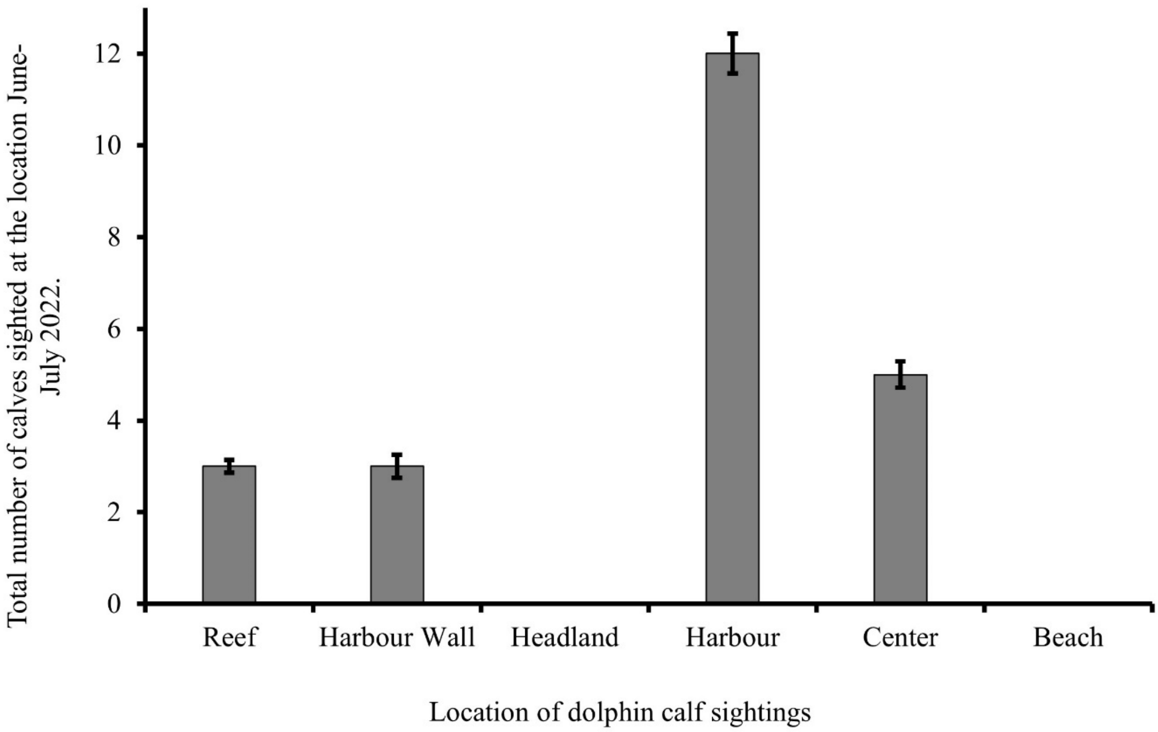

Figure 3 Total Tursiops truncatus *calf sightings at six locations across the study site during June and July 2022 observations. Standard deviation error bars.*

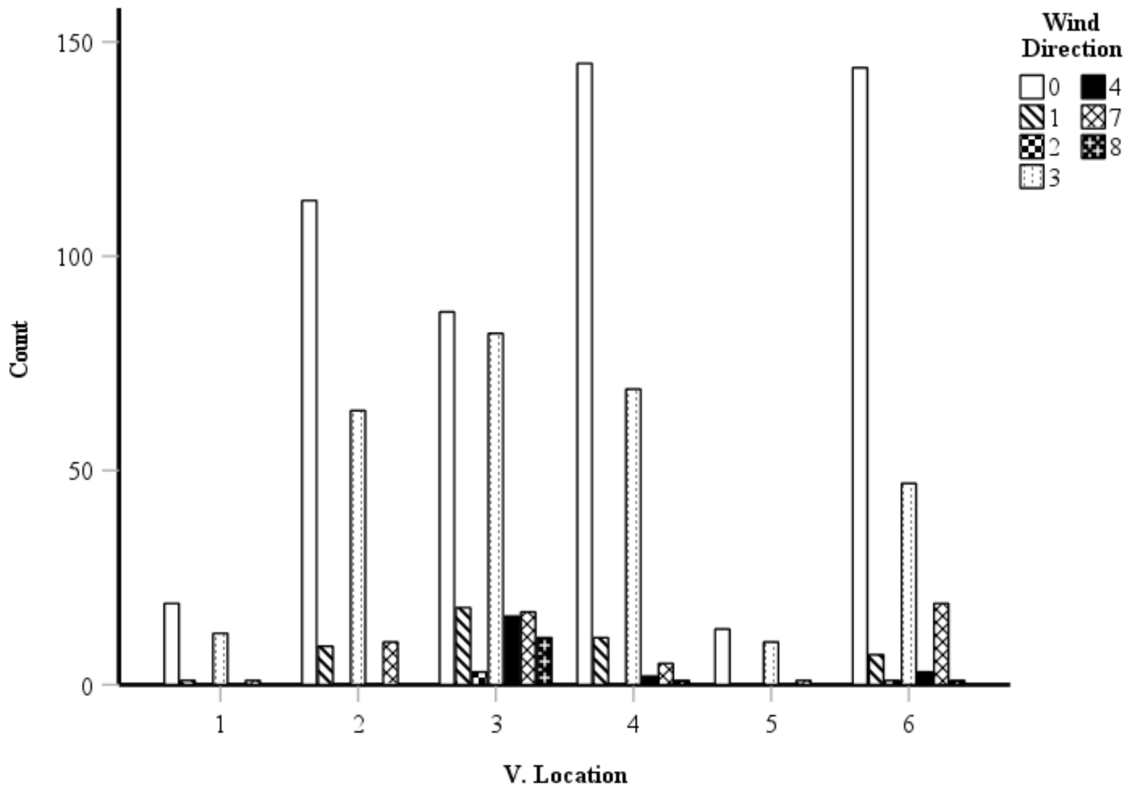

Figure 4 Bar chart of sightings with vessels at one of the six locations during observations June-July 2022. Wind direction was recorded during each observation using a compass as reference. 0= unknown direction, 1= from the north, 2= from the east, 3= from the south, 4= from the west, 5= from the north-east, 6=from the north-west, 7= from the south-east, 8= from the south-west.

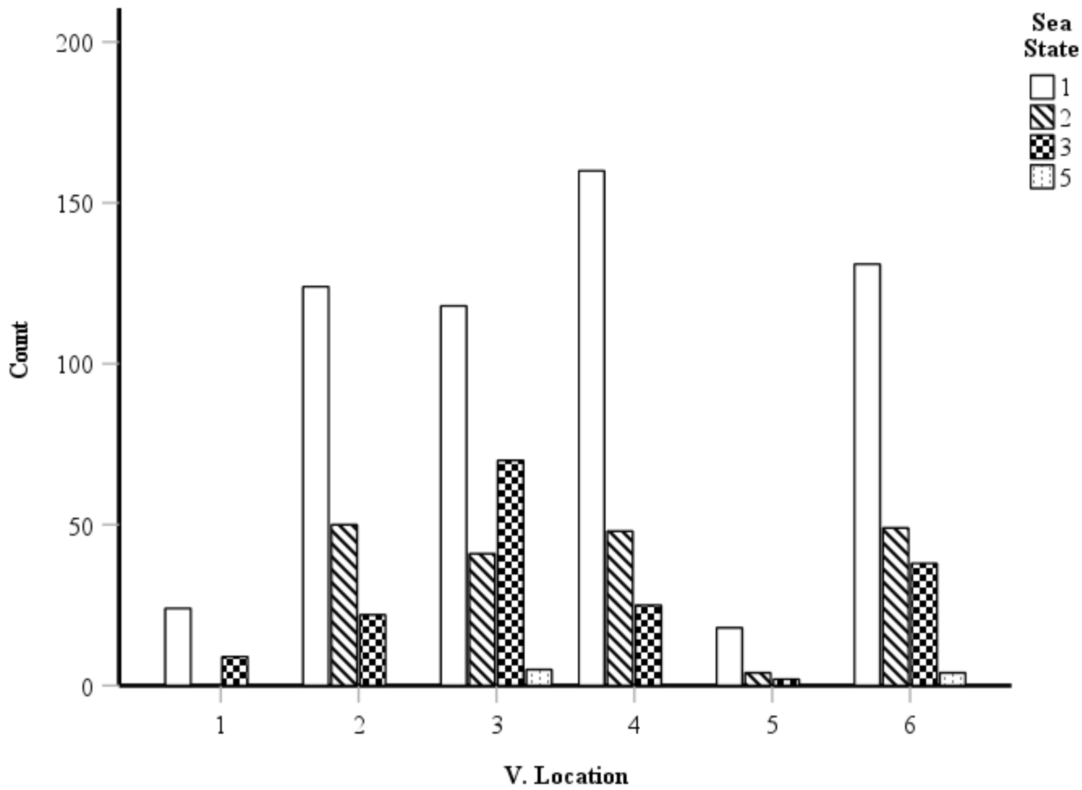

Figure 5 Bar chart of locations recorded with vessel presence during observation June-July 2022. Sea state was also recorded with the vessel presence. Key for sea state follow the Beaufort scale. 1= ripples, generally very calm, 2= small wavelets everywhere but no whitecaps, 3= larger wavelets with some whitecaps, 4= small waves with many whitecaps, 5= moderate waves with lots of whitecaps and some sea spray.

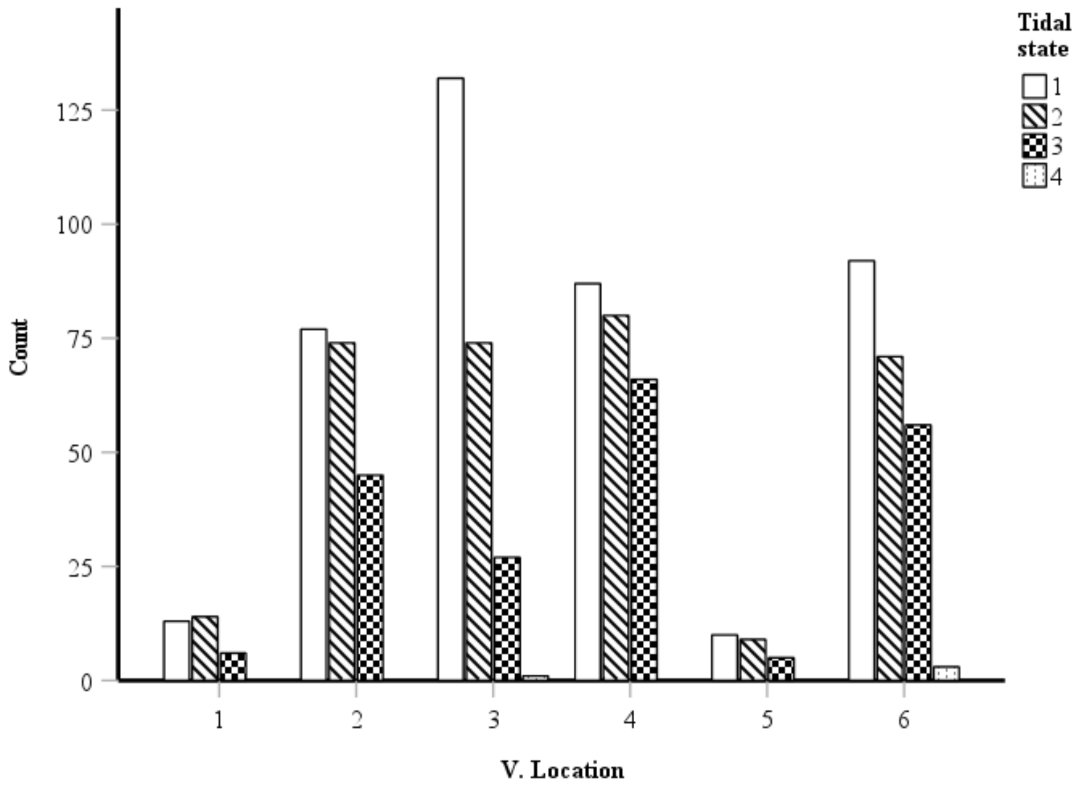

Figure 6 Bar chart of vessel sightings at locations within the study area June-July 2022. Tidal state was recorded during observations. 1= high tide, 2= low tide, 3= rising tide, 4= falling tide.

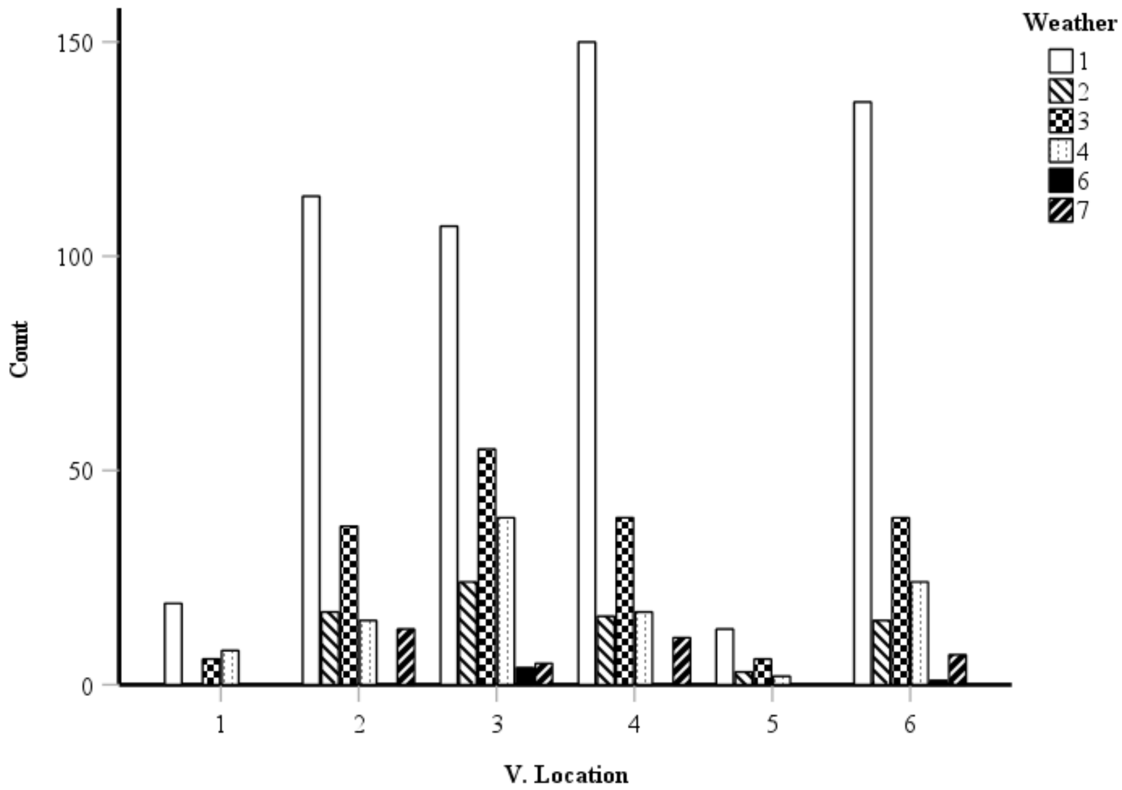

Figure 7 Bar chart of vessel sighting at the six locations across the study site, June to July 2022. Weather conditions were also recorded during observations. 1= sunny, 2=clear, 3=overcast, 4=cloudy, 5=foggy/misty, 6=light showers, 7= raining.

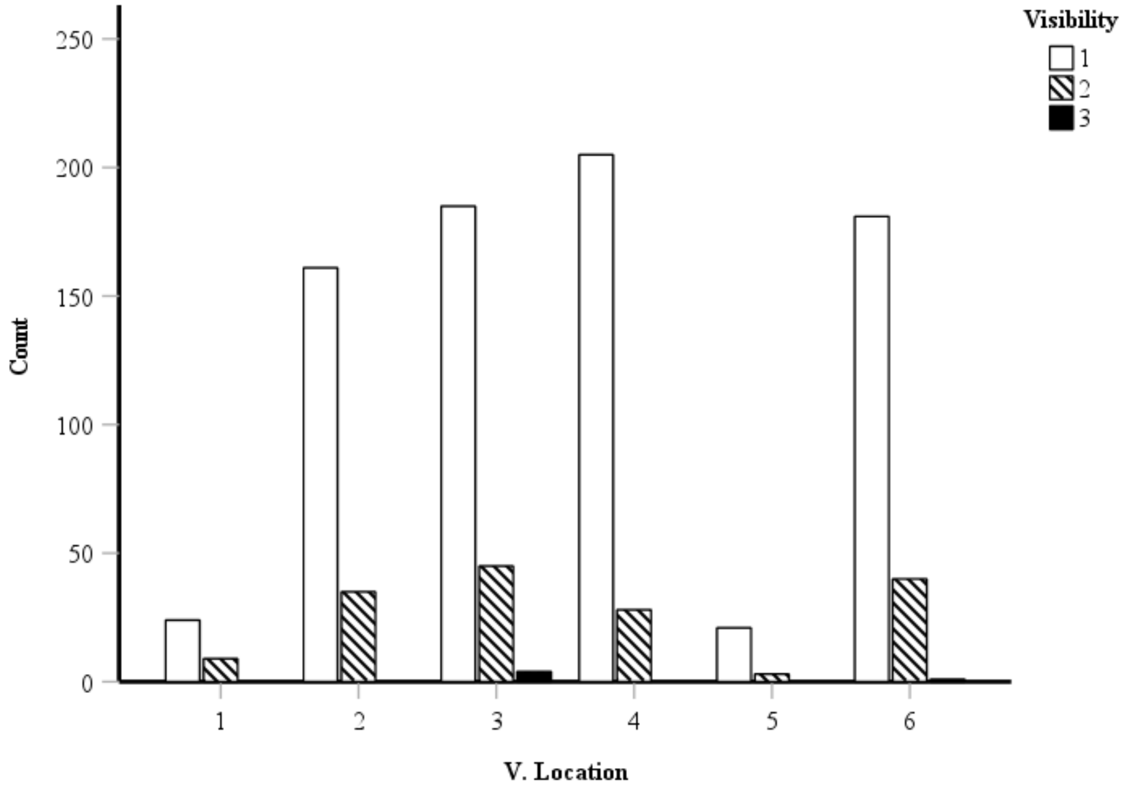

Figure 8 Bar chart of recorded vessel sightings across the six locations within the study area, June – July 2022. Visibility was recorded during observations. The visibility was on a scale set by the Sea Watch Foundation: 1= >10 kilometres, 2= 6-10 km, 3= 2-5 km.

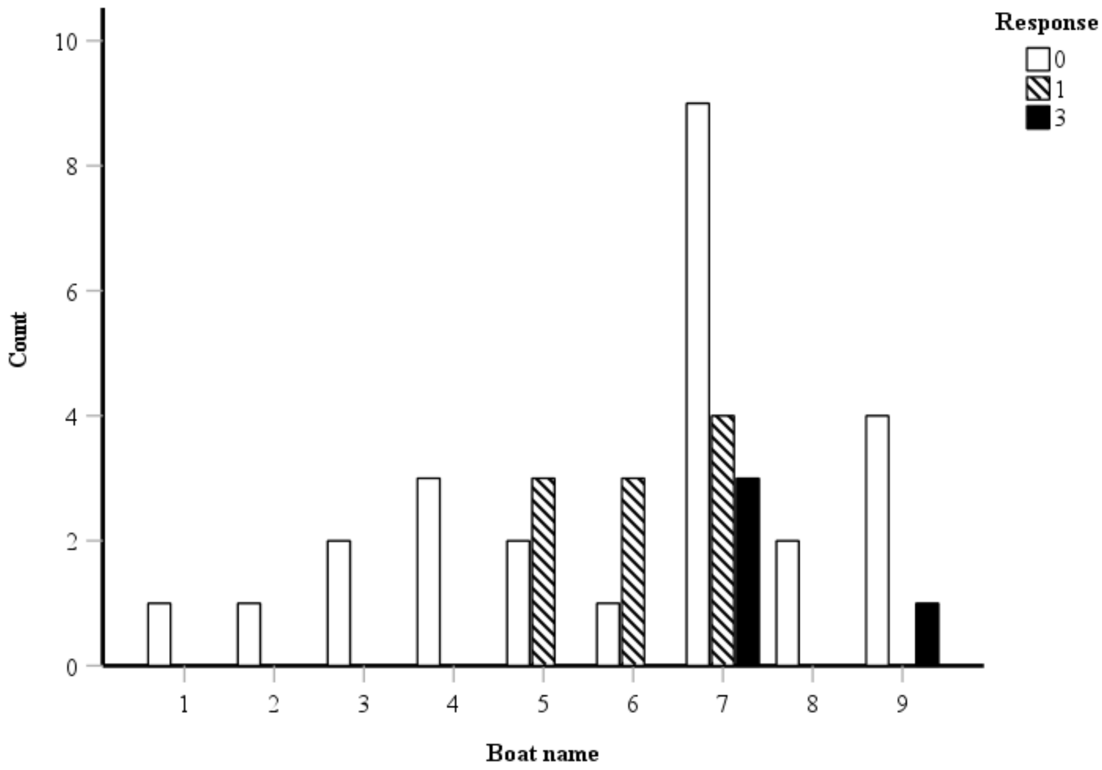

Figure 9 Recorded responses of T. truncatus *to specific boats (identified by features or name), response was divided into 4 types: 1= away from interacting vessel, 2= towards interacting vessel, 3= neutral towards interacting vessel, and 0= unrecorded response. The vessel names are Anna Lloyd (1), black RIB (2), Sulaire (3), Canopy (4), Dreamcatcher (5), Dunbar Castle 2 (6), Ermol 6 (7), Paddle board (8), and SeaMor (9).*

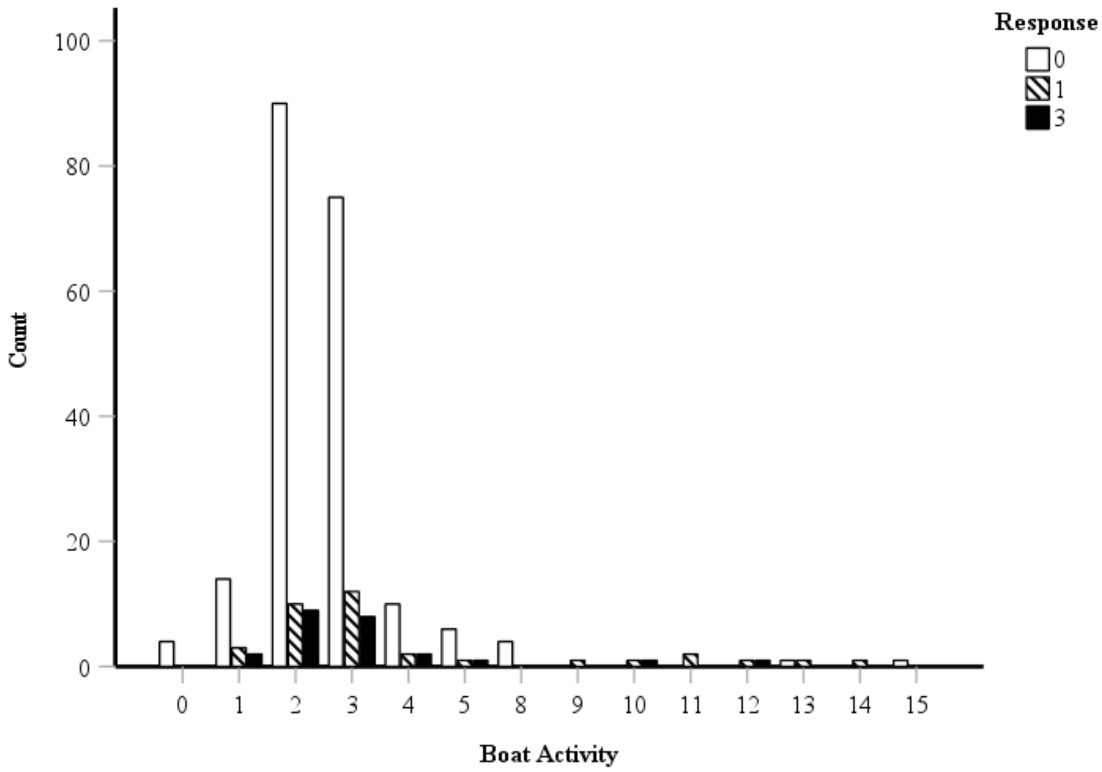

Figure 10 Response of Tursiops truncatus *to specific boat activity, defined as level of adherence to the marine code of conduct towards marine mammals. Response was divided into 4 types: 1= away from interacting vessel, 2= towards interacting vessel, 3= neutral towards interacting vessel, and 0= unrecorded response.*

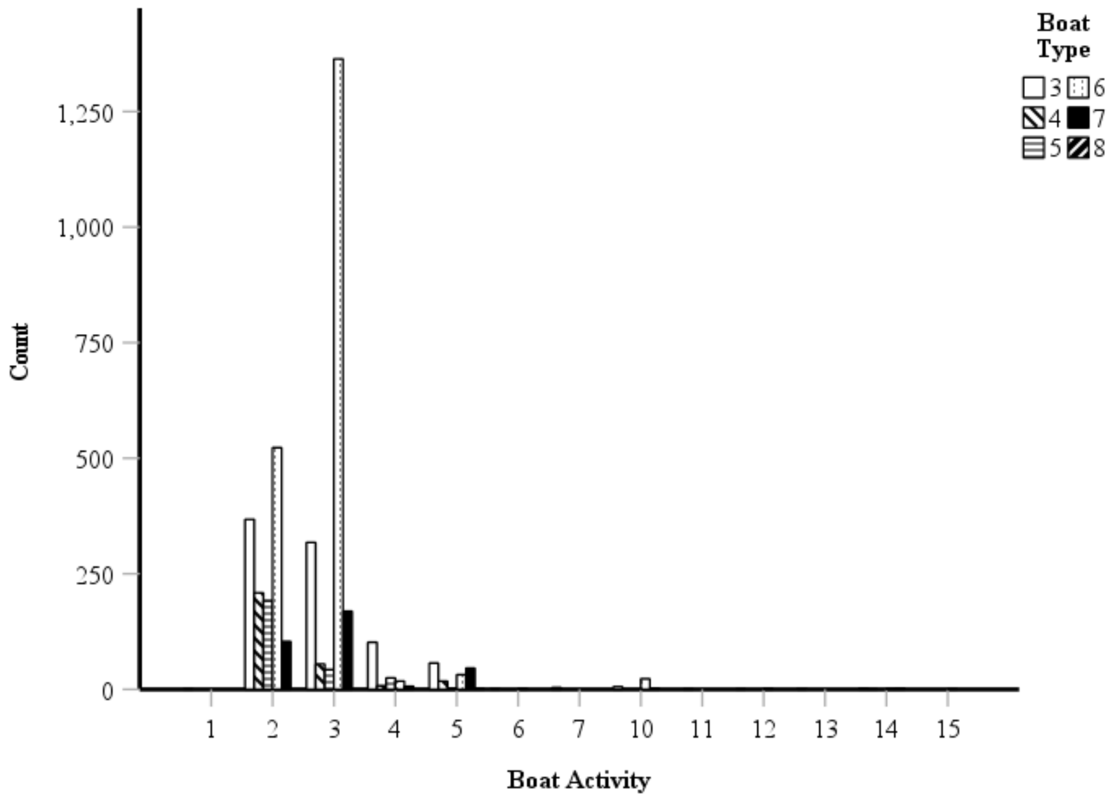

Figure 11 Compliance to the marine code of conduct exhibited by each boat type. Historical data extracted from Sea Watch Foundation database. Boat type: SB (3), YA (4), FI (5), VPB (6), RB (7) and JS (8).

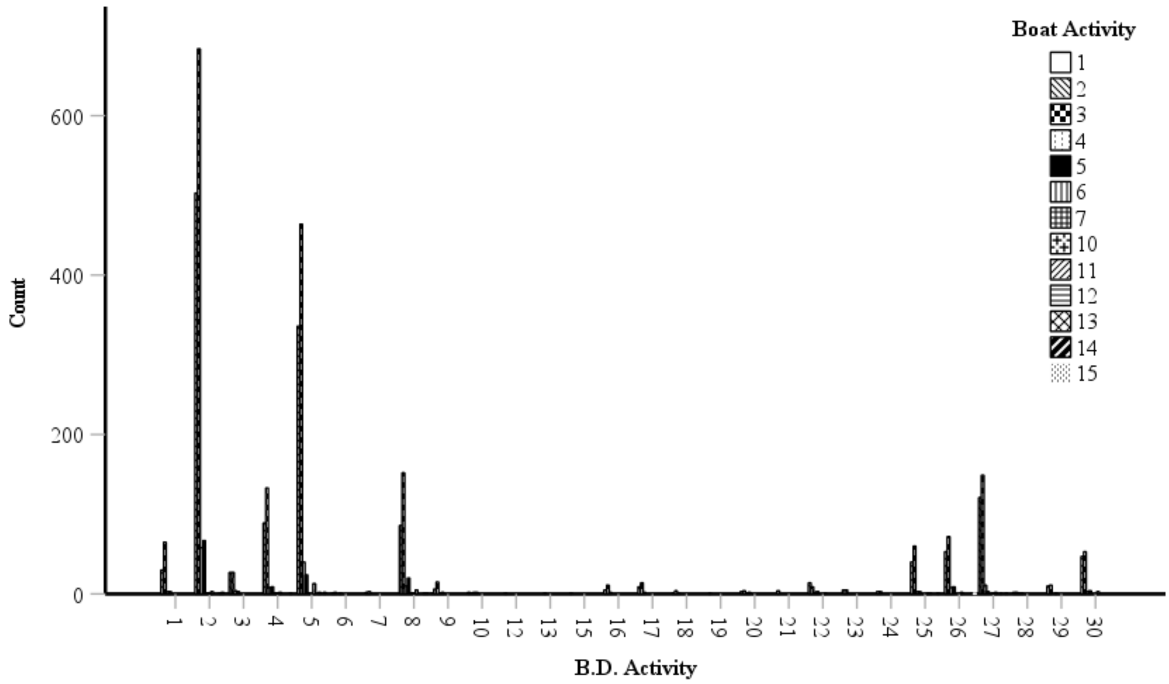

Figure 12 Compliance of vessels to the marine code of conduct coinciding with dolphin behaviour within the study area of New Quay Bay. Data extrapolated from the SWF data base for temporal comparison to the 2022 data set.

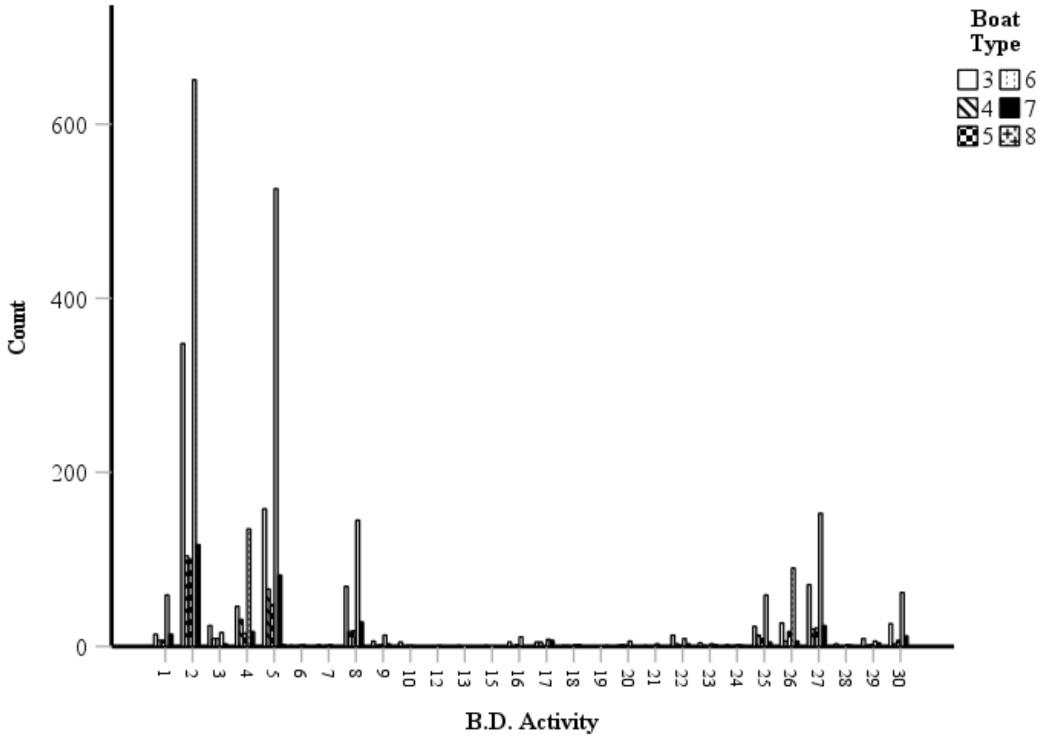

Figure 13 Tursiops truncatus *behaviour in New Quay Bay with vessel traffic categorised into vessel type. Data extrapolated from the SWF database for comparison with the 2022 data set.*

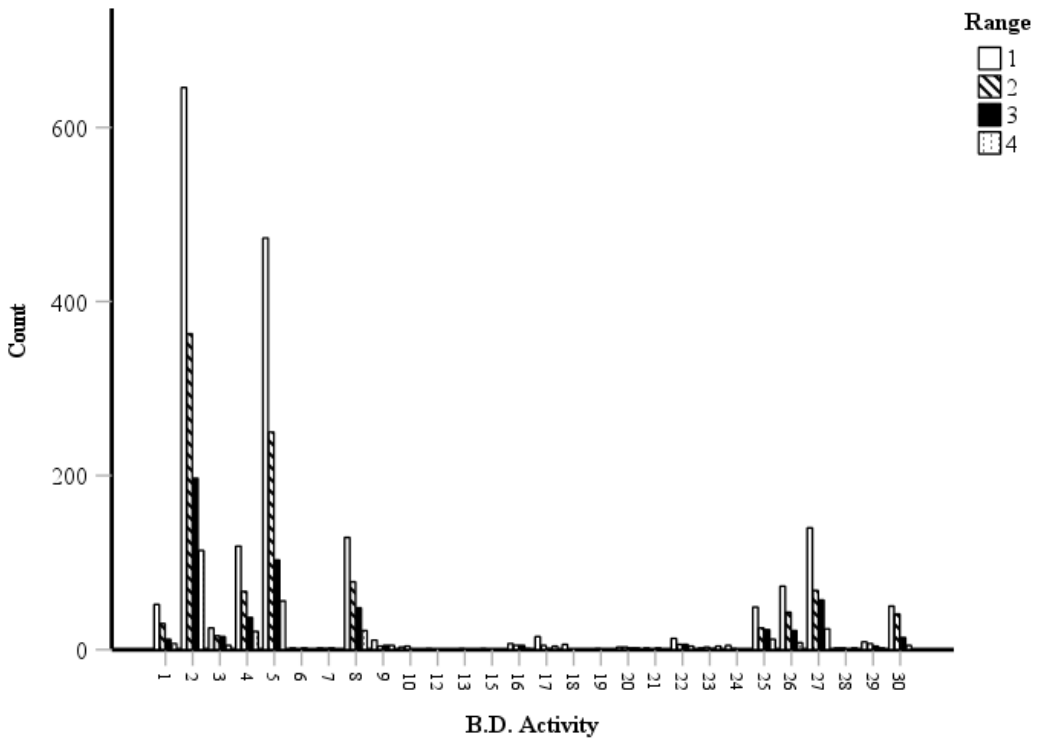

Figure 14 Bottlenose dolphin activity within a range (1-4) of vessels during an interaction. Distance for interactions between dolphins and boats ranges from <50 metres (1), 50-100 metres (2), 100-200 metres (3), and 200-300 metres (4).

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Supplementary Material

Supplementary data tables for formatting

The following supplementary data tables outline the formatting performed on the data before it was imported into SPSS. This numerical formatting was particularly useful for data that contained multiple values, for example, vessel behaviour N1 and N2 were observed in one sighting for a single vessel.

Table 8 Formatted scale of vessel behaviours for easier analysis using SPSS.

Vessel behaviours	Formatted scale
Unknown	0
Y0	1
Y1	2
Y2	3
N1	4
N2	5
N3	6
N4	7
Y0 Y1	8
Y0 N1	9
Y1 Y2	10
Y1 N1	11
Y2 N1	12
N1 N2	13
Y2 N1 N2	14
Y1 N1 N2	15

Table 9 Formatted numerical scale of Tursiops truncatus observed behaviour. All behaviour were first placed into one of five categories: rest, feeding, diving, social, and travel (as indicated in bold in the table).

Formatted scale	Behaviours and code combination	Description
0	0	Unknown
1	**R SURF**	**Rest**
2	**FF SF**	**Feeding**
3	**Div**	**Diving**
4	**AB PB S GS GC**	**Social**
5	**FS NS T B**	**Travel**
6	1, 2, 4, 5	No diving
7	1, 2, 4	No diving or travel
8	2, 4	Social feeding
9	2, 3, 4	Social dive and feeding
10	1, 3	Rest and dive
11	1, 3, 4	No feeding or travel
12	1, 2, 3, 4	No travelling
13	1, 3, 5	Travel with rest and dive
14	1, 2, 3, 4, 5	All behaviour categories
15	1, 3, 4, 5	No feeding
16	1, 2	Rest and feeding
17	1, 5	Travel and rest
18	1, 2, 5	Feeding travel and rest
19	1, 4, 5	Social resting and travel
20	1, 4	Resting and socialising
21	1, 2, 3	Resting feeding and diving
22	3, 5	Travelling with dives

23	3, 4	Social diving
24	2, 3, 4, 5	No rest
25	2, 4, 5	Social feeding and travel
26	4, 5	Social and travel
27	2, 5	Feeding and travel
28	3, 4, 5	Social diving and travel
29	2, 3, 5	Travel with feeding and dive
30	2, 3	Feeding with dive

Supplementary Data Tables from Results

The following tables are from the preliminary data analyses.

Table 10 Preliminary results of T. truncatus presence at each location within the study area.

Location	Reef	Harbour Wall	Headland	Harbour	Center	Beach
Dolphins	309	91	96	158	184	0
Average	2.116438	1.978261	2.042553	2.051948	2.271605	0
Std. Dev.	1.183276	1.79492	1.197052	1.629466	1.483344	0
Max.	6	9	5	9	9	0
Min.	1	1	1	0	1	0

Table 11 Preliminary results of T. truncatus calves and their presence at each location within the study area.

Location	Reef	Harbour Wall	Headland	Harbour	Center	Beach
Calves	3	3	0	12	5	0
Average	0.020548	0.065217	0	0.155844	0.061728	0

Std. Dev.	0.142354	0.249637	0	0.431184	0.289209	0
Max.	1	1	0	2	2	0
Min.	0	0	0	0	0	0