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MSc Marine Biology

Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay

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PRIFYSGOL BANGOR UNIVERSITY

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Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay

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Abstract

The Bottlenose dolphin (*Tursiops truncatus*) is a widely distributed social species. As a consequence of human population growth, anthropogenic activities are intensifying in coastal areas, leading to a higher probability of interactions with wildlife. Vessel activities in inshore waters are of particular concern, as these are often significant feeding and nursery grounds. Vessel intrusion may lead to both short and long-term consequences which affect dolphins at an individual and population level. It is debated whether dolphins respond to vessel activities and what features i.e. vessel behaviour, type and distance, may cause this response to occur.

Vessel and dolphin activities were monitored throughout June and July in New Quay Bay, mid Wales when vessel traffic was approaching its annual peak. Land-based observations were conducted at two locations in the Bay, to assess differences in response behaviour. It was found that the majority (51.2%) of dolphins did not respond to vessel interactions. However, behavioural responses have significantly increased over the past five years, with more positive (18.9%) and negative responses (24.3%), including both vertical and horizontal evasion, recorded this year than previously (2010 to 2014). Comparisons of residency between individuals in the local population revealed that residents display a degree of habituation to specific vessels, thus resulting in fewer response behaviours. Surfacing interval decreased in the presence of vessels, with a greater effect on mother and calf pairs. In time of day and seasonal comparisons, as vessel activity increased, dolphin sightings decreased, showing that dolphins were engaging in short-term site avoidance. Short-term behavioural responses may develop into long-term consequences, such as reduced energy acquisition, lowered reproductive success, and site avoidance. This has the potential to result in an overall population decline, and this has been found in the population inhabiting Cardigan Bay SAC.

Keywords: bottlenose dolphin, vessel interactions, boat disturbance, behavioural response, dive interval

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1.0 Introduction

The common bottlenose dolphin (*Tursiops truncatus*) is one of the most characteristic and recognisable of cetacean species (Leatherwood & Reeves, 1990; Reynolds *et al.*, 2000; Wells & Scott, 2002). As a result of human population growth, anthropogenic activities are increasing in coastal habitats (Vitousek *et al*., 1997), which may have adverse effects on cetaceans. Previous studies have revealed that cetaceans can be disturbed by vessel presence and the nature of the behavioural response towards vessels is dependent upon a variety of natural and anthropogenic factors (Nowacek *et al.*, 2001; Williams *et al.,* 2002, 2006; Lusseau, 2003a, b, 2005, 2006; Constantine *et al.,* 2004; Mattson *et al.,* 2005; Feingold & Evans, 2014a). These include but are not limited to sex, reproductive status, energy requirements, vessel behaviour, speed, vessel type and distance to the animal. The primary objective of this research is to determine whether and how individual bottlenose dolphins respond to the presence of vessels in New Quay Bay, Ceredigion. Do the response movements of dolphins to waterborne vessels differ between individuals depending upon their gender, reproductive status, presence of other dolphins, degree of residency, or activity? And do some populations become "habituated" to certain types of vessels such as tour boats, which run as frequently as every hour in the summer in New Quay Bay? Previous literature has speculated that the vessel type (size and speed), and its "behaviour" i.e. whether it moves in a zigzagging motion or in a fast straight line across the water surface, may actually affect a dolphin's response and behaviour to a greater extent than the mere presence of a vessel (Lusseau, 2006b). This thesis was undertaken to establish whether dolphins in the study area respond to vessel activities and to ascertain the primary causes of vessel disturbance.

1.1 The bottlenose dolphin

First described in 1821 by Montagu as *Delphinus truncatus*, it was later re-defined and re-named in 1855 as *Tursiops truncatus* by Gervais as meaning "Dolphin-like" (Wells & Scott, 1999). The family "Delphinidae" contains 35 members belonging to 17 genera, including the common bottlenose dolphin, along with its closest relative, the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Martin & Reeves, 2002).

The bottlenose dolphin has a robust truncated body with a distinct sickle shaped dorsal fin and clearly defined beak (Leatherwood & Reeves, 1990; Reynolds *et al.*, 2000; Wells & Scott, 2002). Colour ranges from slate-charcoal grey to brown with off-white or pink undersides, with calves displaying a much lighter shade than the adults, which will darken with age (Leatherwood & Reeves, 1990; Reynolds *et al.*, 2000). Adult dolphins range in size from 1.9-4.5 metres and weigh between 90-650 kg. Calves are born at approximately 1.15 m and weigh 18 kg (Leatherwood & Reeves, 1990; Reynolds *et al.*, 2000; Wells & Scott, 2002). Sex determination of this species is particularly difficult due to the lack of sexual dimorphism and the ventral genitalia and mammary slits usually being hidden from view during submersion (Connor *et al*., 2000).

Bottlenose dolphins travel in groups of varying size but generally range between 2-15 individuals, although aggregations of up to 1000 individuals have been documented (Shane & Wells, 1986). Studies conducted in Sarasota Bay, Florida, USA have discovered that life expectancy for the bottlenose dolphin is approximately 40-50 years (Connor *et al*., 2000; Reynolds *et al.*, 2000). These estimates of longevity are largely based on dentinal and cemental growth layers in the teeth (Hohn *et al*., 1989). Age at maturity varies within region, sex and population. However, it usually ranges between 9-11 years for females and 10-13 years for males (Wells & Scott, 1999). As a K-selected species, gestation is a lengthy process lasting approximately 12 months, with a mean calving interval of three years (Leatherwood & Reeves, 1990; Schroeder, 1990; Reynolds *et al.*, 2000; Wells & Scott, 2002). Calves are born all year round, although the highest numbers of births are recorded in the summer months (Wells & Scott, 1999; Reynolds *et al.*, 2000). Bottlenose dolphins are strong swimmers with a travelling speed of 5-11 km.hour^{-1} although they can reach speeds of 29-35 km.hour^{-1} (Fish & Hui, 1991). In shallow coastal waters, dives rarely last more than 3-4 minutes although dives of 15 minutes have been documented in oceanic dolphins, which are recorded to dive to depths of more than 500 metres as an extreme; however, average dive depth is <50 metres (Klatsky *et al.*, 2007).

Bottlenose dolphins are generalist, opportunistic feeders, which switch between prey species depending on their availability and season (Leatherwood & Reeves, 1990; Wells & Scott, 1999; Reynolds *et al.*, 2000). Prey species include cephalopods, benthic, pelagic and schooling fish (Mead & Potter, 1990). Dolphins in Scotland feed on a variety of haddock, whiting, cod and sprat in addition to salmon, flatfish, cephalopods, and sand eels (Santos *et al*., 2001). Welsh bottlenose dolphins have been observed feeding on sea bass, salmon, garfish, conger eel, sand eel and small sharks, such as smooth hounds (Pesante *et al*., 2008a).

Comprehensive studies of dolphin behaviour and vessel interactions in the marine environment can be logistically difficult due to observational limitations. Thus the development of photo identification techniques in the early 1970’s revolutionised the study of cetaceans (Würsig & Würsig, 1977; Würsig & Jefferson, 1990). Individuals could be identified by long-lasting features of their dorsal fins including shape, nicks, notches, pigmented areas, and scarring (Würsig & Würsig, 1977; Würsig & Jefferson, 1990). Through maintenance of photo-identification catalogues, scientists have been able to conduct a variety of analyses, and discover patterns in population size, site fidelity, migration, abundance, and aspects of life history (Würsig & Würsig, 1977; Hohn *et al*., 1989; Würsig & Jefferson, 1990; Williams *et al.*, 1993; Wilson *et al.*, 1997, 1999; Karczmarski & Cockroft, 1998; Lusseau, 2005; Feingold & Evans, 2014a). Photo-ID has also been used in behavioural studies to examine social interactions and social development and as a conservation tool to estimate vessel collision rates (Wells *et al.*, 1980; Wells & Scott, 1997; Williams *et al.,* 2002, 2006; Evans *et al.,* 2011).

Würsig & Jefferson, (1990) argued that to obtain accurate data, natural markings must be unique to the individual, identifiable over time and not be biased to re-sightings. If an animal is unable to be identified from one sampling period to the next, i.e. if it has non-permanent scarring or an unmarked fin, re-sightings cannot be used because they cannot be linked to previous sightings. Individuals such as calves, juveniles and adults, which do not engage in play or fighting activity with conspecifics, may be less prone to scarring and gaining permanent markings (Lockyer & Morris, 1990). However, it is argued that up to 70-80% of bottlenose dolphins can be identified by long-term markings (Bearzi *et al*., 1997; Karczmarski & Cockcroft, 1998). In the Cardigan Bay population, c. 60% of the dolphins are reported to have identifiable marks (Pesante *et al*., 2008a, b; Feingold & Evans, 2012, 2014b). Studies conducted by Lockyer & Morris, (1990) found that the permanency of a scar would be dependent on the severity of the wound. For example, superficial scratches would disappear within a few weeks whilst deeper injuries may be evident for life. Thus animals have to be closely monitored after injury to ensure accurate information of the longevity of scars can be obtained.

1.2 Distribution

The common bottlenose dolphin is a widely distributed species, ranging throughout temperate oceans and tropical waters (Leatherwood & Reeves, 1990; Shane, 1990, Reynolds *et al.*, 2000; Reynolds *et al.*, 2000; Wells & Scott, 2002; see Figure 1). The species is found in a diverse range of marine habitats including shallow coastal waters, deep oceans, estuaries and inshore lagoons (Leatherwood & Reeves, 1990; Wells & Scott, 1999; Reynolds *et al.*, 2000). Coastal populations of bottlenose dolphins have been studied extensively in recent years and are seen to display periodic residency, seasonal migration and repeated residency (Leatherwood & Reeves, 1990; Wells & Scott, 1999, 2002). Some populations, including those within Cardigan Bay, have discrete home ranges whilst others perform long-range movements on a regular basis (Evans, 1995; Arnold *et al.*, 1997; Feingold & Evans, 2014a). Wells *et al.*, (1987) argues that habitats protected from open oceans may attract populations with small movement patterns or site fidelity. However, not all members of the population will be present all the time (Würsig & Harris, 1990) as some, most commonly males (Wells *et al*., 1987) and sub-adults (Wilson *et al*., 1999), may roam over wider areas. Differing levels of site-fidelity result in resident and transient individuals (Weller & Würsig, 2004).

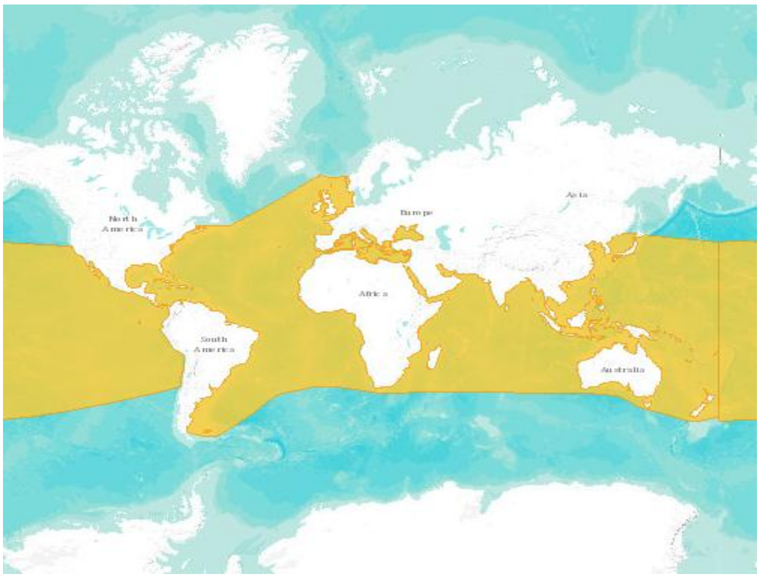

Figure 1. Global distribution of the Common Bottlenose dolphin (*Tursiops truncatus*), as indicated by the yellow area (IUCN, 2014)

1.2.1 Distribution in UK waters

Bottlenose dolphins have been observed in a variety of locations throughout British waters. Within the coastal waters of the British Isles and Ireland, three more or less resident populations exist: Cardigan Bay, West Wales; Moray Firth, NE Scotland; and the Shannon Estuary, Western Ireland (Lewis & Evans, 1993; Wilson *et al*., 1997; Ingram, 2000). Cardigan Bay, Wales, holds the largest population of resident bottlenose dolphins in the UK (Feingold & Evans, 2014a, Figure 2), followed by the population in the Moray Firth, Northeast Scotland (Wilson *et al.*, 1997, 1999; Thompson *et al*., 2005). Bottlenose dolphins have also been observed in other favourable areas, including the East Grampian coast and St Andrews Bay, S.E. Scotland and in Galway Bay, W. Ireland; there are also small populations in the Hebrides and the English Channel (Evans *et al*., 2003; Reid *et al*., 2003). The bottlenose dolphin population in Cardigan Bay, Wales, is often referred to as an "open" population, meaning one that changes in size and composition as a result of births, deaths, immigration and emigration over time. Only a proportion of the dolphins are resident to a particular area throughout the year, thus resulting in a mixture of resident and transient animals (Pesante et al., 2008a, b; Feingold & Evans, 2014a, b), Currently, the population consists of between two and three hundred semi-resident individuals, many of which are regularly seen in New Quay Bay (Feingold & Evans, 2012, 2014a).

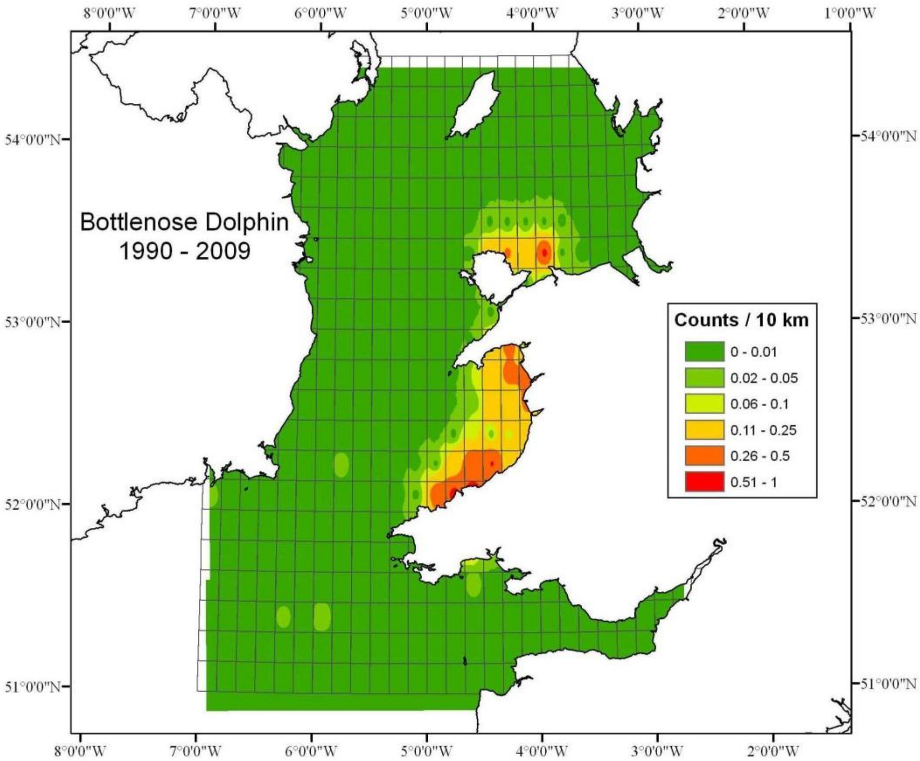

Figure 2. Map of the Bottlenose dolphin distribution in Welsh waters (from Baines & Evans, 2012: Atlas of Marine Mammals of Wales)

1.3 Impacts of vessel traffic

Throughout history, there are numerous accounts of human-dolphin interactions and relationships. Bottlenose dolphins have been observed to provide assistance to stranded swimmers and actively protect them from shark attacks until the swimmer is rescued or makes it to shore (Orams, 1997; Reynolds *et al.*, 2000). Some populations have formed a commensal relationship with local fishermen, which has spanned decades. The dolphins either herd fish towards waiting fishermen or congregate in areas where fish aggregations occur thus informing the fishermen where to drop their nets. In exchange, through the action of fishing damage, fish may become disoriented and easier to catch, thus assisting the dolphins (Orams, 1997; Reynolds *et al.*, 2000). In recent years, human-dolphin encounters are becoming increasingly negative, primarily due to an increase in anthropogenic activities in coastal inshore waters (Vitousek *et al.*, 1997; Constantine, 2004; Lusseau, 2005). Estuaries and coastal waters have become thriving areas for recreation and the marine tourism industry, leading to a substantial rise in vessel traffic (Kruse, 1991; Nowacek *et al.*, 2001; Hastie *et al*., 2003; Lusseau, 2005; Mattson *et al.*, 2005). Vessels are of particular concern in inshore coastal waters due to their high abundance, extensive use, often unpredictable behaviour, high noise level, movement and speed (Richardson *et al.*, 1995; Evans, 1996; Würsig & Evans, 2001). The use by bottlenose dolphins of inshore coastal waters makes this species particularly vulnerable to anthropogenic activities (Bristow & Rees, 2001; Nowacek *et al.*, 2001; Hastie *et al.*, 2003; Mattson *et al.*, 2005; Feingold & Evans, 2014a). Nevertheless, as in Cardigan Bay, these are preferred areas by dolphins as they are valuable feeding and nursery grounds (Bristow & Reeves, 2001; Pesante *et al.*, 2008a; Feingold & Evans, 2014a).

By the early 1990s, whale and dolphin tourism was conducted in over 90 countries and the industry was worth approximately $1 billion (Hoyt, 2001). Twenty years later, the industry has rapidly expanded further due in part to increased media attention and wildlife documentaries. It is now worth approximately $2.1 billion, with at least 13 million people going whale watching annually (O'Connor *et al*., 2009). This could have positive implications for wildlife as it has the potential to raise awareness about conservation, and to educate the general public about the ocean and its species. This is increasingly important as a result of intensifying changes in the ocean, largely due to climate change. A rise in awareness of marine species, such as the bottlenose dolphin, has led to an increase in dolphin watching tourism in coastal waters worldwide. A burgeoning literature now exists monitoring and examining the effects of vessel activity on cetaceans, to establish the long and short-term consequences of this industry (e.g. Nowacek *et al.*, 2001; Hastie *et al.*, 2003; Williams *et al.*, 2002, 2006; Bejder & Samuels, 2003; Lusseau, 2003a, b, 2005, 2006; Mattson *et al.*, 2005). Additional studies have shown that vessel activities can affect aspects of dolphin behaviour (Lusseau, 2003a; Constantine *et al*., 2004), increase swimming speeds (Nowacek *et al.*, 2001), and change swimming direction (Au & Perryman, 1981; Nowacek *et al.*, 2001). Changes in dive interval (Janik & Thompson, 1996; Lusseau, 2003b), breathing synchrony (Hastie *et al*., 2003), inter-animal spacing's (Bejder *et al.*, 1999; Nowacek *et al*., 2001), and residency patterns have also all been observed (Lusseau, 2005; Feingold & Evans, 2014a). The vast majority of previous studies have concluded cetacean-vessel interactions to be largely negative with the majority of cetaceans displaying a variety of avoidance behaviours including vertical and horizontal evasion (Nowacek *et al.*, 2001; Williams *et al.*, 2002, 2006;

Hastie *et al.,* 2003; Mattson *et al.,* 2005; Feingold & Evans, 2014a). An increase in anthropogenic activities not only impacts on animal fauna directly, but may also degrade habitat quality, influencing prey movement and variations in site fidelity (Lusseau, 2005; Mattson *et al.,* 2005; Sini *et al.*, 2005).

Dolphins are subjected to direct and indirect effects created by anthropogenic activity, usually in the form of vessel movements (Nowacek *et al.,* 2001; Mattson *et al.,* 2005; Lusseau, 2006). Direct effects are easily identified and can cause a combination of visual, acoustic and physical distress (Nowacek *et al.*, 2001). Visual disturbances are often caused by vessels, which may behave in an unpredictable manner and cause dolphins to change behavioural patterns such as swim speed and direction (Kruse, 1991; Nowacek *et al.,* 2001; Williams *et al.,* 2002*;* Mattson *et al.,* 2005). Dolphins are subjected to the consequences of physical interactions, of which collisions are the most common. Vessel collisions often lead to injuries such as lacerations, scars and amputation of fins and other body parts; in severe cases these interactions can lead to the death of an individual (Wells & Scott, 1997; Laist *et al.,* 2001).

Acoustic disturbances are increasingly common and can seriously affect a cetacean's behaviour, and may lead to single and mass stranding events (Weilgart, 2007). The bottlenose dolphin is primarily an acoustic creature and therefore sound is vital to numerous aspects of its life. In the presence of vessels, dolphin echolocation and vocalisations have the potential to be masked or altered (Hastie *et al*., 2003; Lusseau, 2003a; Buckstaff, 2004; Mattson *et al.*, 2005). This has the potential to affect dolphins to a significant extent and it is probable that dolphins will change aspects of their behaviour, locomotion and group cohesion to combat the intrusion. Powerboats and other high-speed vessels often emit constant, high amplitude sub-aquatic sound, which has the potential to interrupt communication, disturb echolocation and inflict temporary or permanent damage to a dolphin's auditory structures (Mattson *et al.*, 2005).

Indirect effects are challenging to identify, let alone to evaluate the extent of those impacts at an individual or population level (Nowacek *et al.,* 2001). Examples of indirect effects of human disturbance include a reduction in population size due to the suppression of reproductive capabilities and/or a reduction in the consumption of prey leading to reduced energy intake (Williams *et al.,* 2002, 2006). Additionally, migration and long-term abandonment of favoured sites may occur in highly disturbed areas (Kruse, 1991; Nowacek *et al.*, 2001; Feingold & Evans, 2014a).

Vessel presence has the potential to affect dolphins on both an individual and population level (Nowaeck *et al.*, 2001; Williams *et al.*, 2002; Constantine, 2004). Vessels have been observed to alter individual and group behaviour (Nowacek *et al*., 2001; Constantine *et al.*, 2002; Hastie *et al.*, 2003; Mattson *et al*., 2005). Previous literature suggests that alterations to behaviour can present both long- and short-term consequences to dolphin fitness and survival (Nowacek *et al.*, 2001; Mattson *et al.*, 2005; Williams *et al.*, 2006; Feingold & Evans, 2014a). A variety of short-term response behaviours are observed when interactions occur. Examples include a change in IBI (Inter-Breath Interval) (Janik & Thompson, 1996; Nowacek *et al*., 2001), change in swim direction and speed (Au & Perryman, 1981; Kruse, 1991; Nowacek *et al.,* 2001; Williams *et al*., 2002, 2006; Mattson *et al*., 2005), disruption and variations in vocalisations (Hastie *et al*., 2003; Buckstaff, 2004), and alterations to social cohesion causing group splits or formations (Nowacek *et al*., 2001; Constantine *et al*., 2002; Mattson *et al*., 2005). These are amongst many observed responses that have the potential to seriously affect long-term behaviour (Bejder *et al*., 2006b). Inter-breath interval or dive interval has previously been used to measure the effect that boat traffic has on individuals and groups of dolphins (Janik & Thompson, 1996; Nowacek *et al*., 2001; Williams *et al*., 2002, 2006; Constantine, 2004). Dolphins increase dive intervals in the presence of boats (Nowacek *et al.,* 2001; Williams *et al*., 2002, 2006; Constantine, 2004; Lusseau, 2006). Certain individuals such as mother and calf pairs are more likely to increase their dive interval in the presence of vessels (Williams *et al.*, 2002; Lusseau, 2003a).

It has been previously argued that vessel “behaviour” has the potential to affect dolphins to a greater extent than vessel presence (Lusseau, 2003b). Lusseau (2003b) found that dolphins in Doubtful Sound, New Zealand, were tolerant to vessels that moved in a predictable manner. However, if a vessel moved unpredictably or erratically, these vessels were avoided. Small, fast vessels such as speedboats, jet skis and small engine vessels were observed to display a high quantity of erratic movements when compared with other vessels (Lusseau, 2003a). A large range of odontocetes have been observed to move away from vessels when interactions become prolonged or intrusive (Williams *et al.*, 2002; Lusseau, 2003b).

It has been observed that dolphins will vary their behaviour according to different vessel type. Studies in Cardigan Bay, Wales, have found that individuals will respond positively to particular boats, such as tour boats, but will actively avoid other vessels such as kayaks (Gregory & Rowden, 2001). On the other hand, Lusseau (2003a, b) found that dolphin watching tour boats in New Zealand were having the greatest negative effect on the dolphin population, compared to any other type of vessel. During vessel-cetacean interactions, a variety of behavioural responses have been observed, including but not limited to moving towards a vessel, moving away from a vessel, a neutral response where no change in behaviour is recorded, or a mixed response where dolphins would first move away from an approaching vessel then later swim towards it and *vice versa* (Nowacek *et al.*, 2001; Williams *et al.*, 2002; Mattson *et al.*, 2005; Feingold & Evans, 2014a). Responses also vary in severity. Short-term severe responses include faster swimming speeds, longer dive times, erratic movements, and unusual behavioural responses such as tail slapping (Constantine *et al.*, 2001; Nowacek *et al.*, 2001).

Vessel presence has also been linked to reduced bottlenose dolphin sightings in an area (Gregory & Rowden, 2001; Pierpoint *et al.*, 2009; Vitousek *et al.*, 2011; Feingold & Evans, 2014a). Bristow & Rees (2001) and Gregory & Rowden (2001) found that dolphins were showing a tolerance to increased boat traffic, with a large proportion of the population displaying a neutral response towards vessel interactions, suggesting that the features of the bay potentially outweighed the level of disturbance to which they were subjected. More recently, however, there is evidence to suggest that dolphins are using Cardigan Bay SAC less frequently, and the population in the area is declining (Pierpoint *et al*., 2009; Feingold & Evans, 2014a). Individuals that once lived in the area have been observed in other areas, suggesting there has been increased emigration from the area, potentially due to the consequence of increased vessel presence and activity (Feingold & Evans, 2014a).

1.4 Hypothesis

The aim of this research is to address some of the current gaps in knowledge related to the behavioural response of individual dolphins to different types of vessels, and the unanswered questions concerning group type and composition when an interaction occurs. This will be undertaken by testing the following hypotheses in the inshore coastal location of New Quay Bay, West Wales:

H1 - Individual bottlenose dolphins in New Quay Bay respond differently to vessel interactions dependent upon gender, status, group size, or activity;

H2 – Bottlenose dolphins respond differently to vessels according to vessel type, vessel activity, named vessels, engine size, and distance from the vessel;

H3 – Individuals within the transient population visiting New Quay Bay display more negative responses to vessel interactions than resident individuals;

H4 – As vessel activity increases, a decline in dolphin sightings is observed;

H5 –Behaviours such as feeding and resting are suppressed by vessel presence;

H6 – In the presence of a vessel, a dolphin's dive duration will increase.

1.5 Objectives

Using a combination of photo identification and land-based survey techniques at a coastal location within the Cardigan Bay SAC during June-July 2014, the specific objectives of the project were:

1. To ascertain whether individual dolphins located in New Quay Bay respond differently to vessel interactions. Behavioural responses were recorded to determine whether an individual dolphin, or a mother and calf pair, swim towards, away or display a mixed response, or if no response occurs towards an approaching vessel. Gender, groups (size & cohesion) and residency comparisons were conducted to determine the impact these have on response movement.

2. To establish if dolphins vary response movements dependent on vessel type, engine size or vessel behaviour. Dolphins were observed, to examine whether behaviour varies according to vessel category. For example, dolphins may display a neutral response towards fishing vessels whereas they may avoid small speed craft including jet skis and motorised "ribs".

3. Dolphin behaviour was examined prior to and during vessel interactions to determine if behaviour such as feeding and socialising are suppressed by vessel activities. Dive behaviour was recorded to discover if vessel presence caused longer dive intervals, which may result in long-term repercussions.

4. Observations were conducted throughout the day and season to establish whether vessel presence and abundance affect dolphin sightings and response behaviour.

2.0 Methodology

2.1 Study area

This study was conducted between the 2nd June and 25th July 2014 on a bottlenose dolphin population inhabiting the coastal waters of New Quay Bay, Ceredigion, Wales. New Quay Bay, part of Cardigan Bay, is the largest bay in the British Isles, covering approximately 5500km² (CCC, 2007). In 2004, the southern region of the bay was granted SAC (Special Area of Conservation) status (CCC, 2007; see Figure 3). The SAC stretches from Aberarth in the north, to south of the Teifi Estuary. The location extends approximately twelve miles offshore with a total area of 1039 km² and is home to a resident population of common bottlenose dolphins, *Tursiops truncatus* (Ugarte & Evans, 2006; Pesante *et al.*, 2008a; Veneruso & Evans, 2012; Feingold & Evans, 2014a).

New Quay forms a shallow enclosed basin, surrounded by high cliffs, small coves and long sandy beaches with depths ranging between 1 and 12 metres (Figure 4). The seabed topography is a gradual slope from inshore to offshore with fine sand and silt sediment inshore graduating to coarser sediment offshore, including gravel and cobble stones, although these will occasionally appear in patches inshore (Evans, C.D.R, 1995). The dispersal of sediment into and away from the bay is largely dependent on the tidal current and strength (Baines *et al*., 2000). Cardigan Bay and the Irish Sea are significant marine areas, as they have been identified as feeding and breeding grounds for a variety of cetaceans (Evans P.G.H, 1995; Pierpoint *et al*., 2009; Baines & Evans, 2012). The waters remain fairly calm primarily due to the Irish landmass, which protects them from the Atlantic weather (Evans, P.G.H, 1995). Due to a nutrient upwelling provided by the amalgamation of the North Atlantic warm waters and the cool waters surrounding the northern and southern regions of Ireland, the area provides suitable conditions for plankton growth, upon which a variety of fish, sea birds, cetaceans and seals feed (Evans, P.G.H, 1995).

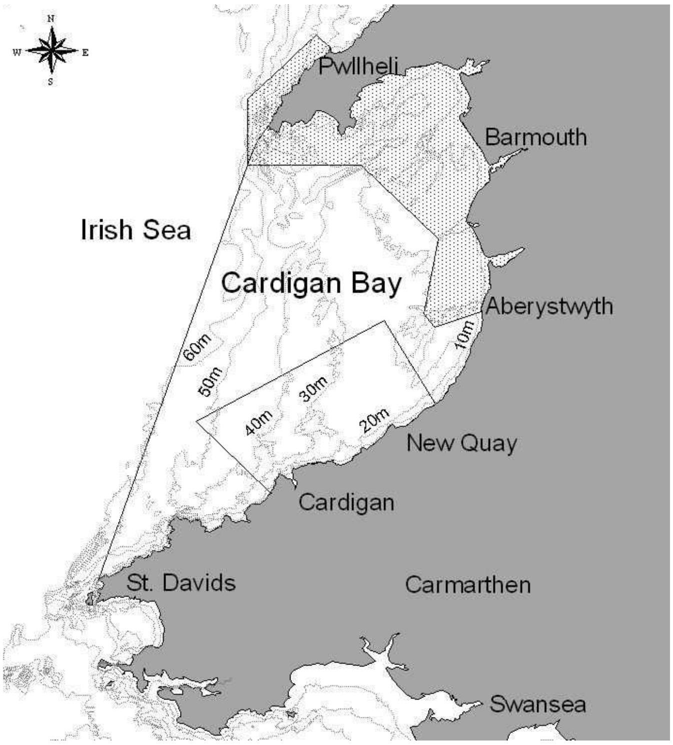

Figure 3. Cardigan Bay Special Area of Conservation (Pesante *et al*., 2008a)

Bottlenose dolphins are listed under Annex II of the European Habitats Directive, for which special protective measures are required (CCC, 2007). The Cardigan Bay population is most commonly observed between April and October (Ugarte *et al*., 2006; Pesante *et al*., 2008a; Veneruso & Evans, 2012; Feingold & Evans, 2014a, b). During the winter months a significant proportion of the population migrates north, up to the Isle of Anglesey, Isle of Man and beyond (Pesante *et al*., 2008b; Veneruso & Evans, 2012; Feingold & Evan, 2014b).

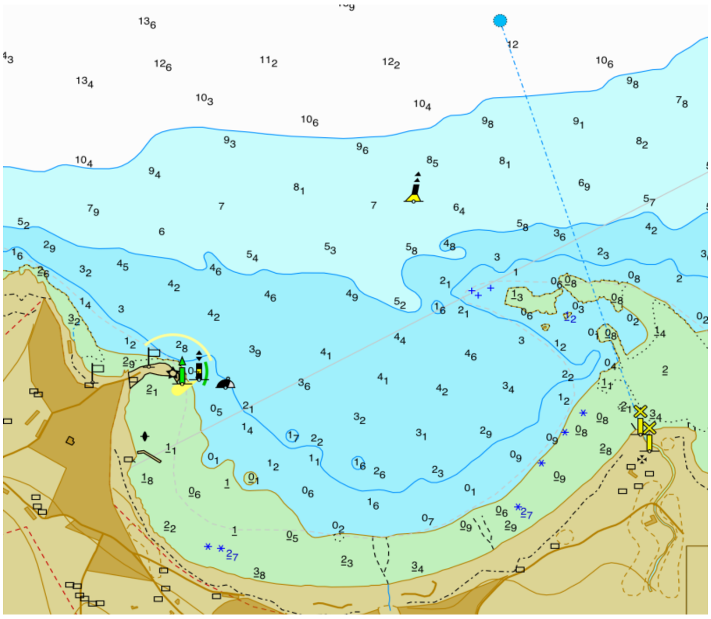

Figure 4. Depth map of New Quay Bay (from Transas iSailor, 2014)

Opportunistic land-based observations were conducted from two sites in New Quay Bay: New Quay headland (52º13´05˝N, 04º21´84˝W) and New Quay pier (52°12′46″N 4°21′32″W) (Figure 5). Land-based observations were selected to remove the bias of vessel-based surveys, which may themselves affect dolphin behaviour. The headland station was chosen due to the high vantage point and broad view over the bay allowing the observer to locate and track dolphins several kilometres away. The pier was selected due to its proximity to the harbour, thus allowing dolphin-vessel interactions to be closely observed and individual dolphins identified, through photo-identification.

Figure 5. The location of the two observation vantage points (indicated by red dots) used in the study. Both positions provided a good view over New Quay Bay (Google maps, 2014)

2.2 Survey design

Land-based surveys from the pier were conducted daily between 07:00 & 21:00 h on week-days (Monday to Friday) and between 11:00 & 17:00 h on weekends, depending on weather conditions and visibility. Observers interchanged every two hours to reduce fatigue and observer bias. Effort and environmental data were collected every 15 minutes, in addition to any dolphin sightings. Effort data consisted of the recording of time, and environmental data - sea state, wind direction, visibility, tidal height and sighting information. Additionally, vessel activity, abundance and interactions were recorded on forms provided by the Sea Watch Foundation (Appendix 1). Vessel presence and abundance were recorded throughout all observations, whether dolphins were present or not.

Headland observations were conducted daily between 09:00 and 15:00 h. Preliminary studies showed this to be the most efficient and effective collection period. Effort, sightings, and interaction data were collected using forms identical to those used to record sightings and behaviour data during the pier observations (Appendix 1).

2.2.1 Vessel encounters

Headland observations were conducted from a view-point on New Quay headland. For the purpose of this investigation, an area of 9 km² was allocated which allowed a 4 km horizontal view outwards from the viewing point. This area was gridded off into smaller sections and displayed as a map (Appendix 2), which was then used by the observers to locate the focal dolphin or mother and calf pair. The map was marked with the initial sighting of the dolphin and the subsequent vessel interactions.

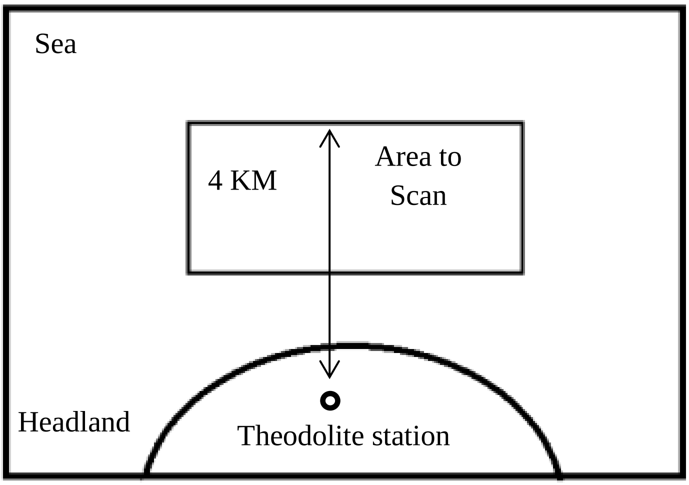

Figure 6. Schematic diagram of the research area

From the headland study platform, 10 x 25 binoculars were used to scan the study area. Once a dolphin or group entered the area, the primary observer would record the dolphin's position and behaviour, and track them with the theodolite (see below for description), noting the theodolite readings, group size, composition and spacing. When an interaction took place, behaviour would be continuously recorded until the interaction ceased. If a group was observed, a focal dolphin was chosen and only its behaviours were recorded. To ensure consistency, the focal dolphin was selected as the animal located at the front of the group. If dolphins were not travelling in a particular direction then the focal dolphin selected would be the animal that was located closest to the observation platform.

If a second observer was present, they would use the digiscope and take photographs which could be used to identify individual dolphins. This would be done in addition to recording dive intervals i.e. the time spent under the water between breaths, when vessels were present, and when vessels were absent from the area, so that accurate comparisons could be made between dive times and the presence and absence of vessels in the immediate area of the dolphins. When vessels were absent from the area and dolphins were present, then behaviour and group spacing and composition were noted every 15 minutes rather than continuously monitored when both vessels and dolphins were present.

When a vessel entered the study area in the presence of dolphins, positions of the focal dolphin and the approaching vessel(s) were recorded. An encounter was defined as any vessel that came within 300 metres of the focal dolphin. Once a vessel was within 300 metres, an interaction occurred and the behavioural response was recorded. Behavioural response was divided into four categories: movement towards (where dolphins actively moved towards a vessel), away (where dolphins displayed an avoidance response to the vessel, including both vertical and horizontal evasion), neutral (where no change in behaviour of the focal dolphin was observed), and mixed (where a dolphin primarily avoided the vessel and then later approached it or firstly approached a vessel to later avoid it).

During observations it was possible for the focal dolphin to move in and out of the study area. If a dolphin moved out of the area for <15 minutes it was counted as the same animal. However, if the dolphin moved out of the theodolite view for more than 15 minutes, the next dolphin to come into the observer's view was recorded as a different dolphin. Data collection was terminated when dolphins moved out of the study area, visibility was reduced, the weather deteriorated, or the day ended.

2.2.2 Theodolite

The theodolite (see Figure 7) referred to above, is a surveyor's instrument which can be used to measure and track cetacean movements from land in a non-intrusive manner (Bejder *et al*., 1999; Williams *et al*., 2002). Theodolite tracking from a cliff vantage point is a relatively cheap and effective way of monitoring cetaceans since a large area can be surveyed simultaneously in comparison to boat-based surveys. Data were collected from the headland using a digital Sokkia DT50 theodolite with a 30x objective. The theodolite was used to determine the horizontal and vertical angles, which were later converted into longitude and latitude when the exact theodolite position height and height above sea level are known. The horizontal reference point used was a weather station to the far left of the headland (52º12.865'N, 4º22.536'W ± 5 m). The theodolite was set to the reference point, giving a horizontal reading of 0º00'00''.

Figure 7. Digital Sokkia DT50 30x objective theodolite (Photograph - Tess Hudson)

2.2.3 Calculation of distances between vessel(s) and focal dolphin

Interaction distances between vessels and dolphins were calculated in Excel using a series of trigonometric formulae, using the method created by Meier (2010). Vertical and horizontal readings from the theodolite were converted into distances, by first converting them into GPS co-ordinates and then calculating the distances between the two GPS co-ordinates to work out the distance between the focal dolphin and the approaching vessel. Co-ordinates were further verified on Google Maps to ensure accuracy. It is necessary to accurately determine height above sea level before trigonometric calculations are undertaken. Headland height was calculated using the rod method (see Frankel & Yin, 2009) as detailed in Meier (2010). Small differences in tidal height can significantly alter the distance calculated by the theodolite, hence a rock was marked at 0.5 m increments from the lowest tide of the season, referred to as the "Referenced Tidal Marks" (RTM) to allow accurate calculations to be completed (Figure 8). As with the other environmental data, this was recorded every 15 minutes.

Figure 8. Target Rock, painted at 50 cm intervals to allow calibration of tidal height in order to calculate distance between vessels and bottlenose dolphins (RTM = 0.7 m about chart datum) (Photograph - Amrit Dencer-Brown)

Theodolite height was calculated using the following equation:

Total theodolite height = Theodolite station altitude + theodolite eye height ± tidal height (above or below RTM)

2.2.4 Sea state and visibility

The Beaufort scale (Appendix 3, Met Office, 2010) was used to determine sea state. Dolphins are difficult to locate once sea state reaches 3 or more, and so during the study, data were collected only when the sea state was two or less (Barco *et al.*, 1999). Sea state was recorded every 15 minutes as the sea surface was observed to change rapidly and regularly throughout the day. Visibility was noted every 15 minutes and recorded on a scale of 1-3, where 1 = <6 km, 2 = 6-10 km and 3 = 10 + km visibility.

2.2.5 Photo identification

A digiscope (Swarovski STX 85 mm objective modular telescope with Canon EOS 40D DSLR camera; Figure 9) was used from the headland and pier observation points to photograph dolphins so that each individual could be correctly identified. Individual dolphins can be identified by the natural markings, shape and any long-term scars on the trailing edge of the dorsal fin, including nicks, notches and permanent pigmentation of the skin (Würsig & Würsig, 1977; Lockyer & Morris, 1990; Würsig & Jefferson, 1990; Bearzi *et al*., 1997; Karczmarski & Cockcroft, 1998). A database containing a catalogue of permanent and semi-permanent marked individuals, was provided by the Sea Watch Foundation (Feingold & Evans, 2012a). Dorsal fin photographs taken in this study were compared with the catalogues so that each marked dolphin could be identified. Photographs of dolphins with clean or unmarked fins were not used in any analyses, as these could not be unambiguously identified with the photographs in the database catalogue.

Figure 9. Swarovski 60x lens digiscope, with Canon EOS 40D. (Photograph - Tess Hudson)

2.2.6 Category of vessels

Vessels present in the study area were categorised according to size and type.

2.2.6.1 Vessel Type

Table 1. Vessel code and type

Boat Code	Boat Type
sMB	Recreational motorboat <15 m
mMB	Recreational motorboat 15-30 m
SB	Speedboat/ rib
YA	Yacht/ Sail boat
FI	Fishing Boat
VPB	Visitor Passenger Boats
RB	Row Boat, Kayak
JS	Jet Ski
R	Research Vessel
FE	Ferry
LS	Large Ship >30 m

Visitor passenger boats such as the *Ermol V*, *Ermol VI*, *Sulaire*, *Anna Lloyd* and *Islander* operate scheduled departures from New Quay pier on a daily basis, weather and sea condition dependent. Other visitor passenger boats and recreational fishing boats such as *Dunbar Castle II* and *3fishes* operate when other boats are full and, therefore, do not depart at such regular intervals.

The *Ermol VI* runs approximately eight times a day every hour between 11:00 and 18:00 h; the *Ermol V* runs trips every two hours between 10:30 and 18:30 h, undertaking on average four trips a day. The *Islander* runs one and a half hour trips between 11:00 and 17:30 h, with a sunset trip at 19:30 h, and usually operates ~6 trips a day. The remaining tourist boats such as the *Sulaire* and the *Anna Lloyd* run ~4-6 times every day during peak season. Other boats such as the *Dunbar Castle II* and *3fishes* leave the harbour once or twice a day on chartered trips for several hours at a time.

2.2.6.2 Categories of Vessel Behaviour

Table 2. Vessel behaviour categories and associated

Boat Activity Code	Vessel Behaviour
Y1	No wake speed & no erratic change of course when passing cetaceans
Y2	Slowed down and gradually stopped
N1	Too fast: wake speed, white water visible
N2	Erratic course to approach, avoid or follow cetaceans

2.2.7 Group cohesion, spacing and behavioural state

A group of dolphins was defined as the number of individuals in close association with one another, generally engaged in the same activity and remaining within approximately 100 metres of one another (Shane, 1990; Bearzi *et al*., 1997). During observations, group size and group composition were recorded, as defined by Bearzi *et al*. (1997) and Feingold & Evans (2014a):

- **Adult** – A dolphin that appears fully-grown (2.5 metres and above).
- **Juvenile** – Roughly two-thirds of adult length; often swimming in close proximity to an adult; will occasionally be swimming independently; colouration is generally lighter than adults.
- **Calf** – Approximately half adult size; swimming in close association with an adult; light vertical creases visible and light grey in colour.
- **Newborn** – Less than half adult length; constantly in close association with the adult; foetal folds visible, and dorsal fin low and rounded.

Individuals and groups of dolphins were observed, and any change in group composition recorded throughout a dolphin-vessel interaction. Disruption to social groups and changes in social cohesion (individual distances), swim speeds, direction of movement and dive interval were noted wherever possible.

Distances between individuals were noted and categorised as: Tight – dolphins recorded less than one dolphin length apart; Loose – animals observed up to four dolphin lengths apart; and Dispersed – dolphins recorded more than four dolphin lengths apart.

Bottlenose dolphin behaviour was categorised in order to define and analyse behaviour and response. The categories used were: Resting/milling (R), Travelling (T) normal swimming (NS), fast swimming (FS), socialising (S), suspected feeding (SF), diving (DIV), feeding (FF), aerial behaviour (AB), percussive behaviour (PB), unknown (U), bow-riding (B), group split (GS), and group form (GF).

Table 3. Description of all behaviours used in the current study

Behaviour	Code	Description
Resting/ Milling	**R**	Dolphins engaged in slow non-directional movements in a tight group, with short regular dive intervals (Shane 1990; Constantine *et al.*, 2004; Lusseau, 2006).
Surfacing	**SURF**	Regular surfacing, with short dives.
Travelling	T	Continuous movement in a determined direction (Bearzi & Politi, 1999).
Normal swimming	**NS**	Dolphins swimming at a continuous pace in short and relatively constant dive intervals (Lusseau, 2006).
Fast swimming	**FS**	Dolphins observed swimming at a fast pace in a determined direction, often leaping out of the water to reduce drag and increase speed (Constantine *et al.*, 2004).
Socialising	**S**	Dolphins observed undertaking a variety of interactive behaviours including leaping, chasing, bodily contact, pouncing and hitting with tail. Other aspects of play and mating have also been recorded (Constantine *et al.*, 2004; Lusseau, 2006).
Suspected feeding	**SF**	Dolphins witnessed in the effort to capture and consume prey, no visible prey observed.
Diving	**DIV**	Dolphins observed diving for long periods, direction varying, believed to be foraging on benthic organisms (Shane, 1990; Lusseau, 2006).
Feeding	**F**	Prey observed being captured and consumed.
Aerial behaviour	**AB**	Acrobatic movements where dolphins are observed to jump clear the water with all or the majority of their body.
Percussive behaviour	**PB**	Dolphins observed to hit or strike the water and landing on any part of its body.
Unknown	**U**	Behaviour displayed is unrecognisable.
Bow-riding	**B**	Riding on the waves generated by vessels, boats and ships.
Group split	**GS**	Dolphin group separates or spaces out >100 m.
Group form	**GF**	Dolphin individuals join one another forming a closely formed group.

2.2.8 Classification of residents and transients

Due to the complicated nature of dolphin surveying and research, it is difficult to define the parameters surrounding populations and group dynamics. Thus, in this study, dolphins have been divided into three arbitrary population categories, following the definitions in Feingold & Evans (2014a):

- Residents are dolphins seen more than 12 times, over at least seven years
- Transients are individuals observed 1-3 times over 1-2 years
- Occasional visitors are individuals seen 4-11 times over 3-6 years

2.3 Data analysis

All analyses were undertaken in SPSS 20 or Microsoft Excel with a significance level of <0.05. A combination of parametric (GLM & ANOVA) and non-parametric tests (Chi-squared and Kruskal Wallis) were undertaken to assess behavioural, sighting and vessel relationships within and between groups, and to test for significance in the hypotheses.

For analysis, behavioural data were divided into five different categories: resting, foraging/feeding (hereafter referred to as feeding), diving, socialising, and travelling (Table 4).

Table 4. Behaviours observed and associated category

Behaviour Category	Behaviour
Travelling	Normal Swimming (NS)
	Fast Swimming (FS)
Feeding	Feeding (FF)
	Suspected Feeding (SF)
Diving	Diving (DIV)
Socialising	Socialising (S)
	Aerial Behaviour (AB)
	Percussive Behaviour (PB)
Resting	Resting (R)
	Surfacing (SURF)

Dive patterns for opportunistic data were analysed due to their demonstrated value in other cetacean disturbance studies (Kruse, 1991; Richardson, 1995; Mann, 2000; Nowacek *et al.*, 2001; Williams *et al.*, 2002; Hastie *et al.*, 2003; Lusseau, 2003b, 2006; Williams *et al.*, 2006). Statistical analyses were performed on inter-breath intervals (IBI), defined as the period of time between breaths. IBI's were split into two categories: "treatment" and "control". "Treatment" IBI's were recorded as those where a vessel was present and within 300 metres of a dolphin. "Treatment" IBI's were compared to "control" IBI's which were defined as occasions when no vessels were present or they were recorded at more than 300 metres from the focal dolphin and there had been no vessel(s) within 300 metres for at least five minutes before or after IBI recordings. Five minutes was selected as the length of time between recordings, based on the research by Nowacek *et al.* (2001), which accounted for the longest dive times made by dolphins in Sarasota, Florida (4 minutes 25 sec, see Irvine *et al.*, 1981).

Two main issues arise when conducting IBI observations: the first is ensuring that the same individual is followed throughout the recording. To allow for this, the dolphin was studied for 15 minutes prior to IBI recordings to ensure that the correct dolphin could be recognised each time. The second issue is accounting for individual variation in dive times with unequal sample size per animal. This was controlled for by using the focal animal as a sampling unit in each analysis (Aebischer *et al.*, 1993). Data from opportunistic IBI sampling were normalised using log-transformation. An unbalanced two-way Analysis of Variance (ANOVA) was conducted using IBI type and individual (focal) animal to compare treatment with control IBI (Miller, 1986).

3.0 Results

Three hundred and eighty six hours of effort data were collected during the study period from the combined observation points. Fifty-four hours of data were collected from headland observations, and 332 hours from pier watches. This resulted in 180 hours of interactions between dolphins and vessels, 19 hours and 161 hours from the headland, and pier, respectively. Data were imported into Microsoft Excel 2010 from the Sea Watch Foundation Microsoft Access database. These were organised and coded before analyses in SPSS 20 were undertaken. The weather varied substantially during the study period, with high north and westerly winds and sea state reaching Beaufort four on occasions. Due to high precipitation there were a number of occasions when the theodolite and digiscope could not be used so as to avoid potential damage to the equipment, and therefore no data were collected.

3.1 Response movement of dolphins to vessel interactions

A total of 201 vessel-dolphin interactions were observed during the study period. Response movements of dolphins to vessel interactions were divided into four categories: away, towards, neutral and mixed. Neutral responses were recorded in 51.2% (N= 103) of all interactions, whilst negative responses (movement away from a vessel) were observed in 24.3% (N= 49) and positive responses (movement towards a vessel) on 18.9% (N= 38) of encounters. Additionally, a mixed response to vessel presence was seen on 5.4% (N= 11) of occasions.

Forty vessel-dolphin interactions were collected from the headland study area during 2014. It was calculated that 60% (N= 24) responded to vessel presence whilst the remaining 40% (N= 16) displayed no change in behaviour or movement. Behavioural change consisted of movement towards a vessel - 10% (N= 4), movement away from a vessel - 42.5% (N= 17), and mixed response - 7.5% (N= 3, Figure 10). Pier observations yielded 161 vessel-dolphin interactions. A total of 46.5% (N= 75) individual dolphins displayed response movement to vessels, 21% (N= 34) moved toward vessels, 20% (N= 33) actively moved away from vessels, and 5% (N= 8) displayed a mixed response to vessel movement. The remaining 53% (N= 86) of individuals displayed no visual behavioural response to vessels or watercraft (Figure 10).

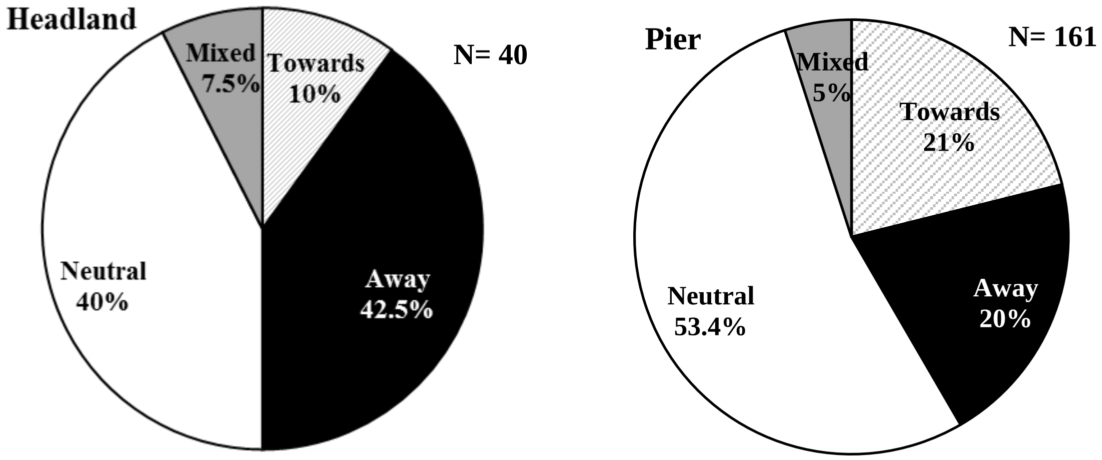

Figure 10. Response movements of individual dolphins to vessels between June and July 2014 at the headland and pier study sites. Responses included movement towards a vessel, movement away from a vessel, a mixed response, and neutral where no change in behaviour was recorded

Response movements of dolphins to vessel activities were compared between 2010 and 2014 (April-July, Figure 11) using the pier observations. From these, it is evident that the proportion of response movements (mainly negative) is escalating with a marked increase in 2014. The proportion of mixed behaviours has remained fairly constant. Neutral response behaviour has also remained consistent.

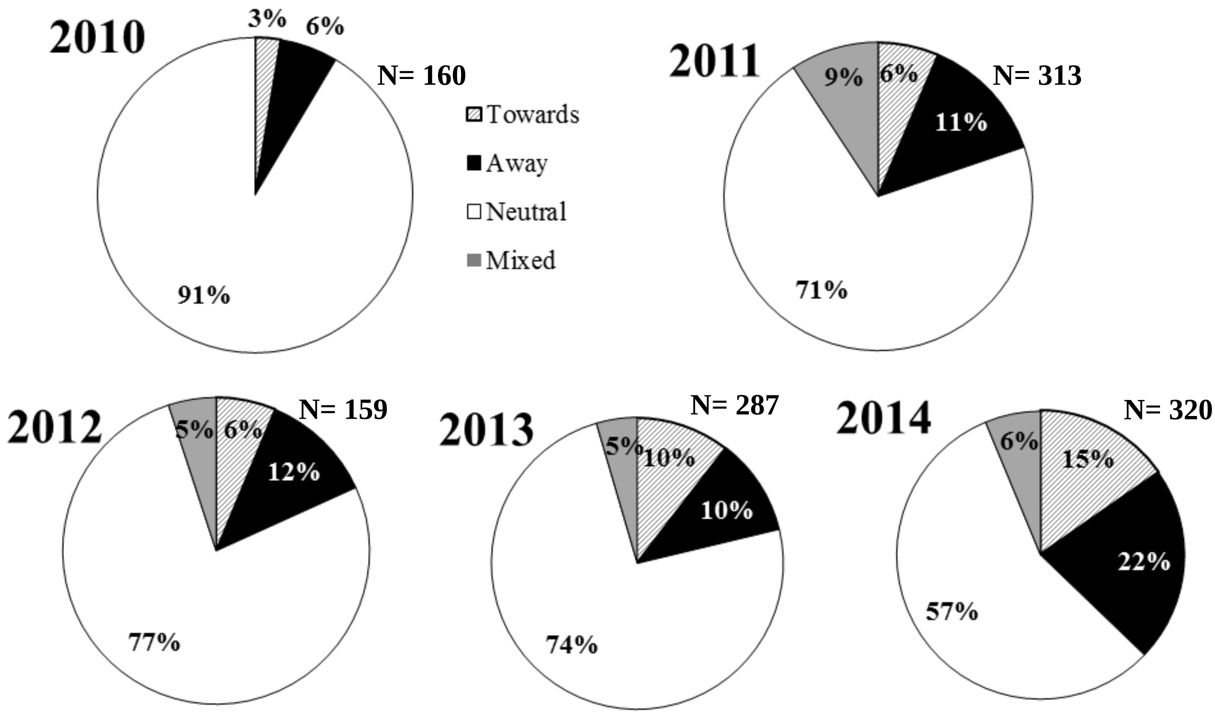

Figure 11. Temporal comparison of the pier observation site, 1st April- July 15th 2010-2014

3.2 Behaviour displayed prior to and during vessel interactions

Dolphins are highly mobile and therefore, are capable of displaying a variety of behaviours within a short period of time. Dolphins were recorded engaging in nine different behaviours prior to vessel interactions (Figure 12, see Table 2 for description). Of these, the most frequently recorded behaviour was normal swimming (45.3%), followed by suspected feeding (14.7%), aerial behaviour (10.8%), socialising (7.3%), surfacing (6.4%), diving (5.9%), fast swimming (4.9%), percussive behaviour (2.4%), and feeding (2%). These were categorised for analytical purposes into travelling, diving, socialising, feeding, and resting (Table 3).

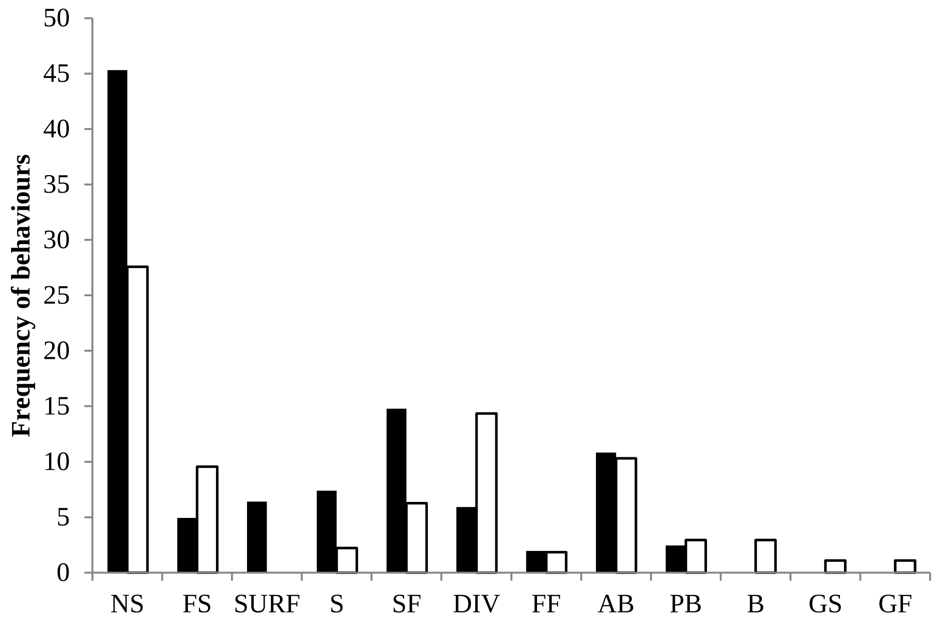

Figure 12. Frequency of behaviours performed prior and during vessel interactions, for combined study sites (NS – Normal swimming, FS – Fast swimming, SURF – Surfacing, S – Socialising, SF – Suspected feeding, DIV – Diving, FF- Feeding, AB- Aerial behaviour, PB – Percussive behaviour, B – Bow-riding, GS – Group splits & GF – Group forms)

During interactions, it was noted that a variety of dolphin behaviours were altered or suppressed by vessel presence (Figure 12). Behaviours such as normal swimming decreased by 18.4% in the presence of one or more vessels, along with suspected feeding which decreased by 43.3%, although analyses found no significant difference in feeding behaviour prior to and during vessel interactions (ANOVA, $F = 0.986$, $df = 4$, $P = 0.322$). Fast swimming and diving behaviour increased by 38.4% and 30.7% respectively during vessel interactions, whilst surfacing behaviour ceased completely when vessels were present in the study area. Observed social behaviour declined by 60% during vessel interactions, although the decline was not statistically significant (ANOVA, $F = 1.403$, $df = 4$, $P = 0.234$, Table 5) prior to, and during vessel interactions. The lack of statistically significant results is attributed to the small sample size.

Table 5. Analysis of variance of behavioural change prior to and during vessel interactions

Behavioural Category	F-Value	Degrees of freedom	P-Value
Resting	0.411	4	0.801
Travelling	0.907	4	0.461
Socialising	1.403	4	0.234
Feeding	0.865	4	0.486
Diving	3.603	4	0.007

3.3 Effects of vessel features

The behaviour which a dolphin displays towards vessels may be dependent on a variety of factors. Examples include vessel type, distance to the vessel, named vessel, vessel engine, number of vessels in the area, and vessel behaviour, all of which will be explored in further detail.

3.3.1 Vessel type

Vessel types were recorded to determine whether dolphins varied their behaviour in response to different vessel types (Figure 13). The most common vessel type was visitor passenger boats (VPB), which accounted for 53.3% of all vessel traffic. Small recreational motor boats were the second most popular vessel accounting for 16.8%, followed by rowing boats (including kayaks) with 8.6%, speed boats and sail boats with 7.6%, and fishing boats at 2.4% (See Table 1 for full vessel descriptions). A chi-squared analysis was conducted on vessel type and dolphin behavioural response. Although an observable difference was noted between VPB's and positive response behaviour more so than any other vessel type. No statistical relationships were found between response behaviour and vessel type (χ^2 = 34.04, df = 24, P = 0.084).

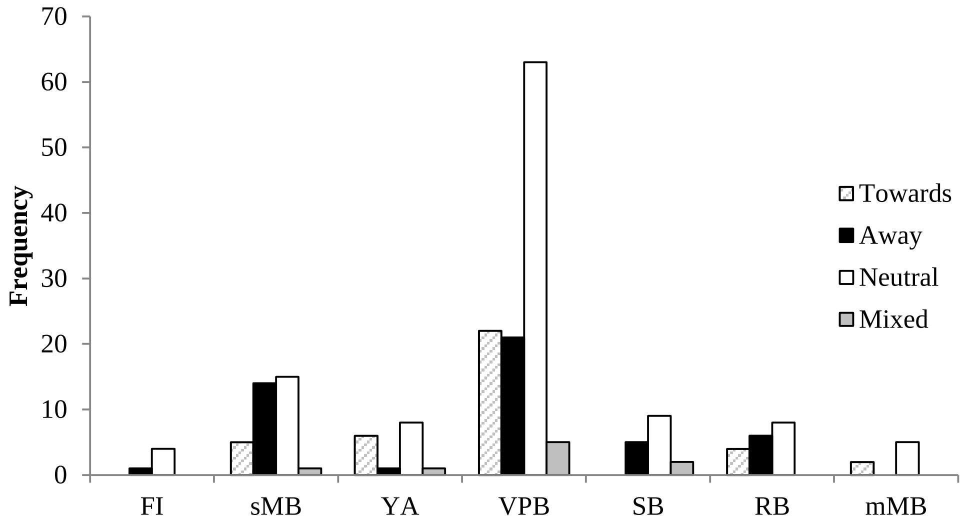

Figure 13. Response movement of *T. truncatus* to differing vessel type

Further analyses found a non-significant relationship between behaviour category and vessel type (F =1.403, df = 6, P = 0.214). *T. truncatus* generally displayed a neutral response to VPB's; whilst yachts yielded the highest percentage (30.3%) of positive behaviours when compared to other vessel types. Small motor boats elicited the highest percentage of negative responses (26.8%), followed by rowing boats at 22% and speed boats at 20%.

3.3.2 Vessel name

A total of 45 named vessels were recorded entering the study area during the study period. It was observed that differences in behavioural response by dolphins occurred between different types of named vessel, which may be linked to vessel behaviour, size and/ or engine type (Table 6). An analysis of variance test was undertaken to determine the variation between groups. A significant relationship was found between dolphin response and named vessels (F = 9.783, df = 1, P = 0.002). The *Ermol V* is a large VPB, which runs every two hours out of New Quay harbour and is equipped with two powerful 128 horse power (HP) outboard engines (Table 6), producing a lot of noise both above and beneath the sea surface. Interactions with this vessel occurred on 26 occasions, in nine of these interactions the vessel was avoided by dolphins by either diving or swimming horizontally away from the noise. The VPB, the *Islander*, is a small metal passenger boat which operates out of New Quay pier approximately every hour and a half, and is powered by twin 60 HP petrol engines (Table 6). The *Islander* was observed to have 18 encounters with dolphins. In ten cases dolphins continued their current behaviour and in three cases, dolphins actively moved towards the vessel. Chi-squared analysis between response behaviour and engine size revealed a significant relationship ($\chi^2 = 244.654$, df = 60, $P < 0.001$).

Table 6. Visitor passenger boat length, engine type and size and response behaviour, where T is towards, A is away, N is neutral and M is mixed

Vessel Name	Length (m)	Engine Type	T (%)	A (%)	N (%)	M (%)	Total
Ermol V	11.5	2x 128 hp diesel	11.5	34.6	53.8	0	26
Ermol VI	10.9	350 hp diesel	13.6	22.7	63.6	0	22
Islander	7	2x 60 hp petrol	16.6	16.6	55.5	11.1	18
Dunbar Castle II	9.7	120 hp diesel	42.8	7.1	42.8	7.1	14
Sulaire	10.05	380 hp diesel	30	20	50	0	10
Anna Lloyd	10.05	2x 150 hp diesel	16.6	8.3	66.6	8.3	12

A chi-squared analysis of named vessels and dolphin behaviour prior to and during vessel interactions yielded a significant relationship ($\chi^2 = 244.654$, df = 60, $P < 0.001$), demonstrating that behaviour was altered during vessel interactions as a result of named vessel interactions. Examination of the data revealed that the majority of dolphins displayed a neutral response to the majority of vessels. However, a higher proportion of negative behaviours were displayed towards the *Ermol V*, *Ermol VI* and the one small recreational motor boat *Whiteshark* (Figure 14).

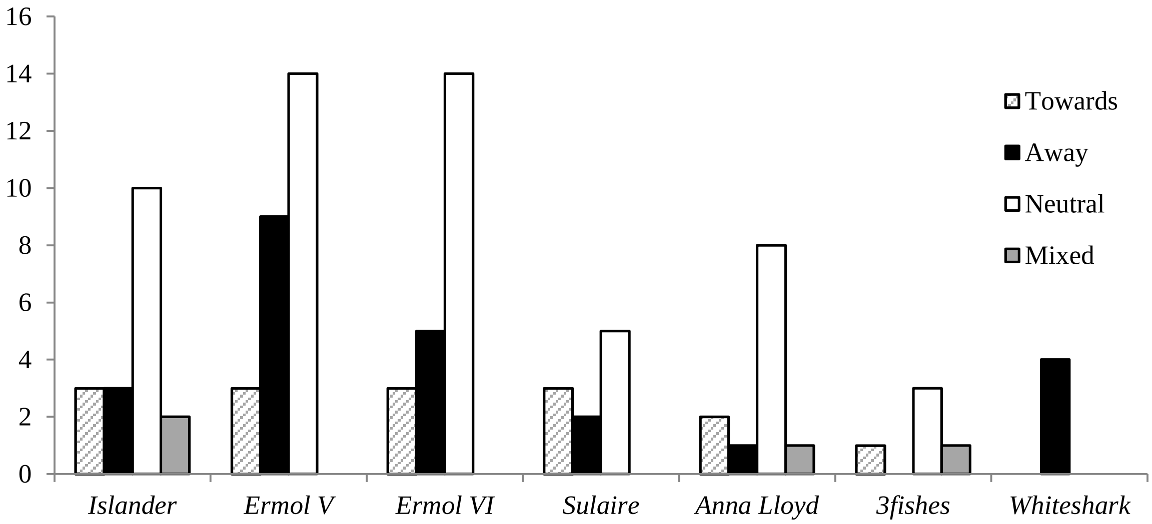

Figure 14. Named vessels and dolphin behavioural response; towards, away, neutral and mixed. Islander, Ermol V, Ermol VI, Sulaire and the Anna Lloyd are dolphin tour boats, 3fishes is a small visitor passenger fishing boat and Whiteshark is a small recreational motorboat

Response behaviour to vessels may be dependent on a variety of factors including distance which is one such factor. It was observed that some vessels, notably the *Islander, Ermol V, Ermol VI* and *Anna Lloyd*, were often observed within 50 metres of the focal dolphin (Figure 15). In a few cases this may have been the result of dolphins actively seeking out the boats. However, the majority were the outcome of vessels moving towards the dolphins.

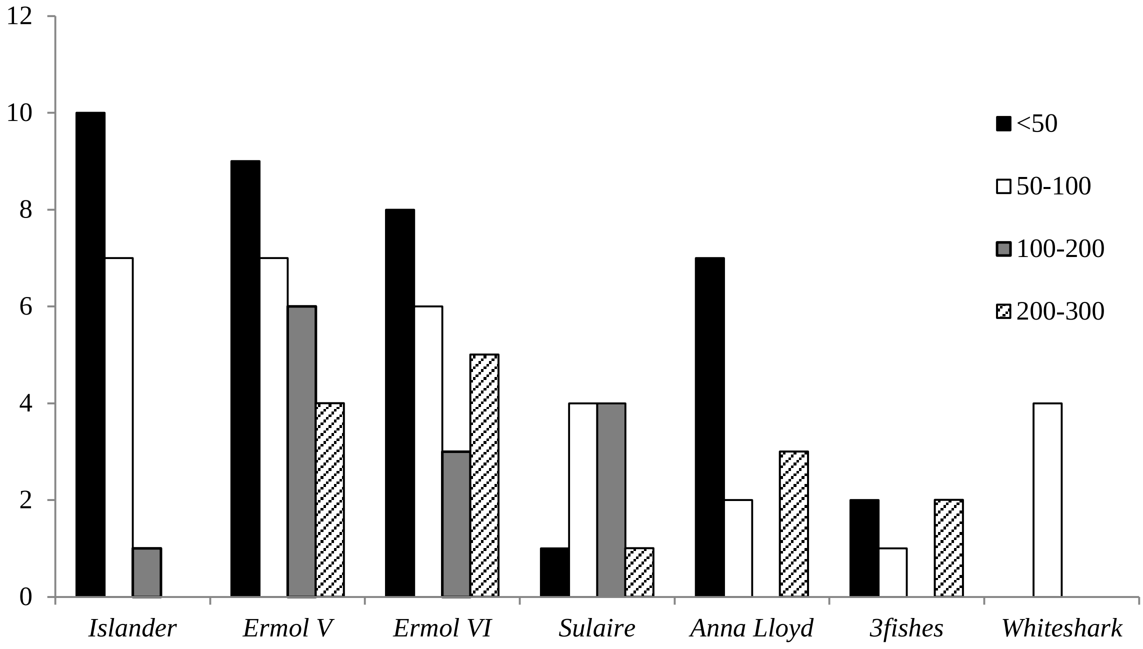

Figure 15. Distance between named vessels and individual dolphins

3.3.3 Vessel behaviour

Vessel behaviour was split into four different categories: Y1, Y2, N1 and N2 (see Table 2 for full description). Observations of vessel activity were conducted from both study locations, and were examined both independently and together (Figure 16-18). For the combined study sites, 46.1% of vessels displayed behaviour Y2 (Slowed down and gradually stopped), 39.5% displayed Y1 (No wake speed & no erratic change of course when passing cetaceans), 7.5% exhibited N1 (Too fast: wake speed, white water visible) and 6.5% showed N2 (Erratic course to approach, avoid or follow cetaceans, Figure 17).

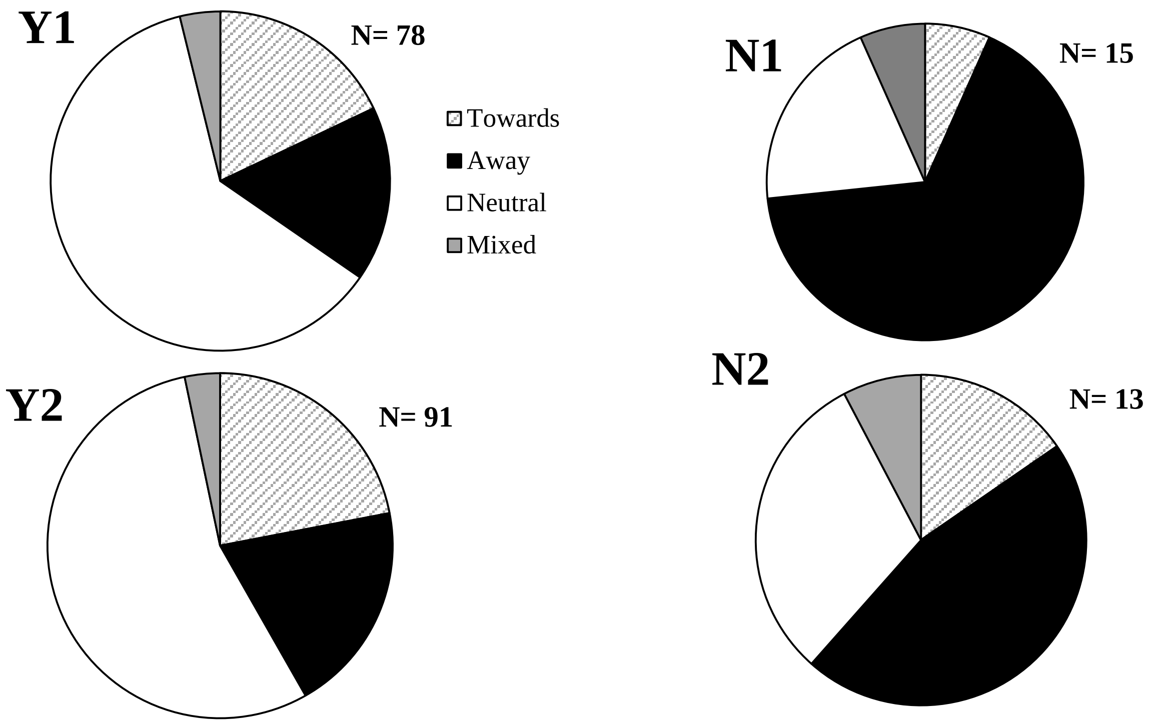

Figure 16. Bottlenose dolphin behavioural responses to vessel activities in New Quay Bay, Wales using data from combined study areas

Behaviour of boats differed considerably throughout the study period, although the majority followed the strict code of conduct, which is implemented to protect cetaceans and to reduce disturbance. VPB's adhered to the code more rigorously than other vessels. Speed boats and small recreational motor boats were most likely to ignore the codes and regulations. They frequently displayed fast and erratic movements, to which the dolphins appeared to respond negatively.

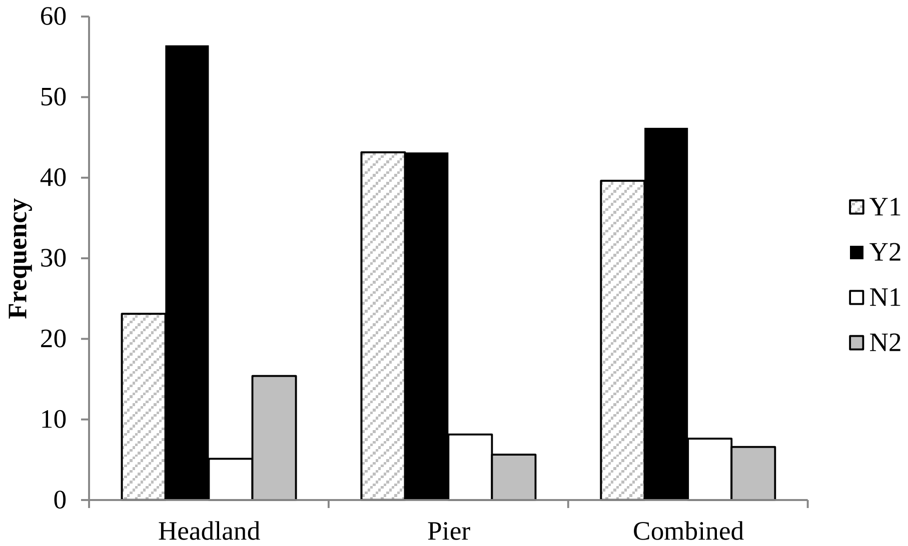

Figure 17. Percentage of vessel behaviour displayed at the two study site and combined

The results revealed that vessels displayed behaviours that were more likely to result in negative dolphin behaviours at the headland study site (Figure 18), which coincides with the higher amount of disruptive behaviour displayed by vessels in the same area (Figure 17). At both sites however, the majority of dolphins responded in a neutral manner towards approaching vessels, regardless of the behaviour of the vessel. A higher proportion of positive behaviour was displayed at the pier study site, which may be linked to the observance of guidelines in front of the harbour of regular vessels such as VPBs.

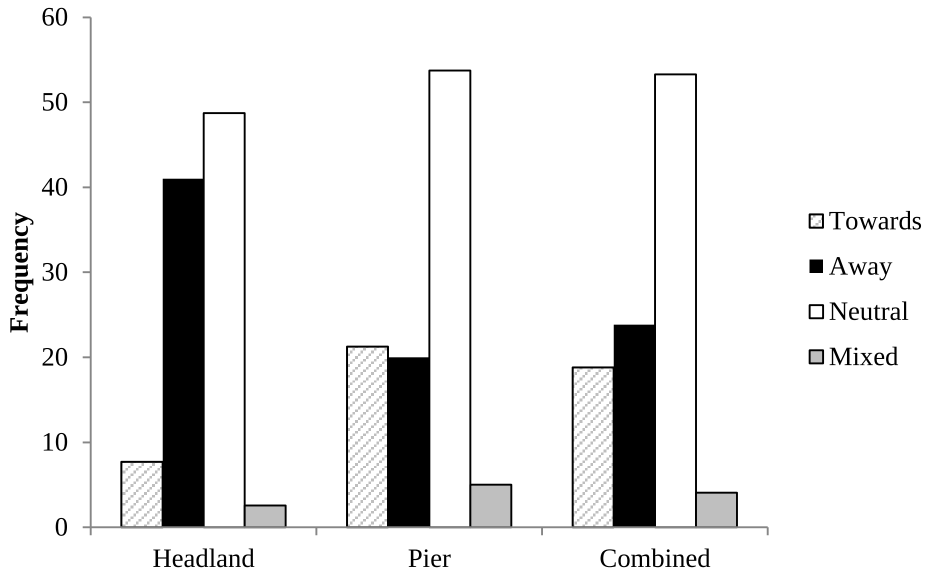

Figure 18. Percentage of response behaviours displayed by bottlenose dolphins as a result of vessel behaviour at each of the study sites and combined

3.3.4 Distance and response behaviour

The distance between individual dolphins and vessels was constantly tracked, with any changes in behaviour and group cohesion noted. The majority of interactions for combined study sites occurred within <50 m (47.7%) of the vessels, followed by 24.1% of interactions occurring at 50-100 m, 15.5% at 101-200 m and 7.7% at 201-300 m. Differences between vessel distances and response behaviour were found to be non-significant (GLM, $F = 0.797$, $df = 4$, $P = 0.528$). However, observable differences do occur in response behaviour in the collected data (Figure 19).

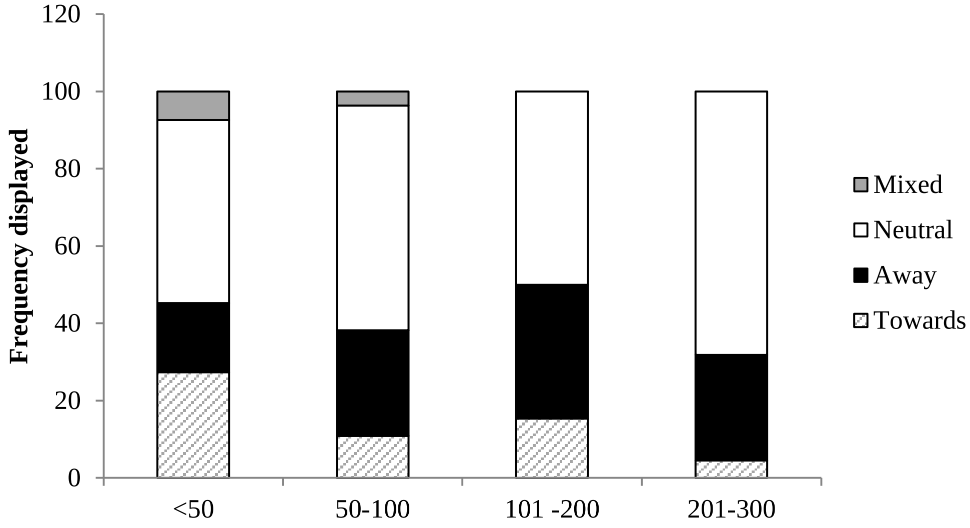

Figure 19. Percentage of response behaviour displayed at four distance categories

3.3.5 Number of vessels within 300 metres

An analysis of variance test between response movement and number of vessels within 300 metres was conducted to determine if having additional vessels within the area affected response movement. However, results were found to be non-significant (F = 1.015, df = 5, P = 0.410).

3.3.6 Group cohesion and spacing

Group size varied considerably throughout the study period and ranged from two individual adults to seven animals, the mean group size being calculated at 1.9 individuals. Group composition consisted of individual animals, mother and calf pairs, and larger groups. Calves were present during 131 (62.6%) of vessel-dolphin interactions, 79 (39.3%) and 52 (25.8%) from the pier and headland, respectively. It was noted that in 51.2% of interactions, dolphins displayed a neutral response regardless of group composition. Individuals and smaller groups were seen to respond to vessels more often in a more negative manner than larger groups, although the difference was not significant (ANOVA, F = 35.549, df = 22, P = 0.626, Figure 20).

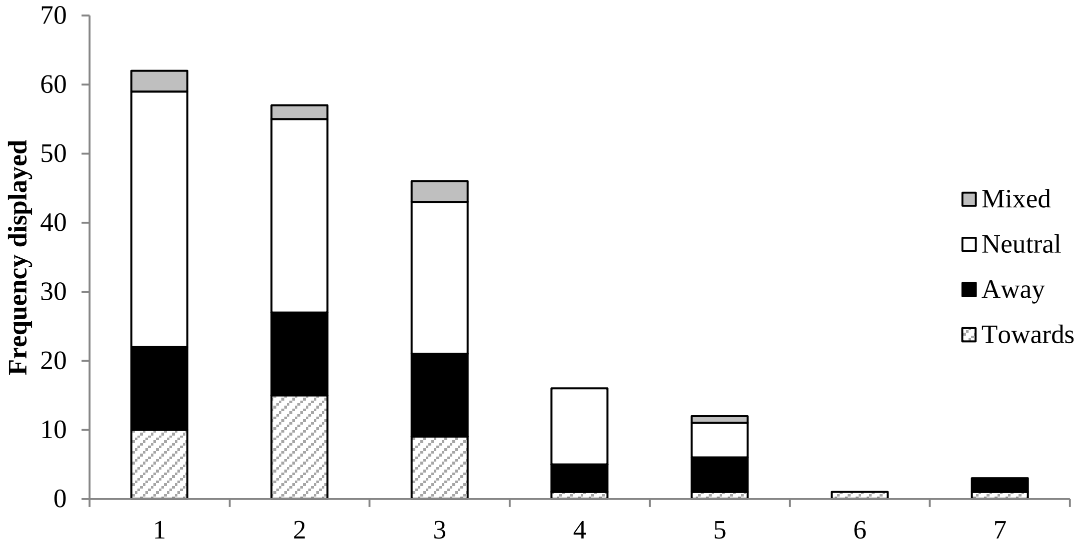

Figure 20. Group size and bottlenose dolphin response behaviour

The distribution of response behaviour was calculated as the same across all categories of group size (Kruskal Wallis, P <0.000). A Pearson's chi-square analyses showed a significant difference between group dispersion, prior to, and during vessel interactions (χ^2 = 31.440, df = 4, P <0.000). Throughout vessel interactions, group spacing and group composition were recorded. In 93.5% of encounters, group cohesion stayed the same; in 3.8% of interactions, group splits were recorded; and in 2.5% of interactions, groups were formed. Group spacings varied considerably during the study. In 16.6% of vessel-dolphin interactions, groups were observed to shift from a tight group formation to a loose or dispersed formation. In 23.4% of cases, dolphins were recorded to change from a loose group to a dispersed group. In 20.8% of encounters, inter-animal spacing decreased and animals grouped closer together. In 38.2% of occasions, no change in group composition was recorded. No significant difference was observed between group spacing and response behaviour (χ^2 = 4.916, df = 4, P = 0.296).

3.4 Time of day

Two-hourly vessel counts were recorded, to assess the potential effects on dolphin behaviour. Mean two-hour vessel counts for the headland study area totalled 11 vessels, whilst the pier yielded 19.6 vessels. It was clear that during peak times when vessel traffic was high, dolphin sightings decreased significantly (χ^2 = 168.7, df = 116, P = 0.001, Figure 21). It is, therefore, possible to accept the hypothesis that "as vessel activity increases, a decline in dolphin sightings is observed". Dolphins were observed most frequently during the morning and late evening, when vessel traffic was at its lowest (Figure 21).

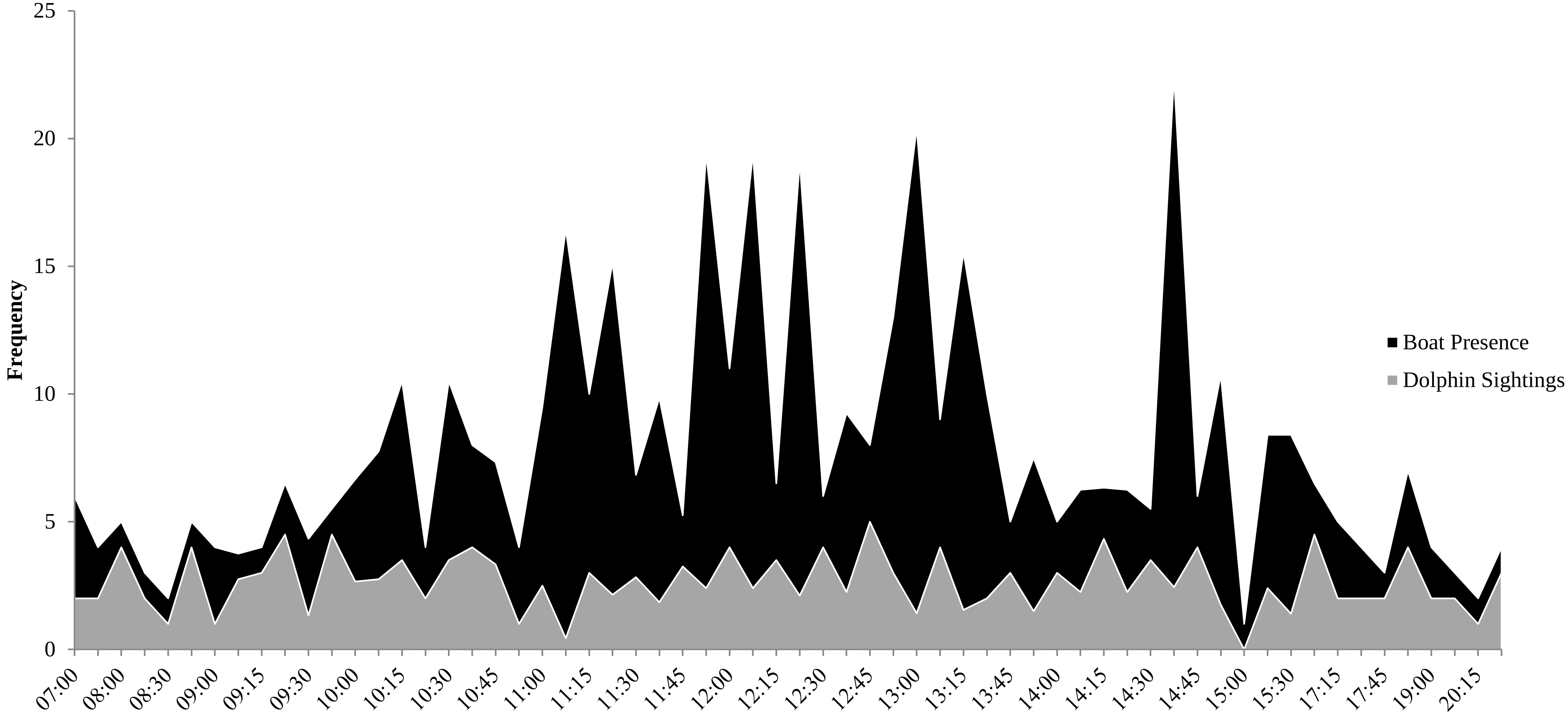

Figure 21. Dolphin sightings and vessel traffic in relation to time of day

3.5 Dolphin and vessel distribution

Observations were collected daily from New Quay pier. In addition to effort and sightings, a map of the harbour area was gridded, and marked with the distribution and abundance of dolphins and vessel presence. This allowed comparisons of site usage to be made. It was found that dolphins spent the majority of the observed time in grid square two (see Appendix 1), which is the area located just offshore from the fish factory, and this accounted for 40% of all dolphin sightings in the area. Grid square five, located off the pier, was also a preferred area for dolphins, accounting for 25% of sightings (See Appendix 1). Twenty-two percent of dolphin sightings were located in grid three, located around the cardinal buoy. Whilst 87% of boats were concentrated around the pier and harbour area, in grid squares two and five. Chi-squared analysis found dolphin and vessel distribution to be significantly different (χ^2 = 148.864, df = 42, P <0.000).

Figure 22. Distribution of *T. truncatus* around New Quay Bay, encompassing the headland & pier study sites. Red colour represents vessel traffic and blue dolphin distribution

3.6 Vessel traffic and dolphin presence

Comparisons of vessel traffic and dolphin sightings between mid-week and weekends were undertaken to establish if vessel abundance and dolphin sightings varied during these times

(Figures 22 & 23). There were no significant differences between weekday and weekend sightings and vessel abundance ($\chi^2 = 30$, df = 27, P = 0.314). This may be the result of a small sample size, since fewer observational hours were collected during the weekend, especially from the headland study area, as there were fewer observers available.

Pre-season (April-June) dolphin presence and vessel encounters were compared to the beginning of peak season (July), to determine if there was a seasonal trend over the study period. An increase in vessel presence was found, with peaks coinciding with periods of good weather (Figure 24). An overall increase in two-hourly vessel counts was also observed for the period 2010-2014.

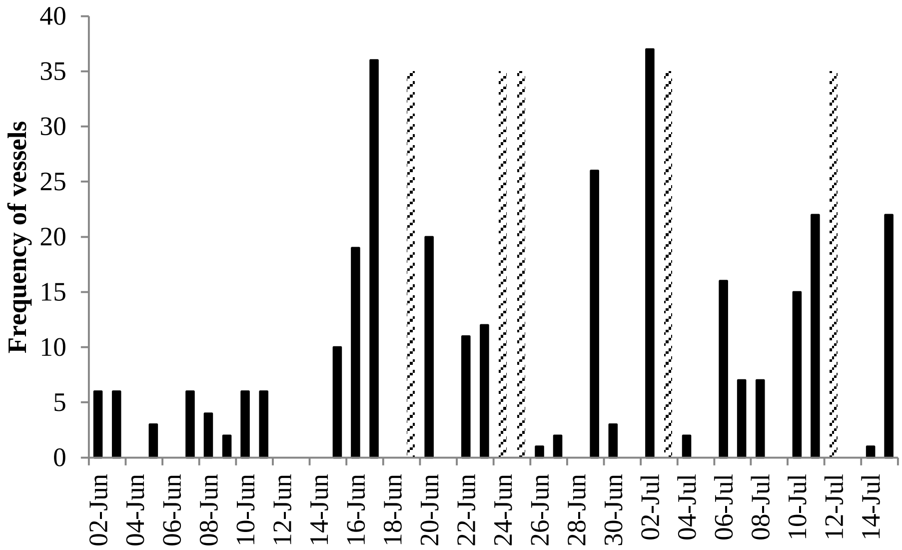

Figure 23. Vessel presence over the study period; shaded areas represent periods of poor weather when data on dolphin-vessel interactions could not be collected

Comparisons between date and response behaviour were found to be non-significant ($\chi^2 = 197.565$, df = 152, P = 0.008), as was vessel name ($\chi^2 = 646.274$, df = 570, P = 0.014), vessel type ($\chi^2 = 267.817$, df = 228, P = 0.036), vessel activity ($\chi^2 = 147.585$, df = 114, P = 0.019) and distance between the dolphin and a vessel ($\chi^2 = 180.802$, df = 152, P = 0.055). However, dolphin behaviour was found to be statistically different over the study period ($\chi^2 = 656.581$, df = 456, P <0.001) as was the number of vessels within 300 m of dolphins ($\chi^2 = 372.47$, df = 190, P <0.001), group size ($\chi^2 = 517.155$, df = 217, P <0.000), and sea state ($\chi^2 = 420.4$, df = 114, P <0.001). Analyses over the study period confirmed that as vessel abundance increased, an associated rise in vessel encounters was observed, thus leading to a rise in response behaviours including negative and positive responses (Figure 24).

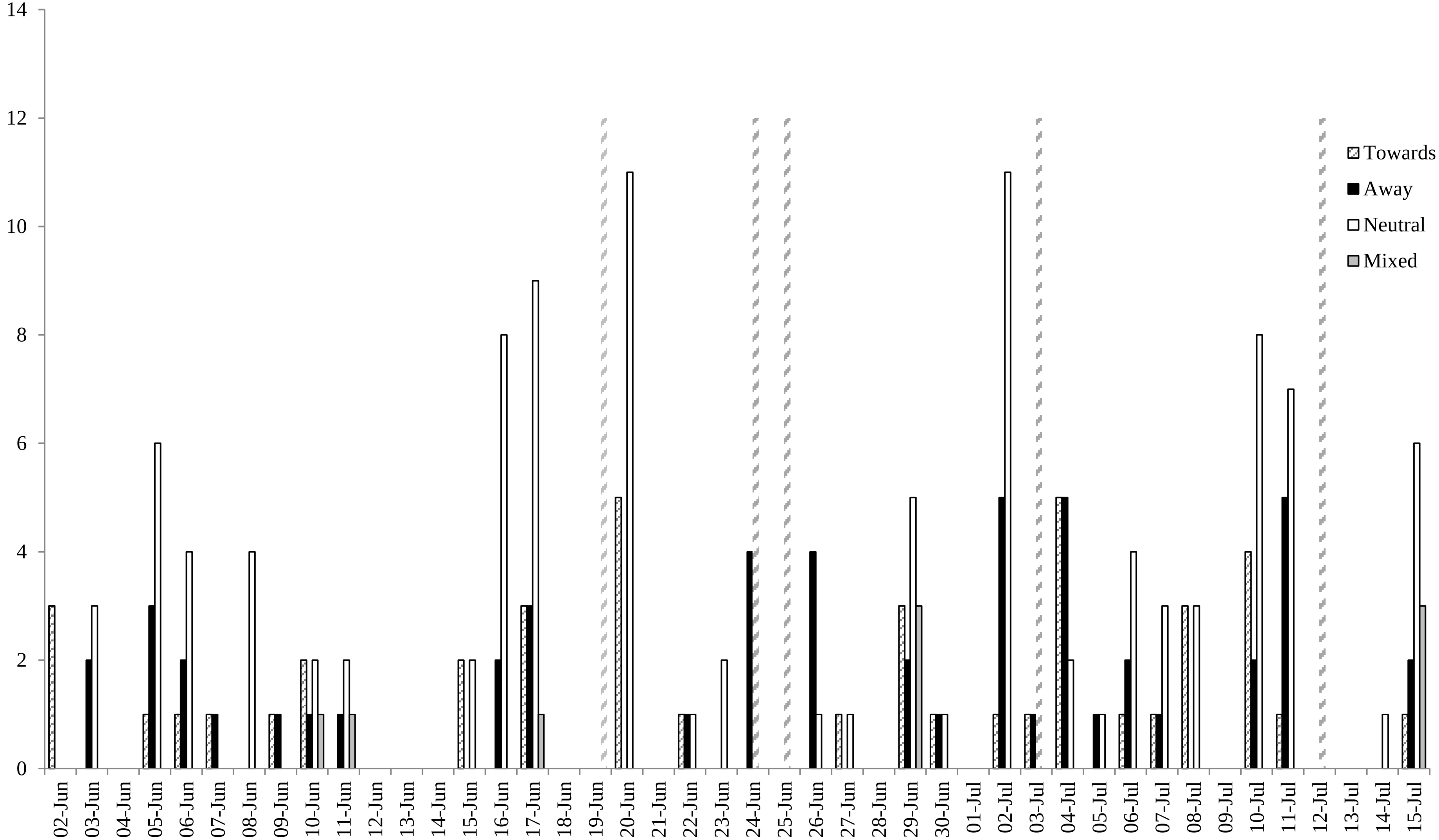

Figure 24. Behavioural response over the study period. Dashed lines represent periods of poor weather / sea state >3

3.7 Dive interval

As expected dive interval did observably increase in vessel presence, although the increase was non-significant, ANOVA, $F = 2.087$ $df = 4$ $P = 0.084$, therefore, the null hypothesis was accepted. When no detectable differences in behaviour were observed during vessel interactions, it was noted that dive time did slightly increase. Through analyses, it was found, that dive interval was evenly distributed across group size, Kruskal Wallis, $P < 0.001$. The distribution of response behaviour was also calculated as the same across all categories of group size, KW, $P < 0.001$. It was found that the distribution of response behaviour varied across dive time, providing a non-significant result, KW, $P = 0.117$. Mother and calf dive intervals were also compared to focal (individual) dolphins. During vessel presence it was recorded that mother and calf pairs dived for longer periods (Figure 25) and often surfaced 100 m or more from the offending vessel. These differences in observed means corresponded with statistical analyses and proved a significant relationship between surfacing interval and mother and calf pairs ($\chi^2 = 156.327$, $df = 102$, $P < 0.001$).

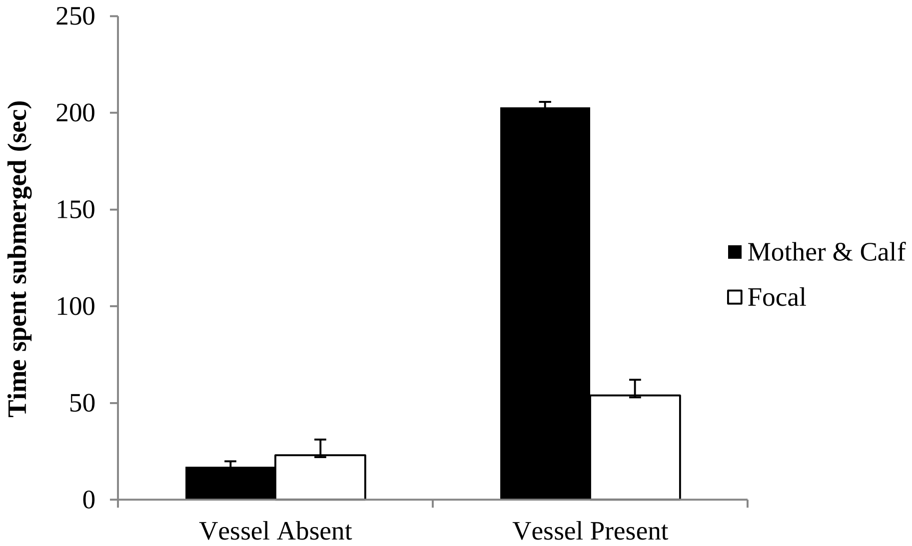

Figure 25. Differences in dive interval (time spent submerged) between mother and calves and focal dolphin

Mother and calf pairs were recorded to undertake the longest dive duration, averaging 202 seconds during vessel interactions. Average dive duration for mother and calf pairs prior to vessel interactions was calculated at 17.1 seconds, showing a significant rise in the period spent underwater between breaths. Dive interval for non-mother and calf pairs also increased from 23.0 to 53.9 seconds although, non-significantly ($\chi^2 = 78.19$, $df = 76$ $P = 0.409$) during vessel interactions.

3.8 Resident and transient populations

Transient dolphins consistently showed more negative response behaviours towards vessel traffic when compared to residents (ANOVA, F = 10.272, df = 2, P <0.001). Thus the hypothesis that "transient individuals display more negative response behaviours towards vessel traffic than the resident dolphin population" can be accepted. Transient individuals displayed a high percentage of negative behaviours towards vessels (58.8%) and displayed no positive response behaviours. The remaining 41.1% showed a neutral response towards vessel traffic (Figure 26). The resident population were discovered to display far less negative behaviours (23.5%) and a higher percentage of positive (38.2%) and neutral behaviours (38.2%) towards vessel traffic (Figure 26).

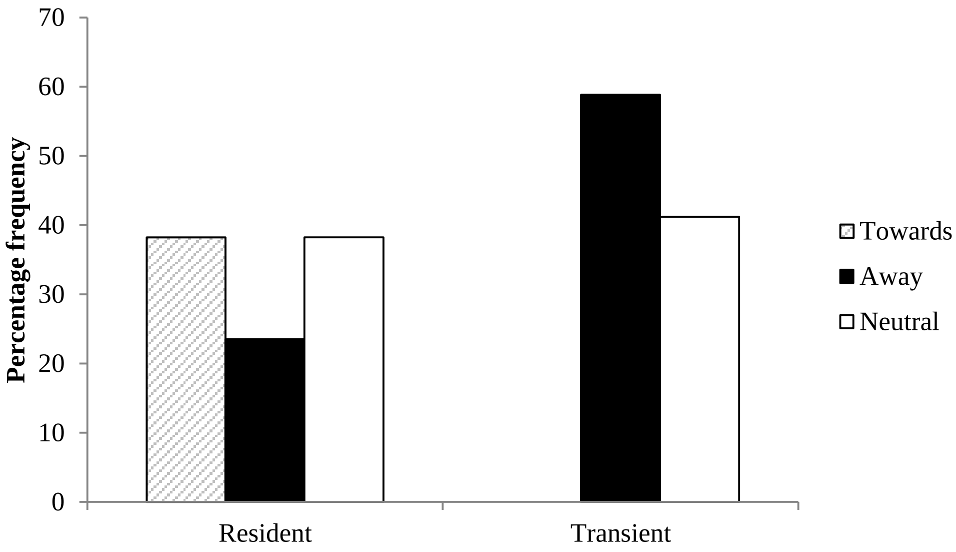

Figure 26. Percentage of response behaviours between resident and transient individuals

Particular individuals were observed very frequently. Examples include 017-03W (Smoothy), 207-07S (Lumpy), 074-03W (Bond), 004-90L (Chris) and 023-03W (Voldemort), and these are all categorised as resident individuals. Experienced resident mother 017-03W (Smoothy) would frequently be observed swimming round vessels surrounding the harbour, along with her calf (Dipper). When interactions became intrusive or unpredictable, she and her calf would undergo a series of long dives and often moved out of the area. On one occasion, a swimmer tried to interact with 017-03W (Smoothy); the response was immediately negative, and the mother and calf left the harbour area instantly.

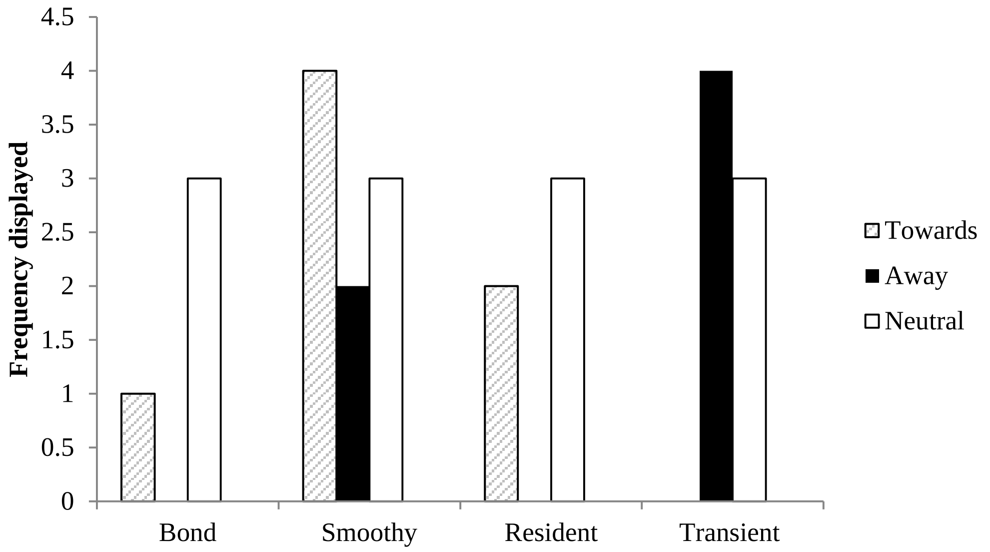

Figure 27. Response behaviour to vessels displaying Y2 behaviour (Vessels that slowed down and eventually stopped) for resident and transient populations. Bond is an adult male and Smoothy an experienced mother

Behavioural responses to vessel traffic were most frequently displayed in the vicinity of Y2 behaving vessels (Figure 27, for description see Table 1). It is evident that mother-calf pairs were more likely to move away from vessels displaying this type of behaviour as the interaction may last some time. It was observed that certain vessel types induced particular response behaviours. For example, small motorised craft induced the highest number of negative responses (Figure 28). Resident individuals were observed to display a higher percentage of neutral and positive behaviours towards visitor passenger boats, whilst transient individuals responded in a more negative manner.

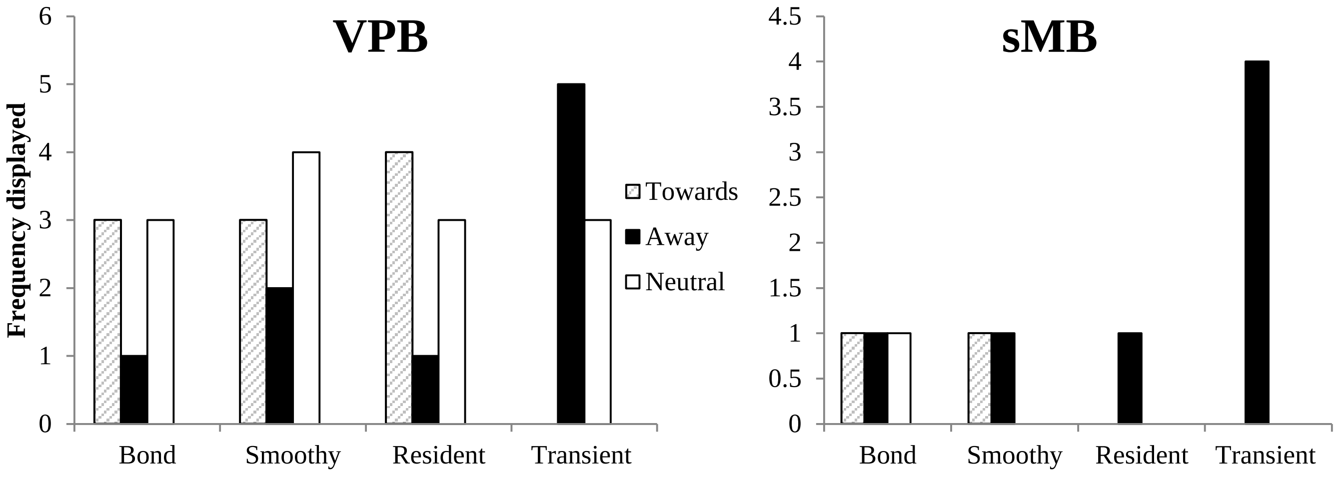

Figure 28. Resident and transient behavioural response to different vessel types. Note differing scale between graphs

3.8.1 Gender and response behaviour

Response behaviour was recorded for male and female resident bottlenose dolphins (Figure 29), as these were the individuals where gender could be confirmed.

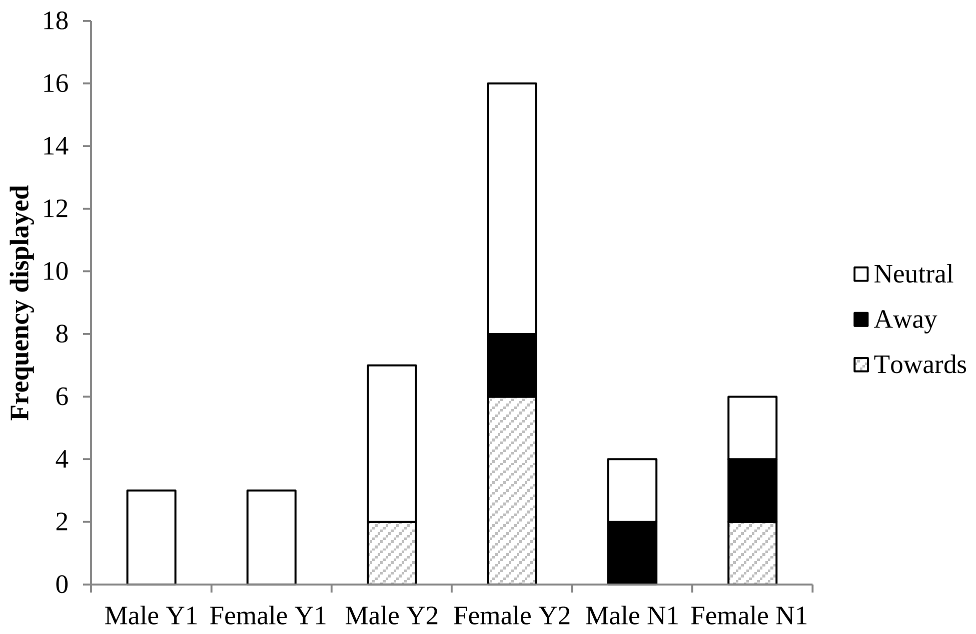

Figure 29. Response movement of male and female dolphins to vessel activity (see Table 3 for vessel activity description)

The relationship between gender and response movement was found to be significant (ANOVA, F = 8.736, df = 2, P <0.001). Due to a small sample size, few comprehensive comparisons could be made. However, females displayed more response behaviours (positive and negative) than male dolphins. During observations of vessel interactions, males showed fewer response behaviours and were less likely to alter their behaviour in the presence of a vessel. Vessels that displayed Y2 behaviour elicited the highest amount of response behaviour (Figure 29). Vessels displaying N1 behaviour caused the highest amount of negative response behaviour. Speed boats caused the highest negative response behaviour in both sexes when compared to other vessel types (Figure 30). Visitor passenger boats elicited the highest percentage of positive response behaviours and neutral behaviours for both genders.

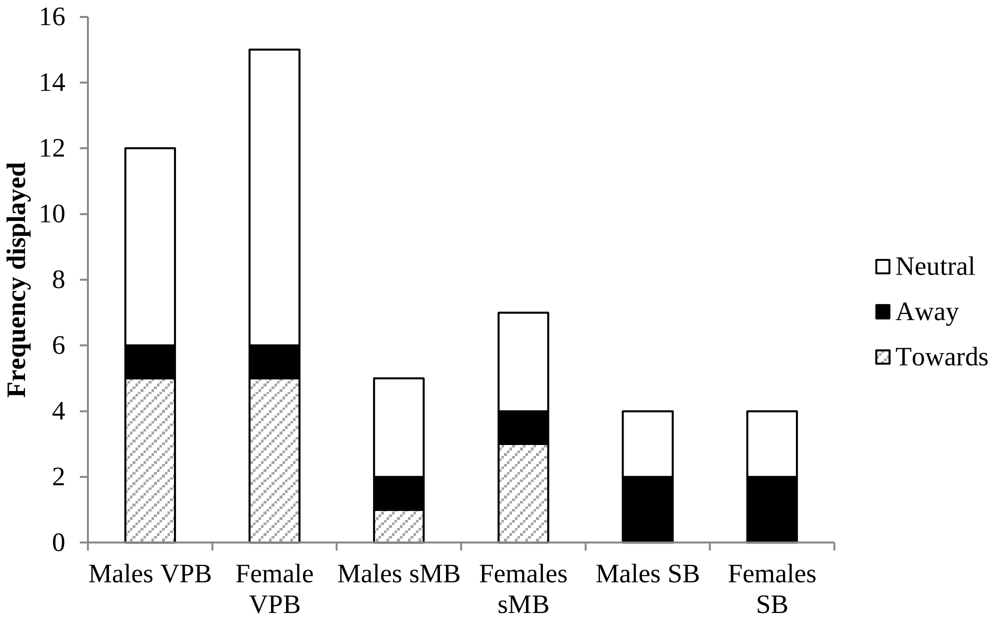

Figure 30. Response movement of male and female dolphins to different vessel types

3.9 Sea state and response behaviour

There were 193 observations during the study period; a moderate sea state was recorded at level 1 during 50.4%, level 2 during 40.8%, level 3 during 6.5% and sea state 0 during 2.1% of observations. High sea state can cause availability bias as it is harder for the observers to locate the dolphins, causing lower abundance and density estimates. It was confirmed that as sea state increased, dolphin sightings declined. However, the effect of sea state on response behaviour was found to be non-significant (ANOVA, F = 2.054, df = 4, P = 0.088).

4.0 Discussion

The results of this study provide evidence for the response movements of bottlenose dolphins to vessel activities in New Quay Bay, mid-Wales.

4.1 Response movement

As suspected vessel activities affected the short-term behaviour and behavioural response of bottlenose dolphins (*Tursiops truncatus*). The majority of vessel-dolphin encounters resulted in a neutral behavioural response (51%), but 24% exhibited negative response movements and 18% positive response behaviour. More than a decade ago, Gregory & Rowden (2001) found the most prominent behavioural response to be neutral (62%), with a higher proportion of negative response behaviour (22%) than positive (16%) in the same area. Veneruso *et al.*, (2011) later found similar results when undertaking a five-year study (2005-2010) in New Quay Bay, studying 2977 vessel encounters. Of these, 13% displayed a negative response, 6% a positive response, and the remaining 82% displayed no visible response behaviour (Veneruso *et al*., 2011). In recent years, however, higher numbers of response behaviours (positive and negative) are being recorded in comparison to previous years, with 2014 yielding the highest recorded negative response of any of the years studied. This can be attributed to an increase in vessel traffic over recent years, which has been directly related to a decrease in bottlenose dolphin sightings in the same areas (Veneruso & Evans, 2012; Feingold & Evans 2014a).

Response behaviour is related to a variety of factors including visual (Richardson *et al*., 1995; Nowacek *et al.*, 2001; David, 2002) and noise impacts and / or a combination of both (Richardson *et al*., 1995; Bejder *et al*., 1999; Jensen *et al.,* 2009). It has been debated whether vessel activities have an effect on fish distribution (Gerlotto & Freon, 1992). These researchers suggested that alterations in dolphin behaviour were the result of changes in fish distribution. Fish such as Atlantic cod (*Gadus morhua*) have been observed to school together, congregating at the seabed as a result of vessel noise (Engas *et al.*, 1995). Additionally, the presence of fishing vessels may lead dolphins to change behaviour due to the presence of a concentrated food source (Papale *et al.*, 2012). Thus, dolphins may alter their behaviour in order to continue feeding, possibly leading to an increased dive duration.

4.2 Behaviour displayed prior to and during vessel interactions

Behaviours such as feeding, resting and socialising are frequently observed to be suppressed during vessel interactions (Nowacek *et al*., 2001; Williams *et al*., 2002; Lusseau, 2006). Lusseau (2006) noted that vessel interactions had an effect on behavioural transitional states. It was observed that behaviours such as socialising, milling and resting transformed into travelling and diving in the presence of a vessel (Lusseau, 2006). Feingold & Evans (2014a) reported that dolphins in Cardigan Bay spend more time travelling and foraging and less time feeding, resting and socialising, and they suggested that this could be a result of decreased food availability, and increased disturbance (Feingold & Evans, 2014a). The evidence collected in the current study supports their findings. It was evident that behaviours such as resting, surfacing, feeding and foraging behaviour ceased, or were significantly reduced, during vessel presence. Whilst behaviours such as fast swimming, travelling, and diving all increased in vessel presence, Pierpoint *et al*. (2009) found that boat interactions caused a marked decline or total cessation of feeding behaviour during vessel interactions. Williams *et al*., (2006) found an 18% decrease in energy consumption when boats were present. This has the potential to lead to reduced prey consumption and an increase in time spent travelling and searching for prey, therefore, increasing energy expenditure, which could lessen reproductive and survival ability (Lusseau, 2006; Williams *et al*., 2006).

The consequences of disturbance at a population level are difficult to assess as long-term data are needed to assess impacts. Additionally, the majority of response behaviour research has been undertaken using surface observations (Hastie *et al*., 2003; Lusseau, 2006; Bejder *et al*., 2006; Feingold & Evans, 2014a), which may not best represent the dolphin's response. It may be beneficial to study sub-surface behaviours similar to those conducted by Nowacek *et al*. (2001), to fully understand response behaviour. Previous studies in Cardigan Bay suggest that the severity of response behaviour and type of behavioural change may be dependent on the type of behaviour being displayed prior to vessel interactions, and that dolphins displaying foraging behaviour were less likely to change behaviour than those displaying social or resting behaviour (Veneruso *et al*., 2011). Similarly, this study found that the response elicited by dolphins was dependent on previous activity; however, there were variations between individual animals.

4.3 Effects of vessel features

4.3.1 Vessel type

Visitor passenger boats were seen more than any other type of vessel in the area (Figure 13) and the majority of these were dolphin tour boats. These vessels were taken into particular consideration as they are observed to behave in a different manner to other vessels, and they try to stay within the dolphin's vicinity (Janik & Thompson, 1996). This is rarely observed in New Quay Bay due to the strict marine code of conduct in place to reduce the levels of disturbance to the dolphin population. The majority of VPB's adhere to the regulations. However, not all boats follow the code, and enforcement is rarely applied. Responses to VPB's vary between countries. In Doubtful Sound, New Zealand and Sarasota Bay, Florida, the majority of responses were recorded as negative, due to the vessels' erratic behaviour, unpredictable movements and often "stalking" behaviour towards the dolphins (Nowacek *et al*., 2001; Lusseau, 2003a, 2005, 2006). In other areas, such as New Quay Bay and Shark Bay, Australia, a more neutral response has been recorded (Gregory & Rowden, 2001; Bejder *et al*., 2006a; Veneruso *et al*., 2011; Feingold & Evans, 2014a) as was found with the current study. Tour boats in New Quay Bay follow established routes and are usually predictable in behaviour. It is suggested that due to the predictable nature of tour boats, dolphins are less likely to respond to them. The current study, as with a study conducted by Veneruso *et al*., (2011), observed that speedboats and small motorised craft cause the greatest disturbance to dolphins, often causing a negative response. Gregory & Rowden (2001) reported that dolphins displayed more positive response behaviour towards VPB's, and this was also found in this study. Non-engine craft such as kayaks were noted to elicit the third highest proportion of negative response behaviour (33%), as has also previously been observed (Gregory & Rowden, 2001).

It is questioned whether dolphins have the ability to habituate to particular vessels, implying that dolphins exposed to regular boat traffic and vessel type will become habituated to certain vessels, and thus exhibit fewer avoidance behaviours, which could potentially improve fitness in the long term, because less energy is consumed avoiding boats unnecessarily (Gregory & Rowden, 2001; Constantine *et al.*, 2004; Mattson *et al.*, 2005; Sini *et al.*, 2005). For example, tour boats leave New Quay harbour every hour during peak season (June-August) and follow specific routes. Thus, vessel movements are often predictable and are unlikely to display erratic movements, which disturb dolphins. Other vessels such as kayaks have been observed to disturb dolphins primarily due to their shallow draft and relatively quiet movements (Gregory & Rowden, 2001; Lusseau, 2006). Having shallow drafts allows kayakers to invade dolphin habitat which other vessels are unable to reach, and this has the potential to cause disturbance to important processes such as reproduction and feeding (Wells, 1993; Nowacek *et al.*, 2001). Additionally, without a motor alerting the dolphins to its presence, kayakers can get relatively close without the dolphin being aware, which can induce a rapid negative response (Gregory & Rowden, 2001).

4.3.2 Vessel name & noise affects

During the study, the name of each vessel was noted where possible in order to determine what traits elicited the greatest response behaviour. A total of 45 named vessels were recorded during the study period, seven of which were VPB's and operated throughout the day. *Dunbar Castle II,* often used as a cetacean research vessel, elicited the highest amount of positive and the least negative response behaviours. By comparison, the larger VPB, the *Ermol V*, caused the highest amount of negative and the lowest amount of positive behaviour when compared to other VPB's. Small recreational craft caused the highest amount of disturbance. All behavioural responses to *Whiteshark* (sMB) were negative due to a disregard of the marine code of conduct. It was observed that with the majority of vessels, as engine size increased, more negative responses were displayed. This was true of all vessels except for the *Sulaire* and *Anna Lloyd* which are both owned by Steve Hartley from the "Cardigan Bay Wildlife Centre", who has a particular long-standing interest in the dolphins of Cardigan Bay, and generally behaves with care around the dolphins, which is probably the reason these boats are exceptions to the trend.

4.3.2.1 Vessel noise

It is well known that engine noise can suppress communication (Ross, 1976; Arveson & Vendittis, 2000; Mattson *et al.*, 2005; Jensen *et al.*, 2009). Vibrations and noise produced by vessels have the potential to affect dolphins to a great extent (Buckstaff, 2004; Mattson *et al.*, 2005). They have been known to disturb vocal communication and food finding by echolocation, and may have further impacts on delphinids, such as temporary and permanent damage to hearing (Mattson *et al.*, 2005). Jensen *et al.* (2009) studied the effect of vessel noise on bottlenose dolphins and short-finned pilot whales, and examined the possibility that vessel noise could reduce habitat quality. It was found that small watercraft travelling at 5 knots in shallow water can reduce the communication range of bottlenose dolphins within 50 metres by 26% (Jensen *et al.*, 2009). The level of cavitation noise (air bubbles which form and collapse on the edge of propeller blades creating medium-high frequency noise levels) increases with speed of vessel and thus it is important to assess vessel speed in addition to its behaviour (Ross, 1976; Evans *et al.* 1992; Arveson & Vendittis, 2000). Whale watching vessels are a significant contributor to underwater noise (Jensen *et al.*, 2009), the VPB *Ermol V* was by far the loudest vessel in the study area, closely followed by the *Ermol VI*, and as a consequence the highest recorded negative responses were to these vessels. By contrast, VPB's with smaller engines were responded to in a positive or neutral manner. Vessels with no engine were seen to elicit a greater number of negative responses as individuals may not have time to alter behaviour, due to little or no warning prior to an interaction. This lack of predictability has the potential to cause greater disturbance and danger potential (Nowacek *et al.*, 2001).

It has previously been suggested that aerial behaviour and tail-slapping are a non-vocal form of communication, instigating travelling behaviour, which may be used when vocal communication is suppressed by vessel noise (Lusseau, 2006). Dolphins in New Quay Bay were observed to display a variety of tail-slaps, aerial and percussive behaviour before undertaking travelling behaviour, and thus it is possible that dolphins were using non-vocal communication to instigate travelling activity. However, no significant differences were found in the frequency of percussive behaviour during vessel interactions and at other times.

4.3.3 Vessel behaviour

It is perceived that as vessel speed increases, and behaviour becomes more erratic and unpredictable, more negative response behaviours are exhibited. Erratic approaches to dolphins and high speed in vessels has been known to alter the behaviour and direction of movement of dolphins in China and North America, for example (Ng & Leung, 2003; Mattson *et al.*, 2005). Due to the implementation of a strict code of conduct in New Quay Bay, dolphins are far less affected by the behaviour of vessels here. Compliance levels of 90% have been recorded which is significantly higher than in other areas of the Cardigan Bay SAC (Pierpoint & Allan, 2006; Richardson, 2012). Due to funding restrictions, little enforcement is implemented and therefore some vessels, most commonly recreational motor craft, can have a profound effect on dolphin response behaviour. It was evident that during bouts of high traffic volume, the majority of vessels adhered to the code regulations.

Comparisons between the headland and pier study sites revealed differing proportions of response behaviours. The headland site yielded a higher proportion of negative responses, in addition to a higher proportion of erratic and reckless vessel behaviour. It is argued that due to the headland location being out of sight of the majority of vessels, observers and enforcement agencies, vessel behaviour becomes more erratic because speed is not regulated in this area, to the same extent as the pier study site. A higher proportion of positive response behaviours were displayed towards vessels at the pier study site. Vessels in this area are required to reduce speed as they enter the harbour which may be a factor contributing towards the higher amount of neutral and positive responses displayed. Another possible factor could be the relatively slow, predictable behaviour of VPB's and other vessels leaving the area, which may also reduce the likelihood of negative response behaviours.

4.3.4 Distance and response behaviour

It has been debated whether the distance to an animal during vessel interactions has an impact on the response exhibited. Lusseau, (2003a) observed that tour boats evoked a negative behavioural response in dolphins when vessels moved into a proximity of <400 m. Studies conducted elsewhere in Cardigan Bay found that when vessels were within 150-300 metres, negative (vertical and horizontal) response behaviours were most likely (Evans *et al.*, 1992). Acevedo (1991) argued that vessels had to pass within 5 metres of dolphins to elicit a diving response. By contrast, Nowacek *et al.*, (2001) found that dolphins exhibit response behaviour from much further away, but he suggested that depth may be a confounding factor in response movement. This trend was also noticed by Jensen *et al.*, (2009) who observed that depth of water had an effect on response behaviour, with more responses in shallower water. It has been suggested that the topography of the seabed may alter the way in which dolphins respond to vessels, due to the fact that sound propagation is poorer in shallower waters, and thus dolphins may not be able to detect vessels at the same distance as in deeper water (Nowacek *et al.*, 2001; Lusseau, 2006). Additionally, in shallow waters there is less of a water column in which to escape (Nowacek *et al*., 2001).

This study found that the majority of behavioural responses (47.7%) occurred at <50 metres, and yet no significant difference was found between distance and response behaviour. However, slight observable trends did occur, and it is possible that with larger sample sizes, significant differences may exist. During this study, more positive responses occurred when a dolphin was within 50 metres of the vessel, and a higher proportion of negative response behaviours were displayed between 101-200 m. This may be a result of visual confirmation of the vessel, and, therefore, dolphins were able to have sufficient time to safely avoid the approaching vessel. It is suggested that response behaviours may be displayed prior to the observer's knowledge since dolphins are able to detect the presence of a vessel before an observer, due to acoustical cues and the visual constraints of the study area. Therefore the results reposted here may not be a true representation of response behaviour with distance.

4.3.5 Number of vessels within 300 metres

Three hundred metres was selected as the distance criterion, because this was the furthest distance that a response behaviour was recorded in the Teifi Estuary, southern Cardigan Bay (Evans *et al.*, 1992). Dependent on survey type, vessel density, and level of boat traffic, encounters were recorded as interacting at different distances. Nowacek *et al*. (2001) recorded a dolphin as interacting with a boat when it was <100 m away, since boats were very frequent, encounters occurring on average every eight minutes during the day. In other regions where vessel traffic is less frequent, interaction distance was recorded at <400 m (Lusseau, 2006). The present study found no significant difference between the number of vessels within 300 m and a dolphin response, consistent with studies conducted in Clearwater, Florida, which found that vessel densities were insufficient to cause a measurable response and suggesting that dolphins were habituated to the level of vessel traffic (Allen & Read, 2000). On the other hand, some studies have argued that dolphins may be disrupted when two or more vessels are present (e.g. Mattson *et al*., 2005). Lusseau (2005) suggested that even a moderate increase in tour companies (from one to two) has been shown to have a negative long-term effect on bottlenose dolphin fitness. This may lead to the displacement of sensitive individuals, and reduced calf recruitment of the remaining animals (Bejder, 2005; Bejder *et al*., 2006b).

4.3.6 Group cohesion and spacing

Group size varied from one to seven individuals. On occasions, group formations and splits were observed. Group size had no significant effect on response behaviour, which supported previous studies in the area (Gregory & Rowden, 2001). Throughout the majority of interactions group spacing remained uniform. Previously, studies have examined whether dolphins may reduce group spacing and congregate closer together during vessel interactions, not only to aid in communication, but also to reduce drag through the water, preventing one dolphin from having the advantage (Weihs, 2004). This closer group cohesion may be linked to a classic predator response, and allow a quicker escape with less water resistance (Weihs, 2004). A tighter grouping has also been hypothesised to aid in minimising individual movements, and therefore, accelerating reactions to potential danger (Bejder *et al*., 1999).

Mother and calf pairs have been observed to increase dive interval in the presence of vessels (Nowacek *et al.*, 2001; Lusseau, 2003b). The results of this study concur with their findings as a significant difference was found between individual, and mother-calf pair behaviour.

4.4 Time of day

Dolphins were observed most often early in the morning and late in the evening when vessel traffic was at its lowest. Nevertheless, they were witnessed at all times of day throughout the study period and at times of high vessel traffic. It is suggested that the primary reason for this is that the benefits of the area outweigh the level of disturbance to which dolphins are exposed (Bristow & Rees, 2001; Gregory & Rowden, 2001). Lamb, (2004) noted that resting behaviour occurred mainly at night in New Quay Bay, and dolphin presence throughout the day varied inversely with vessel traffic.

4.5 Dolphin and vessel distribution

It has previously been established that the headland study site is an important feeding area for bottlenose dolphins (Pesante *et al*., 2008). Strong tidal currents mark it as an ideal feeding ground, due to the aggregation of prey (Pesante *et al*., 2008). The headland study area encompassed three main feeding areas: the shellfish factory to the east, Bird's Rock to the west, and the area surrounding Target Rock, forming the central feeding ground (Figure 22). The majority of dolphin sightings were concentrated in these areas. The shellfish processing factory concentrates upon the shelling of common whelks (*Buccinum undatum*), the shells of which are discarded through a chute onto rocks and the bay below (Denton, 2011). It has been suggested that this process brings small fish to the area, which may in turn attract dolphins. A positive relationship was discovered between abundance of dolphins and amount of discard produced (Denton, 2011). Suspected feeding was one of the most commonly recorded behaviours, and was observed on a daily basis. As in the current study, Hastie *et al.* (2004) found dolphin distributions to be linked to foraging behaviour. It is proposed that the headland represents an important feeding area for bottlenose dolphins, and thus it is important that the marine code of conduct is observed at all times to ensure dolphins are not disturbed.

Throughout headland observations, dolphins were recorded as confining themselves to the shallow inshore waters where the majority of vessels cannot access. This may occur in order to avoid vessel traffic. Lusseau, (2005) noted that during the peak season, dolphins in Milford Sound, New Zealand would situate themselves at the entrance of the fjord where tour boats were unable to venture due to shallow water. Wells (1993) obtained similar findings, and suggested that shallow waters were used primarily for feeding and calf rearing, and serve as a haven from vessel traffic.

At the pier study site, dolphins were most commonly observed close to the fish factory, around the cardinal buoy and off the pier, where, again, their distribution is believed to be related to feeding. Vessels are generally located around the harbour and pier area, and stay between the allotted buoys, usually following a direct route along the coast past the headland site (Figure 22). A small amount of vessels, including one visitor passenger boat (I*slander*), speed boats, small motor boats and kayaks, may venture out to the cardinal buoy. However, there is generally less vessel traffic in this area, potentially due to the reef. Only vessels with shallow drafts can venture into this area.

4.6 Vessel traffic and dolphin presence

It was observed that during the most intense vessel usage period (during each day and in June and July), dolphins were generally absent from the study area. In a direct comparison between pre- and mid-season, it was discovered that as vessel activities increased, dolphin sightings decreased. Previous studies conducted in the study area established that vessel activity is negatively linked to bottlenose dolphin sighting frequencies (Gregory & Rowden, 2001; Pierpoint *et al.*, 2009; Vitousek *et al.*, 2011; Feingold & Evans, 2014a). A study conducted by Pierpoint *et al.*, (2009) found that vessel presence suppressed site usage by bottlenose dolphins in New Quay harbour. This was very evident in 2007 as poor weather during the main tourist season suppressed vessel usage in the bay, which led to a significant rise in dolphin sightings. Pierpoint *et al.*, (2009) also suggested that dolphins less tolerant to vessel traffic may relocate to other areas close by in order to avoid boats or use the site at night when vessel presence was vastly reduced. Lusseau (2005) found that, as boat traffic increased on both a seasonal and daily basis, the less time dolphins spent in the fjord. In addition, a marked decline in resident animals was noted throughout the peak season with an increase in resident numbers as the season came to a close (Lusseau, 2005). In that area, dolphins were regularly seen in the summer months, and rarely in winter during the 1970s. However, since an increase of vessel traffic from 1980, summer dolphin sightings had decreased, whilst winter sightings had shown a significant increase (Lusseau, 2005). It is possible that the same may be true in New Quay Bay. However, watches are not conducted in winter months and, therefore, winter distribution of the majority of residents is currently unknown. It is noted that T-PODs have been deployed year-round at the fish factory and in New Quay Bay, and dolphin presence has been recorded throughout the winter (Pesante et al., 2008a).

It has been suggested that if the size of home range is decreased or restricted during certain periods due to vessel activities, it will ultimately decrease the productivity of the population and its carrying capacity (Richardson *et al*., 1995; Lusseau, 2005). Thus, the population in Cardigan Bay SAC may be in decline due to the increase in vessel activities, as a result of either reproductive suppression or site avoidance. Once the likelihood of interaction with a vessel becomes too high, it is no longer advantageous to elude boats in the short term, as this may lead to further interaction (Nowacek *et al.*, 2001; Lusseau, 2005). The energetic cost becomes too great, and results indicate that dolphins prefer to avoid the area altogether (Lusseau, 2005).

Wells & Scott, (1997) discussed the impacts of collisions on bottlenose dolphins in Florida, USA, during holidays and weekends. It was found that collisions were far more likely to occur during these times, due to the increased amounts of vessel traffic, especially during special holidays such as Independence Day, where boating activity increased significantly. However, in this study no significant or observable difference was noted between weekday and weekend vessel interactions, this may be due to the limited study period.

4.7 Dive interval

Avoidance behaviours have been perceived to be related to predator avoidance strategies as the effect of physical contact with a vessel has been shown to result in injury (Williams *et al*., 2002; Lusseau, 2003a). Diving is an avoidance mechanism, and results here confirm that dolphins undertook longer dives in the presence of vessels as previous studies have shown (Janik & Thompson, 1996; Nowacek *et al*., 2001; Williams *et al*., 2002; Lusseau, 2004, 2005). Short-term avoidance strategies have the potential to lead to long-term impacts such as area avoidance (Lusseau, 2005) and alteration to the population's behavioural budget (Williams *et al*., 2002; Lusseau, 2004), which has the potential to cause significant biological consequences for the reproductive output and energy balance of the population (Williams *et al*., 2002; Lusseau, 2006).

As with previous literature, it has been confirmed that vessel presence increased dive interval in individuals, and to a greater extent in mother and calf pairs. Experienced mothers were observed to increase dive interval more than with any other grouping (Nowacek *et al*., 2001; Williams *et al.*, 2006; Lusseau, 2006). Lusseau (2006) and Nowacek *et al.* (2001) reported that experienced mothers increased dive interval to a greater extent than inexperienced mothers and males. Due to a small sample size, and the lack of marked inexperienced mothers, this study was unable to examine this hypothesis. It is important to monitor the effects of vessels on mother and calf pairs, due to the area being an important calving ground (Evans, 1995; Pierpoint *et al*., 2009; Baines & Evans, 2012). If vessel activities are having an effect on behaviour, it may lead to further disturbance of breeding and rearing practices, which can have additional long-term consequences.

4.8 Resident and transient populations

Resident individuals were observed on a regular basis at both study sites; these individuals were noted to display fewer avoidance responses when compared with transient individuals, as has previously been shown (Janik & Thompson, 1996; Bejder *et al.*, 2006). As expected, the resident population displayed far more neutral responses to vessel traffic and to the presence of regular vessels, showing a degree of habituation. Transient individuals were far more affected by vessel activity, and were more likely to perform negative response behaviour. Transient individuals displayed no positive responses towards vessels, whereas the resident population moved towards vessels on a number of occasions. For example, experienced resident mother 017-03W (Smoothy) would frequently be observed swimming alongside vessels, although if interactions became unpredictable or intrusive, she and her calf (Dipper) performed a series of long dives and moved out of the area. Large resident male, 074-03W (Bond) has also been regularly observed with 017-03W and her calf. In some cases, 017-03W's calf was spotted with 074-03W, and with 017-03W located >250 metres away. 074-03W was often observed in close contact with boats and would frequently actively move towards particular boats such as the *Islander*. Habituation is defined as a behavioural response decrease that results from repeated stimulation that does not involve sensory adaptation, sensory fatigue or motor fatigue (Rankin *et al*., 2009). It is suggested that certain resident members have become sensitised or habituated to specific vessels in New Quay Bay.

4.8.1 Gender and response behaviour

A significant difference was found between gender and response behaviour. As was consistent with this study, previous studies have found that males avoid vessels as soon as they were present; however; females chose to vertically avoid them when interactions became intrusive (Lusseau, 2003b). Lusseau, (2003b) suggested that this may be related to the differing metabolic regime of the sexes. Males were more likely to meet the energetic cost of vessel avoidance due to their greater energy stores. Females preferred to vertically avoid vessels when risk of collision became too great (Lusseau, 2003b). This concurs with the finding that particular individuals may not use avoidance tactics because they cannot energetically afford to (Beale & Monaghan, 2004; Williams *et al.*, 2006). Females were observed to display more positive response behaviour towards vessels, and this may also be a behavioural adaption since bow-riding enables them to save energy as the power is provided by waves produced by the vessel (William *et al.*, 1992).

4.9 Evaluation

The chief limitation associated with this project was the study period. As a result of time constraints data collection could only be conducted during the first six weeks of the summer period. Data collection ceased at the start of the main tourist season (August) and, therefore, data from the peak season could not be included in analyses. However, the trends observed are expected to continue throughout the season.

It is possible that bias arose concerning the perception and availability bias of the surveying technique, meaning that some individuals may be sighted more than others, because they are more habituated or confident around the vessels and area. Although care was taken to ensure observers were trained correctly, observer bias is possible in both the theodolite use and dolphin spotting abilities. It is important to note that behaviour type identification may also vary between observers. It was, therefore, important that secondary observers were present to confirm the behaviour type.

In the absence of identifying features, difficulty arises when verifying theodolite fixes on the same individual at every surfacing. Additionally, only one theodolite was available for use in the study, which made it difficult to collect accurate coordinates of the dolphin and vessel positions simultaneously. It is suggested that a range finder should be used to measure the distance between the vessel and the dolphin, as they are able to accurately measure the distance whilst taking into account the vertical and horizontal elevation of the cliff. If not, two theodolites should be used to ensure the two coordinates are taken at the same time, allowing accurate distances to be calculated. This may prove more accurate than a range finder as they are more accurate at distances >300 m.

Obtaining the correct and accurate theodolite angles is a potential area for error, as miscalculation from a GPS can cause errors of >5 m in calculations, in addition to a further one metre of inaccuracy when measuring exact cliff height (Würsig *et al*., 1991). Cliff height and distance calculations were undertaken using the method proposed by Würsig *et al.*, (1991). Würsig *et al.*, (1991) suggested that a cliff height over 45 m does not require precise measurements of station height, and thus slight inaccuracies may be reduced. Swell height also has the potential to cause an error to distance calculations. Swell height and sea state were recorded every 15 minutes to reduce this error.

4.9.1 Suggestions for further study

Ideally, this project should be conducted all year round to assess the impact that seasonal and vessel traffic variations have on the bottlenose dolphin population, and to further assess the differences between the resident and transient populations. It is recommended that late evening watches are also conducted to examine if dolphins use the site more often during periods when vessel presence is reduced. This study implies that the increasing vessel interactions are leading to a decline in dolphin sightings. However, in to better test this hypothesis, a comprehensive seasonal and temporal study is required, and can then be used as a comparative study to Veneruso et al. (2011), even though winter observations were not conducted in this study.

The use of a video camera was initially integrated into the methodology to allow observers to review footage of interactions for closer examination of the animal's response to vessels, dolphin behaviour, dive intervals and group spacing and composition. However, this was later excluded due to a shortage of extra observers who could have helped film the behaviours. The camera could not be simply mounted on to a tripod and left to run because it had to be closely zoomed for a clear picture of the interaction. Dolphins are actively mobile, and therefore, if a video camera was left to run, the dolphins may be out of frame for the majority of filming. For reliable footage, an observer would have to direct the video camera to follow dolphin movements. It is recommended that additional observers are placed on the headland to assist the primary observer in data collection, tracking and taking of video footage.

It has been found that many factors affect the way in which *T. truncatus* responds to vessel traffic. It is suggested that research be undertaken to discover the extent to which dolphins are affected by vessel noise by measuring received noise levels, and thus calculating the detectability of different vessels in the manner undertaken by Evans *et al.* (1992). This may allow regulations to be implemented concerning vessel noise, which may ultimately lead to fewer disturbances.

5.0 Conclusions

In summary, despite the limitations, a number of important finding were obtained during this study, providing an insight into the behavioural response and sighting frequency of bottlenose dolphins with regards to vessel activities.

Numerous factors influence the severity and type of response behaviour displayed, many of which interplay with another. It is argued that some aspects, such as preceding behaviour, named vessels and engine size have more of a negative affect than others. It is suggested that dolphins prefer vessels that are predictable, as it allows them sufficient time to respond to the vessel. This supports the theory that dolphins have a preferred sound "window". Vessels producing constant, non-changing noise, can easily be detected, and responded to early. Those which produce little or no noise (kayaks) may cause greater disturbance because they are less detectable. At the other end of the scale, loud vessels which, exceed dolphins' preferred sound threshold, may cause disruption as they mask communication, potentially leading to confusion between individuals and groups. This leads to an erratic response.

During the course of this study, it was noted that as vessel activity increased, dolphin sightings decreased, in both seasonal and time of day comparisons. This suggests that short-term behavioural responses may be developing into long-term avoidance strategies (cf. Bejder *et al.*, 2006a). Previous studies have shown that short-term avoidance, will often lead to long-term consequences, such as declines in population size, reproductive ability and site usage (Kruse, 1991; Hastie *et al.*, 2003; Feingold & Evans, 2014a). If negative interactions become a regular occurrence, short-term avoidance will place animals at a disadvantage, as avoidance of one vessel may lead to an interaction with another. As a result, avoidance behaviours become too costly, and it is more efficient to avoid the area altogether until boat intensity has decreased (Lusseau, 2005). This has been identified throughout the current study. Feingold & Evans, (2014a) found a significant decline in bottlenose dolphin abundance in the Cardigan bay SAC in recent years, which supports Lusseau's, (2006) suggestion that habitats that show signs of long-term decline in local population may be due to high intensity tourism in the area. Pesante *et al.* (2008) considered whether behavioural changes due to disturbance might only be short-term, resulting in vessel avoidance and alterations to surfacing behaviour. At the time, there was little evidence for animals shifting distributions away from areas of high vessel activity. However, more recently in this study, and in others, it has become apparent that a shift in distribution is taking place (Pierpoint *et al*., 2009; Feingold & Evans, 2014a).

In conclusion, this study has outlined some key factors that influence behavioural responses of dolphins to vessel activities, with reference to the question as to whether these could lead to declining populations. With increasing vessel activity, the likelihood of interactions escalates, and thus the potential for long and short-term consequences of response behaviour. It is evident that the bottlenose dolphin population in New Quay Bay is exhibiting site avoidance, which may attest to the population decline in Cardigan Bay SAC. It is concluded that this is due to the consequence of increased and specific vessel activity.

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7. Appendix

7.1 Appendix 1 - Sea Watch Foundation land-based effort recording form

OP#= Sightings entered on website?= Photos?=

watch FOUNDATION

NEW QUAY LAND WATCH: EFFORT Name Date:

Map	Effort time (GMT/BST)		Sea	Wind	Visibility	Sighting?	Boat enc #	Spacer	Comments
	Start	End	State	direction					
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						

Data entered by = Data checked by=

watch FOUNDATION

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

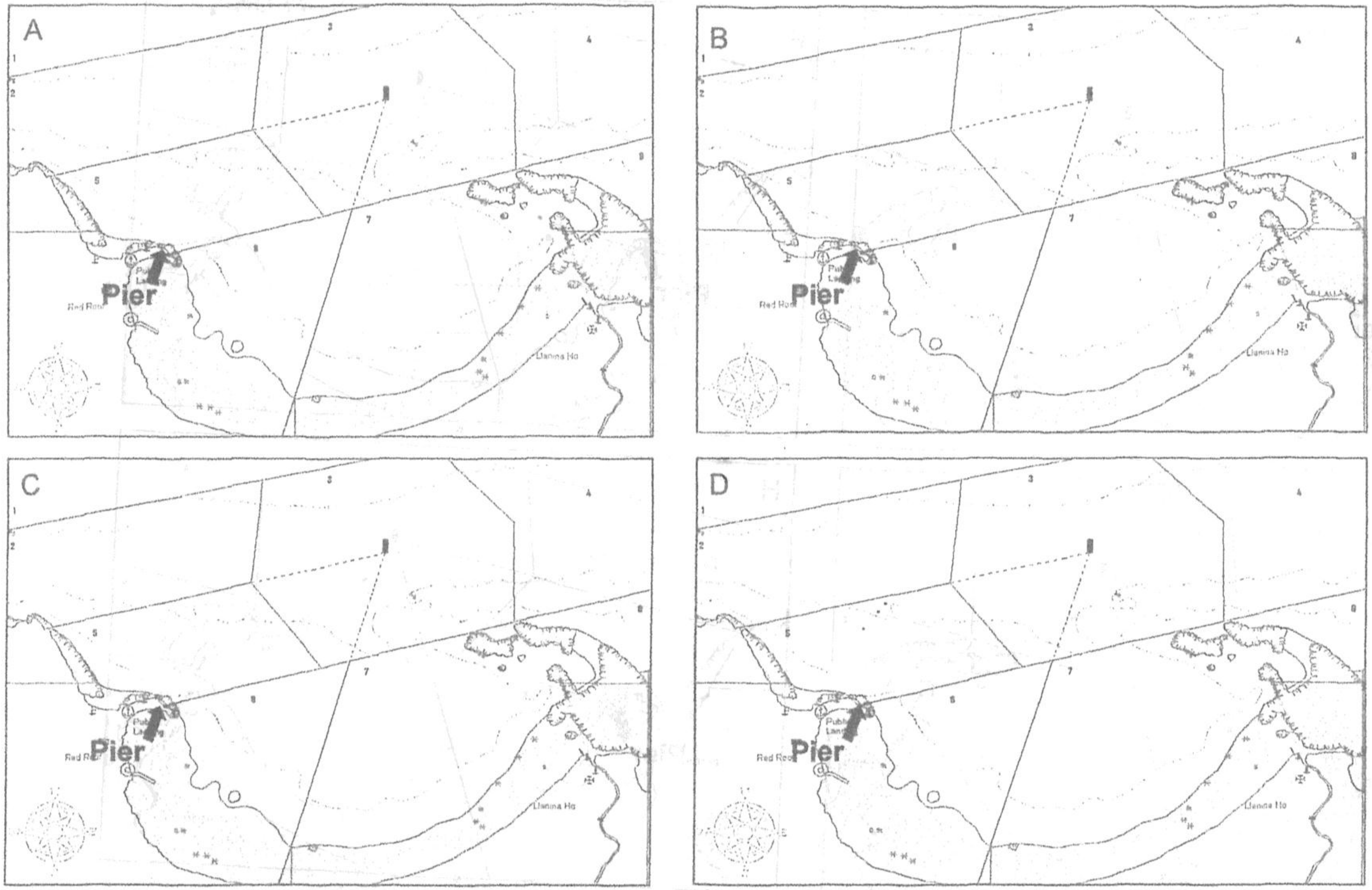
Boat encounters

Boat enc. number	Boat type	Boat Name	No boats <300m	Distance to animals	Boat behaviour	Cetacean behaviour	Reaction to boat
1							A T N U
2							A T N U
3							A T N U
4							A T N U
5							A T N U
6							A T N U
7							A T N U
8							A T N U

Behaviour: R-Resting/milling, SURF-Surfacing, NS-Normal swin (3-6 kn), FS-Fast swim (>6 kn), S-Socializing, SF-Suspected feeding, DV-Long dives, thought to be forgaing at depth, FF-Feeding (fish seen), AB-Aerial behaviour: non percussive, dolphins clear water with whole or majority of their body, PB-Dolphin hits water with any part of body, U-Unknown, O-Other, B-Bowriding, GS-Group splits, disperses, GF-Form close, tight group, NC-No change: applies only to boat encounter when there is no change in animals original behaviour. **Boat's closest distance to cetaceans: A-** Distance is less than 50 metres, B-Distance is between 50 and 100 metres, C- Distance is between 100 and 200 metres, D- Distance is between 200 and 300 metres. **Boat behaviour: Y1-** No wake speed & no erratic changes in course when passing cetaceans, Y2- Slowed down and gradually stopped, N1-Too fast: bow/wake speed, white water visible, N2- Erratic course to approach to avoid/follow cetaceans, N3- Attempted to touch/feed/swim with cetaceans, N4- Exceeded 8 kn inside yellow buoys. Boat names: E6-Ermol VI, E5-Ermol V, DUN-Dunbar, KAT-Katherine Arden (big blue FI), AB2-AB2 (red & black FI), SUL-Sulaire (blue & white passenger boat), ISL-Islander, SAC-SAC boat, KIR-Kirsty Ann (large yellow FI), GAL-Boat Gallois (SWF RIB). Reaction to boat: A-Away, T-Towards, N-Neutral, U-Unknown.

N QUAY LAND WATCH Name: Date & watch start time:

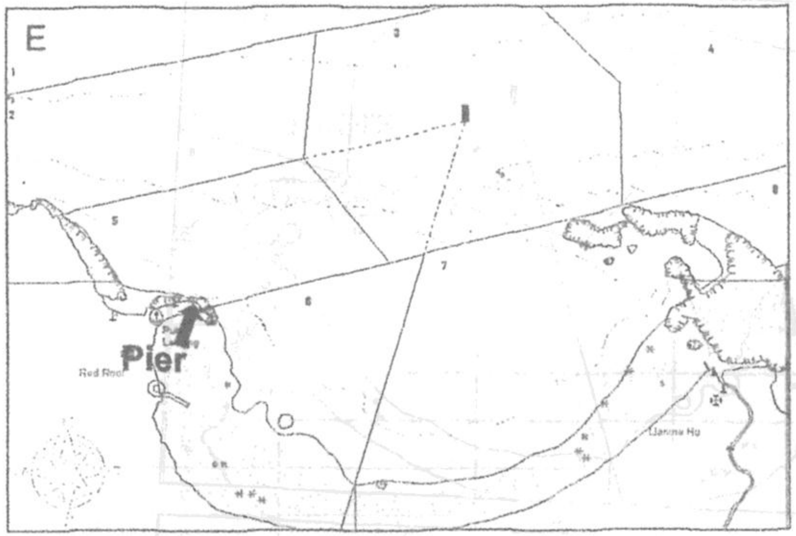
watch FOUNDATION

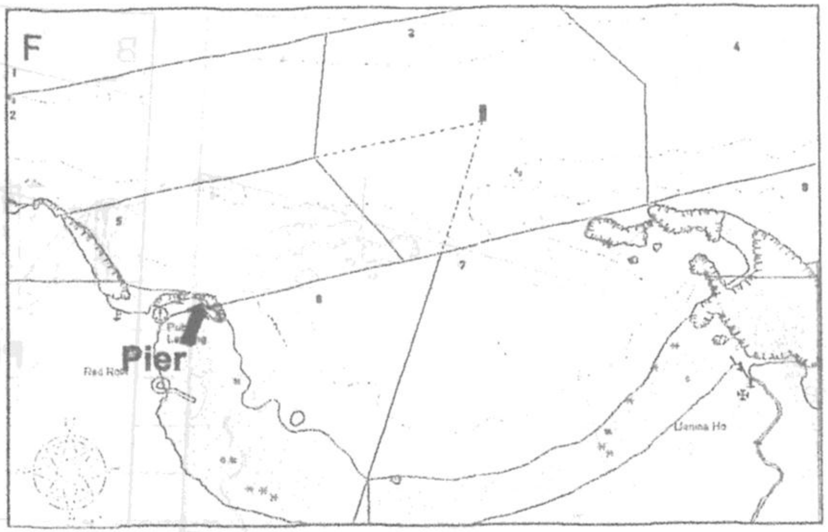


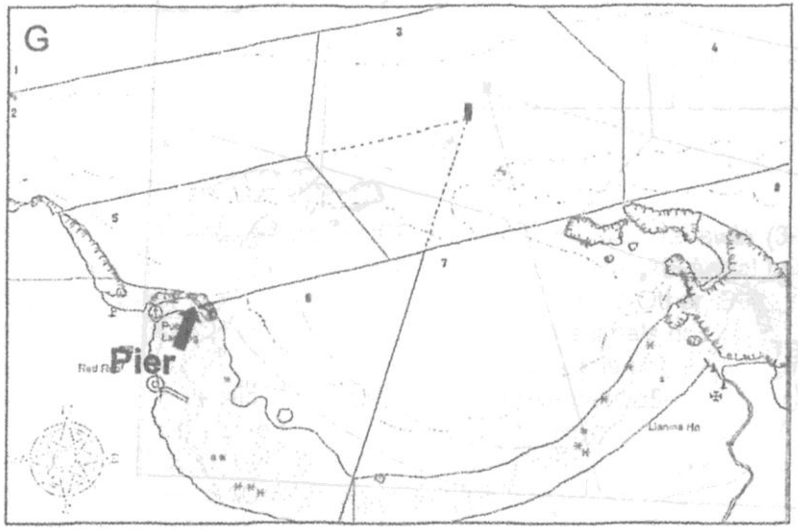
Write the species, number animals & behaviour in the correct location on the map. Note the heading direction with an arrow if there is one. Also add boats that involved in an encounter with a 'X' & boat name/type.

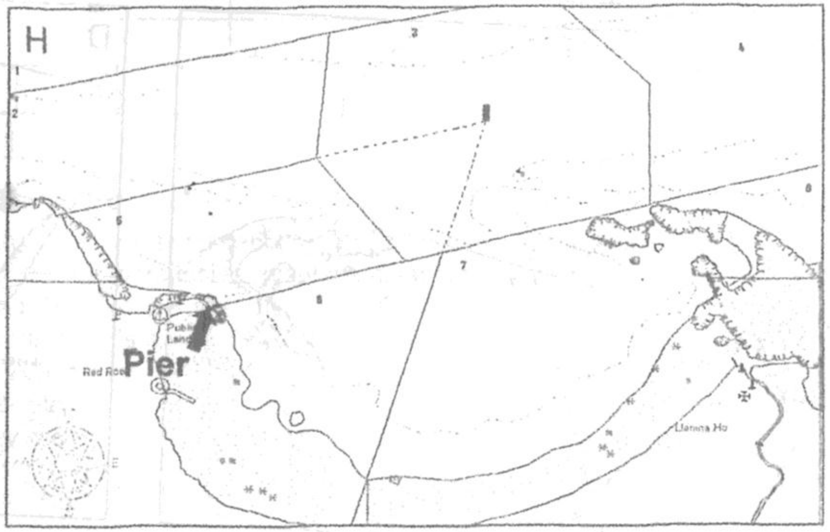
NEW QUAY LAND WATCH **Name:** **Date & watch start time:**

watch FOUNDATION



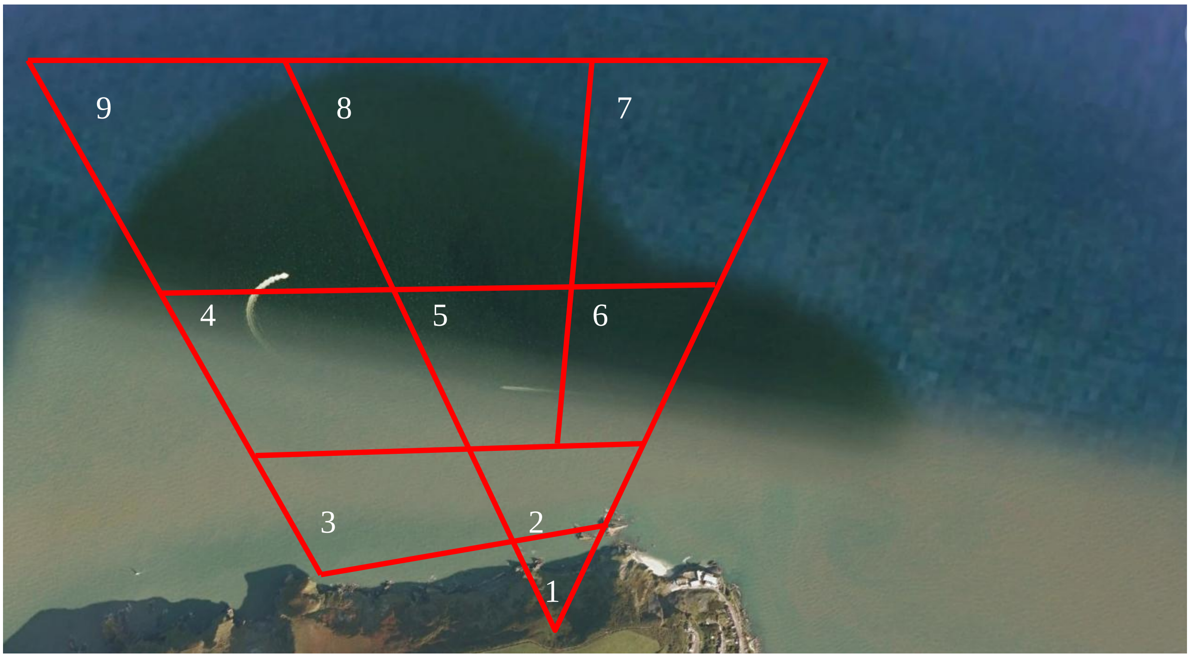






Write the species, number animals & behaviour in the correct location on the map. Note the heading direction with an arrow if there is one. Also add boats that involved in an encounter with a 'X' & boat name/type.

7.2 Appendix 2 – Gridded map of the headland study area



7.3 Appendix 3 – Beaufort scale

Beaufort Force	Windspeed Knots	Description	Sea Condition
0	0	Calm	Sea like a mirror
1	1 - 3	Light Air	Ripples but without foam crests
2	4 - 6	Light Breeze	Small wavelets. Crests do not break
3	7 - 10	Gentle Breeze	Large wavelets. Perhaps scattered white horses
4	11 - 16	Moderate Breeze	Small waves. Fairly frequent white horses.
5	17 - 21	Fresh Breeze	Moderate waves, many white horses
6	22 - 27	Strong Breeze	Large waves begin to form; white foam crests, probably spray
7	28 - 33	Near Gale	Sea heaps up and white foam blown in streaks along the direction of the wind
8	34 - 40	Gale	Moderately high waves, crests begin to break into spindrift
9	41 - 47	Strong Gale	High waves. Dense foam along the direction of the wind. Crests of waves begin to roll over. Spray may affect visibility
10	48 - 55	Storm	Very high waves with long overhanging crests. The surface of the sea takes a white appearance. The tumbling of the sea becomes heavy and shock like. Visibility affected
11	56 - 63	Violent Storm	Exceptionally high waves. The sea is completely covered with long white patches of foam lying in the direction of the wind. Visibility affected
12	64+	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray. Visibility very seriously affected.