Habitat Use and Effects of Boat Traffic on Bottlenose Dolphins at New Quay Harbour, Cardigan Bay

School of Ocean Sciences

MSc Marine Biology

PRIFYSGOL BANGOR UNIVERSITY

1884

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Menai Bridge 2018

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DECLARATION

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Abstract

The bottlenose dolphin population in Cardigan Bay, New Quay, remains one of the best studied populations of dolphins in Europe. The area of Cardigan Bay is of high importance for bottlenose dolphins as it has many shallow areas suitable for calf nurturing and is rich with a variety of fish ranging from salmon, trout and eels, to flat fish and more pelagic fish like herring, providing them with valuable food.

Boat traffic in coastal waters has been recorded as increasing all around the world mainly due to an increase in the use of personal water craft and whale and dolphin watching vessels. Therefore, boat traffic brings understandable concerns for the consequences it may bring for animals that are highly sensitive to noise with complex social lives such as cetaceans. This study examined what kind of changes might have been caused by boat traffic to the semi-resident population of bottlenose dolphins of Cardigan Bay, the largest coastal population of the species within UK. It was found that dolphins react differently to different individual boats, especially those which were recorded less-frequently at the study site. This study observed some short-term and long-term changes in dolphin behaviour and occurrence at New Quay. Dolphins were observed in smaller numbers during the highest periods of boat traffic. The results indicated that changes in dolphin behaviour might be caused particularly by motor vessels (speed boats, small motor boats, etc.) that do not comply well with the code of conduct, and are often observed at this location. Although the majority of dolphin responses were neutral, there was also a high rate of negative responses. This was concluded to be influenced by the fact that New Quay is an important calf nurturing and feeding area for dolphins, and therefore it is worth them taking the risk of facing daily boat traffic.

Acknowledgements

I would like to thank my supervisor, Peter Evans for his great help and support and for sharing with me his experience and passion. Great thanks also to all Sea Watch Foundation interns and volunteers for their hard work in data collection during all twelve years of this study as well as people who have been managing all project. I have participated in internship during summer 2017 when I have met wonderful people. Special thanks to Lauren Bartlett, Abigail Parker and Steph Byford who have inspired me to apply for Marine Biology Course at Bangor University and who have been a great support for me through all my quarries.

During my project I had many great people who helped me one of whom was my field supervisor, Chiara Bertulli without whom this work would be much more difficult. This project would not be the same also without a great help of James Waggitt whose experience in GLM and GAM modelling allowed me to learn more about using those as well as R statistics program. I would like to thank Simone Fick for her help with excel calculations, which also helped in improving this work.

I would like to thank my family and fiancé as well as all my friends who have not forgot me when I left my country and were supporting me in achieving my dreams and believed in me even when I wasn't.

I would like to dedicate this work to the love for wildlife as well as to all people who have supported me among all of the years of my education and raised me in a spirit of caring about surrounding beauty of the world.

"If we can teach people about wildlife, they will be touched. Share my wildlife with me. Because humans want to save things that they love."

~ Steve Irwin

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1. Introduction

1.1 The bottlenose dolphin: characteristics, social life, habits and distribution

The bottlenose dolphins (*Tursiops truncatus*) is the best-known species of the family *Delphinidae* within the order Cetacea (Berta et al., 2015). The morphology of bottlenose dolphins can be different depending on the geographic region. Generally, bottlenose dolphins have a short, bottle-like beak and are of a grey colour with lighter grey on a ventral part of the body (Connor et al., 2000). The sides of the body also have light brush markings (Connor et al., 2000). The coloration, body size, and shape of fins can vary greatly. So far, 20 morphotypes of bottlenose dolphins have been described worldwide (Vermeulen & Cammareri, 2009). For instance, dolphins living in the warm coastal waters are smaller and have wider flippers than those living offshore (Reeves et al., 2003). In cold UK waters, there is only one morphotype of bottlenose dolphin, which is possibly the largest described for this species (UK 1.9-4.5m; worldwide 1.9-3.2m) (Reid et al., 2003). Bottlenose dolphins can be resident, transient, or semi-resident which means that they may live in one location or they may change their habitat or visit it on a regular basis (Shane et al., 1986). For instance, in the area of this study, Cardigan Bay, about 55% of the dolphin population (200-300 individuals) are described as resident, with only 16% of them visiting the site temporarily (mainly during summer months: June-August) (Lohrengel & Evans, 2016). Bottlenose dolphins live in fission (group splitting)-fusion (groups merging) societies, the members of the school changing frequently due to various reasons such as changing relationships between members of the group or due to environmental and external factors e.g. anthropogenic impacts (Couzin, 2006). Changing the school may include separation from one dolphin school and joining another or creating a new group. Group sizes typically range between 2 and 20 dolphins, but sometimes groups may join each other, forming aggregations of hundreds of individuals (Reid et al., 2003). Connor et al. (2000) found that nearshore populations of dolphins may be open with individuals moving from one group to another, whilst group sizes may change depending on births, deaths, emigration and immigration, as has been seen in the Cardigan Bay bottlenose dolphin population (Norrman et al. 2015; Lohrengel & Evans, 2016).

T. truncatus is an opportunistic feeder, feeding on a wide range of fish species including small sharks or rays, and some cephalopods (Wilson et al., 1997). Dolphin foraging behaviour can be performed by group of dolphins cooperating together to catch prey or individuals chasing them on their own (Saayman et al. 1973; Connor et al. 2000). Dolphins have developed abilities to echolocate, and detect food and other objects, and to navigate underwater, using sonar (Simon et al., 2010). Hunting strategies of dolphins can vary across the world depending on the environmental conditions e.g. tides, time of day and prey availability (Scott et al. 1996). In fact, environmental conditions such as tides or season which reflect movements of fish and other organisms may also be an indicator of dolphins abundance, and the time and type of activities being performed (O'Connor et al., 2009). For instance, inshore populations use tides which may aggregate prey and make it easier for them to catch it. Tides are time-dependent so dolphin activity may be correlated with it (CCC, 2008; O'Connor et al. 2009; Vergara Peña, 2014).

Successful hunting and feeding in dolphins is correlated not only with echolocation activity but also with communication between dolphins in a group (Janik, 2013). Dolphin social skills and communication capabilities are believed to have evolved with their complex brain structure (high encephalisation – an increase in the ratio brain/body mass related to the evolution of intelligence) (Berta et al., 2015). The evolution of the dolphin brain has contributed to dynamics within dolphin populations. For instance, males often live in alliances which can last for many years (Wiszniewski et al., 2012) but may also change due to the complexity of social structure of such groups, e.g. competition between alliances for members, and kidnapping of individuals between groups (Connor et al., 2001). Females instead live in schools nurturing calves where the bonds between mother and calf can be long lasting, even up to four years (Scott et al. 1996). Although mixed sex groups are less common then earlier mentioned single-sex groups there has been some observations of those e.g. New Zealand (Lusseau, 2003a). In UK waters in Cardigan Bay, there has not been found any strong associations between dolphins of the same sex (Barnes, 2011). Also, the social bonds between dolphins in Cardigan Bay seem to be weak which might be due to the seasonal movements of many individuals at this location compared with some dolphin communities that are more sedentary (Barnes, 2011).

1.2 The bottlenose dolphin: worldwide and UK distribution

T. truncatus has a wide distribution occurring in estuaries, bays, lagoons, seas and oceans around the world (Jefferson et al., 1993) (Figure. 1). Bottlenose dolphins offshore appear to form separate pelagic ecotypes e.g. in the tropical Pacific and around the Faroe Islands in the eastern North Atlantic (Reid et al., 2003). The northern boundaries of bottlenose dolphin distribution in the Atlantic range from Massachusetts in the US across the southern coast of Iceland to northern Norway. In the Atlantic, the greatest bottlenose dolphin abundance is in the Southwestern Approaches to the British Isles and northern Bay of Biscay, along the edge of the continental shelf (Reid et al., 2003). The bottlenose dolphins in waters worldwide are often observed either in nearshore or offshore populations. As the research over the past years has indicated in the European waters of the Atlantic, the nearshore populations are common in Spain, Portugal, north-west France, western Ireland, the Irish Sea (Cardigan Bay), and north-east Scotland (particularly the Moray Firth; Figure. 2).

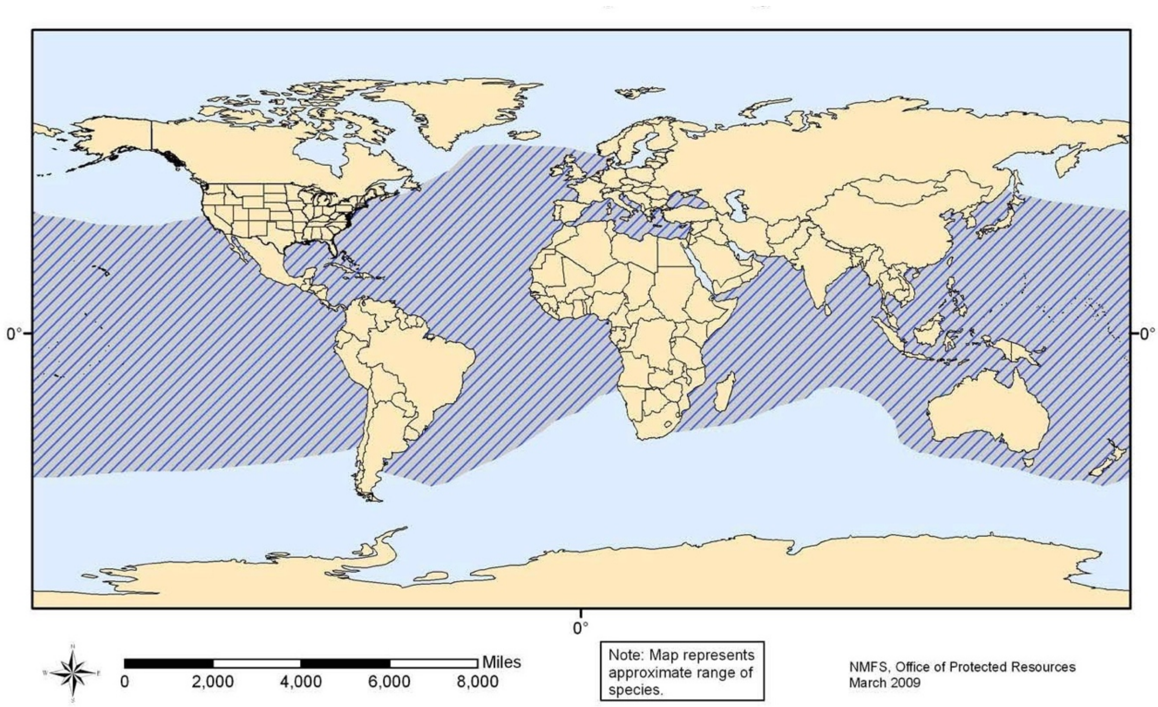

Figure 1. The map of the worldwide bottlenose dolphin distribution marked with blue lines (from NMFS Office of Protected Resources, March 2009, retrieved from nmfs.noaa.gov).

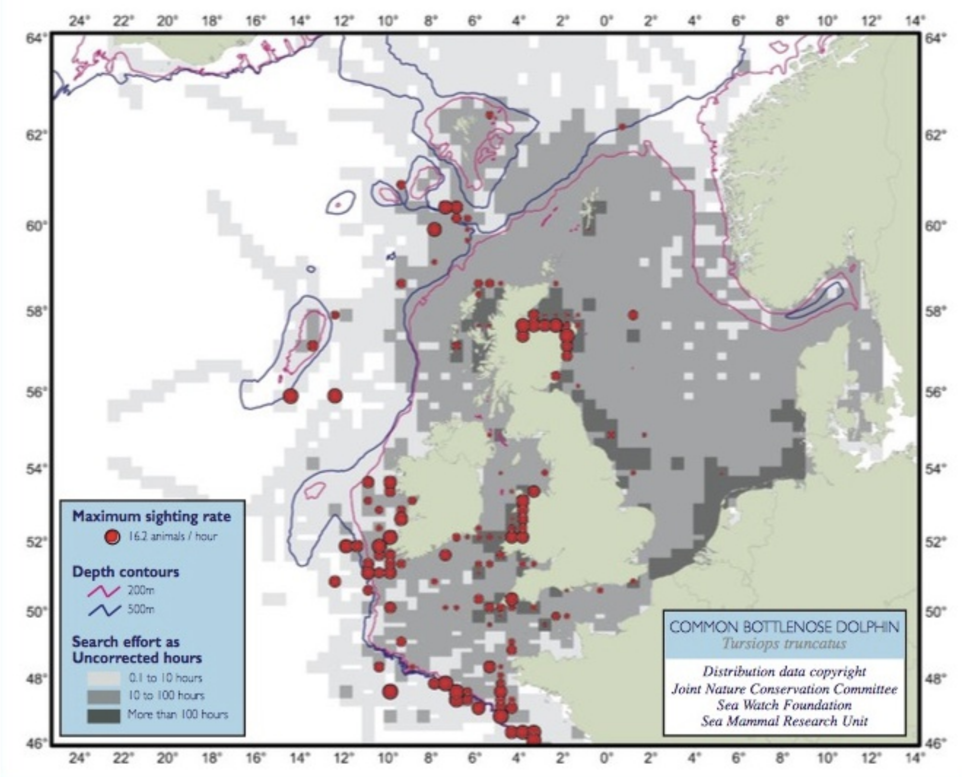

Figure 2. Distribution of the bottlenose dolphins in the UK waters marked with red filled circles. Depth contours (pink 200m and dark blue 500m) displayed on the map (from Reid et al. 2003).

1.3 Bottlenose dolphin exposure to boat traffic

The bottlenose dolphin is the subject of great public interest worldwide, possibly due to its often presence in many locations around the world and common fabular and documentary movies on this species e.g. "Winter" (fabular movie), documentary "The amazing bottlenose dolphin" (National Geographic documentary). This has created new threats to those animals such as long and short-term exposure to dolphin watching boats (Nowacek & Wells, 2001; Williams et al., 2002; Mattson et al., 2005; Lusseau, 2006). Boat traffic has been reported to have increased on a constant basis since the early 1990s mainly due to high number of cargo ships but also to touristic-related boat types such as visitor passenger boats - dolphin watching boats or pleasure crafts like jet skis, kayaks or paddle boards (Lusseau et al., 2006; Tournadre, 2014). Boat traffic can affect in a variety of ways mammals such as bottlenose dolphins because of their sensitivity to noise emitted by the engines or propeller cavitation, and due to the disturbing effect of boat presence on their everyday activities, such as decrease in performance of feeding, resting, or socializing (Au & Green, 2000; Constantine et al., 2004). Other, well described, short-term changes in bottlenose dolphin behaviour in the presence of boats include increasing dive duration (Miller et al., 2008; Arcangeli & Crosti, 2009; Bas et al., 2015, 2017) and travel speeds (Williams et al., 2002; Mattson et al., 2005; Marley et al., 2017). In New Quay, Cardigan Bay, Hudson (2014) has observed that before an encounter with a boat, the most frequently performed behaviours were as following: normal swimming, suspected feeding (high probability of feeding but prey not seen) and aerial behaviours occurred whilst in the presence of boats, the first two of the before mentioned decreased, and instead fast swimming and dive durations increased (Hudson, 2014).

Changes in behaviour are short-term and can be observed more easily than long-term changes by individuals and populations which require a long-term study to be revealed. Scientists such as Miller et al. (2008) and Williams et al. (2006) have proposed the theory that short-term changes such as increase in performance of travelling or changes in animal swimming directions and speeds may be a result of anti-predator like responses of dolphins to a "boat-predator", to increase their chances for survival. Beale & Monaghan (2004) showed that occurrence of anti-predator like response of dolphins to boats and their response to this disturbance depends upon boat number, and behaviour (speed of boat, changes in direction, distance from the animal). Therefore, if the distance between dolphins and boats is smaller because of boat behaviour (rapid changes in direction, increasing speed, etc.), there is a greater probability that the anti-predator like response will occur whereas when the boat behaves in predictable way, the chances for an anti-predator like response decreases (Beale & Monaghan, 2004). In Cardigan Bay, there has been established a Special Area of Conservation where there are regulations on marine traffic, and boats have to slow their speed in the vicinity of dolphins, they must not rapidly change their direction, stay at a distance of 100m from dolphins, and do not follow them if they try to escape (CCC, 2008). Such regulations should have resulted in a reduction of stress related to boat traffic for dolphins in this area, and some studies have suggested their habituation to predictable boat movements (Hudson, 2014). Gregory & Rowden (2001) observed a neutral response to boat traffic (no change in behaviour) in 60% of the dolphins, with only 22% showing negative responses by moving away or changing their behaviour. Some of the long-term consequences of dolphin exposure to boat traffic are a decrease in feeding, reproduction, and communication success (Wursig & Evans, 2001). This kind of disturbance can even lead to further changes such as leaving preferred habitat, declining number of members within dolphins schools and, therefore, changes in group cohesion, and social bonds between dolphins in the area of high marine traffic (Lusseau & Bejder, 2007; New et al., 2013; Richardson et al., 2013; Williams et al., 2014; Marley et al., 2017). Moreover, studies like that of New et al. (2013) suggest that the complex life of bottlenose dolphins in fission-fusion societies might be disrupted by boat activity as fusion in smaller groups increases with fear. Some of the other threats associated with long-term boat disturbance on dolphin behaviour are changes in breathing synchrony which can lead to health problems (Stockin et al., 2008; Schaffar et al. 2009). In Cardigan Bay, few dolphins have been observed with apparent injuries sustained after boat collisions. Dolphins which were observed with various injuries caused by propellers include a peduncle injury to a juvenile dolphin (catalogue no.035-03W) with no sign of healing over time (Lohrengel & Evans, 2017), and juvenile no. 262-13W with a deep nick on the edge of the dorsal fin (Lohrengel & Evans, 2017). None of the animals mentioned had injures which resulted in visible difficulties in movement in everyday life activities (Veneruso & Evans, 2012). Nevertheless, a reduction in the number of dolphins in schools has been observed in both protected and unprotected parts of the bay, which in contrast to the previously mentioned reduction in stress for Cardigan Bay bottlenose dolphins might suggest that marine traffic regulations in these Special Areas of Conservation in Cardigan Bay are not fully successful and need more studies and modification for even better management of this busy location (Richardson, 2012).

Not all of the interactions between boats and dolphins need influence them badly. For instance, there have been many studies recording neutral response of dolphins to boats or positive response like bow-riding (Gregory & Rowden, 2001; Ng & Leung, 2003; Vergara Peña, 2014). Different reactions of cetaceans to boats might be observed not only due to boat behaviour, number or type but also depending on individual, gender and other factors influencing their abundance and behaviour. For instance, in New Zealand, male bottlenose dolphins respond to boats differently to females by diving for longer periods of the time, females perform dives only if the risk of collision is too high (Lusseau, 2003b). This might be explained by the fact that males are larger and this behaviour has a less energetic cost for them than for smaller females (Lusseau, 2003b; Williams et al., 2006). Nevertheless, the response of individuals to threats such as boat traffic might also be different than in groups. For instance, if threatened animals in pods are more likely to stay in more coherent groups whilst individuals will most likely avoid boats by increasing their dive duration, and their swimming speeds (Ng & Leung, 2003).

Changes in cetacean behaviour are not easy to observe as the majority of their life takes place underwater and sometimes what is being observed as a change in one behaviour e.g. decrease in breathing interval indicates it is being followed by change in other activity which may not have been directly recorded e.g. feeding (Shane et al. 1986).

1.4 Factors influencing boat traffic and dolphin responses to it.

Besides interactions between boat behaviour, number, type and dolphin reactions to these, other factors like environmental conditions e.g. sea state, tides, etc. may also have an impact on boat traffic and on dolphin responses to it (Gregory & Rowden, 2001; Nowacek & Wells, 2001; Tosi & Ferreira, 2009). Pierpoint & Allan (2000, 2004) observed in Cardigan Bay that bottlenose dolphin relative abundance appears to decrease when the sea state is lower. Therefore, this might also affect the results of observations on the impact of boat traffic on dolphins due to the lower detection rate of dolphins and decrease in boat traffic at lower sea states. Dolphins use three different types of vocalizations: broad-band short duration clicks for echolocation, wide-band pulse sounds for social reasons, and narrow band frequency whistles, e.g. clicks used for hunting, orientation, and navigation (Janik & Sayigh, 2013; Massey, 2014). The frequencies of those sounds may vary depending on animal excitement and therefore on factors influencing it, e.g. high intensity of boat traffic may cause animals fear, resulting in an increase in frequencies of the sounds emitted or to stop communicating acoustically with pod members (Parsons, 2012). In the noisy environment, dolphin might increase their sound frequencies possibly to avoid overlapping of their sounds with the noise emitted by boats (Jensen *et al.*, 2009). For example, in study by Buckstaff, (2004) dolphins increased their whistle rates within 1 minute prior to vessel approach and decreased it after the boat has passed. On the other hand, frequent changes in their sound frequencies can be of too high-energy cost (Tyack, 2008), pursuing them to stop using sound and finding alternative ways of communication. For instance, studies by Miller et al., (2008) or Noren et al., (2009) have described that performance of surface behaviours increased within 1 minute prior and during the boat approach. This might indicate that the increase in performance of surface behaviour of cetaceans in presence of boats is due to inability of cetaceans to communicate vocally e.g. increase in tail slapping presumably can be performed to pass the information about change in animals swimming direction by integrating visual (tail slap) and acoustic (splash caused by tail slap) communication (Lusseau, 2007; Courbis & Timmel, 2009).

The important environmental factor to consider might also be tides which may bring more nutrients when high and therefore accumulate more fauna but also may help dolphins to capture prey (Gregory & Rowden, 2001). For instance, in Scotland (Morray Firth) which is an important feeding area for bottlenose dolphins presumably due to richness of the estuary of the River Dee in salmon fish, it was found that dolphins presence increase during late afternoon hours (15:00-17:00) when the tide is high (Sini et al., 2005).

Also, the most common performed behaviour was foraging. This was suggested to be a possible evidence for relationship between dolphin presence and up-estuary movement of salmon during the summer months (Sini et al., 2005; Smith & Smith, 1997). Tides also were described to be associated with dolphins movements in presence of the boats in study by (Mattson et al., 2005) were dolphins movement was categorized: “movement with tide”, “movement against the tide”, “across the tide and “no net movement”. Additionally, the change in movement direction was reported when there was observed a change between above described categories.

Environmental conditions may sometimes make it harder to assess if boat traffic is causing the change of dolphin’s behaviour or some other factor (Lohrengel & Evans, 2016). For this reason, it is important to consider recording some of the most important environmental factors which are likely to affect dolphin behaviour in the study location (National Academies of Sciences, 2017).

1.5 Aims and hypotheses

This study aims to compare long-term changes in the occurrence and behaviour of the New Quay bottlenose dolphin population in response to boat traffic and environmental conditions influencing it, based on data collected by Sea Watch Foundation during last twelve years (2006-2018). New Quay is an important area for bottlenose dolphins mainly because of its prey availability and its suitability for nurturing calves. This dolphin population has been researched for many years which allows one to observe long-term changes in different behaviours such as feeding, foraging, swimming fast, normally, travelling, diving, aerial behaviours etc. and monitoring dolphin presence in order to observe effects of the threats such as boat traffic. This kind of information could be helpful in the management of this site and if needed improving it. Such studies allow monitoring of the condition of the bottlenose dolphin population in highly touristic areas like New Quay which in summer is crowded by visitors who may thus have an impact on the local dolphin population by engaging in various activities such as dolphin watching, kayaking, surfing, using speed boats or paddle boats. Therefore, to observe long-term changes a study will be conducted to compare short term changes in dolphin behaviour across the years. To achieve this aim, the following hypotheses will be tested:

H1 Dolphins do not respond to presence of the boats.

H2 The local Code of Conduct is observed by the majority of the boats during the years 2006-2018.

H3 Speedboats and motorboats do not comply with the Code of Conduct and dolphin behaviour will change when the boats will not comply with the codes.

H4 Dolphin behaviour will differ between transitions of the boat absence and presence.

H5 Dolphins number will decrease with the higher levels of boat traffic (2006-2018).

H6 The level of boat traffic and the type of dolphin responses to it is being affected by tides, and sea state.

Testing those hypotheses will help in achieving the objectives of this study which are:

1. To ascertain how dolphin schools, react to boats and whether boat type is affecting their response.
2. To check what proportion of boats, comply with the codes of conduct and to ascertain if dolphin response is different to presence of the boats that either comply or do not comply with the codes of conduct.
3. To ascertain what types of boats do not comply with the code of conduct and to ascertain dolphin response to different boat type.
4. To observe changes in surface behaviours between transitions where boats were present and when they were leaving the area of dolphin sighting.
5. To observe if number of boat passages has an impact on number of observed dolphins (2006-2018).
6. To observe if environmental factors change the number of boat passages and dolphin responses to boats.

2. Methods

2.1 Study Site Characteristics

The location of the study is within Cardigan Bay which covers an area of 5500km^{2}and is the biggest bay in the UK (CCC, 2008). The depth of Cardigan Bay varies between the north and the south regions of the bay. At its eastern edges the bay is rather shallow and its bathymetry does not vary greatly (Evans, 1995; CCC, 2008; Baines & Evans, 2012). The geomorphology of the coast is dominated by rugged headlands with sandy bays between them (CCC, 2010). Such coastlines with many headlands create areas of greater tidal strength than in the rest of the bay where tides are weak with maximum speeds of 0.9m/s (CCC, 2010). Tides within Cardigan Bay are semi-diurnal with 12h 25min between high and low water; however, this time difference increases further to the north of the Bay (CCC, 2009). In the study area, south-westerly and westerly winds come across the Irish Sea. The open coastline of Cardigan Bay favours the formation of steep local waves in this area. The variation in swell is seasonal. During the winter wave height can exceed 1m for half of the time while during the summer it happens for only a quarter of the time (CCC, 2010). The climate in this area is temperate with seasonal variations in parameters such as temperature, rainfall, wind strength, and water turbidity (CCC, 2009). The more precise location of the study is New Quay Bay located within Cardigan Bay. It has a heterogeneous seabed of gravel, stones, and sand deposited between the wall and the headland (CCC,2010). Sediments of sand and stone particles can be found in deeper waters while near the cardinal marker, the seabed consists of rock, sand and weed, therefore creating a well-adapted three-dimensional habitat (Lowe, 2016) (Figure. 3).

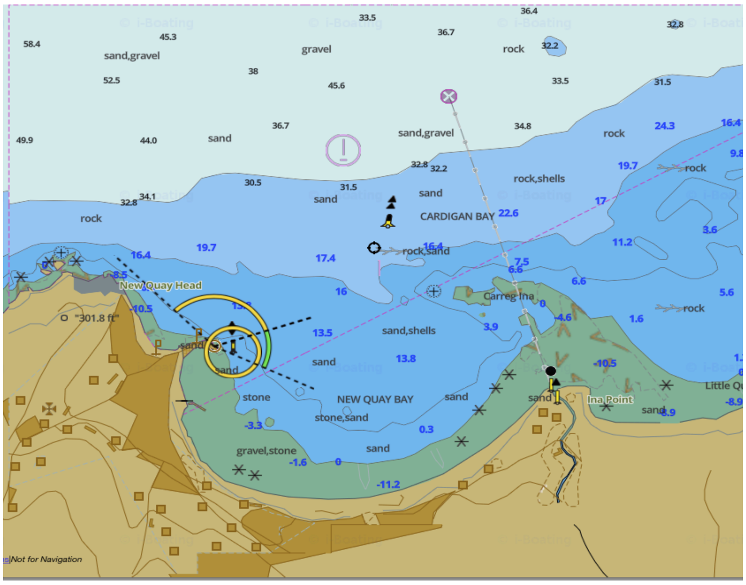

Figure 3. Cardigan Bay, New Quay depth map with sediment types subscribed to the different parts of the bay (from Transas iSailor, 2018).

New Quay Bay is part of the Special Area of Conservation (SAC) which extends from Aberarth, Ceredigion to Ceibwr Bay, Pembrokeshire. It was created mainly for the reason of high importance of this area for bottlenose dolphin abundance, and the suitability of the habitat for calf nurturing (Veneruso & Evans, 2012; Perry, 2016).

Nevertheless, Cardigan Bay SAC is also important for its sandbanks, reefs, sea caves and abundance of river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromyzon marinus*), and Atlantic grey seal (*Halichoreus grypus*) (CCC, 2010). The bottlenose dolphin and Atlantic grey seal are top predators and therefore dependent on lower levels of the food chain in Cardigan Bay as a source of their food (CCC, 2010).

2.2 Land-watch sites in New Quay

Land-watches were conducted from two sites in Cardigan Bay, New Quay. The first location was the harbour in New Quay (Pier) which allowed for close observations of encounters, and second was the coastal path by Birds Rock (headland) also within New Quay (Figure. 4).

Figure 4. Study location (New Quay, Wales) and sites where data were collected (yellow pins)

2.3 Cardigan Bay bottlenose dolphin population

The bottlenose dolphin population in Cardigan Bay consists of between 121-210 individuals, and is of open character, with the number of its members changing not only due to deaths, births but also from emigration and immigration (Ugarte & Evans, 2006; Pesante et al., 2008; Norrman et al. 2015). In general, the species is recorded in this area most frequently over the summer, while during the winter they are much less numerous in the bay (Simon et al. 2010; Nuuttila et al., 2013). Also, calves are being born with higher rate between summer months (June-September) (Feingold & Evans, 2014). Increase in bottlenose dolphin presence during the summer months is thought to be due to a higher density of fish species on which they feed at this time (Baines et al., 2002; Vergara Pena 2014). Cardigan Bay, New Quay is a place thought to be important for bottlenose dolphin calf nurturing. According to annual studies like those conducted by Veneruso and Evans (2012) or Perry (2016) in New Quay, 50% of observations have recorded the presence of calves.

2.4 Cardigan Bay, New Quay bottlenose dolphins boat traffic and other threats

New Quay is a touristic area with growing boat traffic due to the development of water-based activities such as visitor passenger boats surveying with tourists in the area and introducing them to the rich local wildlife. The main attraction of the site is dolphin-watching trips, but recreational fishing is also quite common. An increase in boat traffic has also occurred in row boats and private craft such as small motor boats. The bottlenose dolphin population is protected with codes of conduct which regulate marine traffic and control the behaviour of boats around them (Table 1).

Table 1. Marine traffic regulations (Codes of Conduct) in Cardigan Bay SAC (Special Area of Conservation).

Code	Definition
Y1	Passing cetaceans with no-wake speed or no rapid changes in course
Y2	Boat slows down and stops in the presence of dolphins
N1	Boat does not slow down within 300m of dolphins
N2	Following dolphins by rapid changes in course and speed
N3	Following, touching, and feeding dolphins
R	Boat is a vessel with permission under licence from CCC (vessels under flag when under research)

The response of bottlenose dolphins (positive-towards, neutral-no change in behaviour, negative-away) to boats not complying with the codes were more often negative than when boats were complying with codes (Table 1) (Sampson&Kelsall, 2013; Perry, 2016). Land-watches conducted by Sea Watch Foundation volunteers, interns, students, and researchers on a yearly basis from 2006 in New Quay indicate that the majority of the boats have been complying with the codes of conduct (Pierpoint&Allan, 2006). Nevertheless, the boat type reported to not exceed the rules to the highest extent were speedboats and motor boats (Pierpoint & Allan, 2001). Also, motorboats are the type of the boats which are being observed most frequently in New Quay. The other types of boats which are common are sail boats, paddle boats e.g. kayaks, and visitor passenger boats e.g. dolphin-watching boats, and fishing trip boats (Pierpoint & Allan, 2006). As Bristow & Rees (2009) and Frinault (2015) have shown, the boat type can influence dolphin responses to it. For instance, kayaks in New Quay were reported to have a negative impact on dolphins which were observed trying to avoid them. It is possible that this kind of response to kayaks is being observed due to the usual close distances between dolphins and kayaks, and due to the fact that dolphins may detect them too late to keep a distance which makes them feel safe and comfortable (Bristow & Rees, 2009). The possible predator-like response to boats was also reported in the highly touristic area of New Quay where the abundance of dolphins is decreasing during the busy mid-afternoon period in marine traffic. For instance, Lohrengel & Evans (2016) observed that average encounter rates have decreased by 50% in comparison to previous years of the study. The highest boat traffic within New Quay seems to be during summer months while the site is used not only by local people but also by tourists. The busiest areas within Cardigan Bay seem to be close to the shore (Figure. 5).

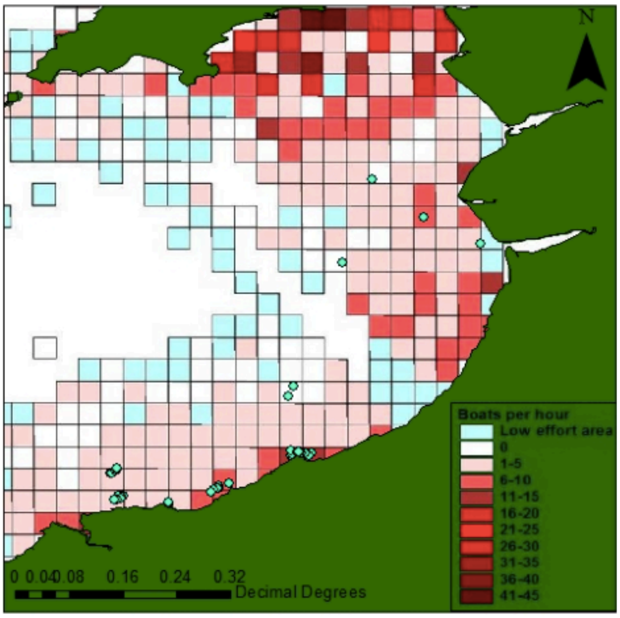

Figure 5. "Boat traffic density in Cardigan Bay. Blue dots indicate recording of bottlenose dolphin whistles"(from Lohrengel et al. 2012).

In Cardigan Bay as well as in the whole of the UK, dolphins have no common predators above them beside humans. In contrast, worldwide, known dolphin predators include sharks e.g. the tiger shark (*Galecardo cuvier*) (Shane et al., 1986).

2.5 Land-watch field work methods

Land-watch field surveys were conducted from 4th of June until 20th July. During the surveys, environmental conditions such as sea state (using the Beaufort scale), visibility (Table 2), and tides (high, low, rising, falling) recorded in 15-minute intervals.

Table 2. Visibility codes and ranges used during land-watches in New Quay, Cardigan Bay for estimating visibility.

Visibility code	Visibility range and description
1	Up to 6 km
2	6-10 km
3	>10 km

During dolphin sightings, records included the number of adults and calves, their distribution and movement direction. Behaviours such as feeding, suspected feeding, normal and fast swimming were recorded every 5 minutes (Table 3).

Table 3. Definitions of surface behaviours recorded during land-watches (from Baş, Amaha Öztürk, and Öztürk 2015; Constantine et al. 2004; Lusseau 2004, 2006; Scheidat et al. 2004; Stensland and Berggren 2007).

Behaviour	Code	Definition
Feeding	FF	Rapid energetic surfacing and dives in varying directions. Often prey can be observed at the sea surface.
Suspected feeding	SF	Rapid energetic surfacing and dives in varying directions. Visible dolphin effort to catch the prey. Prey cannot be observed on the sea surface.
Fast swimming	FS	Fast swimming in one direction, often leap out of the water to increase swimming speed.
Normal swimming	NS	Continuous swimming path with short and frequent dive intervals.
Aerial behaviours	AB	Acrobatic movements, jumping out of the water in a variety of ways.
Percussive behaviours	PB	Hitting water and landing on it with any part of the body.
Resting/milling	R	Slow-movement, synchronous and steady. Quick dives may be observed.
Socializing	S	Interactive activities such as rubbing, chasing, but also genital inspections and play with other dolphins.
Travelling	T	Persistent and directional movement.
Group splits	GS	Dolphin group splits or separates in distance >100m.
Group form close	GC	Dolphins individuals join together to form a close group.
Bow-riding	B	Riding on the waves generated by boats, vessels and ships.
Surfacing	SURF	Often surfacing and short dives.
Diving	Div	Dolphins diving for longer periods of time with changes in direction. Diving might be correlated with foraging.
Unknown	U	Unrecognizable behaviour

For the data collection of boat encounters, the behaviours of the dolphins were recorded every 5 minutes in categories before, during and after the boat approach (Table 4). Land-watches were conducted between three-time frames: morning (7:00-12:00), midday (12:00-16:00), and afternoon (16:00-17:30), evening (17:00-21:00).

Table 4. Dolphins behavioural recordings categories: before, during and after boat approach.

Category	Description
before	No boats within distance greater than 300m.
during	Boats stopping, interested in observations of mammals, clearly trying to stay around the dolphins or passing them within distance not greater than 100m from the animals.
after	Boat which was recorded to have an encounter has passed animals and left them behind. Behavioural records were done in 5 minutes intervals, therefore this category included reporting behaviours 5 minutes after the boat of the interest has left the area where dolphins were observed.

All of the observations lasted two hours each and were undertaken from two sites: New Quay Harbour (Pier) and Birds Rock, an observatory point in New Quay (Headland) (Figure 4). Some of the observations did not cover equal hours as the study sites (Headland and Pier) were in walking distance of 30 minutes e.g. first land-watch at the pier at 07:00-09:00, with the second land-watch on the headland at 09:30-11:30. Sightings included observations of groups and individuals of dolphins. If there were more groups of dolphins sighted at once, if possible their behaviours were recorded separately and described as “before behaviours” meaning no boats were within a distance greater than 300m from the dolphins. If there was more than one group observed at once and they were being approached by boats, then the first sighted group was recorded. The encounters (“during boat approach”) were treated differently, with the various behaviours of the boats recorded based on compliance with the code of conduct, which describes the character of the boat movement (speed, direction of the movement, distance from the dolphins (A. <50m, B. 50-100m, C. 100-200m, D. 200-300m) along with changes in boat behaviour in response to dolphin presence (Table 1). During the encounters, beside recordings of earlier mentioned behaviours (Table 3), dolphin reactions to boats (away (A) (animal disappears), towards (T) (swim towards boat), neutral (N) (does not change behaviour), unknown (U) (response not recorded)) were also assessed.

During two hours of observations, the number of different types of the boats using the site was also calculated. For this reason, the main types of boats recorded included small motor boats (sMB), medium motor boats (mMB), Visitor passenger boats (VPB), row boats (RB), yacht/sail boats (YA), speed boats (SB), fishing boats (FI), Jet Skis (JS), Research Boats (R), Ferries (FE) (Figure 6).

Figure 6. Boat types observed during land-watches in New Quay, Wales (Cardigan Bay) (credits in the photographs).

2.6 Analyses

Sea Watch Foundation data format

Data from land-watches conducted between the years 2006-2018 were taken from the Sea Watch Foundation database. Before conducting analyses, data had to be transformed to a uniform format as years 2006-2009 and 2010-2018 slightly differed from each other in how dolphin behaviours and environmental conditions were recorded. Whenever possible, the new coding from years 2010-2018 was applied to data from years 2006-2009. Due to the lack of some records in the early years of this study, not all analyses have covered years 2006-2009. For instance, analyses on the effect of boat name and type on dolphin response (negative, positive) could not be applied to years 2006-2009 due to the lack of this information. The differences in recorded behaviours and the changes applied are given in Table. 5.

Table 5. List and definitions of behaviours recorded between 2006-2009 and which differed from data from 2010-2018. List contains definitions of behaviours which were recorded in the past and their transition to different behaviour names in order to match the format of data from 2010-2018. For definitions of behaviours for 2010-2018, see Table. 3. *NR- not recorded, N/A not applicable.

Behaviour code 2006-2009	Definition	Behaviour code change in 2010-2018
S1	resting stationary at surface	**R**
S2	milling, intermingling	**S**
S3	deep dives	**DIV**
S4	chasing prey	**FF**
S5	object play	**S**
S6	milling, slaps, leaps	**PB**
T1	slow travel, regular surfacings	**T**
T2	deep foraging with slow travel, long dives	**SF**
T3	fast travel, porpoising, splashing	**FS**
NR	N/A	**AB**
NR		**NS**

Similarly, to differences in behaviour codes between data collected in years 2006-2009 and 2010-2018, there were also some differences in the coding of boat types, which needed formatting to be equivalent (Table. 6).

Table 6. Differences in boat types recorded between 2006-2009 and 2010-2018

Boat type 2006-2009	Definition	Boat type code change 2010-2018
MB	Motor boat	Divided into **sMB** and **mMB**
SB	Speed boat	**SB** Joined together
SS	Speed boat with water skier	
SAIL	Sailing boat	**YA**
CF	Commercial fishing boat	Merged all fish boats recorded together as **FI**
C	Canoe	Merged all Row boats recorded together as **RB**
SCY	Sailing boat	**YA**

Analyses

Analyses were conducted using R statistics and SPSS 22. The significance level for all of the analyses was assessed to be $p>0.05$. Data analyses were performed on two separate datasets: the first one was the Sea Watch Foundation land-watch data collected between 2006-2018, and the second was data collected during this study in June-July, 2018 (Table. 7).

Table 7. Hypotheses with the data time frame included in analyses.

Code	Queries	Data frame
H1	Boat type, name & dolphin response	2010-2018
H2	Compliance with codes of Conduct between years Dolphin response to compliance and non-compliance with codes.	2006-2018 2010-2018 2006-2018, 2010-2018
H3	Compliance with codes by boat type. Dolphin behaviour in presence of boats complying and not complying with the codes.	2006-2009, 2010-2018
H4	Behaviour changes between boat presence/absence transitions.	2018
H5	Number of dolphins & total number of boats during 2h watches	2006-2018
H6	Sea state & dolphin response Tides & dolphin response	2010-2018 2018

Four types of tests were performed: One-Way Analysis of Variance (ANOVA), Chi-square tests using contingency tables and GLM (General Linear Model) and GAM (General Additive Models). Prior to conducting these analyses, their assumptions were tested. Levene's test of homogeneity of variances was applied to test ANOVA assumptions. Similarly, the normality of data distribution was checked with residual plots when fitting GLMs, and if residuals were distributed normally, the model was applied. The assumptions of homogeneity and heteroscedasticity of data have been checked and met in most of the cases of variables tested with GLM models (See Appendix 7.3). If the assumption of normality could not be met for data presented in the binomial GLM, then no data transformation was applied as, according to (Gardner et al., 1995; Piepho, 2009; O'Hara & Kotze, 2010; Nakagawa & Schielzeth, 2010), the GLM model of binomial type deals better with non-normally distributed count data than with square-root or log transformed data, because, as demonstrated by (Jiao, Chen, Schneider, & Wroblewski, 2004; Lindén & Mäntyniemi, 2011; O'Hara & Kotze, 2010), it may change the results and the quality of the fit of the model.

Chi-square test assumptions of the mean expected count of cells which could not exceed 5% cells was restricted. In the following study the neutral responses of dolphins to boats were excluded to check for the marginal dolphin responses. Previous studies such as Gregory & Rowden (2001) and Hudson (2014) have already described relationships between various parameters and dolphin neutral, negative, and positive responses, finding that most responses recorded were neutral. The methodology of this study aimed to find marginal trends in dolphin responses (negative, positive) to boats.

In the analyses, boat types were divided into two groups: boats observed 460-2123 times (VPB, sMB, SB) and boats observed 257-345 times (FI, YA, RB) (See Figure 6 for boat types). To test for the effect of boat name on dolphin response to boats of the names recorded frequently (40-676 encounters) and boat names recorded less frequently (9-32 encounters), the Chi-square test was applied.

The effect of boat type on dolphin response along with boat activity were tested with chi-square, ANOVA and GLM. For the purpose of those analyses boat activity was divided into two categories: compliant (Y1, Y2) and non-compliant (N1, N2, N3, N4). The category of the boat activity was assessed based on earlier explained Codes of Conduct (for the codes, see Table. 1). The analyses of compliance between different boat types were divided into two-time frames because of the fact that during the years 2006-2009 the boat types like small motor boats and medium motor boats were not recorded.

To determine the impact of boat traffic intensity on bottlenose dolphins in New Quay, a GLM (Poisson) analysis was performed on dolphin numbers observed during 2h observations in the presence and absence of boats. The effect of sea state and tides on boat traffic and dolphin response was assessed with a GLM (binomial). The patterns in dolphin numbers between the years 2006-2018 and during different times of day (07:00-09:00, 09:00-11:00, 11:00-13:00, 13:00-15:00, 15:00-17:00, 17:00-19:00, 19:00-21:00) were observed using counts per hour corrected for effort (in terms of hours watched). A similar approach was applied to test for patterns in boat traffic between years and times of the day.

Data collected during this study (in 2018) were divided into events when the boat was either entering or leaving the area, e.g. before to during to after, and observations without those transitions. This has allowed a comparison of differences in performance between key dolphin behaviours in New Quay, such as resting suspected feeding, socializing and other behaviours like diving, surfacing, normal swimming, or aerial behaviours.

The data collected during 13 years of study in New Quay were also used to assess the effect of the number of boats on the number of dolphins observed using the GLM (Poisson) model, based on creating subsets of data showing the number of boats in the presence and absence of dolphins. Those subsets of data were later combined to create a general model showing the number of dolphins observed in relation to the total amount of boats with the minimum and maximum number of animals observed.

Environmental conditions were analysed in two groups. The first group was testing the influence of sea state on boat traffic and dolphin response based on the data collected between 2010-2018. The effect of sea state on dolphin response has been tested with a Chi-square, and the effect of the sea state on the boat traffic assessed with One Way ANOVA. The second part of the tests were conducted on the data collected during June-July 2018 to see if there were any patterns in relation to the tidal cycle (falling, rising, high, low) influencing dolphin negative and positive responses to boat traffic. To check for the effect of those factors, GLM models were applied.

3 Results

This study used data collected on land-watches by Sea Watch Foundation between the years 2006-2018 (May-August). During this time, 8,950 hours of watches were undertaken (Figure.7). The number of hours of watches was largest in 2016 (May-August), N=910h, while the smallest was in 2018 (May-July), N=468h (Figure.7). The greatest effort was undertaken for watches between 09:00-11:00, N=1803h and 11:00-13:00, N=1783h while the lowest occurrence was observed during the time block 19:00-21:00, N=580h (Figure. 8).

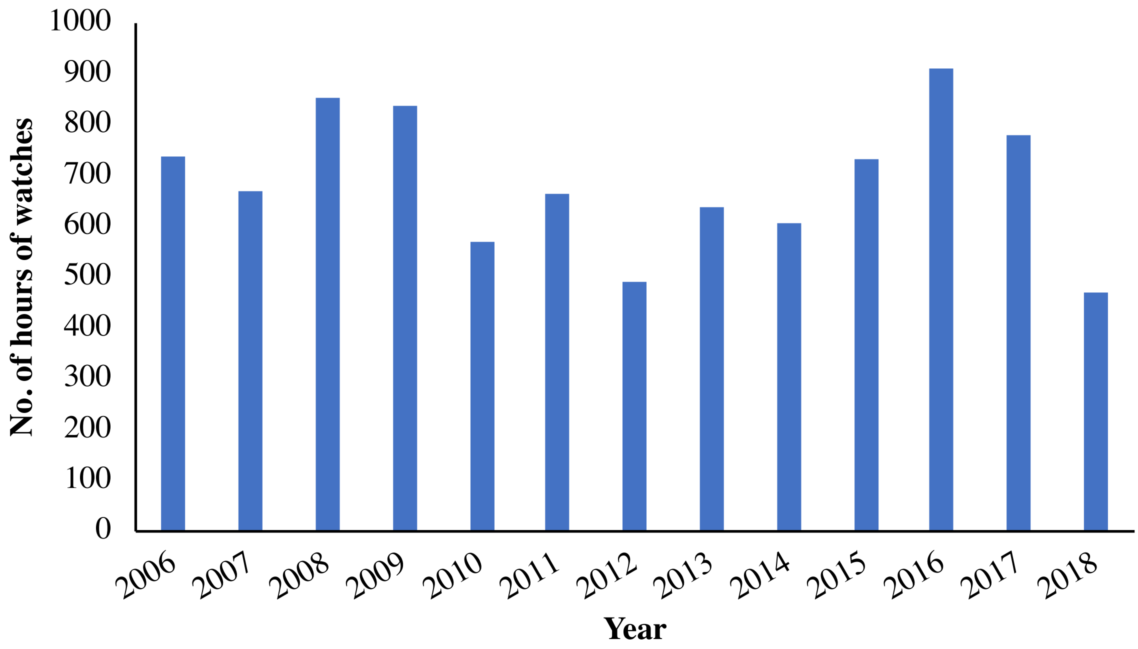

Figure 7. The number of hours of land-watches for bottlenose dolphins, conducted from the pier in New Quay, between the years 2006-2018 (May, August).

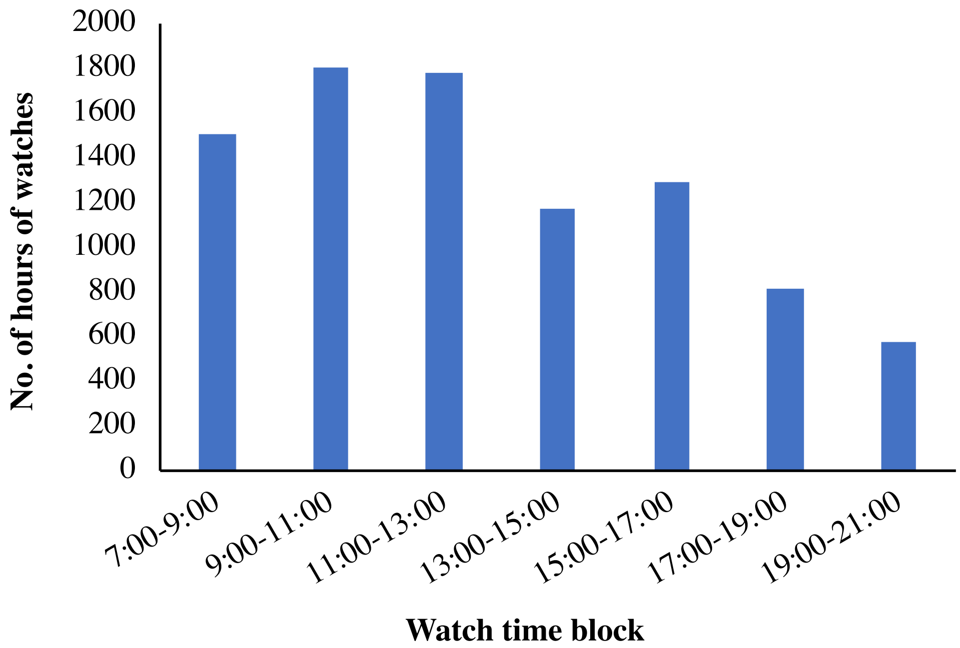

Figure 8. The number of hours spent on watches (2h blocks) during 2006-2018 between different times of the day in Cardigan Bay, New Quay.

Between the years 2006-2018, average dolphin numbers per hour increased steadily to a peak in 2013 (N=7.49 dolphins per hour) with the smallest number occurring in 2006 (N=1.68 per hour) (Figure 9). Since 2013, dolphin numbers across years have been variable but with a general decline (Figure 9). The greatest number of dolphins per hour within a 2h time block decreased from a peak in the early morning at 07:00-9:00h, N=4.7 dolphins/hour to 13:00-15:00h, N=3.1 dolphins/hour, and then increased again between 17:00-19:00 when it reached its highest numbers during the day, N=4.79 dolphins/hour, before declining as sunset approached (Figure 10).

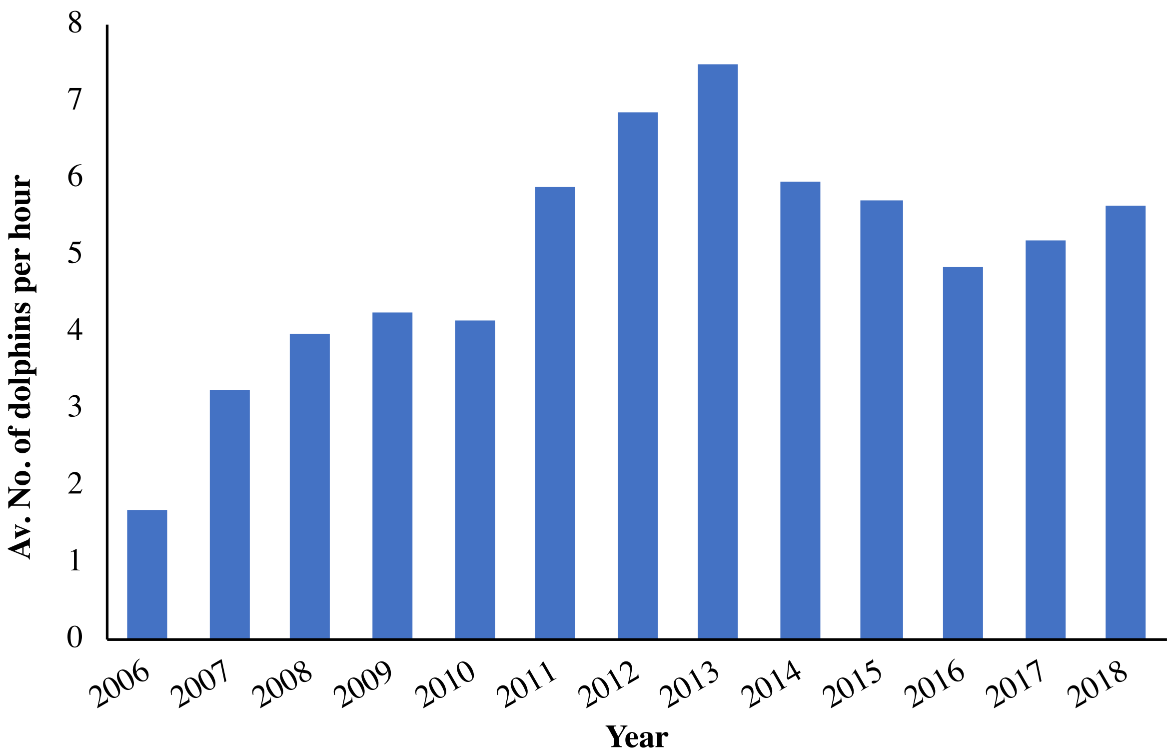

Figure 9. The average number of dolphins observed per hour of effort during years 2006-2018 in Cardigan Bay, New Quay.

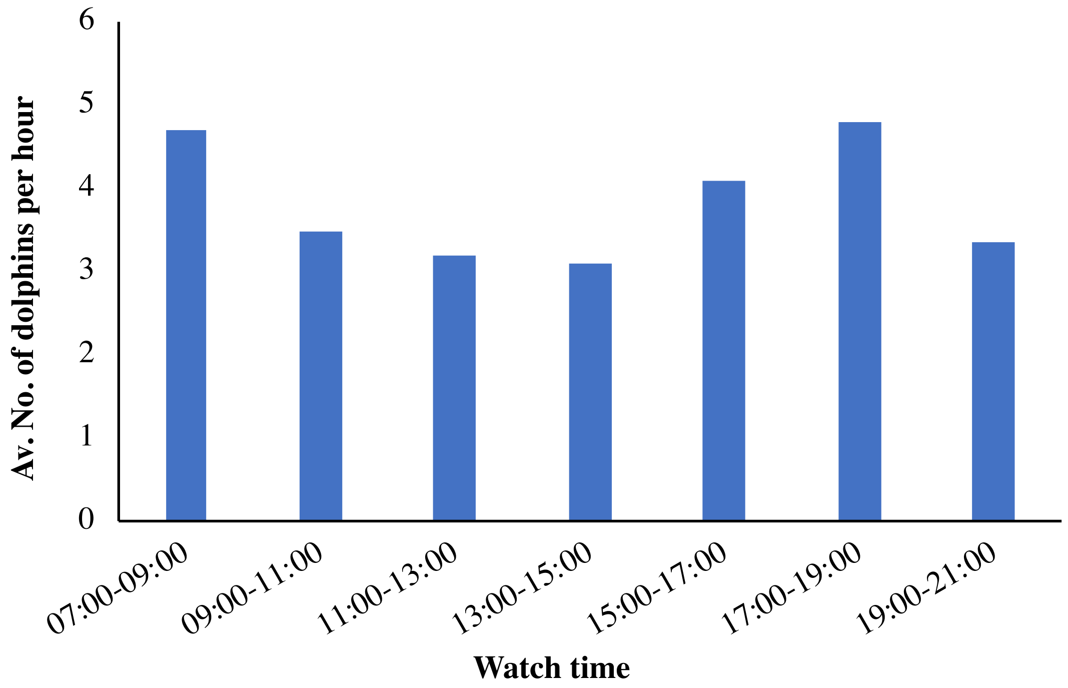

Figure 10. Average number of dolphins observed per effort hour during different times of the day in Cardigan Bay, New Quay.

3.1 Boat traffic among the years

The number of boat passages recorded per hour of watch between 2006-2018 has varied a lot between years with a peak in 2013 (N=13.85 boat passages per hour) but then gradually declining (Figure 11). The boat passages were lowest in 2008 (N=6.49 boat passages per hour). Boat passages peaked during the morning hours (07:00-13:00h). After 13:00h, boat passages declined (Figure 12).

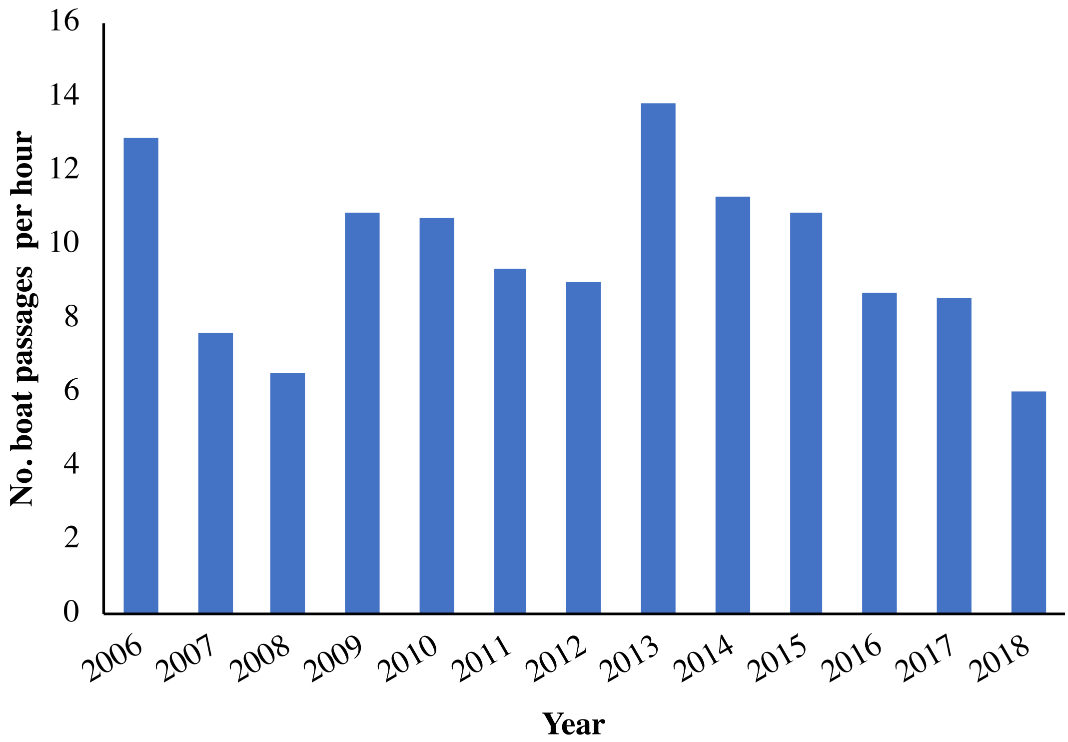

Figure 11. Number of boats recorded per year (2006-2018) during one hour of watch corrected for the effort in Cardigan Bay, New Quay.

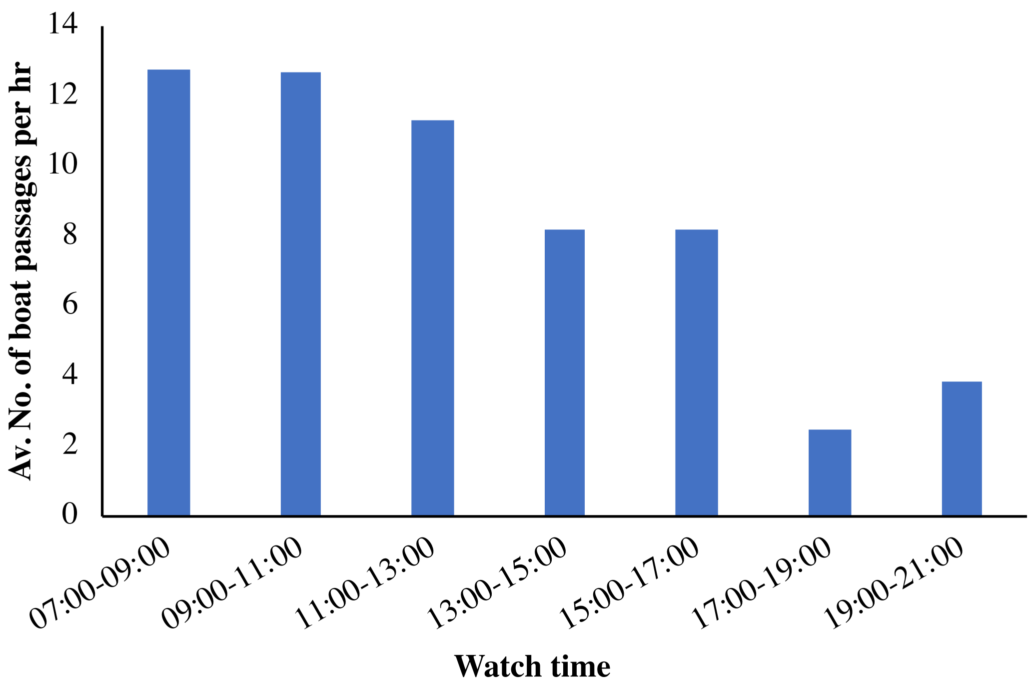

Figure 12. Average number of boat passages per hour of the 2h watch block conducted in Cardigan Bay, New Quay.

The land-watches conducted during the study in 2018 from the Headland and Pier in New Quay were collected during 130h of observations.

3.2 Long-term (2006-2018) data analyses of dolphin responses type and name of the boats.

3.2.1 Dolphin responses to different boat types

The binomial GLM analyses were conducted after reviewing that the Autocorrelation (ACF) test showed small autocorrelation, indicating that this type of test is suitable for these data (Appendix 6.3).

Vessel types were compared to assess whether dolphin responses differed between them. The types of boats which were recorded during encounters most frequently between the years 2010-2018 were VPB (N=2,091), sMB (N=438), and SB (N=450). Negative or positive responses were recorded in 612 of observed encounters whilst not included in analyses neutral responses were recorded in 2367 of recorded encounters (N=2979). During those encounters, dolphin negative responses were recorded in 41.6% of sightings (N=612) for VPB boats, in 10.9% of sightings for sMB (N=612), and in 10.8% of sightings (N=612) for SB. The number of positive responses was less frequent and was recorded in 26.3% (N=612) encounters with VPB, 6.7% with sMB, and 3.59% with SB. The GLM model revealed that there was a weak significant difference in dolphin negative and positive responses to those boat types ($X^2_{(2,\ 3061)} = 6.13$, p=0.04). There was a small difference in dolphin response to SB, which was more frequently negative than the comparable responses to sMB and VPB (Table 8). Nevertheless, despite these differences in dolphin response to SB, VPB and sMB, it was more likely that all of the boat types will be perceived by dolphins negatively rather than positively. The probability of a positive response was weak among all of the boats (Figure 13).

Table 8. General Linear Model (GLM) parameters (±SE) showing relationship between the probability of dolphin positive response to most frequently (460-2123 times) recorded in encounters boat types. Standardised coefficients are shown to enable comparison between dolphin response (negative, positive) to different boat types. The intercept indicates the character of the relationship between dolphin response and boat type.

Variable	Estimate
SB	As reference
sMB	0.61±0.27
VPB	0.49±0.23
p	0.04

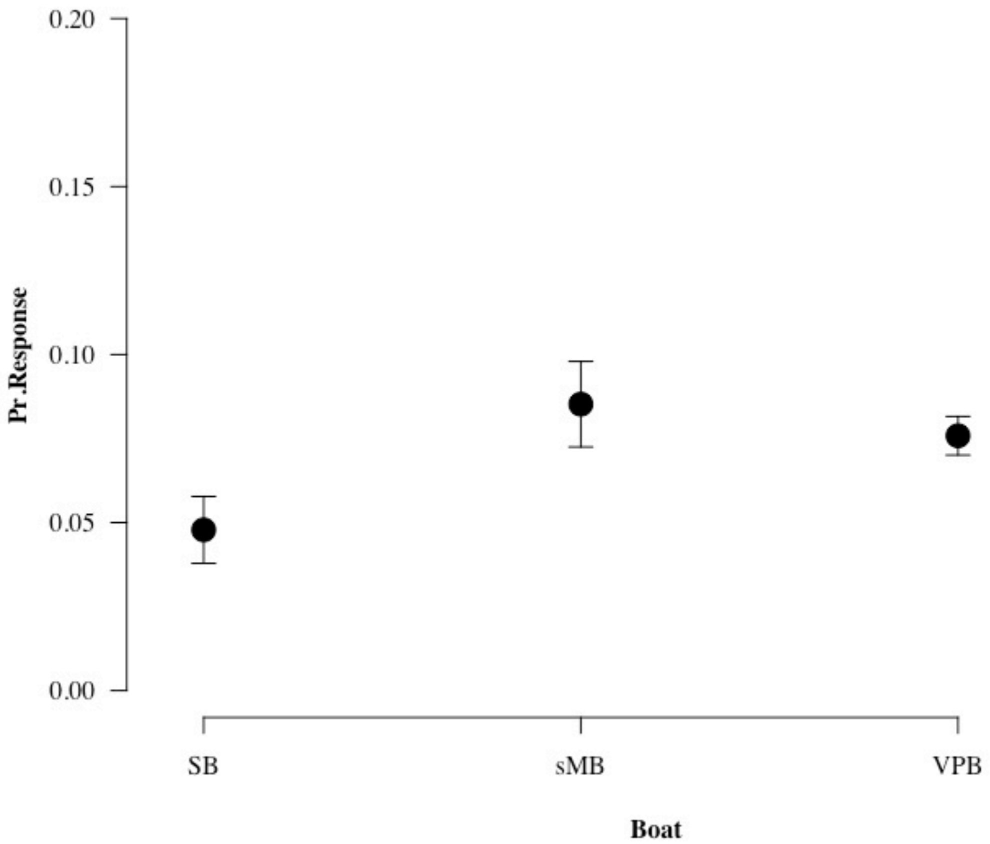

Figure 13. The probability of a dolphin positive (y=1) and negative response (y=0) to the most frequently recorded boat types (SB-speedboats, sMB-small motor boats, VPB-visitor passenger boats) in encounters recorded in New Quay between 2010-2018 (May-August) together with standard errors.

Less frequently recorded boat types such as RB, YA, FI were observed in 257-345 of encounters. The number of positive responses in relation to the presence of RB was observed in 41.5% (N=65) of encounters, for FI in 47.4% (N=57) of encounters, and for YA in 55.6% N=72) of encounters, higher than for any of the previously mentioned boats. Nevertheless, differences in dolphin positive and negative responses to these less frequently observed boats were not significant ($X^2_{(2,908)}$ = 1.66, p=0.43). The probability of a positive response by dolphins to less frequently recorded boat types was low. It was more likely that dolphins respond negatively to any of the boat types than they will respond positively (Table 9).

Table 9. General Linear Model (GLM) parameters (±SE) showing the relationship between the probability of a dolphin positive response to less frequently recorded boat types (257-345 times) observed in encounters. Standardised coefficients are shown to enable a comparison between dolphin responses (negative, positive) to different boat types.

Variable	Estimate
FI	As reference
RB	-0.21±0.28
YA	0.12±0.03

3.2.2 Dolphin responses to boats of different names

The most frequently recorded boats were all of VPB type: “Anna Lloyd” (ANN), “Dunbar” (DUN), “Ermol V” (E5), “Ermol VI” (E6), “Islander” (ISL), “ORCA”, “Sulaire” (SUL), and “Viking” (VIK). The overall number of encounters with the above listed boats was between 40-676 times that of other vessels. Of 332 encounters, 54.2% resulted in a negative response and 45.7% in a positive response. The non-significant probability between the most frequently recorded boat names and dolphin positive responses ($X^2_{(7,\ 324)}$ = 7.43, p=0.38) found the greatest difference between the boats ANN and VIK with about 60% probability of a positive response compared with the boat of the name ORCA, with about 20% probability of a positive response (Figure 14) (Table 10).

Table 10. Probability of dolphin positive y=1 and negative y=0 responses to the less frequently recorded (9-32 times) boat names in New Quay between 2010-2018, together with standard errors.

Variable	Estimate
ORCA	As reference
SUL	1.02±1.16
DUN	1.15±1.19
ISL	1.26±1.12
E6	1.49±1.11
E5	1.69±1.22
ANN	2.01±1.27
VIK	2.30±1.39

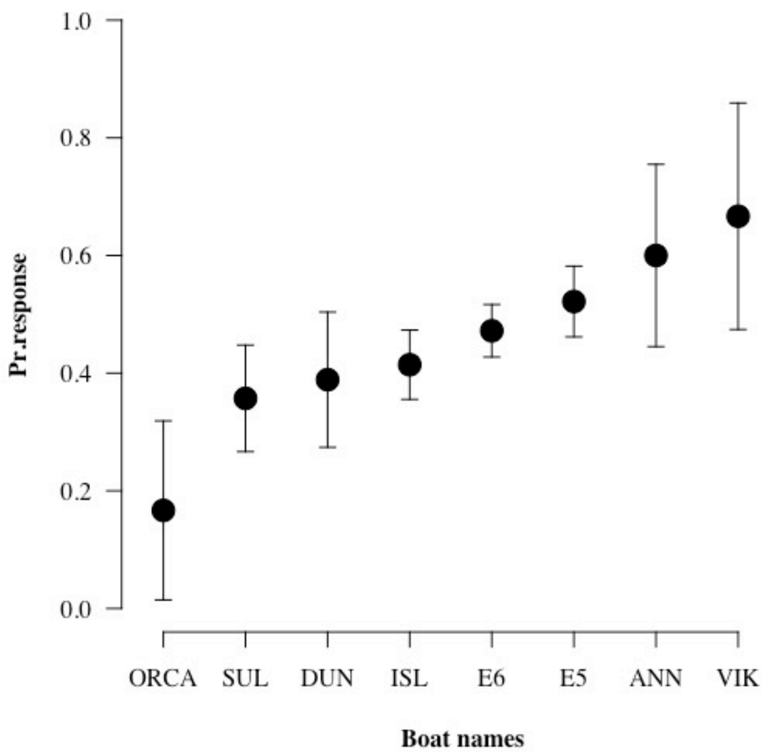

Figure 14. Probability of dolphin positive y=1 and negative y=0 responses to the most frequent (40-676 times recorded) boat names in New Quay between 2010-2018, together with standard errors.

Boat names recorded less frequently in encounters (9-32 times) were FI boats: AB14, M116, AB2-AB2, and VPB, boats which were more frequently running fishing trips than other types of trip, e.g. 3Fishes, Legend (LEG), and another Lifeboat (LIF), KAT, GAL. Those boats were recorded in 35 encounters resulting in either a positive or negative dolphin response. During a few encounters with each of those boats, the greatest probability of a positive response was reported for 3Fishes, AB2-AB2, KAT, Lifeboat, and Legend. The remaining boats (AB14, GAL) were observed to influence dolphins negatively (Figure 15). The few records for each of these boat names have resulted in large standard errors for the predicted relationships between those boats and dolphin responses (Figure 15) (Table.11). The differences between dolphin responses for different boat names were significant ($X^2_{(7,20)}$ =17.34, p=0.02).

Table 11. General Linear Model (GLM) parameters (±SE) showing the relationship between the probability of a dolphin positive response to less frequently recorded boat names (9-32 times) observed in an encounter. Standardized coefficients are shown to enable comparison between dolphin response (negative, positive) to different boat types.

Variable	Estimate
AB14	As reference
GAL	$-4.02*10^{-11}±9.82*10^{3}$
M116	$1.84*10±6.21*10^{3}$
3Fishes	$1.95*10±6.21*10^{3}$
AB2-AB2	$1.98*10±6.21*10^{3}$
KAT	$2.07*10±6.21*10^{3}$
LEG	$3.19*10±9.82*10^{3}$
LIF	$3.19*10±8.21*10^{3}$

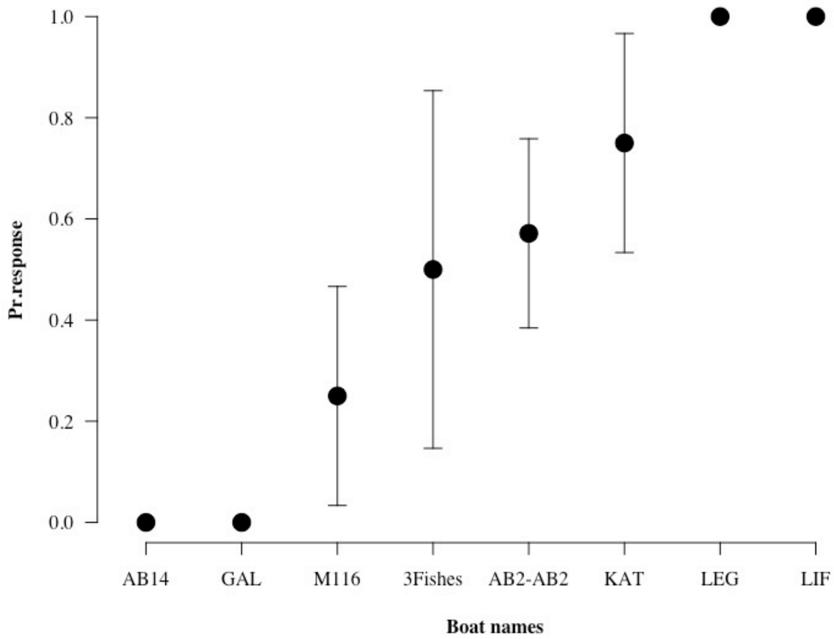

Figure 15. Probability of a dolphin positive response y=1 and negative response y=0 to less frequent (9-32 times) named boats recorded in New Quay in 2006-2018 together with standard errors.

3.3 The long-term analyses (2006-2018) of compliance with the code of conduct among the boats, and dolphin responses to it.

Most boats observed within the New Quay area were complying with the Code of Conduct between years 2006-2018 (See Table.1). The smallest number of recorded boat activities (either complying or not complying with the code) were observed in years: 2006 (N=114), 2007 (N=161), and 2018 (N=278) while for years 2008-2017 the number of records ranged between 429 and 559. Observations of boat activity revealed that they were applying marine traffic regulations in 78.6% of encounters and in 21.4%, they were not (N=835).

There was a significant difference between the number of boats complying with the code during the years 2006-2018 ($X^2_{(12,\ 5657)} = 41.55$, $p=3.96*10^{05}$). The largest difference was observed in the probability of boats complying with codes between 2017 (92%) and the years 2008, 2014, and 2016 with a probability of 86% for compliance with the code. The years 2014 and 2016 had a lower probability of compliance with codes than in 2015 (Figure 16). Nevertheless, all of the years were observed with a rather high probability of compliance with the code of conduct (86-95%). The difference in compliance with the code among years was likely to be due to different levels of effort among the years than to actual differences (Table 12; Figure 16).

Table 12. General Linear Model (GLM) parameters (±SE) showing the relationship between the probability of compliance y=1 and non-compliance with the code of conduct among the years 2006-2018 in New Quay.

Year	Estimate ±SE
2006	As reference
2007	-0.33±0.41
2008	-0.54±0.36
2009	-0.27±0.36
2010	-0.42±0.35
2011	-0.42±0.36
2012	-0.24±0.36
2013	0.13±0.37
2014	-0.56±0.35
2015	-0.11±0.35
2016	-0.57±0.35
2017	0.33±0.37
2018	0.02±0.39

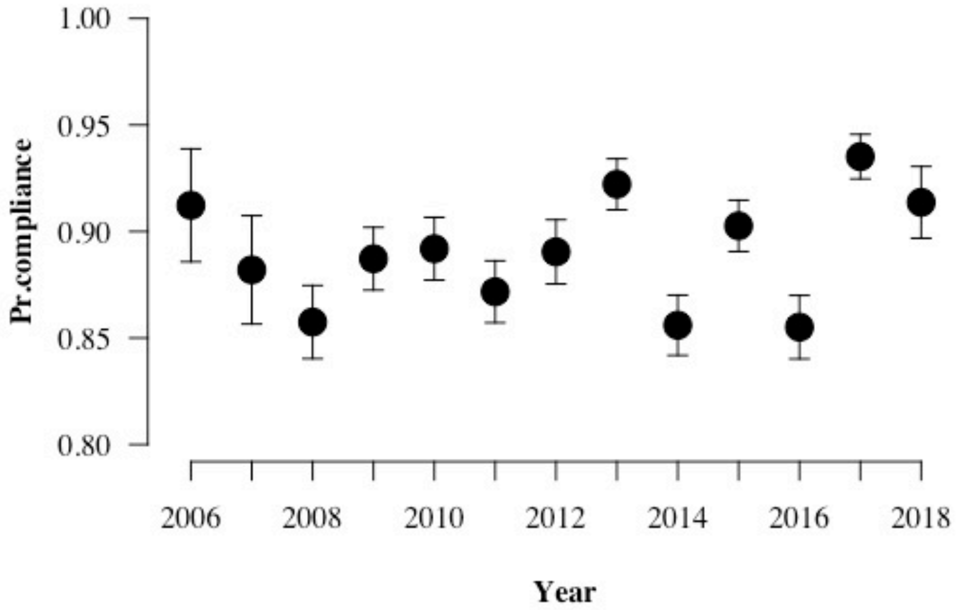

Figure 16. Prediction of boat compliance with the code of conduct in New Quay between the years 2006-2018, compliance with the code y=1, non-compliance with the code y=0.

3.3.1 Compliance with the code of conduct by different boat types (2006-2018)

As explained in the methods, the following analyses were conducted for two-time frames separately, first 2006-2009 and second 2010-2018. Compliance with the code of conduct varied significantly between different boat types during the years 2006-09 ($X^2_{(4,\ 1126)} = 795.28$, $p=7.23*10^{-9}$). The greatest differences in the predicted model were accounted for by the lower compliance with the code of conduct by boat types: SB and RB (ranging between 77% and 81%), and the higher compliance with the code in the more often recorded VPB (94%) (Figure 17; Table 13). In the years 2010-18, the compliance with codes also significantly depended on boat type ($X^2_{(6,\ 4488)} = 2612.2$, $p=2.2*10^{-16}$). Similar to the earlier period, 2006-2009, the biggest differences in the predicted model were accounted for by lower compliance with the code of conduct by boat types: SB and RB (ranging between 70% and 78%), and also for the sMB (about 79%) recorded since 2010. The boat type which has complied with codes at the highest rate was again VPB (about 98%) (Figure 18; Table. 14).

Table 13. General Linear Model (GLM) parameters (±SE) showing the relationship between the probability of compliance y=1 and non-compliance y=0 with the code of conduct by different boat types (SB - speed boat, RB - row boat, FI-fishing boat, YA - yacht/sailing boat, VPB - visitor passenger boat) in 2006-2009 in New Quay. Number of observations for each of the boat types is also given.

	SB	RB	FI	YA	VPB
Estimate	-0.85	-0.45	As reference	0.28	0.78
SE	±0.27	±0.32		±0.31	±0.31
N	214	121	194	239	363

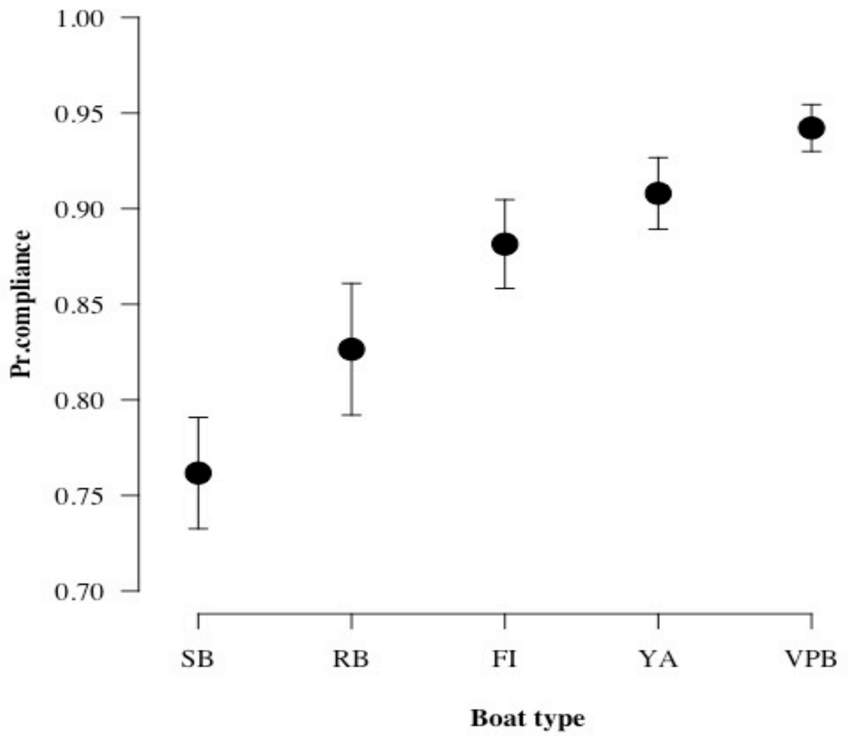

Figure 17. Prediction of boat types complying with the code of conduct (y=1for full compliance) and boat types not complying with the code y=0 in New Quay, 2006-2009.

Table 14. General Linear Model (GLM) parameters (±SE) showing the relationship between the probability of compliance y=1 and non-compliance y=0 with the code of conduct by different boat types (mMB - medium size motor boat; RB - row boat, SB - speed boat, sMB - small motor boat, VPB - visitor passenger boat, YA - yacht/sailing boat in 2006-2009 in New Quay. Number of observations for each of the boat types is also given.

	SB	RB	sMB	FI	YA	mMB	VPB
Estimate	-1.15	-0.67	-0.63	As reference	0.12	0.43	1.61
SE	±0.20	±0.22	±0.21		±0.25	±0.55	±0.22
N	497	338	564	273	378	49	2396

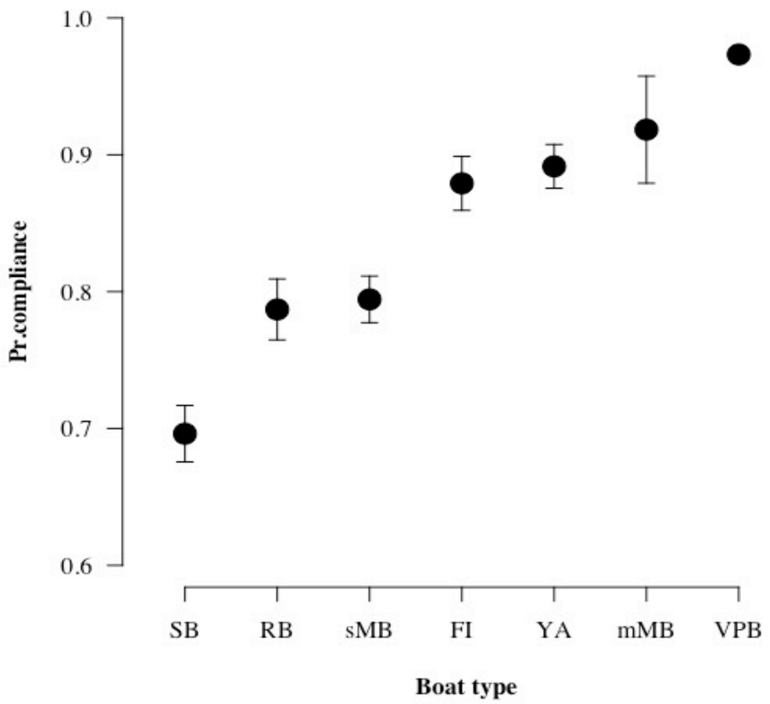

Figure 18. Prediction of boat types complying with the code of conduct y=1 and boat types not complying with the code y=0 in New Quay, 2010-2018.

3.3.2 Changes in dolphin behaviour in relation to activity of the different boat types (RB, sMB, SB) to account for most of the non-compliance with the code of conduct.

Row boats (RB) were one of three boat types complying with the code less than the rest of the boats described. There were 245 encounters with RB recorded between 2006-2018 during which 30 boats complied with the code and 215 did not.

Dolphin behaviour was significantly different between encounters where the boat was complying with the code and when it was not (X^2=90.64, p=2.2*10^{-16}). During encounters with row boats, it seemed that dolphins performed a wider variety of behaviours (e.g. normal swimming, (NS), aerial behaviour (AB), feeding seen fish (FF), socialising (S) more frequently then when the raw boat (RB) was complying with the code. However, important behaviours like resting were performed more frequently when the boat was complying with the code (Figure 19).

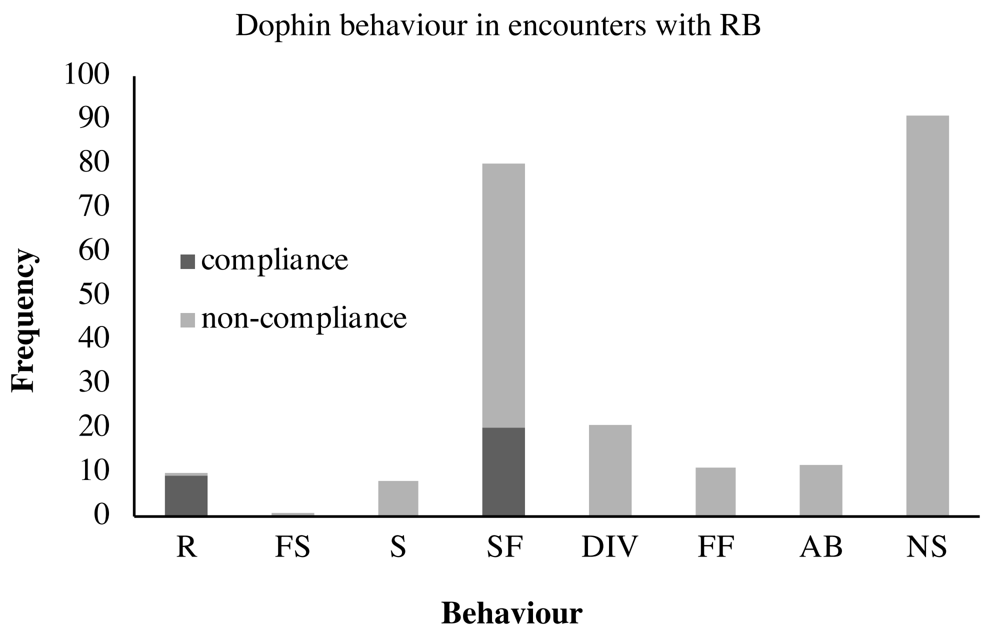

Figure 19. Dolphin behaviours recorded in encounters during which row boats (RB) were complying with the code and dolphin behaviours where RB were not complying with the code in New Quay, 2006-2018. In the graph, R - rest, FS - fast swim, S - socialise, SF - suspected feeding, DIV - diving, FF - feeding (fish seen), AB - aerial behaviour, and NS - normal swim.

Another type of boat which did not comply with the code was speed boats (SB), with a similar pattern to other boat types (Figure. 20).

In encounters with speed boats, the majority of events were when the boats were complying with the code (N=93) than when they were not (N=45). However, their compliance with the code was significantly less than for the other boat types. Dolphin behaviours which were recorded during encounters with speed boats were resting (R), fast swimming (FS), socialising (S), suspected feeding (SF), feeding seen fish (FF) and percussive behaviour (PB). The greatest changes were observed in behaviours resting (R), suspected feeding (SF) and diving (DIV) (Figure. 20). However, none of the described differences were significant (X^2=8.6, p=0.19).

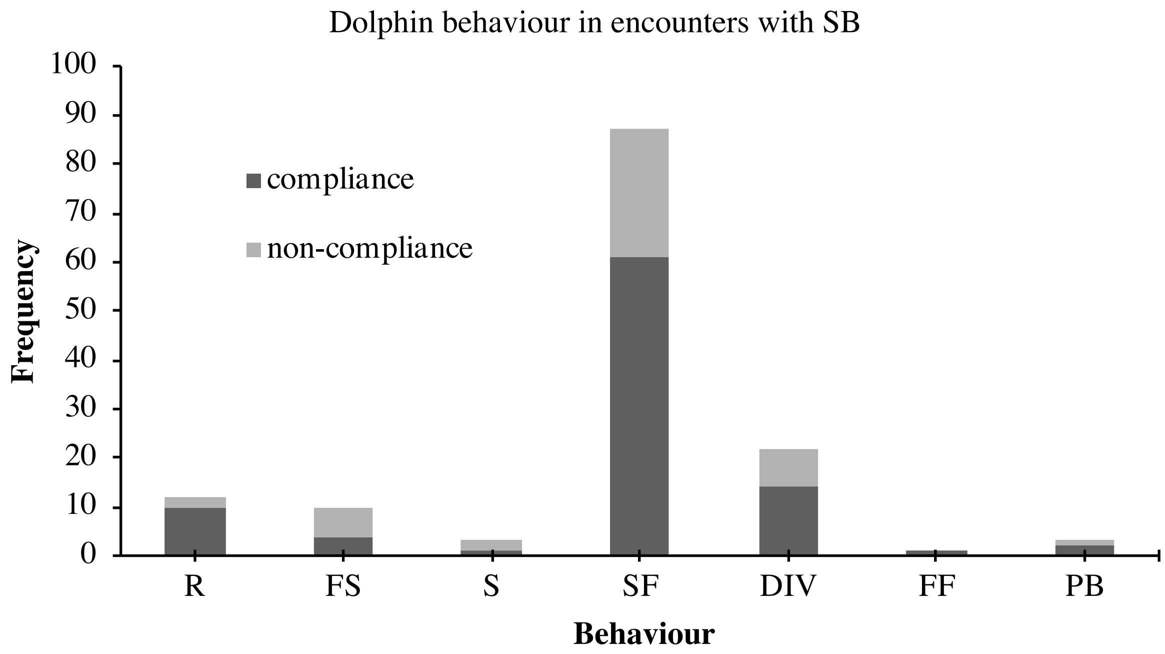

Figure 20. Dolphin behaviours recorded in encounters during which speed boats (SB) were complying with the code and dolphin behaviours where SB were not complying, New Quay, 2006-2018. In the graph, R - rest, FS - fast swim, S – socialise, SF - suspected feeding, DIV - diving, FF - feeding fish seen, PB - percussive behaviour.

The last type of boat observed with the smallest number of encounters when it was complying with the code was small motor boats (sMB) (Figure 21). In general, when observed on their own, sMB also complied with the code in the majority of encounters (N=160 out of 223). However, the difference between dolphin behaviours in encounters when sMB were complying with the code and when they were not, was significant (X^2=22.51, p=0.004). The behaviours performed in encounters with sMB were resting (R), fast swimming (FS), socialising (S), suspected feeding (SF), diving (DIV), feeding seen fish (FF), percussive behaviour (PB), aerial behaviour (AB) and normal swimming (NS) (See Table.4

for definitions). The greatest differences were observed in normal swimming (NS) which was performed more frequently when sMB were complying with the code, and at the same time the increase in fast swimming (FS) when they were not complying with the code (Figure 21). Other differences were between resting (R) which was observed only in encounters with sMB complying (Figure 21). Aerial behaviour (AB), diving (DIV) were performed most often when the code was complied.

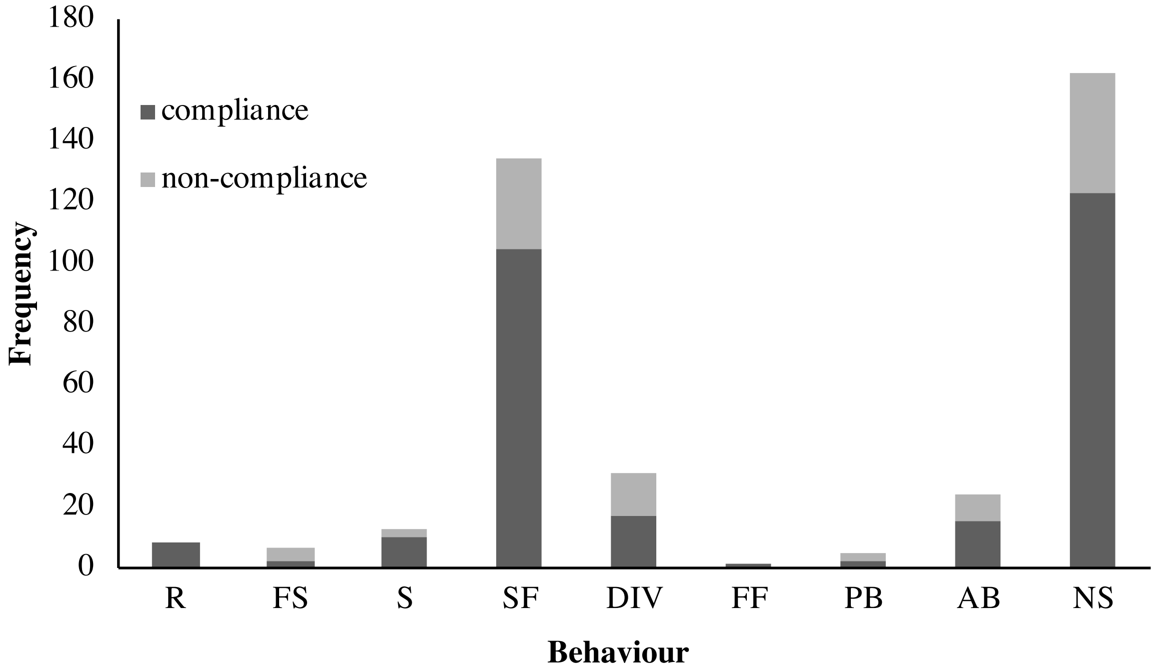

Figure 21. Dolphin behaviours recorded in encounters during which small motor boats (sMB) were complying with the code and dolphin behaviours where sMB were not complying with the code in New Quay, 2010-2018. In the graph, R - rest, FS - fast swim, S - socialise, SF - suspected feeding, DIV - diving, FF - feeding (fish seen), PB - percussive behaviour, AB - aerial behaviour, NS - normal swim.

3.3.3 Dolphin responses to boats complying and non-complying with the Code of Conduct

There were 327 positive responses and 508 negative ones during 835 encounters (compliance N=656, non-compliance N=179). There was a significant difference in dolphin responses to boats complying and not complying with the Code of Conduct ($X^2_{(2, 4060)}$ = 217.67, p=2.2*10^{-16}). Positive responses were more probable when boats were complying with the Code of Conduct (Figure 22).

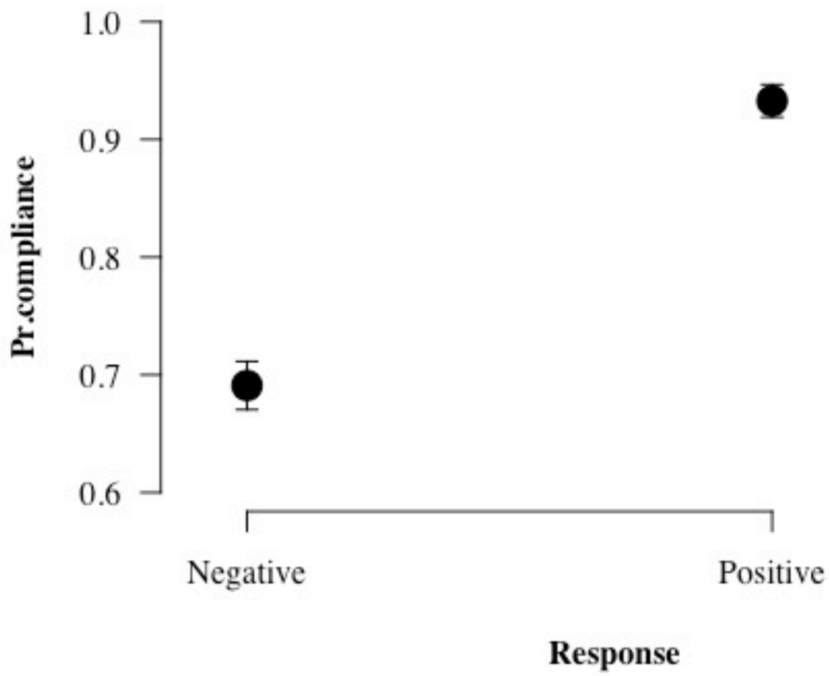

Figure 22. Prediction of the boats complying y=1 and non-complying y=0 with the code of conduct and associated dolphin positive and negative responses in New Quay, 2010-2018.

3.4 Dolphin behaviour changes in relation to transitions in boat traffic (before, during, after).

In June-July 2018, the data collected from the cliff and Pier in New Quay allowed for testing whether the transitions in boat presence (during) and absence (before, after), or the steady state (no transition) had an effect on the dolphin behaviour budget.

The number of transitions observed was 216, and the behaviours analysed were resting (R), surfacing (SURF), suspected feeding (SF), normal swim (NS), aerial behaviour (AB), diving (DIV), and socialising (S). None of those behaviours were performed at a significantly different frequency when comparing observations during and without transitions (Table 15). However, in some of the behaviours, a small difference between transition and non-transition events was observed. For instance, if resting behaviour or socialising was observed at all, it was more likely when there was no transition in boat traffic (Figure 23). However, suspected feeding was observed with higher probability when there were transitions in boat traffic.

Table 15. The Chi-square ANOVA (for GLM) results for differences between dolphin behaviours (R-rest, SURF-surfacing, NS-normal swimming, AB-aerial behaviour, DIV- diving, S-socialising) performed in transitions (before, during, after boat appearance) and without transition. Chi-square result, d.f. degrees of freedom, N-total number, p-significance value.

Behav.	R	SURF	SF	NS	AB	DIV	S
d.f=1	**N=400**						
Chi-square	**3.02**	**1.22**	**3.27**	**0.07**	**0.01**	**1.23**	**1.71**
p	**0.08**	**0.27**	**0.07**	**0.78**	**0.90**	**0.27**	**0.19**

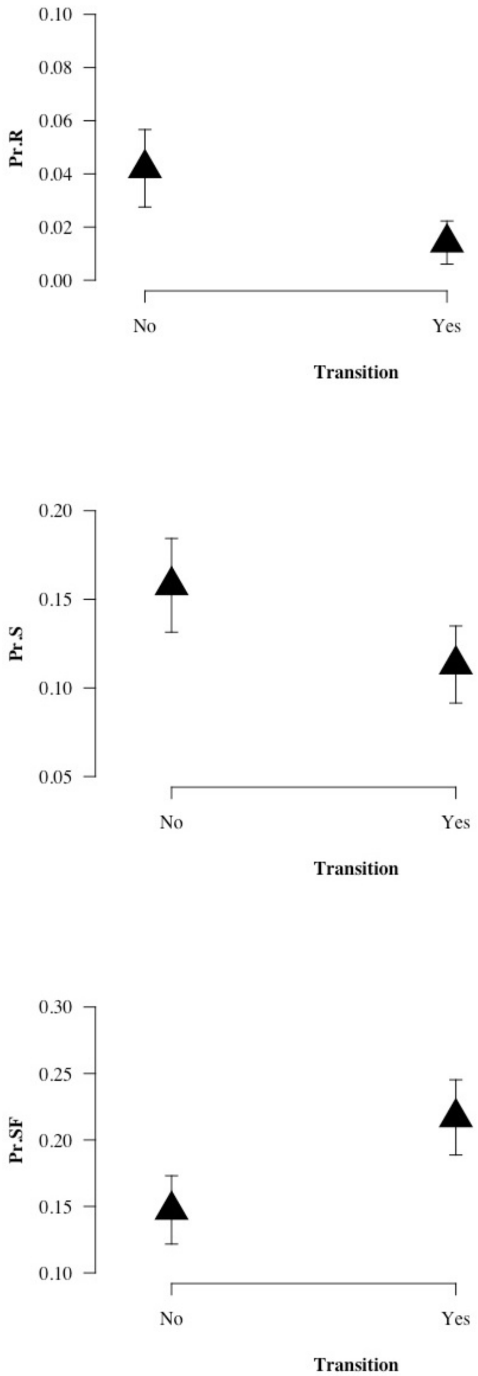

Figure 23. Patterns in probability of performance for some of the observed bottlenose dolphin behaviours (R-resting, S-socialising, SF-suspected feeding) during transitions and without transitions. Transition = observations between before, during or after boat approach, No transition = sightings without changes in boat traffic behaviour.

3.5 Changes in the total number of dolphins in accordance to changes in boat traffic observed during 2h land-watches.

There was a significant negative relationship between the presence of dolphins in the years 2006-2018 in New Quay, depending on the number of boats observed during the two-hour watches ($X^2_{(1,4373)}$ =10.44, p=0.001). If there were more boats observed, it was more likely that dolphins would be absent (Figure 24). There was also a significant negative relationship between the number of dolphins observed and the number of boats during a two-hour land-watch ($X^2_{(1,2642)}$ =4.47, p=0.03) indicating that the higher the number of boats, the lower the number of dolphins were observed (Figure 25). During a two-hour land-watch, the maximum number of boat passages observed was 140, and the maximum number of dolphins was 11.

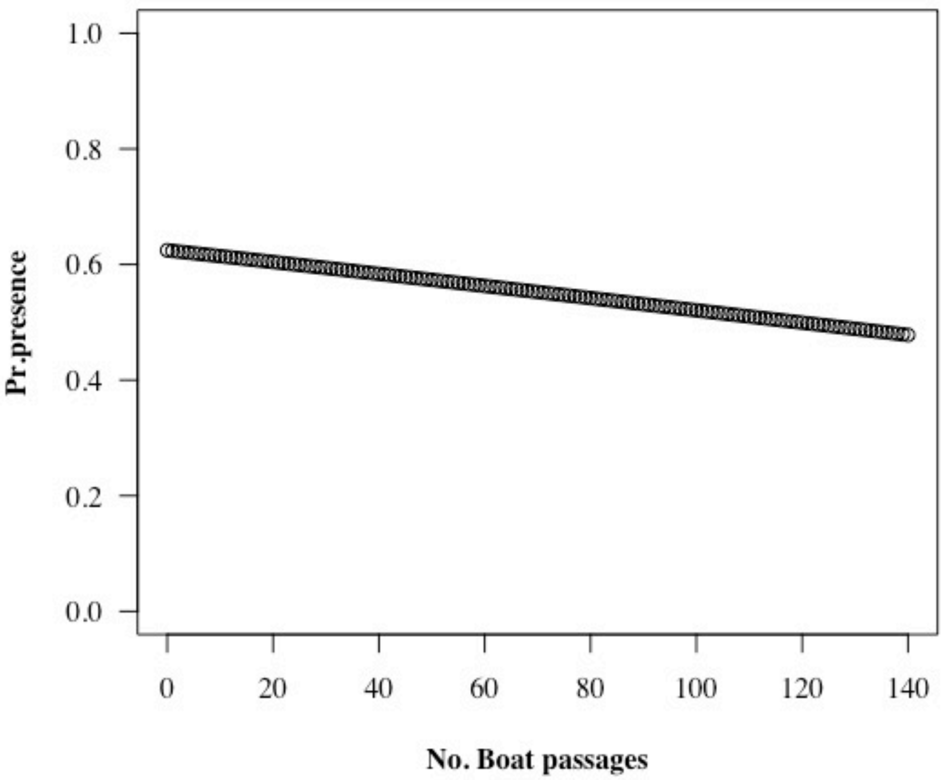

Figure 24. Prediction of bottlenose dolphin presence y=1and absence y=0 in relationship with number of boats passing in Cardigan Bay, New Quay during 2h land-watches.

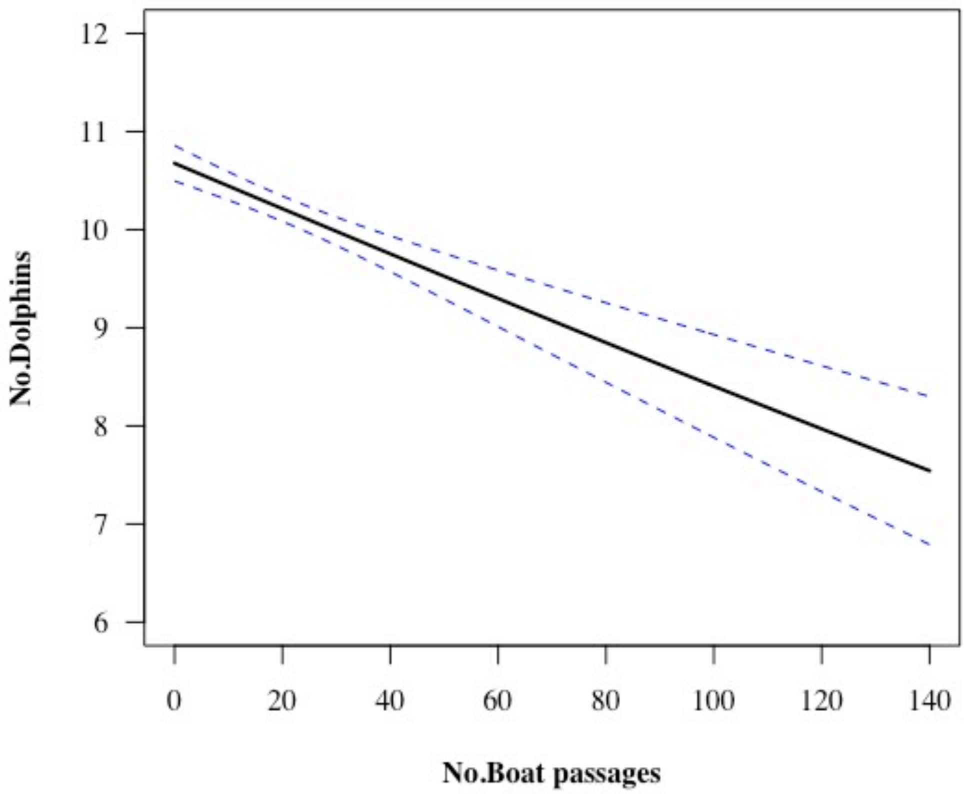

Figure 25. Relationship between number of dolphins and number of boat passages observed during two-hour land-watches in New Quay between 2006-2018 (May-August) together with the standard errors (dashed line).

There were no significant differences in dolphin group sizes with changes in boat traffic $X^2_{(1,2034)} = 0.02$, p=0.8. Most of the groups observed consisted of two dolphins (N=1364). The next most common number of dolphins seen in a group was three dolphins (N=467), followed by four dolphins (N=135).

3.6 Effect of environmental factors (sea state, tides) on boat traffic and bottlenose dolphin responses to boats.

The largest amount of negative and positive responses was recorded during sea state 1 and 2 between the years 2010-2018. There was no significant effect of sea state on the dolphin response to boats ($X^2_{(5,657)} = 2.71$, p=0.7) (Figure 26).

The One Way ANOVA analysis was conducted after testing that the assumptions of homogeneity of variance were met ($F_{(5,\ 643)} = 1.917$, p=0.09). Boat traffic has not been significantly affected by sea state within the range that watches were conducted ($F_{(5,643)} = 1.19$, p=0.31) (Table 16).

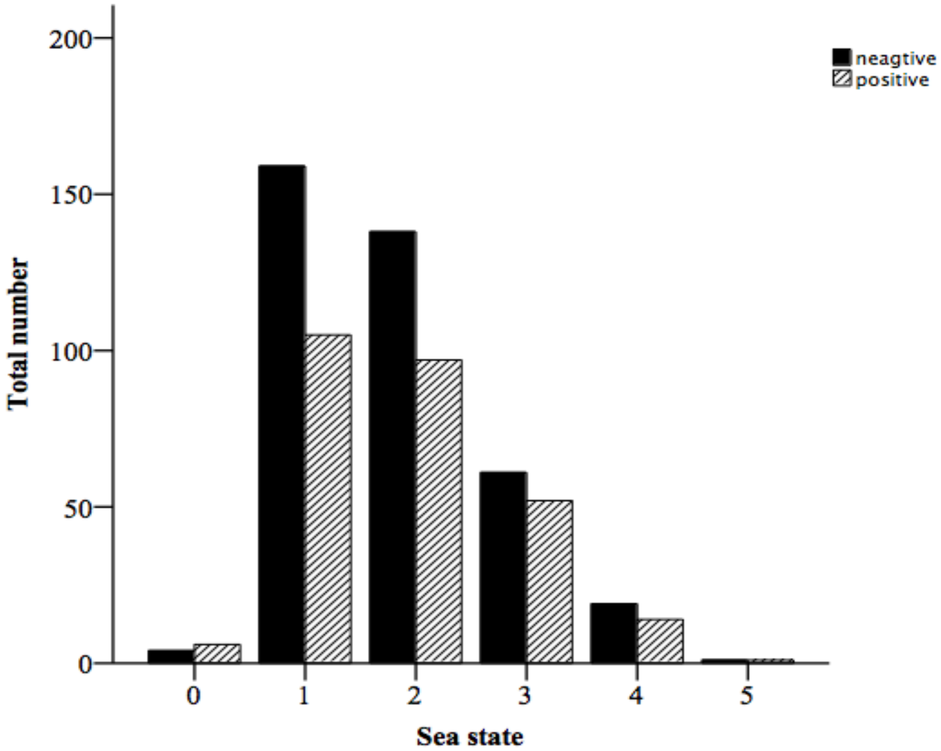

Figure 26. Total number of observations of negative and positive dolphin responses to boats in different sea state conditions (Beaufort scale) in New Quay between 2010-2018.

Table 16. One-Way ANOVA results on the effect of sea state on boat traffic intensity in New Quay. N-number of observations, M-mean, SD-standard deviation, F-value, p-significance level.

Sea state	**0**	**1**	**2**	**3**	**4**	**5**		
One-Way ANOVA							**F**	**p**
N	10	262	230	112	33	2	1.19	0.31
M	1.60	1.75	1.93	1.73	2.76	1.00		
SD	1.08	2.02	3.12	1.45	2.67	0.00		

There was a significant relationship between a rising tide and the response of dolphins to boats ($X^2_{(1,73)}$ = 4.36, p=0.04). When the tide was rising, there was a higher probability of recording a positive response of dolphins to boats while when the tide was falling, it was more likely that dolphins will respond to boats in a negative way (Figure 27).

However, there was no such pattern observed in dolphin responses to high and low tide times ($X^2_{(1,74)}$ =1.3, p=0.25). The number of boats observed within 300m from dolphins did not change significantly due to either a rising tide ($X^2_{(6,74)}$ = 5.45, p=0.49) or a high tide ($X^2_{(6,68)}$ = 3.31, p=0.789). There was no difference in a number of dolphins observed in accordance to changes in tide (low, high, rising, falling) ($X^2_{(3,403)}$ = 324.57, p=0.97).

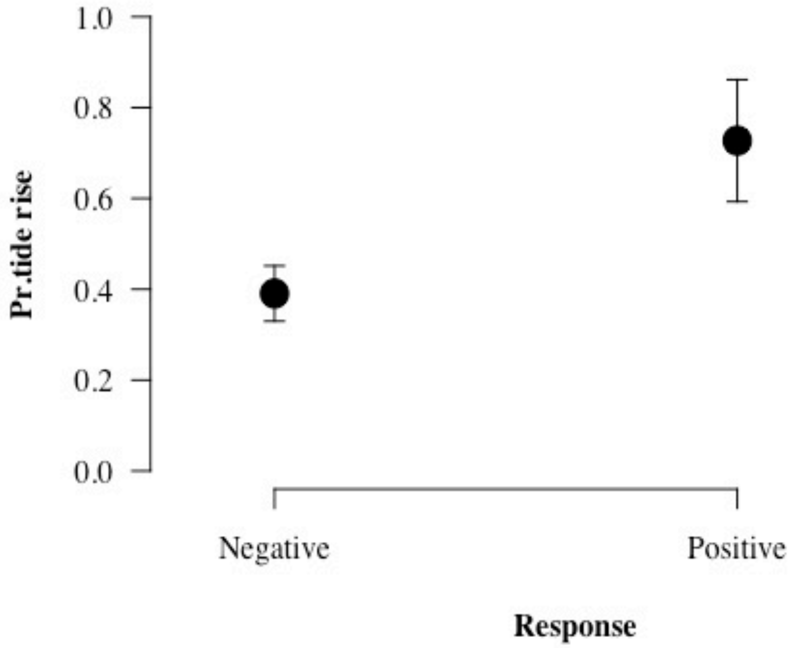

Figure 27. Prediction of a rising (1) and falling (0) tide with associated dolphin negative and positive responses to boat traffic (based on the time of the sighting and tide tables from willyweather.co.uk) in New Quay (June-July 2018).

4 Discussion

Boat traffic and its impact on bottlenose dolphin presence & behaviour has been a subject of interest for many scientists all around the world because of increasing concerns for their conservation (Acevedo, 1991a; Connor et al., 2000; Lusseau, 2004; Williams et al., 2014). Observations of dolphin behaviours and studies to identify causes for fluctuations in their performance are challenging due to the large number of possible influencing factors. These include environmental factors such as food availability, or anthropogenic impacts like boat traffic (Lamb, 2014). Differences in behaviour found by various studies may also indicate changes in other than those behaviours observed (Shane et al., 1986). Therefore, limiting the factors which might influence observations of dolphin behaviours is advisable. In New Quay Bay, studies on bottlenose dolphin behaviour and boat traffic have been conducted for the last 12 years using a non-intrusive method of dolphin observation, land-watches. This study allowed the detection of some short-term and long-term changes in dolphin behaviour in relation to boat traffic which is especially high during the summer months around New Quay (Gregory & Rowden, 2001; Pierpoint *et al.*, 2009).

4.1 Boat type

As has been previously shown by studies of boat traffic impacts on cetaceans, differences in parameters of various boat types might affect dolphin behaviours and their response towards boats. In a number of studies (Pierpoint & Allen, 2000, 2004, 2006; Hudson, 2014) conducted in southern Cardigan Bay, it has been shown that the boat types which were most abundant in the area were VPB. This has also been the case for this study. The fact that VPB accounted for the most abundant type of boat observed in New Quay is not surprising as the site is well-known for tourist wildlife tours, fishing and dolphin watching trips, which are increasing in rate during summer months (Gregory & Rowden, 2001). Studies by Pierpoint & Allen (2004, 2006), and the results presented by this study were consistent, indicating that the number of recorded encounters was the greatest for boat types like VPB and SB. Nevertheless, the data analysed by this study for the years 2010-2018 also found a large number of encounters of sMB. This had not been recorded by previously mentioned studies probably due to the fact that there was no division in recorded motor boats (e.g. no counts for small motor boats, middle sized motor boats. The number of small motor boats has increased in coastal waters in many places around the world as their popularity is higher nowadays due to easier accessibility and an overall trend towards more leisure activities (Buckstaff, 2004; Lemon *et al.*, 2006; Miller, et al., 2008; La Manna, 2010).

Several authors (e.g. Pierpoint & Allen 2004, 2006; Bristow & Rees, 2009; Veneruso & Evans., 2012; Hudson, 2014) have discussed differences in dolphin behaviours and their responses towards different boat types, and have found the greatest amount of negative responses towards various motor boats, and this was also found to be true for this study. Speedboats had the greatest negative effect on dolphins. However, dolphins also responded negatively towards sMB and VPB although the results were non-significant. Hudson (2014) found the most negative reactions occurred from sMB but observed dolphin neutral and positive responses towards VPB (though non-significant). These differences might be due to the fact that Hudson (2014) compared differences in dolphin neutral, negative and positive responses towards each of the boat types separately whilst this study compared differences in probability of positive dolphin response towards different boat types, revealing the smallest differences in the two marginal dolphin behaviours (negative and positive response). In this study, boat types were divided into those most frequently observed, as discussed above, and those boat types recorded less frequently. For both less and more frequently recorded boat types, the number of negative responses was higher than the number of positive responses. The higher amount of negative responses has been previously mentioned by several authors (Veneruso & Evans 2012, Sampson & Kelsall 2013, Hudson 2014, Perry 2016) and cited as explaining observed decreases in the presence of dolphins related to increases in boat traffic across years. The increased boat traffic between 2006-2018 was not observed in this study, and therefore the higher number of negative responses could possibly be explained by other factors such as boat activity varying for each boat type and dolphin responses to it.

4.2 Boat names

Dolphins responded significantly differently to less frequently observed boat names. The fact that less-frequently observed vessel names (AB14, GAL, M116) more often elicited a negative response than the more frequently recorded names (ORCA) might indicate that dolphins at New Quay became partially acclimated to the boats they know, but were more likely to respond negatively to the boats which appear at this site less frequently (see also Acevado, 1991a,b; Gregory & Rowden, 2001; Wright et al., 2007). Negative and neutral responses which have not been included in these analyses seem to be recorded at the highest rate for this site which might suggest that dolphins have mixed responses towards both boats which they know and the ones which they know less or do not know at all (Hudson, 2014). This might depend on a mixture of factors, e.g. dolphin responses might be different when they are feeding than when they socialise because of the amount of disturbance which might be caused by boats at that time (Parsons, 2012).

The possible explanation of different responses by dolphins towards boat names might be due to boat parameters such as size, engine type which generate different frequencies of propeller cavitation sound. The other explanation for varied dolphin responses to boats is that they behave in a different manner thus determining the animal's response. For instance, the majority of boat names observed to which dolphins reacted negatively in this study were medium-sized fishing boats e.g. AB14, M116. Some of the fishing boats might have a negative effect on bottlenose dolphins because they scare away their prey with noise, or disturb dolphins from hunting successfully due to sound masking (Popper & Hastings, 2009; Tyack, 2009). Taking also into consideration the fact that fishing boats might stay a close distance to dolphins for a longer period of time as they are fishing this might mean that this kind of noise exposure is of too high a level for dolphins to be around it. As was shown by this study, such situations can result in a dolphin negative response leading to it leaving the area where the fishing boat remains active.

4.3 Boat behaviour

As previously mentioned in the introduction, boat behaviour in parts of Cardigan Bay SAC is being regulated by Codes of Conduct established in 2004 by Ceredigion County Council (CCC) (CCC, 2008). Within Cardigan Bay, there are two Special Areas of Conservation: Cardigan Bay SAC and Pen Lyn a'r Sarnau SAC. The areas in the northern part of Cardigan Bay including Pen Lyn a'r Sarnau are much less controlled by boat traffic regulations. Therefore, it may have an impact on dolphin responses to boats in all of Cardigan Bay as individual dolphins can range across all of Cardigan Bay (Lohrengel & Evans, 2016, 2017). This study revealed that in the protected area there was a significantly higher probability of a positive dolphin response to boats when complying with the Codes. There are different regulations in boat traffic depending on the country. For instance, boat-traffic regulations in South West Australia differ from those restricted in Cardigan Bay, mainly with one rule saying that there cannot be more than two boats within 100m of dolphins (Allen et al., 2004). Despite an overall good response by dolphins to compliance with codes in New Quay, it might be that the high frequency of neutral and negative responses recorded is affected by the fact that the same group of dolphins has been exposed to the simultaneous approach of many boats. Cardigan Bay codes do not regulate the number of boats which can approach animals over a certain amount of time, and, therefore, the same group of dolphins can be exposed to boat encounters for a long time (Garrod & Fennell, 2004).

The observed difference in dolphin responses to boat types in this study has been affected by different levels of compliance with the codes by different boat types (2006-2009 and 2010-2018). Dolphins responded more positively to boats complying with the codes than to the boats that did not comply with them. The type of boat observed to comply most with the codes was VPB whilst the lowest observed compliance was for sMB, SB, and RB. Dolphin behaviour has changed significantly in response to non-compliance of codes by small motor boats and speed boats. In both cases, the most affected behaviours were resting, suspected feeding, and socialising. Those behaviours are of high importance for cetacean health, and overall well-being of the population. The decrease in time spent on resting and socialising might affect the animal's ability to reproduce successfully (Nowacek & Wells, 2001; Lusseau, 2004; Holt *et al.*, 2015). For instance, Miller *et al.* (2000) found that low-frequency sonar of boats causes humpback whales to lengthen their songs which could affect their breeding success as singing in this species is thought to be a crucial element of male and female mating. Longer singing may also indicate that whales cannot communicate so well due to the noise. Therefore, it is important that bottlenose dolphins in New Quay remain undisturbed when they are resting or socialising.

4.4 Dolphin occurrence in association with boat traffic

This study has found significant differences in dolphin presence depending on boat traffic. The number of dolphins decreased with increasing boat traffic. Pierpoint et al. (2009) compared the average count of boats to counts of dolphins and found that dolphin numbers decreased with increasing boat traffic, which is consistent with this study. The possibility of human disturbance by vessels particularly recreational craft, has been mentioned by Lohrengel et al. (2017). The present study describes land-watch observations conducted at a single site in Cardigan Bay, New Quay, whereas other studies have applied to a wider region (Feingold & Evans, 2012; Veneruso & Evans, 2012; Lohrengel & Evans, 2016, 2017). The number of dolphins observed in New Quay harbour also varied between years. Cetacean avoidance of locations with high boat traffic has been recorded in several places around the world e.g. Shark Bay Australia (Bejder et al., 2006), New Zealand (Lusseau, 2004), and Hong Kong (Piwetz et al., 2012). Those studies found an overall decline in dolphin presence, which was not the case in this study as New Quay dolphins do not appear to leave the area. New Quay remains one of the most important places for bottlenose dolphins in Cardigan Bay, providing shallow waters for nurturing calves and a richness of food. The summer season in which this study took place is one of the most important times for dolphins in Cardigan Bay. This may be associated with the breeding season but also with a high density of mackerel and herring migrating towards the estuaries especially at the end of the season (Feingold & Evans, 2014). Vergara Pena (2014) has mentioned that the difference in bottlenose dolphin site usage between years could be accounted for by shifts in pelagic fish distribution. As was discussed by Baines & Evans, (2012), Veneruso & Evans, (2012), and Evans *et al.* (2015), sites such as Cardigan Bay, especially Special Areas of Conservation where bottlenose dolphins are observed on a regular basis, are of great importance. Within Cardigan Bay, the sites where bottlenose dolphins are distributed at the highest rate on a regular basis cover areas from Aberaeron to Cardigan, more precisely off New Quay Headland, Ynys Lochtyn, Mwnt, Pen Peles, and Aberporth (Feingold & Evans, 2014). This seems to be the case as dolphin distribution in Cardigan Bay suggests that although there is an increase in offshore populations, these have been observed mainly north of New Quay, whereas the coastal populations are recorded regularly from year to year (Ugarte & Evans, 2006; Pesante, 2008; Feingold & Evans, 2014; Norrman et al., 2015). New Quay remains an important place for dolphins despite the threat that boat traffic may pose (Beale & Monaghan, 2004). Presumably it is worth the risk since this study indicates that dolphin presence has not changed much over the years. This theory is consistent with the one discussed by Gill et al. (2001) which suggests that animals affected by anthropogenic disturbance may remain there to perform important activities such as feeding, even if it means experiencing a high risk of disturbance, if there is no other area of similar suitability close by. This interpretation of the presence of a bottlenose dolphin population in New Quay was also suggested by others (Gregory & Rowden, 2001; Bristow & Rees, 2001; Hudson, 2014; Lamb, 2014). Although New Quay is not the only suitable site for bottlenose dolphins in Cardigan Bay, it is one of those sites mostly occupied by dolphins, and therefore is thought to be of high importance for them.

4.5 Dolphin behaviour changes in association with transitions in boat traffic (before, during, after).

The decrease in performance of crucial behaviours such as resting, feeding and travelling between transitions of boat presence and absence was observed also by Arcangeli & Crosti, (2009) in Western Australia. Another study demonstrating changes in behaviour as important for the population was conducted by Lemon *et al.*, (2006) who analysed dolphin behaviours before, during and after experimental approaches of a powerboat, and found that dolphins when approached, switched from milling to travelling (9 out of 12 powerboat approaches). The change in behaviour noted by Lemon et al. (2006) was suggested to be due to the fact that dolphins have learned that a powerboat is approaching them and thus started to avoid it. The list of studies that have observed changes in behaviours between boat presence and absence is long, as well as differences between the type of behaviours that they observed to change. This study found non-significant patterns in a decrease in behaviours such as socialising and resting, and an increase in suspected feeding between transitions of boat presence and absence (before, during, after). This pattern might indicate that bottlenose dolphins in New Quay increase feeding because they cannot socialise and rest in the presence of boats. More studies on transitions between behaviours would be needed to provide sufficient background for this theory, but such explanations of similar changes in dolphin behaviour were already suggested by Wright *et al.* (2007). It was suggested that chronic stress experienced by marine mammals can lead to increased secretion of GCs (Glucocorticoids) which in extreme situations (constant exposure to the source of chronic stressor) may be even passed by the mothers on to offspring, and lead in extreme situations to shortened lifespan and health problems (Wright et al., 2007; Vyas et al., 2016).

Hudson (2014) observed differences in site usage indicating the importance of two main places (the areas near New Quay Head, and within the Harbour, the areas near Cardinal Buoy indicating those were important feeding areas characterised by shallow waters with a reef. The conclusion was that those sites are used by a smaller number of boat types as not all of them can access the area due to its shallow character. If resting and socialising behaviours are substituted with feeding, then dolphin might try to change the feeding area unless some other psychological or physiological factor encourage them to do so. Based on the fact that dolphins are faithful to the same sites for feeding, it is less likely that this theory applies to the New Quay dolphins. Nevertheless, studies on individual responses of both resident and transient dolphins could reveal if that theory is applicable for any of the dolphins within New Quay Bay.

4.6 Environmental factors, and their effects on boat traffic and dolphins

All of the above relationships between boat traffic and dolphin behaviour must be taken with caution as there are multiple environmental factors which might have affected the observed patterns. These have been observed independent of dolphin responses with boats. For example, although the sample size for assessing the influence of tides (low, high, rising, falling) was small, when the tide was rising, the number of positive dolphin responses towards boats was also higher. According to Gregory & Rowden (2001), at both Ynys Lochtyn and New Quay, dolphin movements have been correlated with tides, with dolphins moving with the tidal flow or during slack water, in relation to feeding. Nevertheless, there were no diurnal patterns in the dolphin movements. The relationship between dolphin responses and tides was tested in the current study and appeared to be significant, although more studies are recommended to gain more significant and informative results. The larger number of positive responses recorded during falling tides may be correlated with feeding behaviour which during a rising tide could be easier for prey capture, as was explained by Mendes *et al.* (2002) and Waggitt *et al.*, (2018). During a falling tide, boat disturbance might be perceived more negatively by dolphins due to the increased difficulty of successful hunting in the presumably noisier environment. Dolphin responses to vessels may be related to behaviours engaged in at the time of the boat's approach (Lemon et al., 2006). For instance, bottlenose dolphins in New Zealand were recorded to respond more often negatively to the presence of boats when socialising (Constantine & Baker, 1997).

4.7 Evaluation

The limitation of this study was the short-time for field work needed to answer some new questions which could not be addressed with previously collected data. There might be bias in both data gained from SWF and from my observations. The data might be biased by the fact that many observers participated in data collection over all of the years, and there might have been differences in how different observers perceived the same behaviours of dolphins. There is also the possibility that the same individual dolphins were reported more than once as no photo-ID was used in this particular study. Another issue that applied to the collection of data in June-July 2018 was the choice of time intervals in which observations of dolphin behaviours were made before, during and after boat approaches that would allow for observing quick changes in dolphin behaviour and at the same time would be possible to record and not miss important sightings.

Therefore, four-time intervals were tested at the beginning of the study: 15-minutes, 5- minutes, 3-minutes and 1-minute. The 5-minute interval was chosen for this study to be the most adequate as it allowed for capturing changes in dolphin behaviours and at the same time allowed the observer to record those.

4.8 Suggestions for future studies

For future studies, I would recommend continuing looking for the effects of boat traffic impacts on mother-calf pairs and comparing it with other dolphin responses. As has been discussed above the New Quay area is of high importance for nurturing calves (Pierpoint *et al.*, 2009; Baines & Evans, 2012), and the study by Hudson (2014) has shown some differences in dive durations of mother-calf pairs and focal animals. Therefore, finding the above-mentioned differences in behaviours would possibly allow for recording more differences in responses towards boats. Also, I would recommend considering more environmental factors such as water pollution, tides and sea state which might be important at this study site, and have an additional impact on dolphin responses towards boats.

For conducting field work, I would not recommend splitting it into two locations unless there is enough time for conducting a valuable number of watches at different sites and comparing them. This is important as previous studies such as Hudson (2014) have shown that there is a difference in responses of dolphins to boat traffic at the two sites that she included in her analyses (Headland and Pier). Also, the current study has analysed differences in dolphin behaviour between presence and absence of boats in the area of observations (based on recorded before, during, after) transitions. It could be valuable to conduct more studies on such differences as they might indicate significant differences which have not been revealed in this study (possibly due to small number of samples), but which have shown some weak patterns in important behaviours such as socialising, resting and suspected feeding, and potentially could be used to gain more information on long-term changes in behavioural budget.

4.9 Conclusions

The findings of this study indicate that there do appear to be long-term changes in dolphin behaviour and occurrence at New Quay, with dolphins responding to boat traffic by lowering their abundance during the highest traffic. This may be particularly the case for motor vessels that do not comply well with the code of conduct, such as speed boats and other small motor boats. Nevertheless, assessing the consequences of long-term changes for the population is a difficult task (Lusseau, 2003b; Lussean, 2004; Bejder, 2005; 2006 Williams et al. 2006). Finding evidence that boat traffic has a long-term consequence on dolphin health and overall population well-being can be assessed either based on the fact that dolphins have left the site which was not the case in this study, or based on information that long-term consequences of boat traffic on the population had occurred (Nowacek & Wells, 2001). It is known that boat traffic is causing short-term changes which also have an impact on animals as discussed in this study. In New Quay, the bottlenose dolphin population is experiencing a number of short-term changes, e.g. shortened times resting and socialising, described as changes in surface behaviours during encounters, which might be perceived as longer-term changes due to their repeatability across years (2006-2018). Studies by Bejder et al., (2006), Lusseau, (2004), Seuront & Cribb, (2011) discussed the consequences of chronic short-term stress and concluded that it might eventually cause long-term changes in a population e.g. through health issues. It would be interesting to find what energetic costs dolphins pay for constant changes in behaviour. This would allow a further view on the character of observed changes. This might be especially important as the bottlenose dolphin population in New Quay is of both a transient and resident character, and, therefore, what is being observed in New Quay might not only be a result of what is changing at this site but also a result of individual dolphin experience gained during travelling through different waters.

Due to changes in important dolphin behaviours such as a decrease in resting and socialising in the presence of boats such as SB and sMB that were not compliant with codes of conduct, it might be advisable to add to the codes of the Cardigan Bay SAC, indicating the consequences for not complying with codes, and potentially creating small no-access areas which would possibly allow dolphins to perform those behaviours crucial for health and well-being. This might be especially important as this study has found that the number of motorboats such as sMB is the second highest after VPB at this site, indicating that their impact, especially when not compliant with codes, might be of great importance. Nevertheless, more studies on different types of dolphin behaviour and transitions in behaviours correlated with changes in boat traffic might help to identify what kind of physiological and psychological changes boat traffic cause for the bottlenose dolphin population in New Quay.

In conclusion, this study has found mainly short-term changes in bottlenose dolphin behaviour in New Quay, indicating that the character of boat traffic (boat number, type, name, activity) indeed has effects on dolphin responses. Although the majority of dolphin responses not included in the analyses were neutral, there was also a high rate of negative responses. This was concluded to be influenced by the fact that New Quay is an important calf nurturing and feeding area for dolphins and therefore is worth taking the risk of facing daily boat traffic. Boats operating regularly in New Quay Bay mainly observed the code, which brought a positive response of dolphins.

5 References

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6 Appendix

6.1 A1- Sea Watch Foundation land-watch form (modified), New Quay Harbour

sea watch FOUNDATION

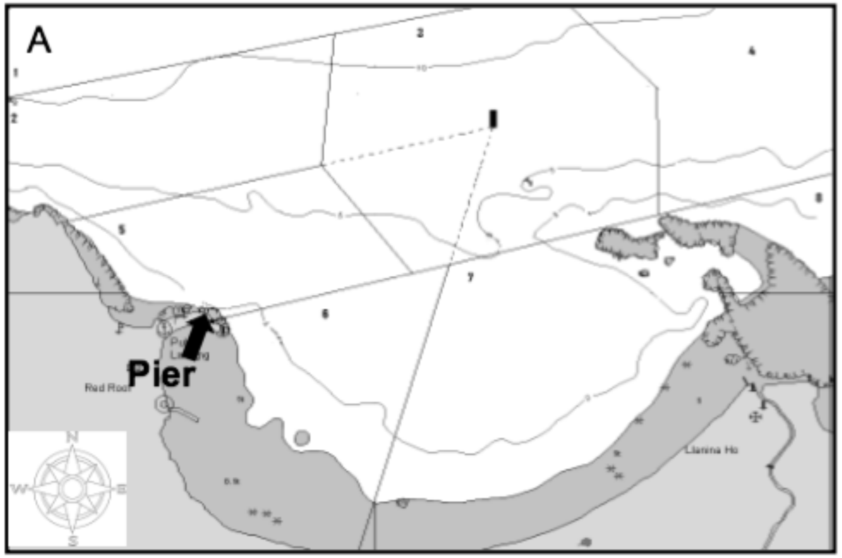
NEW QUAY LAND WATCH: EFFORT Name: Date:

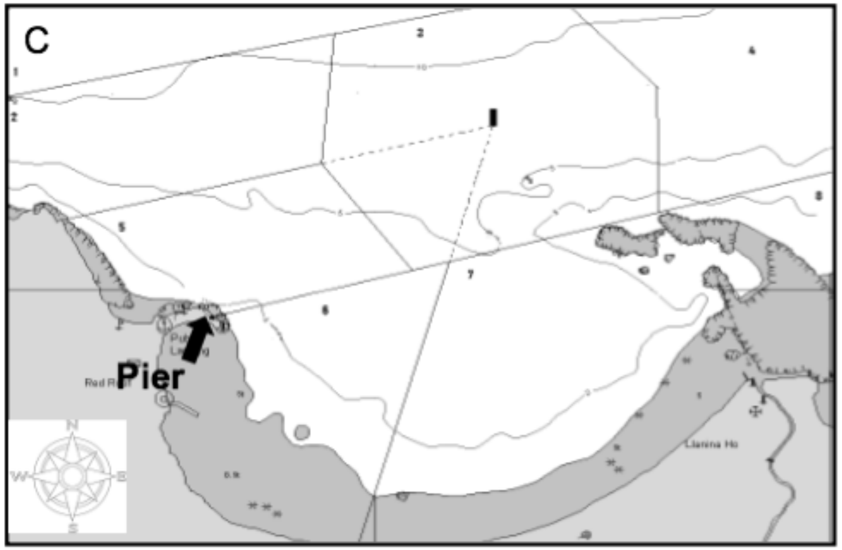
Map	Effort time (GMT/BST)		Sea	Wind	Visibility	Sighting?	Boat enc	Notes
	Start	End	state	direction			no.	
A								
B								
C								
D								
E								
F								
G								
H								

Number of boats seen

BOAT TYPE		Log	Total	BOAT TYPE		Log	Total
sMB	Recreational motor boat <15m			RB	Row boat, kayak or other paddled craft		
mMB	Recreational motor boat 15-30m			JS	Jet Ski		
SB	Racing type speedboat or RIB			R	Cetacean research boat		
YA	Any boat under sail (including windsurfer)			FE	Ferry		
FI	Fishing boat			LS	Ship >30m		
VPB	Visitor passenger boat						

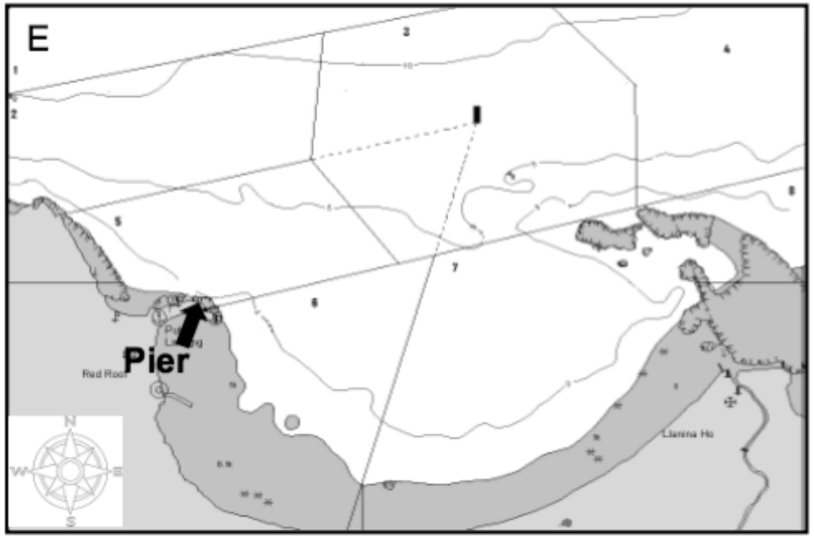
NEW QUAY LAND WATCH **Name:** **Date & watch start time:**

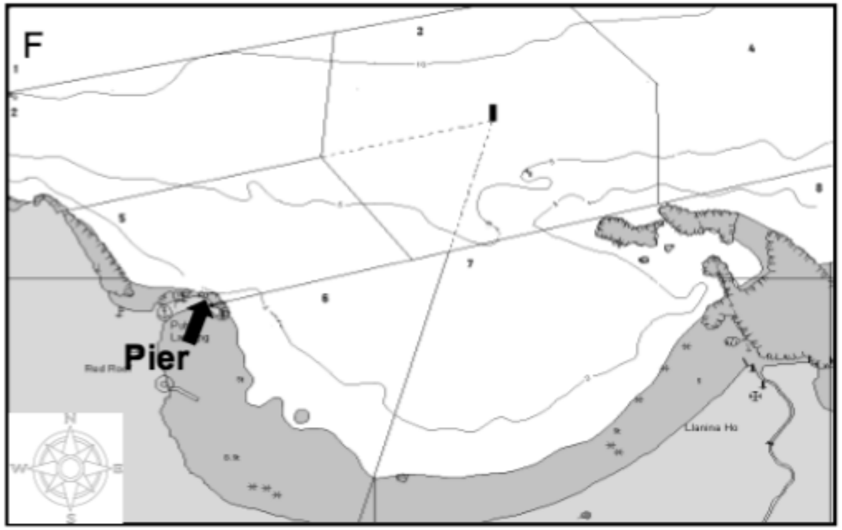


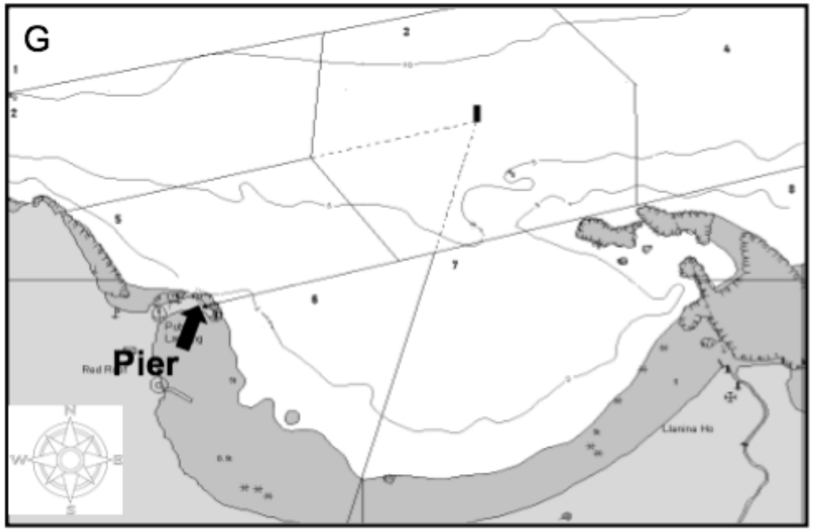


Write the species, number animals & behaviour in the correct location on the map. Note the heading direction with an arrow if there is one. Also add boats that involved in an encounter with a 'X' & boat name/type.

NEW QUAY LAND WATCH **Name:** **Date & watch start time:**







Write the species, number animals & behaviour in the correct location on the map. Note the heading direction with an arrow if there is one. Also add boats that involved in an encounter with a 'X' & boat name/type.

Behaviours recorded in interval: Observer: Date: Site:

			Encounters																								
Set	Time (BST)	Map	Boat type	Boat name	No. boats <300m	Distance to animals	Boat behaviour	Cet. behaviour															Reaction to boat				When recorded: before, during, after
								R	SURF	NS	FS	S	SF	DIV	FF	AB	PB	U	O	B	GS	GF	**A**	**T**	**N**	**U**	

6.2 A2- Sea Watch Foundation land-watch form (modified), Coastal path, view point, New Quay.

6.3 Residuals for GLM and GAM tests

1. Boat types and dolphin response residuals for GLM-more frequent

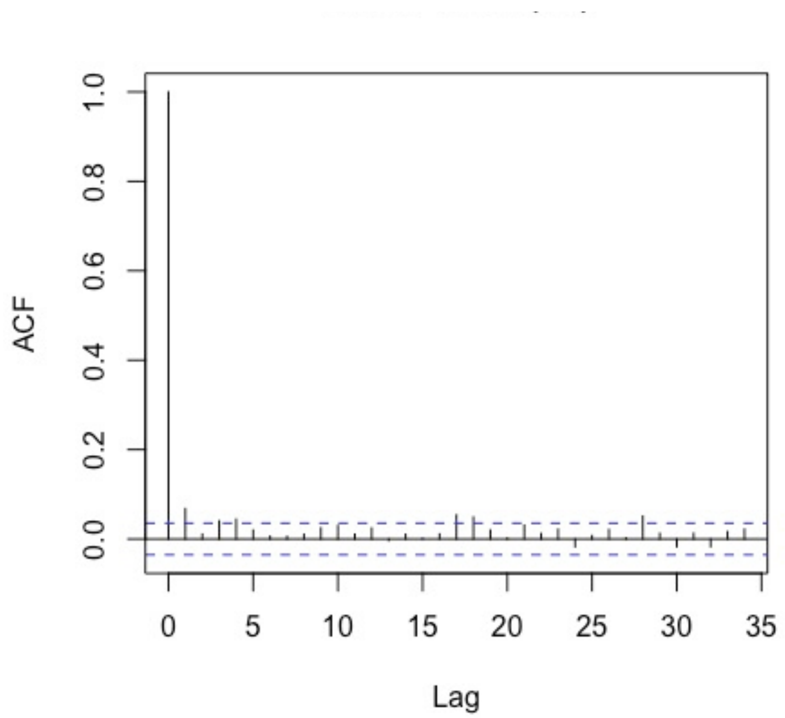


Figure A1. Residuals-boat types (more frequent) vs dolphin response

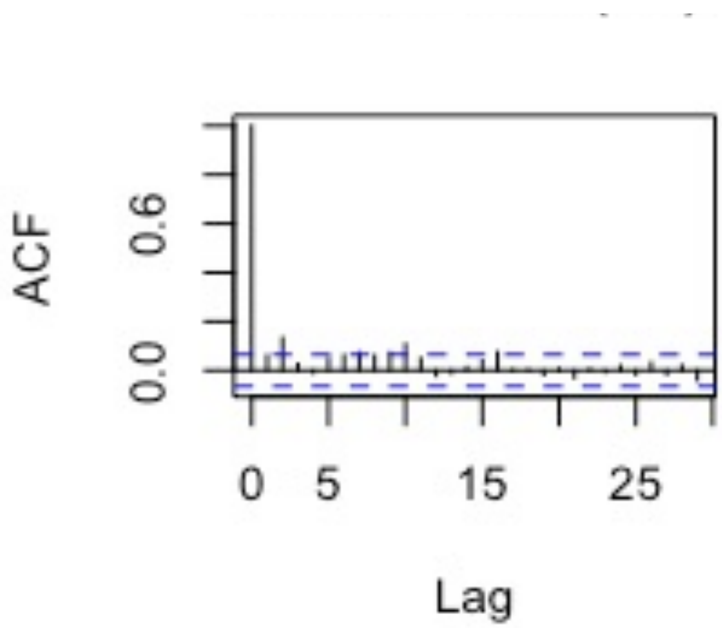


Figure A2. Residuals- boat types (less frequent) vs dolphin response

2. Boat names residuals for GLM

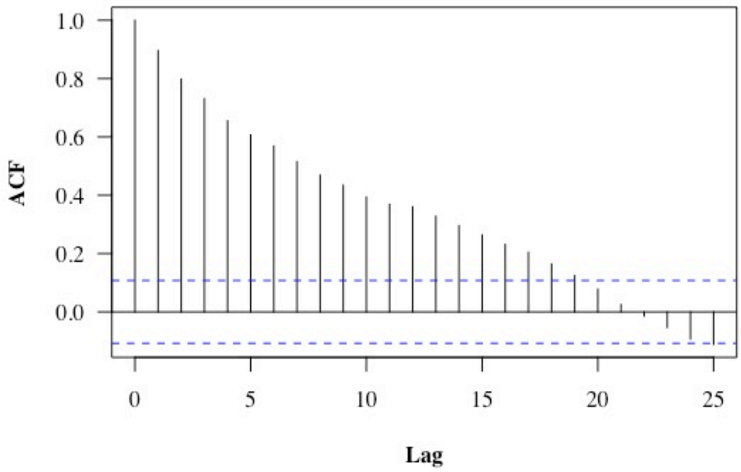


Figure A3. Residuals for binomial GLM testing differences between dolphin responses and less frequently reported boat names.

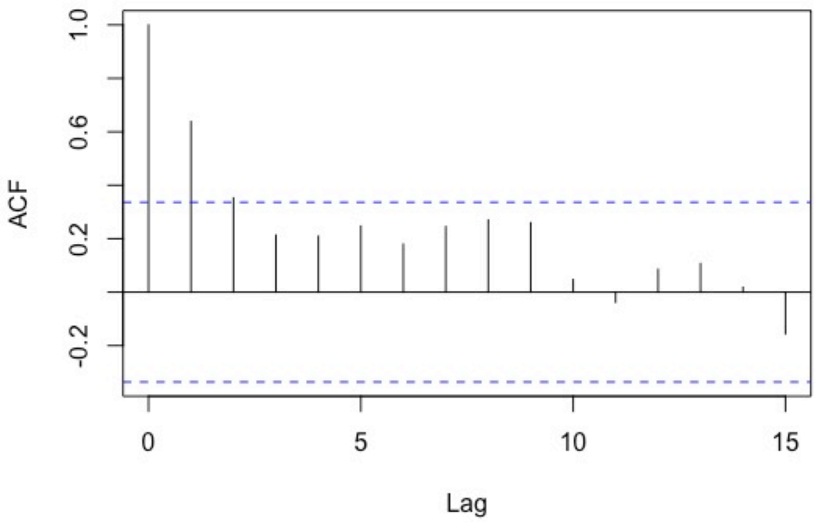


Figure A4. Residual for binomial GLM testing differences between dolphin responses and most frequently recorded boat names.

3. Compliance with codes by year, residuals for GLM

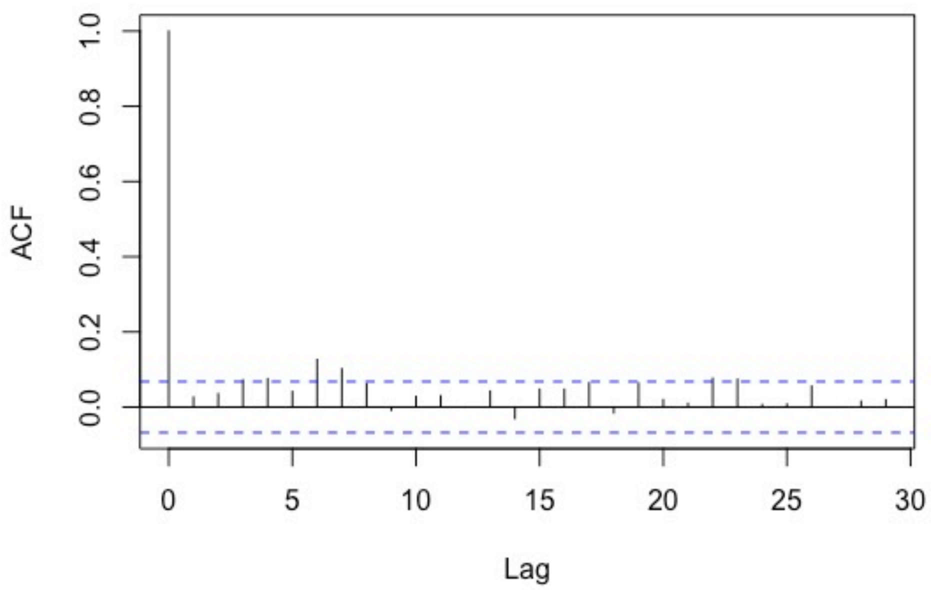


Figure A5. Residuals-compliance with codes and dolphin response.

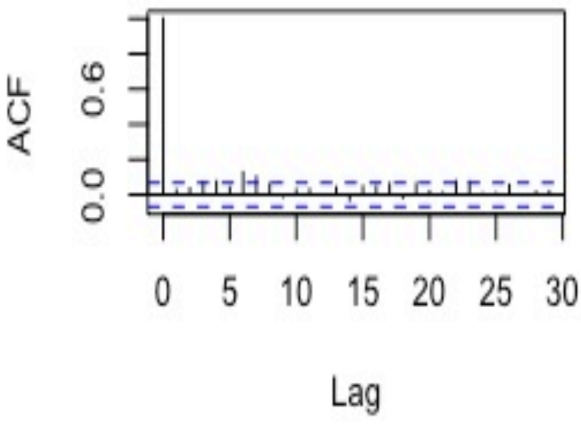


Figure A6. Residuals for compliance with codes and associated dolphin responses.

4. Boat type compliance 2006-2009 and 2010-2018, GLM more frequently recorded boat types.

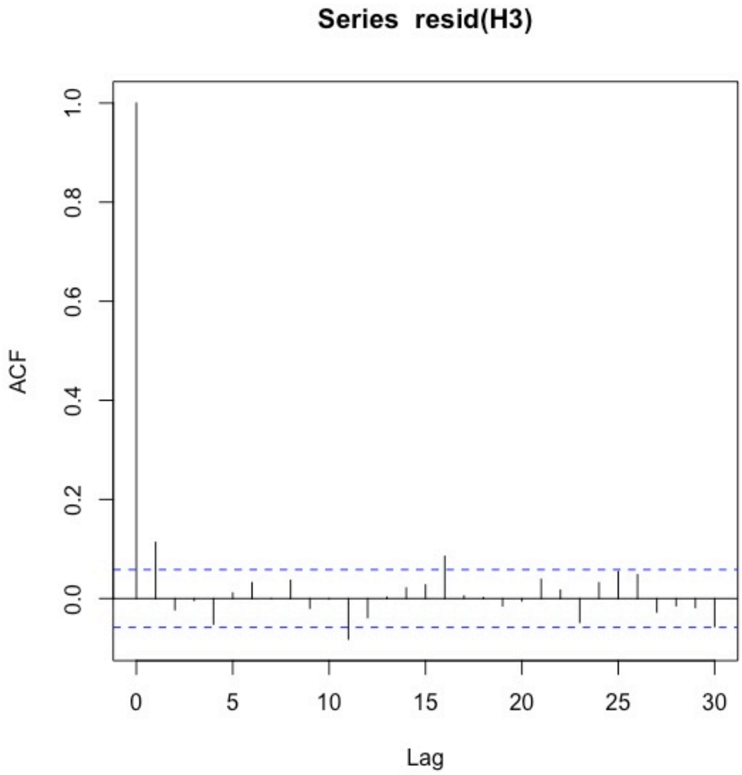


Figure A7. Residuals for test of compliance in more frequently recorded boat types 2006-2010

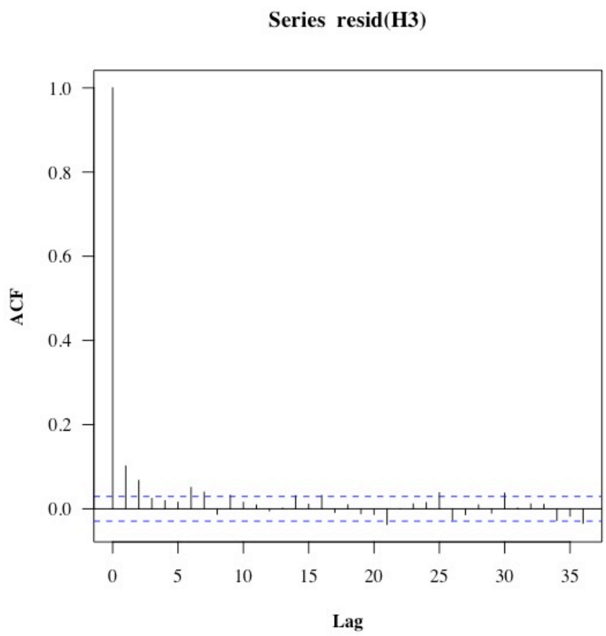


Figure A8. Residuals for test of compliance in more frequently recorded boat types 2010-2018

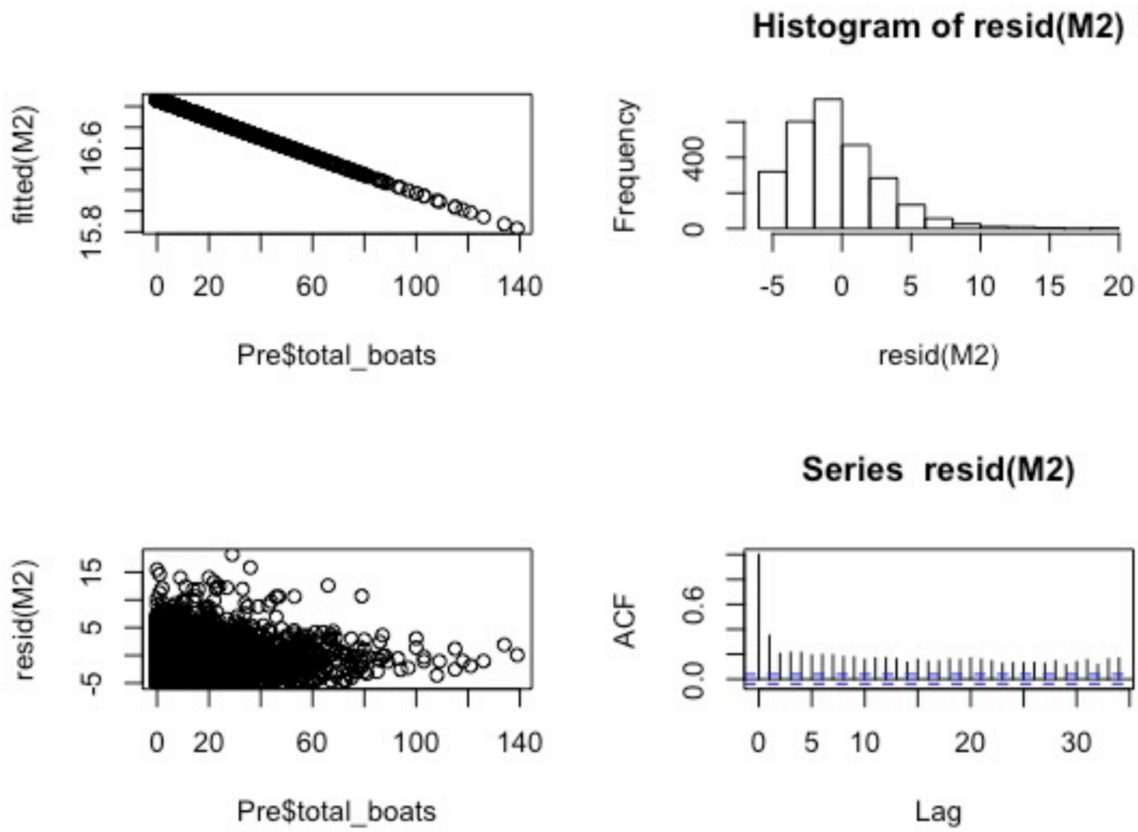


Figure A9. Residuals, histogram for Poisson GLM testing relationship between dolphin number and number of boat passages

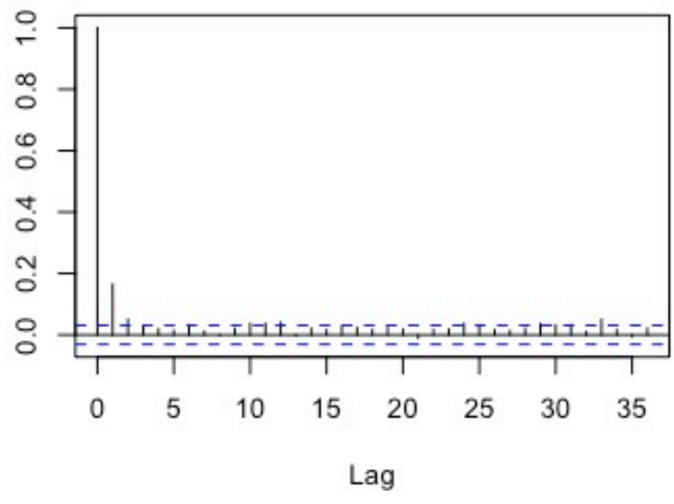


Figure A10. Compliance with codes by year, residuals

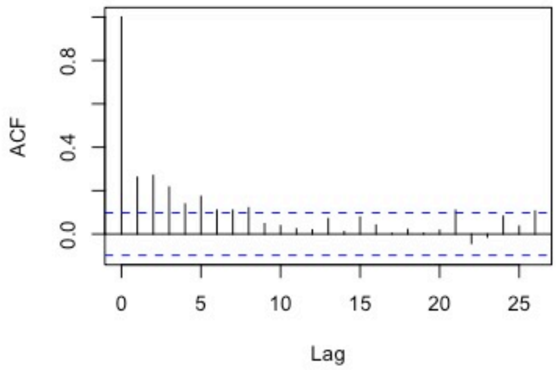


Figure. A11 Residuals for boat traffic transitions vs suspected feeding

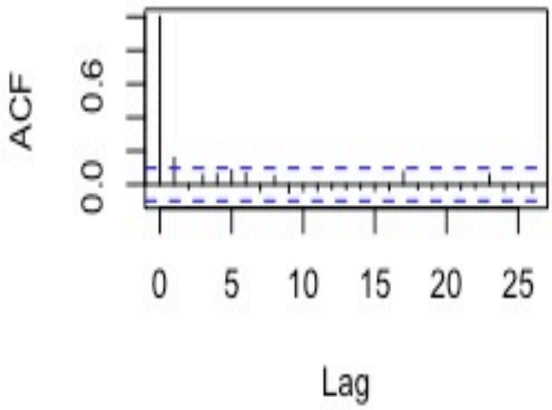


Figure A12 Residuals for boat traffic transitions vs resting

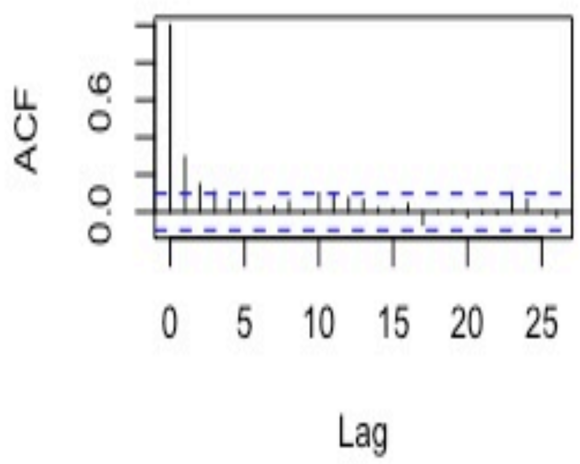


Figure A13. Residuals for boat traffic transitions vs socialising

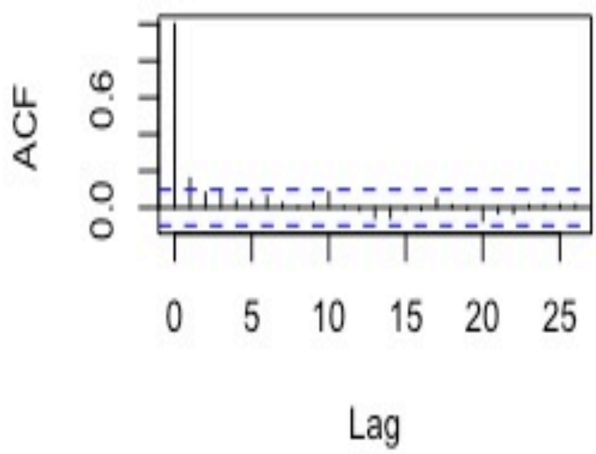


Figure A14. Residuals for boat traffic transitions vs normal swimming

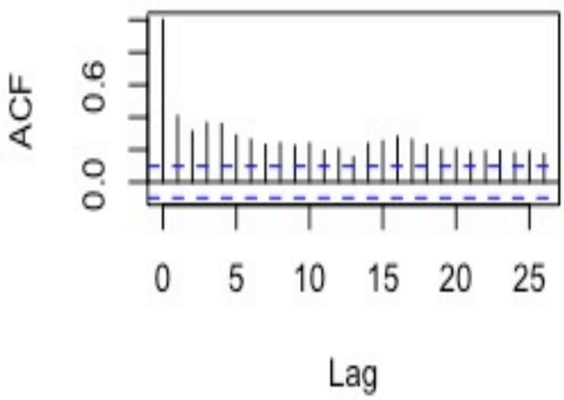


Figure A15. Residuals for boat traffic transitions vs diving

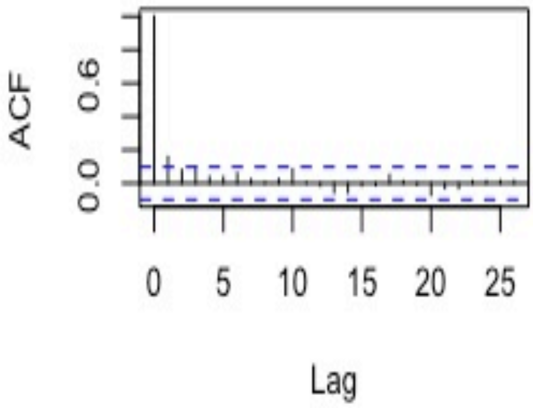


Figure A16. Residuals for boat traffic transitions vs aerial behaviour

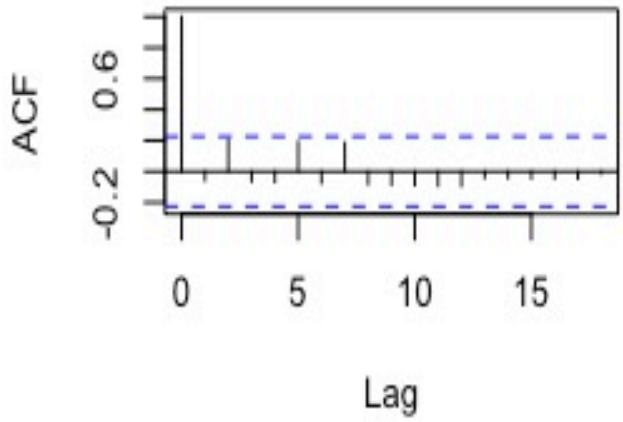


Figure A17. Residuals for high y=1 tide and rising tide y=0 effect on dolphin response to boat traffic.

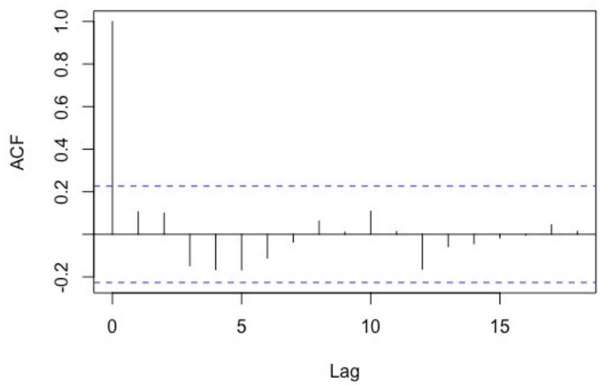


Figure A18. Residuals for low tide y=1 and falling tide y=0 effect on dolphin response to boat traffic.